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V. N. Saks, Editor

THE JURASSIC–CRETACEOUS BOUNDARY AND THE BERRIASIAN STAGE IN THE BOREAL REALM

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INSTITUTE OF GEOLOGY AND GEOPHYSICS, SIBERIAN BRANCH
(Institut Geologii i Geofiziki Sibirskogo Otdeleniya)

NORTHEASTERN COMPLEX RESEARCH INSTITUTE,
FAR-EASTERN CENTER
(Severo-Vostochnyi Kompleksnyi Nauchno-Issledovatel'skii
Institut DVTs)

MINISTRY OF GEOLOGY OF THE USSR
(Ministerstvo Geologii SSSR)

RESEARCH INSTITUTE OF THE GEOLOGY OF THE ARCTIC
(Nauchno-Issledovatel'skii Institut Geologii Arktiki)

SIBERIAN RESEARCH INSTITUTE OF GEOLOGY, GEOPHYSICS
AND MINERAL RESOURCES
(Sibirskii Nauchno-Issledovatel'skii Institut Geologii, Geofiziki
i Mineral'nogo Syr'ya)

ALL-UNION RESEARCH GEOLOGICAL PROSPECTING
OIL INSTITUTE
(Vsesoyuznyi Nauchno-Issledovatel'skii Geologorazvedochnyi
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V. N. Saks, Editor

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(Granitsa yury i mela i Berriasskii yarus v boreal'nom poyase)

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INTRODUCTION

In recent years the question of where to draw the boundary between the Jurassic and Cretaceous systems has frequently been discussed in the scientific literature and at many international (Luxembourg, 1962 and 1967; Lyon, 1963; Moscow, 1967; Budapest, 1969) and All-Union conferences, but no consensus has been reached. Since the main sections of the Tithonian stage of the Jurassic and the Berriasian stage of the Cretaceous are situated in the Mediterranean region of Europe, the analysis has centered on material from Southern Europe. However, excellent sections of Jurassic-Cretaceous boundary layers exist in higher latitudes of the northern hemisphere, and they are characterized by a rich and diverse boreal fauna that is very different from the Tethyan fauna. These sections have hardly been used for clarifying the problem of the boundary, and it is to make up for this shortcoming that this book is presented. An in-depth study of the boundary layers of the Jurassic and Cretaceous is of special interest in the Soviet Union, since Jurassic and Cretaceous deposits yield many economically important fossils (oil and gas in Western Siberia and along the Lena and Vilyui rivers, sedimentary iron ores in Western Siberia, large ore deposits in the Northeast and Far East of the USSR, and many others). Detailed geological surveys in areas of development of the Jurassic and Cretaceous also require that as detailed a differentiation as possible be made of mapped deposits and that reliable boundaries be drawn between the systems and strata. All this gives us reason to hope that this book will be welcomed. A discussion of the boundary between the Jurassic and Cretaceous necessarily involves the question of the Berriasian stage, its scope, subdivisions and interregional correlations. Following the resolutions of the Lyon Colloquium on the Lower Cretaceous (1963) and of the Interdepartmental Stratigraphic Committee of the USSR (1967), the independent status of the Berriasian stage is generally recognized, although some workers annex the Berriasian to either the Valanginian or the Tithonian, and even draw the boundary between the Jurassic and Cretaceous through the Berriasian.

Since the stratotype of the Berriasian stage is situated in southern France and is characterized by a Mediterranean fauna, it is very difficult to identify this stage in regions of the totally distinctive boreal fauna. We have nevertheless tried to show that, within the limits of accuracy of biostratigraphic correlations, it is possible to pinpoint the Berriasian stage in regions where boreal marine fauna is developed, even though we admit that there is a certain arbitrariness in correlating the Boreal and Tethyan realms.

We identify a Boreal paleobiogeographic realm in the northern hemisphere, and it is the characterization of the Berriasian age, its deposits and the boundary between the Jurassic and Cretaceous periods within the Boreal Realm that forms the content of this book. We deliberately restricted our survey to marine deposits and the marine fauna of the Boreal Realm, ignoring continental deposits and the development of land vegetation in the geological period under consideration, since we do not yet have enough quantitative data for such a precise demarcation of the boundary between the Jurassic and Cretaceous systems or for stage-by-stage classification of the boundary layers in the continental strata as we do for the marine facies. Furthermore, research into this question with reference to the continental deposits, the land vegetation, and the terrestrial and freshwater fauna would require quite a different team of workers and should be the subject of an independent investigation.

The present work is based on descriptions of the main sections of the Berriasian and the boundary layers of the Volgian and Valanginian stages in the Boreal Realm within the USSR. The distribution of these sections, studied by the authors of this collection, is shown in Figure 1.

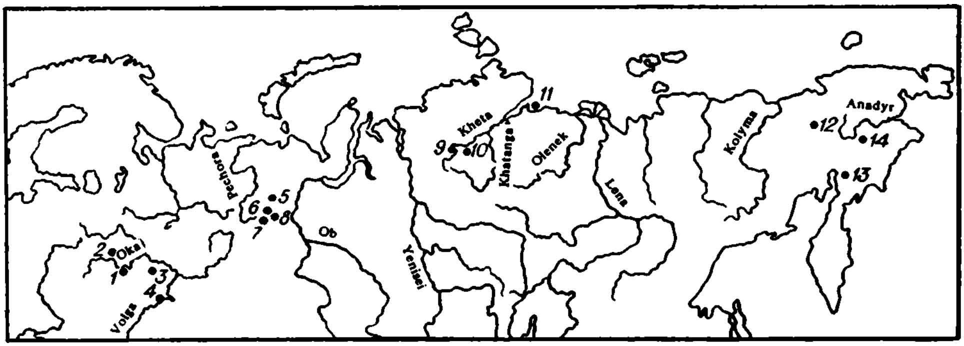


FIGURE 1. Main sections of the Berriasian in the Boreal Realm within the USSR, described in this book:
1) Oka River, below the mouth of the Pron'ya River; 2) Voskresensk; 3) Menya River near the village of Mishukovo; 4) Volga River, near Kashpir; 5) Yatriya River; 6) Yany-Man'ya River; 7) Tol'ya River; 8) Mauryn'ya River; 9) Kheta River; 10) Boyarka River; 11) Cape Urdyuk-Khaya (Paks Peninsula); 12) Pereval'naya River, basin of the Bol'shoi Anyui River; 13) Pontoteiskie mountains; 14) Main River.

We have thought it necessary to describe various groups of fauna that have not been covered, primarily ammonites, as these are of prime importance for a stratigraphic analysis of Mesozoic marine sediments.

It must be pointed out that some aspects of the systematics of Berriasian ammonites have been interpreted variously by investigators, including authors of the present work who are specialists on these fossils. For consistency of presentation, we shall adhere to the system proposed by N. I Shul'gina (Chapter IV, general survey of Berrasian boreal ammonites). The point of view of other authors is given in Chapters II and IV in the sections written by them.

The Berriasian boreal belemnites were described earlier by V. N. Saks and T. I. Nal'nyaeva (1964, 1966), bivalve mollusks by V. A. Zakharov (1966, 1970), Brachiopoda by A. S. Dagis (1968), and Foraminifera partly by V. A. Basov (1967, 1968, 1969) and E. F. Ivanova (1970). In addition, there are articles containing a description of different genera and species of Berriasian boreal fossils to which we will refer later.

The following bodies affiliated to the Academy of Sciences of the USSR took part in this work: the Institute of Geology and Geophysics of the Siberian Branch (V. N. Saks, V. A. Zakharov, E. F. Ivanova and T. I. Nal'nyaeva) and the Northeastern Complex Research Institute (V. P. Pokhialainen); participating from the Ministry of Geology of the USSR were: the Research Institute of the Geology of the Arctic (N. I. Shul'gina, Z. Z. Ronkina, V. A. Basov, M. D. Burdykina, and E. G. Yudovnyi), the Siberian Research Institute of Geology, Geophysics and Mineral Resources (A. V. Gol'bert, I. G. Klimova, E. E. Romanova, and L. Ya. Trushkova), and the All-Union Research Geological Prospecting Oil Institute (I. G. Sazonova). General supervision was by V. N. Saks. M. V. Savenkova and I. N. Radostev contributed greatly to the layout.

Chapter I.

EVOLUTION OF CONCEPTS ON THE BOUNDARY BETWEEN THE JURASSIC AND CRETACEOUS SYSTEMS AND THE BERRIASIAN STAGE

The Cretaceous system was identified in 1822 by d'Halloy in the Paris Basin and by Conybeare and Phillips in England. In 1829 Brogniart identified the Jurassic in the Jura Chain in Switzerland; a few years later, Thurmann (1836) referred the strata overlying the Jurassic deposits in the Jura Mountains to the Neocomian. D'Orbigny (1852) proposed drawing the Jurassic-Cretaceous boundary between the Portlandian and the Neocomian stages, the latter of which he divided into two substages. The lower of these substages corresponds to what we understand as the Berriasian, Valanginian, and Hauterivian. One year later, in 1853, Desor established the Valanginian stage at the Valangin hinge at the base of the Cretaceous in the Neuchâtel canton of Switzerland. He matched the lower boundary of the Valanginian (and accordingly of the whole system) with the position of the roof of the freshwater sediments of the Purbeckian which crown the section of the Jurassic in the Anglo-Paris and Franconian basins and, in particular, underlie the marine Valanginian in the stratotypic section. In 1865, Oppel showed that the upper horizons of the Jurassic system in the Mediterranean Region, which he identified as the Tithonian stage, are composed of marine sediments. Almost at the same time, in 1867, Pictet described a limestone horizon in southern France, near the village of Berrias (département of Ardèche, vicinity of Largentière) to which he gave the name Berriasian and which he placed at the base of the Cretaceous. In 1871, Coquand suggested that the Berriasian be considered a lower substage of the Valanginian, but soon afterward Renevier (1873) advocated designating the Berriasian as a separate stage. This was supported by Koenen (1902), Mazenot (1939), Müller and Schenk (1943), and by many workers in the last twenty years, on the grounds that in the stratotype of the Valanginian the marine beds overlying the Purbeckian are younger than the Berriasian with regard to their fauna. In 1885, Choffat named the lowermost strata of the Cretaceous in Portugal, which more or less correspond to the Berriasian in volume, infra-Valanginian. This term was later adopted, for example, by Spath (1924, 1947) to designate the bottom stage of the Cretaceous, although neither the priority rule nor the meaning of the name itself justified its acceptance.

On finding, in a section of Berriasian limestones, *Natica leviathan* Pict. (also known from the lower Valanginian of Switzerland) together with *Hoplites malbosi* Pict., an ammonite that is especially characteristic of the Berriasian, Kilian (1895) contended that the Berriasian corresponds to the lower Valanginian. On the other hand, Toucas (1890), Haug (1911), and A. P. Pavlow (1891) placed the Berriasian in the Tithonian, although Haug and Pavlow later changed their minds and referred the so-called upper Berriasian, the beds with *Hoplites boissieri*, to the Cretaceous while continuing to consider the strata with *Hoplites privasensis*, *H. chaperi*, and *Perisphinctes transitorius* as Tithonian (Aquilonian according to Pavlow).

Similar views prevail also at present. The *Virgatosphinctes transitorius* zone at Rohožinka and Stramberk in Czechoslovakia or the two zones *Berriasella delphinensis* and *B. chaperi* which replace it in southeastern France constitute the upper part of the Tithonian stage, while the *B. boissieri* zone was for a long time considered the only zone of the Berriasian stage (or, if this stage is not recognized, the lower substage of the Valanginian), and it was from this zone that the Cretaceous was agreed to begin.

Meanwhile, some investigators claimed that the Berriasian should be referred to the Jurassic (Retowski, 1893; Haug, 1898), that Berriasian deposits are synchronous with the upper Tithonian deposits (Barthel, 1962), and, finally, that the Berriasian and upper Tithonian should be united and placed in the Cretaceous (Herbert, 1869; Paquier, 1900; Eristavi, 1962). Until very recently most Soviet workers considered the Berriasian as the lower substage of the Valanginian (Luppov, 1959; Drushchits, 1966; etc.).

In Western Europe the boundary layers of the Jurassic and Cretaceous are very often composed of freshwater and brackish-water sediments, and here the position of the boundary between the systems is usually defined on the basis of the ostracod fauna and is understood variously by different investigators. For instance, Bartenstein (1954, 1965) draws the Jurassic-Cretaceous boundary in the North German Lowland, between members 3 and 4 of the Wealden (below the Deister sandstones), Wienholz (1965) places it much lower, within the Münder marls (under the upper bench), and Kemper (1968) matches it with the boundary of the Münder variegated marls and serpulite (limestone with *Serpula coacertata* Blum.).

At the Colloquium on the Lower Cretaceous (Colloque sur le Crétacé Inférieur) which was held in Lyon, in 1963, a review of the stratotypes of all the stages was followed by a recommendation to recognize a separate Berriasian stage with two zones: *Berriasella grandis* (lower) and *Berriasella boissieri* (upper). In accordance with the section of the stratotype in Switzerland (Neuchâtel canton), the Valanginian stage was understood to comprise two zones: the lower, *Kilianella roubaudiana* and the upper, *Saynoceras verrucosum*. In view of the inadequate paleontological characterization of the stratotypic section of the Valanginian, the Colloquium proposed the section of the Valanginian in the Vocontian trough (southeastern France) as the parastratotype. Once these recommendations on the stratotypic region were adopted, there was no longer any reason outside France and Switzerland to consider the Valanginian as embracing the Berriasian.

A similar decision to accept the validity of the Berriasian stage was adopted in 1964 by the Mediterranean Mesozoic Committee in Cassis (France). In 1967, the Berriasian gained recognition by the Interdepartmental Stratigraphic Committee of the USSR as a stage at the base of the Cretaceous system (Luppov, 1970).

On the Russian Plain Nikitin (1888) described Jurassic-Cretaceous boundary layers with *Hoplites (=Riasanites) rjasanensis*, *H. swistowianus*, and *H. subrjasanensis*, species that are related to the upper Tithonian and Berriasian ammonites of Western Europe, and covering beds with *Olcostephanus (=Surites) spasskensis*, *O. unzhensis*, and other species.

Bogoslovskii (1895) separated the lowest layers of the Cretaceous into the Ryazan horizon, in which he distinguished three strata (with *Hoplites rjasanensis*, with *H. rjasanensis* and *Olcostephanus spasskensis*, and with only *Olcostephanus spasskensis*). He considered that the Ryazan horizon could most probably be correlated with the zone *Hoplites (=Berriasella) boissieri* in Western Europe. A. P. Pavlow (Pavlow, 1896) proposed that two zones be distinguished in the Ryazan horizon: *Hoplites rjasanensis* and *Olcostephanus spasskensis*. His suggestion to refer the first zone to the Aquilonian, that is, to the Jurassic, and to begin the Lower Cretaceous with the second (Pechora stage) was based on the similarity of *Riasanites* to the Tithonian species of *Berriasella*, but this was not accepted by Soviet investigators, since *Riasanites* was encountered together with the Berriasian *Berriasella boissieri* in the Caucusus. Moreover, his suggestion contradicted on the one hand the marked difference of the fauna of the upper Volgian stage and that of the *Riasanites rjasanensis* zone (whose ammonite complexes have a completely different generic composition) and, on the other hand, the large degree of coincidence between the fauna of the *R. rjasanensis* and *Surites spasskensis* zones (the group *S. spasskensis* is present in both zones).

Pavlow considered that his greatest achievement was to establish the two mentioned zones of the lower Neocomian in Russia, which are clearly traced in the vicinity of Syzran and in the Ryazan Province. He noted that only one of these zones is developed in the northern part of the Simbirsk Province, but that it is remarkable in that it presents a rich and diverse fauna of the group *Ammonites (=Surites) stenomphalus* together with West Europe Neocomian species: *Oxynoticeras gevrilianum* and *O. marcouisianum*. Pavlow concluded that the upper half of the Ryazan horizon is nothing other than the northern Simbirsk lower Neocomian. Unfortunately, he gave only lists of ammonites which are by no means substitutes for the descriptions and figures that are essential for an objective comparison of these very heterogeneous forms. Pavlow's works contain no precise indication of the sites of occurrence of the ammonites. He writes: "in the northern part of the Simbirsk Province, the Alatyr-Kurmysh and Kurmysh districts," etc. Just which sections of the "northern Simbirsk lower Neocomian" is correlated with the sections described by Bogoslovskii (1897) remains unclear. The list of ammonites presented by Pavlow does not make it possible to assert their common age.

In 1901, taking note of the critical remarks made by Nikitin and Bogoslovskii, Pavlow wrote more cautiously on the beds with *Olcostephanus spasskensis* in the Ryazan Region and the beds with *O. stenomphalus* in the Kurmysh District: "I assumed that the boundaries of these two deposits do not coincide precisely, that one of them may have begun to be formed a little earlier than the other, but in general there is every reason to state that they are synchronous." In 1907, Pavlow came up with a fundamentally new zonal subdivision: the *Hoplites rjasanensis* zone is, as before, referred to the Aquilonian as the upper zone of the Jurassic, a separate *Olcostephanus spasskensis* zone is singled out at the base of the Lower Cretaceous, and above it the *Oxynoticeras gevrilianum* and *Olcostephanus stenomphalus* zone. Pavlow never completed his work in the Sura Basin, and his ammonite collection was lost.

Zonov (1937) referred two zones to the Berriasian on the Russian Plain: a lower *Riasanites rjasanensis* zone and an upper *Craspedites (Tollia) stenomphalus* and

C. (T.) spasskensis zone. According to him, layers with *Pseudogarnieria* and *Proleopoldia* (the *Pseudogarnieria undulato-plicatilis* zone) are traced above these beds in the Oka River basin, and about them he writes (1937, p. 44): "Whereas the underlayers indisputably belong to the top of the Berriasian, the age of the strata with *Pseudogarnieria* remains an open question owing to the absence (or rather the non-discovery) of typical *Platylenticeras gevrilianum* on the platform." In his 1938 publication Zonov reported that he had found a phosphorite intercalation with *Proleopoldia* cf. *kurmyschensis* (Stchir.) and *Pseudogarnieria* sp. (cf. *undulato-plicatilis* Stchir.) along the Neplozha River near the village of Mosolovo (Ryazan Region) above the layers with *Tollia spasskensis,* and above this intercalation sands with sandy phosphorites containing *Temnoptychites* sp.

Sazonov (1951) proposed that Bogoslovskii's Ryazan horizon be promoted to the rank of a stage and that two zones be distinguished: a lower zone, *Riasanites rjasanensis,* and an upper zone, characterized by the new ammonite genus *Surites* (type species *S. pechorensis* Sazon.). In his papers of 1953 and 1955, Sazonov continued this policy; in the 1955 work the upper zone was named *Tollia spasskensis.* The *Tollia stenomphala* zone was placed in the lower Valanginian, and above it beds with *Pseudogarnieria undulato-plicatilis* were identified.

Luppov writes (1952, p. 220): ". . . It must be admitted that from the point of view of faunal development (mainly ammonites), there is justification for making the Berriasian a stage. In fact, the Berriasian sediments differ markedly from the overlying deposits of the Valanginian in their ammonite composition." "However," Luppov notes, "if we approach the matter from the point of view of the bulk of the Berriasian, we apparently see that the formation of the ammonite complex was discontinuous. . . and did not correspond to the durations of each of the following stages of the Cretaceous system. . . Therefore, in accordance with the view more widely accepted among Soviet geologists, it would be better not to distinguish a Berriasian stage but to include the deposits it embraces as a lower substage of the Valanginian stage."

Gerasimov (1955) identified the Berriasian stage on the Russian Plain, but included in it only the *Riasanites rjasanensis* zone, referring the *Tollia stenomphala* zone to the lower Valanginian.

In 1963, in a report to the Sixth Congress of the Carpathian-Balkan Geological Association, Sazonova suggested that the Berriasian stage should be identified on the Russian Platform. The report was published in Poland in 1963 and in the USSR in 1965. A little earlier, in 1962, Saks and Shul'gina proposed singling out the Berriasian in Siberia, giving it the status of a stage.

Spath (1947, 1951) and Arkell (1956) shared Pavlow's opinion on the Jurassic age of the *Riasanites rjasanensis* zone, citing finds of *Riasanites* in the upper Tithonian of Argentina. Later, in his Treatise (1957), Arkell referred his finds in Argentina and Mexico to the genus *Riasanites* with a question mark. Nevertheless, the tendency to consider the *Riasanites rjasanensis* zone as Jurassic and to correlate it with the Tithonian persists among West European geologists.

Marek, Bielecka, and Sztejn (1969) favored drawing the Jurassic-Cretaceous boundary between the *Berriasella grandis* and *B. boissieri* zones, i.e. within the French Berriasian.

They assumed that the *B. grandis* zone corresponds to the upper Volgian substage in Russian and hence that the Cretaceous begins with the *Riasanites rjasanensis* zone. Such a conclusion contradicts the structure of the stratotype of the Berriasian in France and could therefore only be acceptable if the Berriasian stage were replaced by the Ryazan stage. Since the Ryazan horizon was proposed later and does not have stratigraphic contacts either at the base (washout) or at the roof, this suggestion must be rejected.

In reports presented by Barthel (1967) and Zeiss (1967) to the Second International Colloquium on the Jurassic system, which took place in Luxembourg, and also in an article published at the same time by Casey (1967), the idea was put forward that the upper Volgian substage of the Russian Plain could be correlated with the Berriasian of France. Siberian material repudiates this hypothesis outright. The upper Volgian substage of Siberia to its upper *Chetaites chetae* zone inclusive contains the *Virgatosphinctes* characteristic for the Tithonian of Europe, while the lower zone of the substage, *Craspedites okensis,* features *Berriasella (Lemencia)* aff. *richteri* (Opp.), permitting this zone to be correlated with the lower zone of the upper Tithonian of France, that is, the *Berriasella delphinensis* zone.

Wiedmann (1967, 1968), basing himself on these facts like the Soviet investigators, connects the upper Volgian substage with the upper Tithonian and the Siberian Berriasian with the European Berriasian. He and Marek (Marek, 1967) locate the Berriasian of the Russian Plain at the level of the upper zone of the French Berriasian, *Berriasella boissieri.* Proceeding from the similarity between the ammonite complexes in the upper Tithonian and the Berriasian of Southern Europe, Breistroffer (1964) and Wiedmann include the Berriasian zones *B. grandis* and *B. boissieri* in the upper Tithonian and accordingly they begin the Cretaceous with the Valanginian.

As will be shown in the following chapters, many arguments in favor of referring the Berriasian to the Jurassic can be found in the boreal material too. Along with this, there are grounds for placing the Berriasian closer to the Valanginian than to the Tithonian. Even the schemes of the distribution of ammonites in the boundary layers of the Jurassic and Cretaceous given by Wiedmann (1968, p. 351) allow for a double solution to this question according to the age limits of development of ammonite families and subfamilies, and, what is more, they do not provide a basis for refusing to recognize an independent Berriasian stage.

Let us examine the division of the Berriasian into zones. Kilian (1907–1913) interpreted the Berriasian as being contained in the *Hoplites boissieri* and *Olcostephanus (Spiticeras) negreli* zone. Haug (1911) distinguished two zones: *Spiticeras negreli* and *Thurmannia boissieri.* Müller and Schenk (1943) singled out the *Parodontoceras (=Berriasella) callistoides* and *Thurmannites boissieri* zones.

Spath (1942) proposed that the Berriasian (infra-Valanginian according to his terminology) be divided into zones, taking the data on the Boreal Realm into account. He distinguished a lower zone Spiticeratan with the subzones *Spiticeras acutum, S. damesi* and *S. latior* and an upper Subcraspeditan zone with the subzones *Craspedites spasskensis, Tollia tolli* and *Craspedites stenomphalus.* But this scheme did not justify itself, since no confirmation was found in any specific section that beds with *Spitceras* underlie beds with *Subcraspedites.*

After studying the ammonite fauna of the top of the Jurassic and base of the Cretaceous of France, Mazenot (1939) divided the Berriasian stage into three horizons. The last upper Tithonian horizon with *Berriasella chaperi* Pict. is overlain by: 1) the horizon of *Berriasella paramacilenta* Maz. and *B. grandis* Maz. with *Spiticeras ducale* Nath. and *S. obliquenodosum* Ret.; 2) the horizon of *Berriasella boissieri* Pict. with *Dalmasiceras dalmasi* Pict., *Neocomites occitanicus* Pict., *N. subalpinus* Maz., *Neocosmoceras rerollei* Parq., and *Negreliceras negreli* Math.; 3) the horizon of *Kilianella* aff. *pexiptycha* Uhl. and *Thurmannites* aff. *pertransiens* Sayn with *Berriasella boissieri* Pict., *B. pontica* Ret., *B. paramacilenta* Maz., and *Dalmasiceras dalmasi* Pict. This division is highly speculative and, as will be seen below, the horizons were not confirmed in the stratotype of the Berriasian.

Renevier (1873) proposed that the zone *Hoplites (=Kilianella) roubaudianus* and *H. (=Thurmanniceras) thurmanni* be considered the lower zone of the Valanginian. For the northern part of West Germany Koenen (1902) isolated the zone *Oxynoticeras gevrilianum, O. heteropleurum,* and *Polyptychites diplotomus* as the lower zone of the Valanginian. This zone, which corresponds to the lower part of the *Kilianella roubaudiana* zone, came to appear later in many works under the name Platylenticeratan (Spath, 1924) or *Platylenticeras heteropleurum* (Müller and Schenk, 1943). Wright (1952) pointed out that there is a time gap between the *Berriasella boissieri* and *Kilianella roubaudiana* zones. A recent tendency has been to single out a *Kilianella lucensis* zone at the base of the Valanginian under the *Kilianella roubaudiana* zone (Wiedmann, 1968).

In 1939, Bodylevskii worked out a scheme showing the sequence of faunistic complexes in the Upper Jurassic and Lower Cretaceous deposits of northern Siberia, distinguishing here a complex with *Subcraspedites* aff. *groenlandicus* Spath and *Buchia volgensis* (Lah.) in the infra-Valanginian and a complex with *Tollia tolli* Pavl. in the lower Valanginian. The middle Valanginian begins with the complex with *Temnoptychites* sp. In 1944, Bodylevskii gave a similar scheme for subdividing the boundary layers of the Jurassic and Cretaceous for the Northern Urals and in 1949, one for the basin of the Pechora River.

At the 1954 Interdepartmental Conference on the Stratigraphy of the Mesozoic Deposits of the Russian Platform the following zones were recognized for the upper Volgian stage: 1) *Kachpurites fulgens,* 2) *Craspedites subditus* and *C. okensis,* 3) *C. kaschpuricus* and *C. nodiger;* and for the lower Valanginian: 1) *Riasanites rjasanensis* (within the Ryazan horizon) and 2) *Tollia stenomphala* (with *Pseudogarnieria, Proleopoldia, Chandomirovia,* and *Surites tzikwinianus*). The middle Valanginian begins from the *Temnoptychites hoplitoides* zone. All these zones were ratified in the resolutions of the next conference held in 1958, but the Berriasian and the Ryazan horizon were made synonyms of the whole lower Valanginian, while *Surites spasskensis* (Nik.) and *Euthymiceras,* forms that are typical of the Ryazan horizon, were added to the list of species characteristic for the *Tollia stenomphala* zone.

The *Tollia stenomphala* zone came to be established as follows. A. P. Pavlow identified beds with *Olcostephanus stenomphalus* in the Sura basin as beds with *Olcostephanus* containing *O. stenomphalus* (Pavl.) and *Olcostephanus* species related to *stenomphalus,* together with *Pseudogarnieria* and *Proleopoldia.* He described the species *Olcostephanus* *stenomphalus* from two specimens of ammonites from the Spilsby sandstones in England and from the Simbirsk Province (Pavlow, 1890). It emerged later that the two specimens belong to different species of the genus *Surites;* the Russian specimen was lost, while the English one is deposited in the British Museum (Natural History) in London (a plaster cast of it is in the Chernyshev Museum in Leningrad). Spath (1947) suggested that this specimen be considered the lectotype of the species, and therefore it was inadmissible to distinguish the zone here according to it until analogous forms were found in Russia. Sazonova (1965) also made a mistake in instituting the genus *Bogoslovskia* according to the species *stenomphalus* (Russian specimen), because this specimen, which has moreover been lost, does not have the right to the name *stenomphalus.* In the present work, Sazonova has proposed to institute the Russian specimen as a new species, *Bogoslovskia pseudostenomphala* I. Sazon. n. sp. and to consider it as the genotype of the genus *Bogoslovskia.* In the opinion of Shul'gina, the species *stenomphalus* and the species related to it should be placed in the genus *Surites* (subgenus *Bogoslovskia*). As for the zone, Zonov quite rightly suggested back in 1937 that it should be named the *Proleopoldia kurmyschensis* or *Pseudogarnieria undulato-plicatilis* zone, particularly since there is no certainty that Pavlow's ammonite originates from it and not from the lower *Surites spasskensis* zone. The concept of the *Tollia stenomphala* zone was subsequently extended to the beds with *Surites* sp., which contradicted Pavlow's initial proposal and introduced still more confusion into the notions on the stratigraphy of the bottom Cretaceous strata of the Russian Plain.

In 1956, the Interdepartmental Stratigraphic Conference on Siberia acknowledged the *Taimyroceras taimyrense* zone as the upper zone of the upper Volgian stage and recognized the zones *Paracraspedites spasskensis* and *Tollia stenomphala* in the lower Valanginian. The *Tollia stenomphala* zone was understood to be comprised in the beds with *T. tolli* Pavl. In 1960, the Interdepartmental Conference on the Stratigraphy of Western Siberia transferred the upper Volgian *Taimyroceras laevigatum (=T. taimyrense)* zone to the lower Valanginian for no good reason. The 1963 Urals Stratigraphic Conference essentially just endorsed the 1956 resolutions on Siberia concerning the topmost strata of the Jurassic and lowermost strata of the Cretaceous.

In 1963, Saks, Ronkina, Shul'gina, Basov, and Bondarenko with the participation of Bodylevskii, Vasilevskaya, Gerke, Mesezhnikov, and others worked out a more precisely defined scheme for the stratigraphy of the Jurassic and Cretaceous of the northern USSR. The zones *Craspedites okensis, Taimyroceras taimyrense* and *Chetaites chetae* were distinguished at the top of the Volgian stage, while in the lower Valanginian (Berriasian) the zones *Paracraspedites spasskensis* (with the subzones *Chetaites sibiricus, Hectoroceras kochi,* and *Paracraspedites analogus*) and *Tollia tolli* were isolated. The *Polyptychites michalskii* zone (with the subzones *Temnoptychites syzranicus* and *Astieriptychites astieriptychus*) corresponds to the middle Valanginian. This system was approved by the Interdepartmental Stratigraphic Conference on Northern Siberia held in 1964 and, with a few amendments, was also accepted by the Tyumen Stratigraphic Conference of 1967 for Western Siberia.

Saks and Shul'gina later made some changes to the system, singling out a separate Berriasian stage within the former lower Valanginian (Saks and Shul'gina, 1962, 1964), making the subzones of the *Surites (Paracraspedites) spasskensis* zone separate zones, splitting the *Craspedites okensis* zone into three subzones (Saks et al., 1968) and, finally, dividing the *Tollia tolli* zone into two zones, the lower of which *(Bojarkia mesezhnikowi)* remained in the Berriasian and the upper *(Neotollia klimovskiensis)* was transferred to the lower Valanginian (Saks and Shul'gina, 1969).

In 1967, the Joint Plenum of the Jurassic and Cretaceous Commission of the Interdepartmental Stratigraphic Committee of the USSR adopted the zones *Riasanites rjasanensis and Surites spasskensis* for the Berriasian of the Russian Platform. The plenum referred the *"Tollia stenomphala"* zone (with *"Platylenticeras"*) to the bottom of the Valanginian. The top of the Berriasian or the base of the Valanginian (the *Tollia tolli* zone) in Siberia was acknowledged to require further study.

A new scheme for zoning the Lower Cretaceous was given by Sazonova and Sazonov (1967) for the Russian Platform. They distinguish the zones *Riasanites rjasanensis* and *Bogoslovskia stenomphala* in the Berriasian (or Ryazan) stage (a more suitable name for the latter would be one taken from one of the species of *Surites* present in this zone). Beds with *Pseudogarnieria* and *Proleopoldia* were shown at the base of the lower Valanginian under the *Temnoptychites hoplitoides* zone. This cleared up the question of the stratigraphic position of the boundary layers of the Berriasian and Valanginian in the European part of the USSR.

In 1969, Gerasimov suggested that the zones *Riasanites rjasanensis* and *Surites tzikwinianus* be identified in the Berriasian of the Russian Platform (instead of *S. spasskensis*, which is distributed throughout the Berriasian). This is hardly acceptable, since *S. tzikwinianus* (Bogosl.) begins to appear in the *Riasanites rjasanensis* zone (in the section near Kashpir). It would therefore be better to retain the index species *S. spasskensis* (Nik.), proposed by Nikitin, for the second zone of the Russian Berriasian.

Chapter II.

MAIN SECTIONS OF THE BERRIASIAN STAGE IN THE BOREAL REALM WITHIN THE USSR

The best and most complete sections of the Berriasian stage and of the boundary layers of the Jurassic and Cretaceous within the Boreal Realm in the USSR are to be found 1) in the north of Middle Siberia: on the Kheta and Boyarka rivers and on Cape Urdyuk-Khaya (Paks Peninsula on the shore of the Laptev Sea), 2) in the Cis-Polar Urals, in the basin of the Severnaya Sos'va River (on the Yatriya, Yany-Man'ya, and Tol'ya rivers), and 3) on the Russian Plain (on the Oka River near Staraya Ryazana, in the Sura River basin on the Mepa, and on the Volga near Syzran in the vicinity of Kashpir). These are the sections that will be described in this chapter. The sections which have been studied in greatest detail, layer by layer, with the use of lithological-geochemical and paleontological-taphonomic methods are those in northern Middle Siberia and the Cis-Polar Urals, each of which were researched during a number of years by teams of investigators from the Institute of Geology and Geophysics of the Siberian Branch of the Academy of Sciences of the USSR, the Institute of Geology of the Arctic, and the Siberian Research Institute of Geology, Geophysics, and Mineral Resources. In addition, the chapter includes a description of a section of the Berriasian in boreholes in the West Siberian Plain and in the extreme northeastern part of Asia.

NORTHERN MIDDLE SIBERIA

Berriasian sediments crop out in the basins of the Kheta, Boyarka, Maimecha, Popigai, and Anabar rivers, near Cape Urdyuk-Khaya, and in the lower reaches of the Olenek and Lena rivers. The degree of exposure varies, and therefore so does the extent to which the outcrops have been studied. The sections on the Boyarka and Kheta rivers and near Cape Urdyuk-Khaya have been most thoroughly investigated by paleontologists and paleoecologists, who have explored each stratum. The procedure for layer-by-layer description is explained in the article by Zakharov and Yudovnyi (1967). The aims of layer-by-layer lithological investigations are to determine types of rocks according to the granulometric and mineral composition and to study their composition, the nature of contacts, bedding, nodules, color, and the thickness of the deposits. In the north of Middle Siberia, Berriasian sediments are represented mainly by sandy, silty, and clayey rocks. An accumulation of gravelly-pebbly material is occasionally found. The rocks are loose, sometimes consolidated to various extents. Strongly cemented rocks occur in individual thin (to 0.7 m) intercalations and in concretions of various form and size.

Three main rock-forming minerals, quartz, feldspars, and leptochlorites, are noted in the sandy and silty rocks. Rock debris makes up 1–3, rarely 5–10%. The first two minerals are encountered everywhere, while the leptochlorites are concentrated in isolated intercalations, sometimes constituting 50%.

Three types of rock are identified according to the quantitative proportion of these minerals among the sands and silts: quartzo-feldspathic, feldspathic-quartz, and leptochloritic.

The paleontological-taphonomic investigations included, along with the determination of the systematic composition of the organic remains, observations of the nature of burial of the fossils and their state of preservation. Traces of the life activity of soft-bodied organisms were also studied. Attention was likewise paid to the absence of fossils, which is in itself a very significant sign.

The following types of burial were distinguished (Zakharov, 1966): a) valves and individual whole shells evenly distributed in the bed; b) coquina accumulations in the form of intercalations, lenses and nests; c) shells buried in situ or near the original place. The fossils were in various states of preservation, from well preserved bivalve specimens to individual dissociated valves and different-sized fragments. Diagenesis of shells was observed (mineralization, compaction, dissolution).

Observations were made of the orientation of the fossils (distinct, weak, absent), the degree of their rounding (not rounded, poorly rounded, well rounded), and of the transport of shells and their fragments (no transport, negligible transport, considerable transport).

The benthos was grouped according to its ethological features. Eleven ethological types were identified and classed into four ethological groups. Species were referred to a particular ethological type on the basis of the ethology of adult specimens. Primarily macrobenthos was taken into consideration in the ethological characterization.

Quantitative assessment of the fossils was conducted in the field. The evaluation was performed according to the following categories: very rare (1–2 specimens) – 1 point, rare (3–5 specimens) – 2 points, frequent (6–10 specimens) – 3, very frequent (11–15 specimens) – 5, many (a few tens of specimens) – 9, very numerous (many tens of specimens) – 30, abundance (hundreds of specimens) – 100 points. The number of points (1, 5, etc.) indicates the proportion of each category in the complex (oryctocenosis). They are used to plot curves showing the amount of benthos in strata. This quantitative assessment is somewhat relative and subjective, but unfortunately, no more convenient method of accurately determining the amount of fossils under field conditions has been worked out. The fairly detailed breakdown proposed rules out gross errors when calculating the proportion of a certain fossil or category.

One of the principal features of the sections studied is the fact that each of them is represented by fossils which were formed in different facial zones of the basin. The following are exposed: on the Kheta and Boyarka rivers, sediments of the basin's littoral zone (upper part of the sublittoral), in different parts of the Boyarka section, sediments of the middle sublittoral, and near Cape Urdyuk-Khaya, the most deepwater (of those studied) deposits (bottom of the sublittoral).

The underlying strata were studied mainly within the upper Volgian substage (zones

Craspedites okensis, Craspedites taimyrensis, and *Chetaites chetae*) and the overlying strata within the lower zone of the Valanginian stage (the *Neotollia klimovskiensis* zone). In order to keep the text short and consistent, we describe the sections by members.

KHETA RIVER

Along the Kheta River, sediments which finds of ammonites place in the upper Volgian substage and the Berriasian stage are found in bluffs and on the towpath on the sector from Gavrilin ulov to 2 km below the mouth of the Bukataya River.

Upper Volgian rocks are represented mostly by silts and Berriasian rocks by fine-grained sands. Concretions of calcareous sandstones and siltstones are frequent.

JURASSIC SYSTEM. UPPER SERIES. VOLGIAN STAGE. UPPER SUBSTAGE

A detailed description of upper Volgian sediments revealed along the Kheta River is given in the book "Key section of Upper Jurassic deposits of the Kheta basin" (Saks et al., 1969). We will just mention here that ammonite finds enabled us to establish all the upper Volgian zones (*Craspedites okensis,* 26.5 m; *Craspedites taimyrensis,* 23.5 m; *Chetaites chetae,* 0.5 m) that can be identified in Siberia. The upper Volgian rocks are represented in the main by leptochloritic greenish brown clayey silts with large (to 2.5–3 m) loaf-shaped and spherical concretions of dark gray calcareous leptochloritic siltstones. The visible thickness of the upper Volgian sediments is 50.5 m.

CRETACEOUS SYSTEM. LOWER SERIES. BERRIASIAN STAGE

About 2 km below the mouth of the Bukataya River, on the left bank of the Kheta, sandy-silty sediments are exposed in which Berriasian ammonites are found. Bedrock outcrops extend along the shore for more than 600 m at a height of up to 2 m above the river level and are covered with small boulders and pebbles almost all along. No direct contact is observed between the sediments of the upper zone of the Volgian stage *(Chetaites chetae)* and of the lower zone of the Berriasian stage *(Chetaites sibiricus).* The Berriasian strata dip northward at an average angle of 4–5°. The section was studied in detail in 1969 by means of boreholes and trenches, which gave a clearer idea of the structure of the section, although it led to no appreciable amendments to the results yielded by previous stratigraphic investigations in 1961 (Saks et al., 1965).

Zone *Chetaites sibiricus* (visible thickness 5.0 m)

Layer 1 (visible thickness 4.0 m)

Lithological description. Sand fine-grained, greenish-tobacco in color, with nests and intercalations of plant detritus.

Paleontological description. Ammonites: *Chetaites* sp., *Surites* (? *Subcraspedites*) n. sp., *Subcraspedites (Borealites)* cf. *suprasubditus* (Bogosl.), (*Praetollia* (?) sp., *Hectoroceras* sp. Bivalves: *Astarte veneris* d'Orb. (very many), *Parallelodon* sp. (many), *Entolium nummulare* (Fisch.) (frequent), *Aguilerella anabarensis* (Krimh.) (frequent), *Musculus* aff. *sibiricus* Bodyl. (frequent), *Pinna* sp. (very rare), *Plagiostoma incrassata* (Eichw.) (rare), *Liostrea* cf. *sibirica* Zakh. n. sp. (very rare), *Camptonectes (Boreionectes)* cf. *imperialis* (Keys.) (very rare), *Neocrassina (Anabarella) vai* (Krimh.) (rare), *Cucullaea* ind. sp. (very rare), *Buchia* sp. (very rare), *Protocardia* ind. sp. (very rare). Scaphopoda: *Dentalium* sp. (very frequent). Brachiopoda (rare): *Fusirhynchia micropteryx* (Eichw.), *Ptilorhynchia* aff. *glabra* Dagys, *P.* aff. *seducta* Dagys, *Pinaxiothyris* (?) n. sp. Worms: *Serpula* sp. (frequent).

Ethology. Benthic representatives clearly predominate over semipelagic forms in the oryctocenoses. The benthos consists mainly of the burrowing ethological type (53%), and byssus forms are numerous (22.8%). Other groups low in abundance (Table 1).

Taphonomy. The 0–0.5-m interval contains concretions of calcareous sandstone that

TABLE 1. Layer-by-layer ethological description of macrobenthos from Berriasian sediments on the Kheta River

No. of layer		Sessile		Embedded			Free-lying			Vagrant		
		byssus	cemented	anchored	burrowing	boring (corroding)	silting-up	immobile	adhering by suction	creeping	flapping (swimming)	actively moving
I		22.8	5.7	5.7	53.0		5.7	1.4		1.4	4.3	
II		59.0	8.8	5.7	15.1		7.6	3.8				
III		19.1			59.0		3.1	9.4		9.4		
IV	interval 0–1.7 m	34.0			49.0		2.2	5.4			9.4	
IV	interval 3.7–4.0	4.3		1.4	83.0		2.1	2.8			6.4	
IV	interval 4.5–6.5				50.0					25.0	25.0	
V			50.0					50.0				

are very rich in fossils. The sands have a sparse fauna. *Astarte* and *Parrallelodon* as a rule have both valves, but the shell layer of many shells is destroyed, and the shells are corroded and disintegrate readily. The brachiopods are also bivalve. A *Pinna* shell was found buried in situ. It is difficult to determine the type of fossil cenosis; the invertebrate remains were probably buried near their habitat in moving water and were quickly filled up with sand. Bivalves are very rare. At the level of 1.5 m above the base a shell of *Boreionectes* was found lying on the flat (right) valve. In the 1.5–3.2-m interval fossils were found only in small concretions. The upper part of the layer (the 3.2–4.0-m interval) shows abundant fossils. In the lower part of the interval the bivalves are buried in nests consisting of individual valves and fragments of valves. Valves are often found one inside the other. Whole shells are rare. Individual valves lie with the convex side up in the upper part of the layer. A number of large shells of *Pinna* were buried in situ (Figure 2).

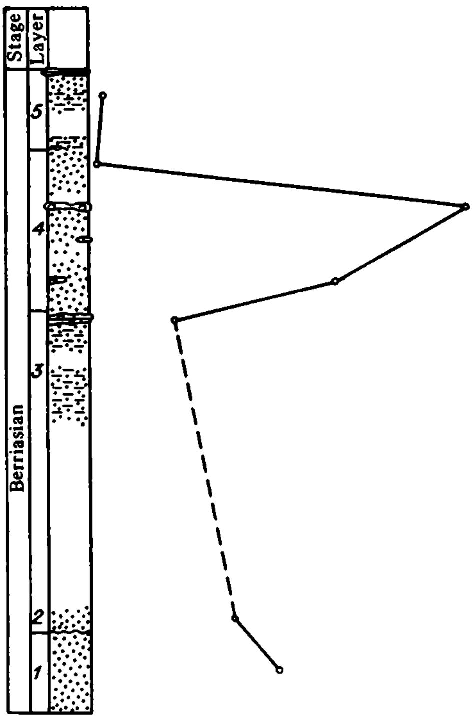


FIGURE 2. Quantitative distribution of benthos in Berriasian sediments on the Kheta River, Khatanga basin

Layer 2 (visible thickness 1.0 m)

Contact with layer 1 eroded along the surface.

Lithological description. Sandstone fine-grained, with glauconite, dark yellow, with irregularly shaped concretions of calcareous sandstone that is dark green, very dense, and viscous. Concretions 10–20 cm long and 3–5 cm in diameter. Majority of concretions without fauna.

Paleontological description. Ammonites: *Chetaites* (?) sp., *Subcraspedites* sp., *Surites* sp., *Paracraspedites* (?) ind. sp. Belemnites: *Cylindroteuthis (Cylindroteuthis) lepida* Sachs and Naln., *C. (C.) luljensis* Sachs n. sp., *C. (Arctoteuthis) repentina* Sachs and Naln., *C. (A.) porrectiformis* And. Bivalves: *Buchia terebratuloides* Lah. (very many), *Boreionectes* cf. *breviauris* Zakh. (rare), *Liostrea sibirica* Zakh. n. sp. (in litt.) (frequent), *Pleuromya* cf. *uralensis* d'Orb. (very frequent), *"Musculus" sibiricus* Bodyl. (very rare), *Astarte (Astarte)* ind. sp. (frequent), *Pinna* ind. sp. (frequent), *Inoceramus* ind. sp. (very rare). Brachiopoda (frequent): *Lenothyris ovalis* Dagys, *Taimyrothyris* cf. *humilis* Dagys, *T.* n. sp., *Pinaxiothyris* (?) n. sp., *Ptilorhynchia* aff. *seducta* Dagys, *P.* aff. *glabra* Dagys. Worms: *Serpula* sp. (rare). Foraminifera: *Marginulinopsis borealis majmetchensis* Bass., *M. chetae* Bass., *Astacolus trigonius* Bass., *Lenticulina* aff. *pseudoarctica* E. Ivan., *Epistomina* ex gr. *reticulata* (Reuss).

Ethology. As in layer 1, benthic remains distinctly predominate over remains of semipelagic forms. Byssus forms are most plentiful (mainly *Buchia*); the cemented, burrowing, silting-up, and anchored ethological types are extremely characteristic, although no one of them predominates over the others.

Taphonomy. Finds of large brachiopods are most frequent at the base of the layer. All shells with two valves. Large (adult) and small (young) specimens encountered together. Ostreidae evenly distributed in the layer. The shells are as a rule whole and well preserved. *Boreionectes* also with two valves, but the shells are frequently broken. *Pleuromya* buried in situ typically found higher up in the section. Small shells of *Astarte* sparsely scattered in the rock. The roof of the layer shows numerous *Buchia:* whole specimens and well preserved individual valves at different ontogenetic stages. In places the rock is enriched with detritus from shells of *Buchia* and other bivalves. The dominant type of fossil cenosis is the autochthonous fossil thanatocenosis.

The fauna was collected from concretions of layers 1 and 2 on the towpath in the sector where beds with *Chetaites* crop out. Ammonites: *Chetaites sibiricus* Schulg., *Ch.* cf. *sibiricus* Schulg., *Paracraspedites stenomphaloides* Swinn., *Subcraspedites (Borealites)* ex gr. *suprasubditus* (Bogosl.), *S. (S.)* ex gr. *anglicus* Schulg., *Praetollia* (?) sp., *Surites (Surites)* cf. *tzikwinianus* (Bogosl.), *S. (S.)* aff. *tzikwinianus* (Bogosl.), *Argentiniceras* (?) n. sp. Belemnites: *Lagonibelus (Lagonibelus) sibiricus* Sachs and Naln. Bivalves: *Astarte (Astarte) veneris* d'Orb. (plentiful), *Neocrassina (Anabarella) vai* (Krimh.) (frequent), *Camptonectes (Boreionectes)* cf. *imperialis* Keys.) (frequent), *Parallelodon* sp. (many), *Pinna* aff. *suprajurensis* d'Orb. (very frequent), *Entolium nummulare* (Fisch.) (frequent), *Cucullaea* sp. (rare), *Musculus* sp. (very rare), *Oxytoma (Oxytoma)* sp. (very rare), *Protocardia* sp. (rare), *Inoceramus* ind. sp. (very rare), *Pseudolimea arctica* Zakh. (very rare), *Buchia volgensis* (Lah.), *B.* cf. *fischeriana* (d'Orb.).

Stratigraphically higher there is a break in the observations. Large boulders cover about 6 m of the section of the Berriasian. The overlying part has been almost entirely stripped by trenches and prospect holes. However, ammonites of the genus *Hectoroceras* were not found in the original bedding. According to 1961 data, the *Hectoroceras kochi* zone occupies 3 m of the section of sandstones, in which the following fauna was discovered: *Hectoroceras kochi* Spath, *Surites (Surites)* cf. *subtzikwinianus* Bogosl., *S. (S.)* n. sp. (aff. *subtzikwinianus* Bogosl.), *Cylindroteuthis* sp., *Buchia volgensis* (Lah.), *"Musculus" sibiricus* Bodyl., *Liostrea* aff. *anabarensis* Bodyl., *Camptonectes (Boreionectes) imperialis* aff. *asiaticus* Zakh., *Entolium demissum* (Phill.), *Pleuromya* sp., *Tancredia* sp. (Saks et al., 1965). In 1969, only one concretion with *Hectoroceras kochi* Spath was found on the towpath between holes 1 and 2, which uncovered beds with *Chetaites.*

Layer 3 (5.0 m)

This layer may be referred to either the *Hectoroceras kochi* zone or the *Surites analogus* zone, since only *Subcraspedites* is found in the original bedding.

Lithological description. Sand fine-grained, silty, micaceous, light brownish green. The 1.0–1.5-m interval contains fragments of mineralized wood, abundant small pebbles of traps, and intercalations and nests of plant detritus. Horizontal stratification noticeable in the 3.0–4.0-m interval.

Paleontological description. Ammonites: *Subcraspedites (Subcraspedites)* sp. (one specimen from the upper part of the layer). Bivalves (top of the layer): *Camptonectes (Boreionectes) imperialis* Keys. (frequent), *Buchia* cf. *volgensis* Lah. (frequent), *Arctica* sp. (frequent), *Cucullaea arctica* Bodyl. (rare), *Protocardia* sp. (frequent), *Tancredia* sp. (many), *Panopea* (?) sp. (frequent), *Astarte (Astarte) veneris* d'Orb. (frequent), *Goniomya* ind. sp. (very rare), *Oxytoma (Oxytoma)* sp. (very rare), *Pinna* ind. sp. (rare). Foraminifera: *Marginulinopsis borealis* aff. *majmetchensis* Bass., M. spp., *Lenticulina* spp., Dentalina spp.

Ethology. Practically only benthos represented in the oryctocenoses. Semipelagic forms very rare. Various shallow-burrowing forms extremely characteristic (59%), byssus type constituting a considerable proportion (19.1%), immobile and creeping organisms present in equal amounts (9.4%).

Taphonomy. Fauna is encountered rarely in the 0–1.5-m interval, mainly in the form of small fragments of valves of *Astarte* (?) and *Tancredia* (?). No fossils found in the 1.5–4.0-m interval. The bulk of the fauna is concentrated at the top of the layer for the most part in large concretions of calcareous silty sandstone, from which well-preserved bivalves were collected. In the sand, on the other hand, fragments of mollusk shells predominate. Type of fossil cenosis not determined.

The following fauna was found on the towpath behind the first heap of large boulders in concretions of calcareous sandstone of varying composition. Ammonites: *Hectoroceras kochi* Spath, *Chetaites chetae* Schulg., *Ch.* sp., *Praetollia* aff. *maynci* Spath, *Surites (Surites)* cf. *subanalogus* Schulg. n. sp., *S. (S.)* cf. *tzikwinianus* (Bogosl.), *S. (S.)* ex gr. *spasskensis* (Nik.), *S. (S.)* n. sp., *Subcraspedites (Ronkinites)* cf. *primitivus* Swinn. Belemnites: *Cylindroteuthis* sp., *Acroteuthis (Acroteuthis)* cf. *explanatoides polaris* Sachs and Naln. Together with *Surites* bivalves were found: *Camptonectes (Boreionectes)* cf. *imperialis* (Keys.) (very frequent), *Arctotis* cf. *anabarensis* (Petr.) (in accumulations), *Entolium* *nummulare* (Fisch.) (frequent), *Tancredia* sp. (frequent), *Panopea* (?) sp. (very frequent), *Buchia volgensis* (Lah.), *B.* cf. *okensis* (Pavl.) (frequent), *Astarte (Astarte) veneris* d'Orb. (many), *Isognomon* ind. sp. (frequent), *Arctica* sp. (many), *Pinna* cf. *romanikhae* Zakh. (rare), *Cucullaea* cf. *arctica* Bodyl. (rare), *"Musculus" sibiricus* Bodyl. (frequent), *Trigonia* ind. sp. (very rare), *Goniomya* ind. sp. (very rare), *Protocardia* sp. (frequent).

Zone *Bojarkia mesezhnikowi* (visible thickness about 10 m)

Layer 4 (6.5 m)

Boundary with layer 3 not observed, apparently passing in sands.

Lithological description. Sand fine-grained, light yellow. Small, loose concretions of ferruginized coquinoid sandstone very often encountered at the base of the layer. Large concretions of calcareous sandstone rich in bivalves confined to the middle part of the layer.

Paleontological description. Ammonites: *Bojarkia* (?) ind. sp. (about 2.5 m from the base of the layer). Bivalves (0–1.7-m interval): *Buchia* ex gr. *volgensis* (Lah.) (very many), *Entolium nummulare* (Fisch.) (many), *Tancredia* sp. (very many), *Camptonectes (Boreionectes) imperialis* (Keys.) (very frequent), *Panopea* (?) sp. (frequent), *Arctica* sp. (many), *"Musculus"* aff. *sibiricus* Bodyl. (rare), *Oxytoma (Oxytoma)* aff. *expansa* (Sow.) (very rare). Foraminifera: *Vaginulina phragmifera* Bass., *Reinholdella (Pseudolamarckina) tatarica* Rom. Traces of life: *Arctichnus* cf. *arcticus* Zakh. (frequent).

Ethology. Remains of semipelagic forms not found. Benthos represented mainly by two ethological groups: sessile (byssus type, 34%) and embedded (burrowing type, 49%).

Taphonomy. This interval is characterized by nestlike accumulations of shell fragments and individual valves. Whole shells are most numerous among *Tancredia* and *Cyprina*. Valves of *Buchia* as a rule dissociated; many shell fragments. Isolated valves of *Boreionectes* sometimes lodged one inside the other and lying parallel to the bedding.

Type of fossil cenosis: allochthonous fossil thanatocenosis.

The 3.7–4.0-m interval is a horizon of calcareous sandstone concretions with an abundance of fauna. Bivalves: *Tancredia* (?) sp. (plentiful), *Buchia* ex gr. *keyserlingi* (Trautsch.) (very frequent), *Mactromya* sp. (frequent), *Pleuromya* sp. (frequent), *Liostrea* aff. *anabarensis* Bodyl. (very rare), *Panopea* sp. (frequent), *Camptonectes (Boreionectes) imperialis* (Keys.) (frequent), *Pinna* cf. *romanikhae* Zakh. (frequent), *Pseudolimea arctica* Zakh. (rare), *Entolium nummulare* (Fisch.) (many), *Astarte (Astarte) veneris* d'Orb. (frequent), *Neocrassina (Anabarella) vai* (Krimh.) (rare), *Arctica* sp. (rare). Brachiopoda: *Lingula* sp. (rare), Terebratulidae (rare). Traces of life: *Arctichnus arcticus* Zakh. (very rare).

Ethology. Semipelagic forms very rare. Benthos exceptionally rich and diverse. Various burrowing forms make up more than 75% of the benthos. Other ethological types (byssus, anchored, silting-up, immobile, and flapping) very sparsely represented.

Taphonomy. Typical of the 2.0–4.0-m interval are nestlike accumulations of fossils in which shells of *Tancredia* predominate. Coquina lenses also encountered. Shells of bivalves scattered haphazardly in these accumulations. Valves of *Buchia* often found one inside the other.

Type of fossil cenosis: allochthonous fossil thanatocenosis.

At the top of layer 4 (4.5–6.5-m interval) an admixture of silt becomes noticeable in the sand. Fauna sparse. Bivalves (isolated finds in concretions): *Quenstedtia* sp., *Protocardia* sp., *Arctica* sp., *Entolium* ind. sp. No fauna found in the sand.

Layer 5 (visible thickness 3.0 m)

Contact with layer 4 clearly recognizable from the change in the composition and color of the rock.

Lithological description. Sand fine-grained, silty, dark gray, micaceous. A lenslike intercalation of calcareous sandstone (0.3 m) occurs at the roof.

Paleontological description. Ammonites: *Bojarkia* ex gr. *mesezhnikowi* Schulg., *Tollia* sp. Bivalves: *Camptonectes (Boreionectes) imperialis* aff. *asiaticus* Zakh. (frequent), *Anomia* sp. (frequent on valves of *Boreionectes*).

Ethology and taphonomy. Only free-lying *Boreionectes* and *Anomia* attached to their valves encountered from among the benthos. *Boreionectes* evenly and sparsely scattered through the layer (mainly in the lower part). Whole shells lie on the less convex (right) valve. They were apparently buried close to their place of habitat.

The ammonites *Surites (Surites)* n. sp. and *Bojarkia* ex gr. *mesezhnikowi* Schulg. and the belemnites *Lagonibelus (Lagonibelus) superelongatus* Blüthg., *Acroteuthis (Acroteuthis) arctica* Blüthg., and *A. (A.) explanatoides* Sachs and Naln. were collected in concretions on the towpath at the level of layers 4 and 5.

VALANGINIAN STAGE. LOWER SUBSTAGE

Farther to the north from the outcroppings of the Berriasian rocks, Lower Cretaceous sediments are submerged under Quaternary sediments. Only some 22 km west-northwest on the left bank of the Kheta, above the mouth of the Tannak River, is there an isolated outcrop of lower Valanginian siltstones and sandstones with *Temnoptychites* sp. (Saks et al., 1959).

BOYARKA RIVER

Deposits that can be dated from finds of fauna to late Volgian, Berriasian, and Valanginian time are distributed in the lower reaches of the Levaya [Left] and Pravaya [Right] Boyarka rivers, after which they are traced for about 20 km in the area where these two rivers come together and farther downstream along the Boyarka. Thick (to 50–100 m) members of rock are exposed in most outcrops for several tens, sometimes hundreds, of meters. The rocks are laid bare in succession both in a single exposure and in a number of separate, similar outcrops, so that the layers can be studied in several sections. The upper Volgian and Berriasian rocks are represented mostly by silts and clays, while the lower Valanginian rocks (*Neotollia klimovskiensis* zone) consist mainly of fine-grained, less often fine to medium-grained, sands. The rocks are weakly cemented. Concretions of calcareous sandstones, siltstones, and clayey limestones are periodically encountered. The layers dip monoclinically northeast at an angle of 1–7°.

JURASSIC SYSTEM. UPPER SERIES. VOLGIAN STAGE. UPPER SUBSTAGE

Zone *Craspedites okensis* (17 m)

Sediments which finds of ammonites place in the upper Volgian substage (*Craspedites okensis* zone) are exposed in the lower reaches of the Levaya and Pravaya Boyarka. Clayey-silty rocks of the upper Volgian substage with erosion are disclosed here, overlying ferruginized siltstones of the middle Volgian substage.

The sediments of the *Craspedites okensis* zone are described in detail in the book "Key section of Upper Jurassic deposits of the Kheta basin" (Saks et al., 1969). The zone consists of clayey-silty rocks of various shades of dark gray and brownish green, in some places of variegated color. Many (10–30% or more) grains of leptochlorites; thin (1–10 cm) intercalations of grayish yellow plastic clay traced periodically. Beaded intercalations and individual concretions of clayey and silty limestones visible throughout the section at various intervals. Remains of ammonites, belemnites, bivalves, foraminifers, and gastropods (very rare) are found.

After a gap in the observations, equal to about 10 m of the section, sediments of Cretaceous age are stripped. No contact is disclosed between them and the underlying upper Volgian rocks in the Boyarka basin. The part of the section missing here (the zones *Craspedites taimyrensis* and *Chetaites chetae* of the upper Volgian substage and *Chetaites sibiricus* of the Berriasian stage) is almost fully exposed, as noted before, on the Kheta River.

CRETACEOUS SYSTEM. LOWER SERIES. BERRIASIAN STAGE

Three zones are identified in sediments of the Berriasian stage in the Boyarka basin: *Hectoroceras kochi, Surites analogus,* and *Bojarkia mesezhnikowi.* Berriasian rocks are laid bare in the lower reaches of the Levaya and Pravaya rivers and farther downstream along the Boyarka along its right bank for a distance of more than 3 km. They are represented primarily by clays, silts, and varieties transitional between these. There are a considerable number of concretions of various form and size, composed of calcareous clays and siltstones; plant detritus and wood remains also present. Rocks saturated with shells of ammonites, belemnites, and bivalves; many foraminifers.

Zone *Hectoroceras kochi* (26.5 m)

Member I (layers I–IV; 15 m)

Lithological description. The lower part of the member (0–4-m interval) contains clayey silt; higher up in the section the rock gradually becomes increasingly finer-grained, passing into silty clay in the 4–6-m interval and into well-sorted clay in the middle part of the member (6–10-m interval). The rock is greenish gray, in parts greenish brown. The silts show thin lenses and small nests that are filled with clay and small (0.1–0.2 m) concretions consisting of calcareous siltstone. A thin (0.2 m) lenslike intercalation of gray silty limestone occurs in the clays in the upper part. The limestone is seamed with fissures that are filled in with calcite. Above this intercalation the clay becomes more silty. A large number of small (0.05–0.15 m) calcareous concretions appear here; they are variously shaped and often contain mollusk shells. After a break (a talus of Quaternary sediments), equal to three meters of the section, a 2-m layer of clays analogous to those described in the 6–10-m interval is revealed.

Paleontological description. Ammonites (very frequent): *Hectoroceras kochi* Spath, *Subcraspedites (Borealites) suprasubditus* (Bogosl.), *S. (B.)* aff. *suprasubditus* (Bogosl.), *Surites (Surites)* cf. *tzikwinianus* (Bogosl.), *S. (S.)* cf. *spasskensis* (Nik.), *S. (S.)* aff. *spasskensis* (Nik.), *Surites (Bogoslovskia)* ex gr. *stenomphalus* (Pavl.). Belemnites (very rare): *Cylindroteuthis (Arctoteuthis)* cf. *baculus* Crickmay, *C. (A.)* cf. *porrectiformis* And. Bivalves: in the 0–4-m interval *Buchia volgensis* (Lah.) (very frequent), *Prorokia transitoria* Zakh. (many), *Inoceramus* ind. sp. (very rare), *Nucula* sp. (rare), *Modiolus* ind. sp. (very rare); in the 4–6-m interval *Prorokia transitoria* Zakh. (frequent); in the 6–15-m interval *Prorokia transitoria* Zakh. (many), *Inoceramus* ind. sp. (frequent), *Modiolus* ind. sp. (very rare), *Buchia* ind. sp. (frequent in places). Gastropoda rare. Foraminifera (rare): *Ammodiscus veteranus* Kosyr., *Marginulinopsis borealis majmetchensis* Bass., *Marginulina glabroides* Gerke et al.

Ethology. The macrobenthos falls into two ethological types from two groups: sessile and vagrant (creeping, sometimes byssus forms predominate) (Table 2). Semipelagic ammonites and belemnites distributed throughout the section of the member.

Taphonomy. Shells of *Prorokia* well preserved in the 0–3-m interval; bivalve specimens predominate, evenly distributed in the rock. The shells of bivalves and ammonites in the concretions are filled with calcite or are empty. The 3.5–4-m interval shows many small lenses composed of fragments of *Buchia* and *Prorokia* (?) shells. Flattened shells of *Prorokia* and ammonites encountered. In the 4–10-m interval poorly preserved mollusk shells are evenly scattered in the rock, without particular orientation; some specimens are flattened. In the 13–15-m interval corroded shells of *Prorokia* are found very often in accumulations. Type of fossil cenosis: allochthonous fossil thanatocenosis with elements of an autochthonous thanatocenosis.

The overlying horizons are revealed on the right bank of the Boyarka at the meeting point of the Levaya and Pravaya Boyarka. The break in the observations is of about 4 m along the section.

TABLE 2. Layer-by-layer ethological description of macrobenthos from late Volgian, Berriasian, and early Valanginian sediments on the Boyarka River

No. of layer	Sessile		Embedded			Free-lying			Vagrant		
	byssus	cemented	anchored	burrowing	boring (corroding)	silting-up	immobile	adhering by suction	creeping	flapping (swimming)	actively moving
Late Volgian time											
XXII–XXIII	43			43					14		
XXVI	35.7			64.3							
Berriasian											
I	28.6								71.4		
III	49.4								50.6		
V	55.6			3.6					40.8		
VI	71.4								28.6		
VII	85.0								15.0		
VIII	66.7			13.3					20.0		
X	81.8								18.2		
XII	70.6			3.9		3.9			11.8	5.9	3.9
XIII	55.2	1.8		6.9		13.8			12.0	6.9	3.4
XIV	34.2			8.6					40.0	8.6	8.6
Early Valanginian											
XV	23.1	4.5		27.7			21.6		16.9	6.2	
XVIa	4.8			5.4		3.0	19.8		61.6	5.4	
XVIb	37.5			25.0			9.4			28.1	
XVII	6.8		4.6	27.2			22.8		27.2	11.4	

Member II (layers V–VI; 7.5 m)

Lithological description. Clay silty, in places with a high (28.7%) concentration of fractions > 0.001 mm. Higher up in the section of the member there is a certain increase in the content of silty material, and the rock becomes a clayey silt. Its color is greenish gray, in places yellowish brown (around nests with plant detritus). Nests, and in the upper part of the member a thin (0.05–0.1 m) intercalation of grayish yellow plastic clay, are periodically observed. Horizons and individual concretions of calcareous siltstone traced throughout the member. The size of the concretions is from 0.02 to 0.15–0.2, more rarely 0.5 m, and their form is various (ellipsoidal, pear-shaped, dumbbell-like, beaded intercalations).

Paleontological description. Ammonites (frequent): *Hectoroceras kochi* Spath, *Sub-*

craspedites (Subcraspedites) anglicus Schulg. n. sp., *S. (S.) pressulus* (Bogosl.), *S. (S.) subpressulus* (Bogosl.)., *S. (S.)* aff. *subpressulus* (Bogosl.), *S. (Ronkinites) rossicus* Schulg. n. sp., *Surites (Surites)* cf. *clementianus* (Bogosl.), *Phylloceras* sp. Belemnites (frequent): *Cylindroteuthis (Arctoteuthis) baculus* Crickmay, *C. (A.) repentina* Sachs and Naln., *Lagonibelus (Lagonibelus) elongatus* (Blüthg.), *L. (L.) sibiricus* Sachs and Naln., and others. Bivalves: *Buchia volgensis* (Lah.) (very frequent), *B. fischeriana* (d'Orb.) (frequent), *B. uncitoides* (Pavl.) *(rare)*, *B. lahuseni* (Pavl.) (rare), *B. unschensis* (Pavl.) (rare), *B. terebratuloides* (Lah.) (rare), *B. andersoni* (Pavl.) (rare), *B. okensis* (Pavl.) (frequent), *Inoceramus* ind. sp. (frequent), *Astarte* sp. (rare), *Nucula* sp. (rare), *Lucina* (?) ind. sp. (rare). Apart from these bivalves, the following are found in the upper part of the member: *Prorokia* ind. sp. (frequent), *Oxytoma (Oxytoma)* ind. sp. (very rare). Brachiopoda: *Lingula* ind. sp. (very rare). Foraminifera (rare): *Astacolus trigonius* Bass., *Lenticulina* aff. *sossipatrovae* Gerke and E. Ivan., *L. gudinae* E. Ivan.

Ethology. Sessile (mainly byssus) bivalves dominate the benthos; creeping forms are present in smaller numbers. The burrowing type is represented by a few *Lingula.*

Taphonomy. In the 0–4.5-m interval fossils are most numerous at its beginning, *Buchia* being especially abundant. On the whole, however, the shells are relatively evenly distributed through the layer. Whole specimens frequently encountered. In loose rock the shells are flattened and oriented parallel to the bedding; in concretions they are in an excellent state of preservation. Type of fossil cenosis: allochthonous fossil thanatocenosis with elements of autochthonous thanatocenoses. In the 2.5–7-m interval fossils are found either in the form of individual specimens or in small accumulations of 2–4 specimens. Large valves of *Inoceramus* and small shells of *Prorokia* are buried together. Small *Astarte, Buchia, Prorokia,* and *Nucula* are often represented by specimens with both valves. Shells well preserved. In the upper part of the member large *Buchia* and small *Inoceramus* are discovered together. Type of fossil cenosis: primarily autochthonous fossil thanatocenoses. Contact with overlying member even.

Zone *Surites analogus* (24.2 m)

Member III (layers VII–VIII; 11.5 m)

Lithological description. Silt clayey, greenish gray, in the upper half of the member mainly gray with nests of a chestnut-brown color. Intercalations enriched with small (0.05–0.15 m), elongate concretions composed of calcareous sandy siltstone periodically noted. Small patches with phosphatic substance sometimes observed in the concretions. A lenslike intercalation 0.5–0.7 m thick of gray calcareous siltstone, heavily crevassed, occurs in the 5.5–6-m interval. The crevasses are filled with calcite. A considerable admixture (11.5%) of sandy material is contained in the concretions of calcareous siltstone in the upper part of the member.

Paleontological description. Ammonites (frequent): in the 0–5.5-m interval *Subcraspedites (Subcraspedites) anglicus* Schulg. n. sp., *S. (S.)* ex gr. *pressulus* (Bogosl.), *Subcraspedites (Ronkinites)* aff. *primitivus* Swinn., *Surites (Surites) analogus* (Bogosl.), *S. (S.)*

subanalogus Schulg. n. sp.; in the 5.5–11.5-m interval *Surites (Surites) analogus* (Bogosl.), *S. (S.) subanalogus* Schulg. n. sp., *S. (S.) clementianus* (Bogosl.), *S. (S.)* cf. *clementianus* (Bogosl.). Belemnites (frequent): *Cylindroteuthis (Arctoteuthis) baculus* Crickmay, *C. (A.) repentina* Sachs and Naln., *Lagonibelus (Lagonibelus) superelongatus* (Blüthg.), *L. (L.)* cf. *sibiricus* Sachs and Naln., L. (L.) *gustomesovi* Sachs and Naln., *Pachyteuthis (Pachyteuthis) subrectangulata* (Blüthg.). Bivalves: *Buchia volgensis* (Lah.) (very many), *B. okensis* (Pavl.) (frequent), *B. subokensis* (Pavl.) (rare), *B. spasskensis* (Pavl.) (rare), *B. trigonoides* (Lah.) (rare), *B. fischeriana* (d'Orb.) (very rare), *Camptonectes* cf. *lens* Sow., *Nucula* ind. sp. (frequent), Pectinidae gen. and ind. sp. (very rare), *Pleuromya uralensis* d'Orb. (rare). Foraminifera (very rare): *Marginulina glabroides* Gerke, *M. zaspelovae* Rom., *M. secta* Bass., *Lenticulina pseudoarctica* E. Ivan. et al.

Ethology. The majority (to 85%) of all the finds of benthos are byssus forms, mainly *Buchia*. Creeping forms relatively rare. Burrowing *Pleuromya* present in upper part of member. About 25% of fossil finds belong to semipelagic ammonites and belemnites.

Taphonomy. Shells of *Buchia* are numerous throughout the member, but two intervals, 0–1.5 and 3–4.5 m (Figure 3), are especially rich in them. Accumulations of individual valves and whole shells of *Buchia* are found here. Specimens are often to be found entombed together, some with the convex valve facing down, others with it facing up. Small (young) shells are buried alongside large ones in some places. The shells are well preserved in the concretions, flattened in the loose rock. In the 1.5–3.0-m interval there are fewer *Buchia* than in the other intervals, but instead there are many well-preserved rostra of belemnites and shells of ammonites buried almost perpendicular to the surface of the bedding. The 5.5–11.5-m interval reveals isolated small lenses consisting of shell detritus. The belemnites are typically well preserved in this interval. Phragmocones are often preserved alongside the rostra. Type of fossil cenosis: weakly displaced fossil allochthonous thanatocenosis with elements of an autochthonous thanatocenosis.

The overlying rocks are revealed 0.3 km downstream. The break in the section does not exceed 3 m.

Member IV (layers IX–X; 7.7 m)

Lithological description. Silt clayey, with a small admixture of sandy material. Rock greenish gray, individual areas brownish yellow. Upper part of the member showing small (5 X 10 cm) nests and lenses (to 1.5 m long) of grayish yellow plastic clay. Intercalations of calcareous siltstone occur at the base of the member and also in the 3.5–3.7-m interval. Individual small (0.1–0.2 m) spindle-shaped, oval or irregularly shaped concretions of calcareous siltstone are distributed throughout the visible part of the member. Some concretions confined to the middle part of the member contain calcium phosphate cement and an appreciable amount (to 5%) of leptochlorites.

Paleontological description. Ammonites (rare): *Surites (Surites) subanalogus* Schulg. n. sp., *S. (S.)* aff. *analogus* (Bogosl.), *Surites (? Bojarkia)* sp., *Lytoceras* sp. Belemnites (rare): *Lagonibelus (Lagonibelus) superelongatus* (Blüthg.), *Cylindroteuthis (Arctoteuthis) repentina* Sachs and Naln., *Pachyteuthis (Simobelus) curvula* Sachs and Naln.,

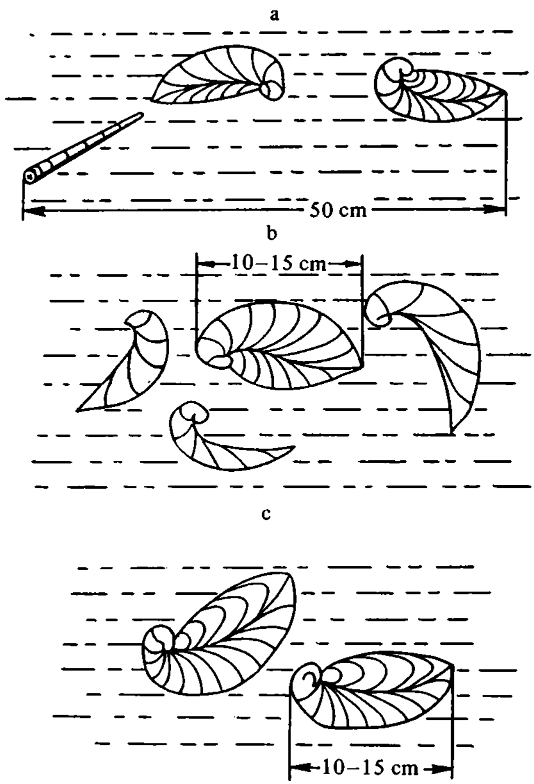


FIGURE 3. Nature of burial of *Buchia* shells in the lower part of member III of layer VII of the Boyarka section: a) at a level of 1.5 m from the base of the member; b) 1.5–3.0-m interval; c) 3.0–4.5-m interval.

Acroteuthis (Acroteuthis) anabarensis (Pavl.). Bivalves (many in the 3.7–7.7-m interval): *Buchia volgensis* (Lah.), *B. uncitoides* (Pavl.), *B. trigonoides* (Lah.). Gastropoda: *Turritella* ind. sp. (rare).

Ethology (for the 3.7–7.7-m interval). Benthos exceptionally homogeneous, mainly of the byssus type *(Buchia)*.

Taphonomy (for the 3.7–7.7-m interval). *Buchia* especially abundant in two intervals, 3.7–4.2 and 6.7–7.2 m, where they form nests and accumulations of separate valves, less often of whole shells. Orientation not clear, but the dominant trend is for the convex valve to face upward. Shells in a good state of preservation. Predominant type of fossil cenosis: autochthonous fossil thanatocenosis. Contact with overlying sediments uneven; nests and pockets (up to 10 cm deep) are seen, filled with grayish yellow plastic clay and small fragments of charred, disintegrated wood.

Zone *Bojarkia mesezhnikowi* (19.6 m)

Member V (layers XI–XIV; 19.6 m)

Lithological description. Silts clayey and sandy-clayey. Rock grayish green, with patches of yellowish brown that are as a rule developed around pieces of charred wood. A 0.2–0.5-m light-gray lenslike intercalation of finely sandy limestone traced at the base of the member. Higher along the section are a few small (to 0.3 m) spherical accumulations, and in the upper part of the member (10.6–19.6-m interval) mass accumulations, of irregularly shaped (ellipsoidal, spindle-shaped, dumbbell-like) concretions of calcareous siltstone. The size of the various-shaped concretions is 0.05–0.07, rarely as much as 0.2 m. A horizon enriched with plant detritus with an abundance of small bivalve shells is observed in the 6.6–6.9-m interval.

Paleontological description. Ammonites (very frequent at the top of the member): *Bojarkia mesezhnikowi* Schulg., *B. bodylevskii* Schulg. n. sp., *Tollia tolli* Pavl., *T. tolmatschowi* Pavl., *Tollia* sp. Belemnites (frequent): *Pachyteuthis (Simobelus) curvula* Sachs and Naln., *Lagonibelus (Lagonibelus) sibiricus* Sachs and Naln., *Cylindroteuthis (Arctoteuthis) porrectiformis* And., and others. Bivalves: *Buchia volgensis* (Lah.) (very many), *Camptonectes (Camptonectes)* cf. *lens* (Sow.) (rare), *Pleuromya uralensis* d'Orb. (rare), *Oxytoma* cf. *expansa* Phill. (very rare), *Nucula* sp. (frequent), *Astarte* ind. sp. (very rare), *Pinna* ind. sp. (rare), *Entolium* ind. sp. (rare), *Inoceramus* ind. sp. (very rare), *Lima (? Lima)* ind. sp. (very rare), and others. Scaphopoda: *Dentalium* ind. sp. (rare). Gastropoda: small forms (very frequent). Brachiopoda: *Lingula* sp. (very rare). Crustacea: rare at the beginning of the member, frequent in the upper part. Crinoidea (stem joints): very rare. Foraminifera: *Marginulina* cf. *occultata* Bass., *M. zaspelovae* Rom., *M. impropria* Bass., *Astacolus bojarkaensis* Bass. n. sp., *Lenticulina raritas* E. Ivan., *L. gudinae* E. Ivan., *Reinholdella (Pseudolamarckina) tatarica* Rom., and others. Traces of life: galleries of detritus eaters (rare).

Ethology. The byssus type predominates (to 70.6%) in the lower part of the member (0–4.5-m interval), mixed with a small number of creeping, flapping, actively moving, burrowing, and silting-up invertebrates. In the 4.5–10.5-m interval the amount of creeping varieties increases somewhat. In the upper part of the member (10.5–19.6-m interval) the benthos is characterized by a large variety of ethological types, the byssus type dominant (55.2%).

Taphonomy. *Buchia* shells evenly distributed in the 0–4.5-m interval; nests, lenslike accumulations, and thin (0.1–0.2 m) intercalations formed in parts. Dissociated valves mostly found; very many specimens of small and medium size. Frequent finds of small gastropods, and at the end of the interval isolated finds of *Pinna* shells, buried in situ. The 4.5–10.5-m interval shows isolated rare specimens of *Buchia.* Small gastropods, *Nucula,* and *Astarte* very frequent. The fauna is very unevenly distributed in this interval. In the 5.5–9-m interval shells of *Pinna* and *Pleuromya* buried in situ are found in abundance. Large, medium-sized, and small shells of *Buchia* entombed together. Whole shells of *Nucula* encountered here. Fossils are rare in the 9–10.5-m interval. In the upper part of the member in the 10.5–19.5-m interval, specimens of *Buchia* are scattered throughout the section, but they are most numerous at the levels of 12, 13, and 14 m. Individuals with both valves relatively rare. Adults (large) and juveniles (small) entombed together. Type of fossil cenosis: allochthonous fossil thanatocenosis with elements of autochthonous thanatocenoses.

After a break in the observations of 5–6 m, a series of sands is revealed which is to be placed in the Valanginian stage according to the ammonite finds.

VALANGINIAN STAGE. LOWER SUBSTAGE

Zone *Neotollia klimovskiensis* (42 m)

Member VI (layers XV–XVI; 16.3 m)

Lithological description. Sand fine-grained, silty in parts, greenish gray, with leptochlorites. Lenslike areas with a fine oblique lamination in the upper part of the member. Lenses up to 0.6 m long, 0.05–0.1 m thick. Stratification emphasized by plant detritus. The layers dip northward and eastward at an angle of up to 5°. In the lower part of the member, in the 0–8-m interval, there are numerous large (to 0.5 m), irregularly shaped concretions of calcareous fine-grained sandstones with a multitude of mollusk shells; smaller (0.15–0.2 m), round concretions of sandstones with carbonate phosphate cement, fragments of charred wood, and structures of *Rhizocorallium* up to 0.5 m long and 0.03 m in diameter are observed. There are somewhat fewer concretions in the 8–14-m interval; two intercalations (one at the beginning and one at the end of the interval) of medium- to fine-grained dark gray sandstone with calcite cement are present. The lower intercalation contains masses of mollusk shells, especially of *Arctica*, which often form lenslike accumulations up to 5 m in extent and 0.1 m thick. The upper part of the member discloses many traces of life; sometimes galleries and burrows cut across the slightly sinuous boundary with the overlying layer.

Paleontological description. Ammonites (rare): *Neotollia klimovskiensis* (Krimh.). Belemnites (frequent): *Lagonibelus (Lagonibelus) sibiricus* Sachs and Naln., *Pachyteuthis (Pachyteuthis) subrectangulata* (Blüthg.), *Acroteuthis (Acroteuthis) chetae* Sachs and Naln., *A. (A.) lateralis* (Phill.), *A. (A.) bojarkae* Sachs and Naln., and others. Bivalves: 0–4-m interval: *Buchia* ex gr. *keyserlingi* (Lah.) (many), *Camptonectes (Boreionectes) imperialis asiaticus* Zakh. (frequent), *Neocrassina (Anabarella) vai* (Krimh.) (frequent), *Astarte (Astarte) veneris* d'Orb. (very rare), *Aguilerella anabarensis* (Krimh.) (very rare), *Arctotis anabarensis* (Petr.) (rare), *Liostrea anabarensis* Bodyl. (frequent), *Lima (Limatula) consobrina* d'Orb. (very rare), *Arctica* sp. (frequent), *Tancredia* sp. (frequent), *Entolium* sp. (rare). Traces of life: *Rhizocorallium* sp. (frequent), *Arctichnus arcticus* Zakh. (very frequent).

4–8-m interval: *Buchia* ex gr. *keyserlingi* (Lah.) (many), *Musculus sibiricus* Bodyl. (very frequent), *Camptonectes (Boreionectes) imperialis asiaticus* Zakh. (many), *Arctica* sp. (numerous in places), *Entolium demissum* Phill. (frequent), *Liostrea anabarensis* Bodyl. (many in the upper part), *Arctotis anabarensis* (Petr.) (in places numerous), *Neo-*

crassina (Anabarella) sp., *Astarte (Astarte) veneris* d'Orb. (frequent), *Tancredia* sp. (very frequent). Gastropoda: very frequent. Traces of life: *Rhizocorallium* sp. (frequent), *Arctichnus arcticus* Zakh. (frequent). Worms: *Serpula* spp. (frequent). Foraminifera: *Glomospirella gaultina* (Berth.) (very rare), *Marginulina* aff. *zaspelovae* Rom. (very rare).

8–14-m interval: at the base of the interval coquina containing *Arctica* sp. (abundance), *Camptonectes (Boreionectes) imperialis asiaticus* Zakh. (very many), *Buchia* ex gr. *keyserlingi* (Lah.) (very frequent), *Entolium nummulare* (Fisch.) (frequent), *E. demissum* (Phill.) (frequent), *Liostrea anabarensis* Bodyl. (frequent), *Musculus sibiricus* Bodyl. (very frequent), *Cucullaea arctica* Bodyl. (rare), *Lima (Limatula) consobrina* d'Orb. (very rare), *Aguilerella anabarensis* (Krimh.) (very rare), *Tancredia* sp. (many). Gastropoda: *Turritella* sp. (very rare).

Above the coquina the following are found: *Buchia* ex gr. *keyserlingi* (Lah.) (many to frequent), *Arctotis anabarensis* (Petr.) (rare to frequent), *Entolium* spp. (rare to frequent), *Liostrea anabarensis* Bodyl. (very rare), *Camptonectes (Boreionectes) imperialis asiaticus* Zakh. (rare). Foraminifera: *Vaginulina phragmifera* Bass. (in litt.) (rare). Traces of life: *Arctichnus arcticus* Zakh. (frequent), galleries of detritus eaters (frequent). Fragments of charred wood up to 0.05 m in diameter are sometimes found.

Ethology. In the 0–8-m interval the benthos is represented by all four main ethological groups in more or less equal amounts: sessile (27.6%), embedded (27.7%), free-lying (21.6%), and vagrant (23.1%). Semipelagic forms are chiefly belemnites, more rarely ammonites.

Creeping bivalves predominate at the beginning of the 8–14-m interval, and there are also many immobile forms. Other types encountered relatively rarely. The ratio of the different ethological groups in the upper part of the interval is similar to that described for the 0–8-m interval.

Taphonomy. Fossils numerous and evenly distributed in the 0–2.0-m interval. Accumulations of *Buchia* shells with two valves typical. Numerous finds of *Tancredia* buried in situ. Oysters usually also with two valves. Relatively many small shells of *Boreionectes* belonging to young specimens. Other bivalves represented as a rule by dissociated valves. Type of fossil cenosis: autochthonous fossil thanatocenosis with elements of an allochthonous thanatocenosis.

In the 2–4-m interval *Buchia* is represented usually by only convex valves that are uniformly scattered through the layer; there are whole oyster shells, generally lying on the convex valve.

In the 4–6-m interval it is the horizon between 5 and 5.5 m that has the richest fauna. *Boreionectes* is particularly plentiful, and the shells of adult and young individuals are entombed together. Most of the shells lie on the flat valve. Many individual valves. This intercalation contains a lens of coquina made up of shells of *Arctotis* entombed in the vertical position ("rose" type of burial, Zakharov, 1966). Although all kinds of forms are found buried together, isolated parts of the intercalation along the strike are enriched some with one, some with another species of bivalve: *Boreionectes, Arctica, Musculus, Arctotis, Buchia.* Oysters often encrust the shells of Pectinidae. Type of fossil cenosis: predominantly weakly displaced allochthonous thanatocenosis with elements of an autochthonous thanatocenosis.

An abundance of fauna is discovered in the 6.0–8.0-m interval. Oysters are especially numerous, *Boreionectes* not so plentiful. Many *Arctica*. Oysters very often with both valves; *Arctica* represented by isolated valves. Fossil thanatocenosis as in the 4–6-m interval.

The taphonomic characteristics of the lower and upper parts of the 8–14-m interval differ markedly. At the bottom of the interval is an accumulation of shells of the coquina type, consisting mainly of shells, individual valves and fragments of *Arctica*, and smaller numbers of *Boreionectes* and *Tancredia*. This is a typical allochthonous fossil thanatocenosis. Fossils are relatively sparse in the upper part of the interval. There are mostly isolated valves of *Buchia*, *Arctotis* and *Entolium*, evenly distributed in the rock, only sometimes forming accumulations. The whole mass of sediments is pierced with the galleries of mud eaters. Small accumulations of fauna are grouped around valves of *Boreionectes*. The shells are in various states of preservation. Type of fossil cenosis: allochthonous fossil thanatocenosis.

The boundary with the overlying member is wavy in areas (length of ridges 0.15–0.2 m, height 0.03 m).

Member VII (layer XVII; 2.3 m)

Lithological description. Sand medium-fine-grained, with leptochlorites, greenish gray, with small inclusions of various form, filled with black clayey-silty rock. These are apparently traces of the life activity of mud eaters and *Arctichnus arcticus*. At a distance of 0.6–0.8 m from the top of the member are many lenses and thin (0.02–0.03 m) horizontal and sloped bands of clay stretching for up to 2 m. An oblique, lenslike, rarely horizontal, stratification is observed, with a dip angle of up to 10° and a dip azimuth 20°NNE. In the upper part of the member the grain size of the material gradually increases, and a small amount of gravel, less often small pebbles, appears. Here are many shells of mollusks, often forming coquinoid intercalations up to 0.1–0.15 m thick. The sand in this part of the member is enriched with leptochlorites and is accordingly brownish black.

Paleontological description. Belemnites (frequent): *Acroteuthis (Acroteuthis) bojarkae* Sachs and Naln. and others. Bivalves: *Buchia* ex gr. *keyserlingi* (Lah.) (frequent), *Camptonectes (Boreionectes) imperialis asiaticus* Zakh. (many), *Entolium nummulare* (Fisch.) (very frequent), *Liostrea anabarensis* Bodyl. (very rare), *Arctica* sp. (many), *Astarte* sp. (frequent). Brachiopoda: Terebratulidae (rare). Traces of life: *Arctichnus arcticus* Zakh. (frequent), *Rhizocorallium* sp. (many).

Taphonomy. No shells were found in the 0–2-m interval, except at the boundary between members VII and VI, where a number of valves belonging to *Buchia* and *Boreionectes* were encountered. Here numerous tubes of *Arctichnus* often transect the boundary, and there are traces of the type of *Rhizocorallium* sp. The fauna in this member is mainly confined to the upper part of the layer. Fragments of bivalve shells predominate. Valves of Pectinidae forming a "coquina pavement." There are sometimes lenslike accumulations of shells that are frequently covered with a fine ribbon of clay. The length of the coquina lenses is up to 1 m, and their thickness is 0.1 m. Type of fossil cenosis: allochthonous fossil thanatocenosis.

Contact with overlying sediments sinuous in areas. Isolated grains of gravel found in the zone of contact.

CAPE URDYUK-KHAYA (PAKS PENINSULA)

On the east shore of Paks Peninsula, near Cape Urdyuk-Khaya to the north and south of the fault of the NNW strike, which has an amplitude of about 25 m (Figure 4), the following are exposed: on the southern upthrown side, where the section is most complete, sediments of the upper Oxfordian, Kimmeridgian, Volgian, Berriasian, and Valanginian (the rocks dip southeast at an angle of 7–30°), and on the northern downthrown side Volgian and Berriasian sediments dipping near the fault line to the southwest at an angle of 9–45°. The rocks on both sides are faulted to a lesser degree, owing to which the same layers, including the boundary layers between the Jurassic and Cretaceous, can be observed repeatedly in a number of exposures (layer 18 and others in Figure 4). The sediments of the upper substage of the Volgian stage conformably overlie the rocks of the *Epivirgatites variabilis* zone of the middle substage (Basov et al., 1970).

JURASSIC SYSTEM. UPPER SERIES. VOLGIAN STAGE. UPPER SUBSTAGE

Zone *Craspedites okensis*

Member VI (exposure 33, layers 10–14; exposure 32, layers 3–7; 7.0 m)

Lithological description. Clay silty, argillite-like, consisting of alternating intercalations of dark gray, brownish gray, and bluish gray. The brownish clay is thin-laminated, platy, while the bluish clay is massive, fragmented (with conchoidal fracture), and greasy to the touch. The platy clays have a higher content of organic matter and pyrite. Thin (0.02–0.03 m) intercalations of plastic gray clays are found which are often jarositized on the weathered surfaces and dark yellow in color, forming distinct, thin interlayers on the dark wall of the exposure. Nests of jarositized yellow clays are sometimes observed.

Nine intercalations of lenslike and loaf-shaped concretions of various form and size (usually from 0.05–0.2 x 0.3–0.7 to 0.4–0.5 x 2.0–3.0 m) and with a complicated structure are traced in the member. The central part of these concretions is represented by brownish gray, almost black pelitomorphic calcareous phosphatic substance, while the peripheral part is made up of lighter-colored fine-grained clayey siderite, less often calcite. There are areas with abundant mottlings of pyrite. The clays and concretions contain shells of mollusks and foraminifers and pieces of mineralized wood up to 2.0 m long (in the lower part of the member); remains of crustaceans are commonly found in the platy clays.

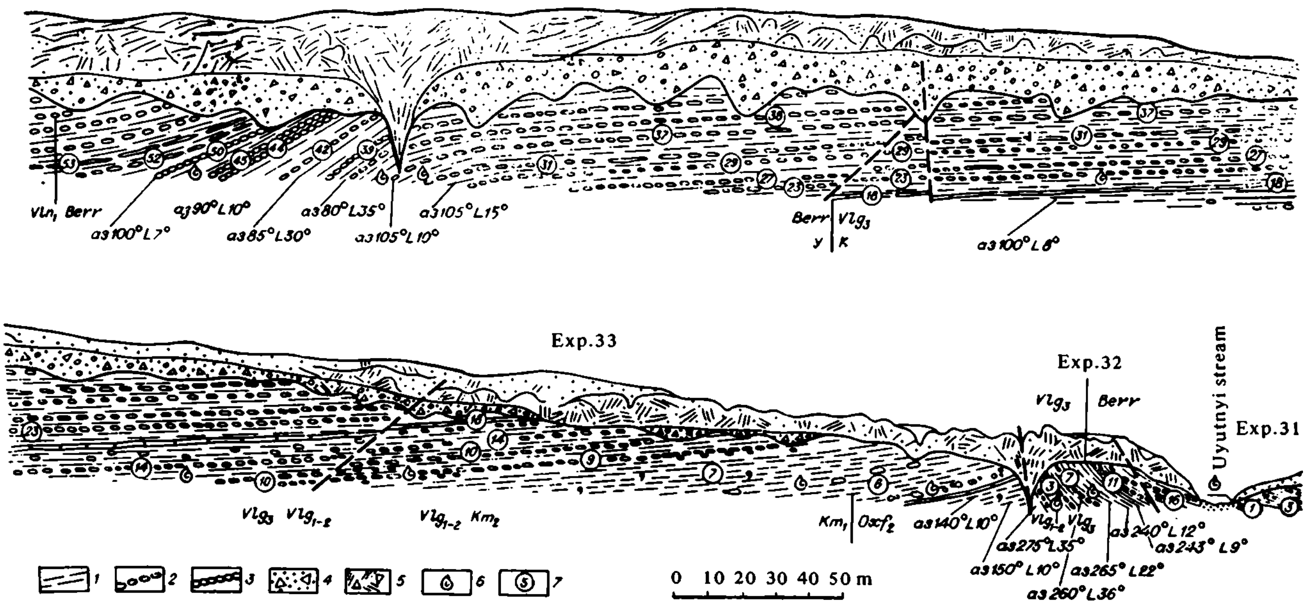


FIGURE 4. Geological profile near Cape Urdyuk-Khaya:
1) clays and silts; 2) concretions; 3) concretionary intercalations; 4) deluvial taluses; 5) tundra cover; 6) chief ammonite finds; 7) No. of layers.

Paleontological description. Ammonites: *Virgatosphinctes* sp. (in the bottom 2.5 m of the member), *Craspedites (Craspedites)* cf. *okensis* d'Orb. (throughout the member except for the bottom 1–1.5 m). The taluses contain *Virgatosphinctes* sp. and occasional *Lytoceras* sp. Belemnites: layer 10 – *Pachyteuthis (Pachyteuthis) apiculata* Sachs and Naln. *Cylindroteuthis (Arctoteuthis) comes* Voron., described by Voronets (1962), is evidently confined to the base of this member. From exposure 32, layer 6 – *C. (A.) porrectiformis* And. Bivalves: *Buchia fischeriana* (d'Orb.), *B.* cf. *subinflata* (Pavl.), *B.* sp., *Lima* sp., *Lima (Limatula)* cf. *consobrina* d'Orb., *Aequipecten (?) arachnoideus* Sok. and Bodyl. (many). According to Voronets (1962), *Buchia subinflata* (Pavl.) is confined to this member. Crustacea: Decapoda. Foraminifera: *Hyperammina* aff. *aptica* Dain and Damp., *Ammodiscus veteranus* Kosyr., *Haplophragmoides emeljanzevi* Schl., *H. schleiferi* Schar., *H. volossatovi* Schar., *Recurvoides* ex gr. *obskiensis* Rom., *Ammobaculites* sp., *Trochammina rosacea* Zasp., *T. septentrionalis* Schar., *Gaudryina* ex gr. *gerkei* (Vass.), *Saracenaria* ? *vermis* (Gerke) (in litt.), *Geinitzinita arctocretacea intercolaris* Gerke, *Marginulina* aff. *impropria* Bass., *Lenticulina* aff. *sossipatrovae* Gerke and Ivan., *Planularia pressula* Schl.

Taphonomy. Flattened shells of *Buchia* found in nests; Pectinidae scattered along the surface of the bedding in accumulations of several specimens together with remains of crustaceans. Remains of *Buchia* are rarely found together with those of Pectinidae and crustaceans. *Buchia* plentiful in intercalations of bluish clays, Pectinidae and crustaceans abundant in brownish laminated clays. Type of fossil cenosis: weakly displaced autochthonous fossil thanatocenosis.

Zone *Craspedites taimyrensis*

Member VII (exposure 33, layers 15 and 16; exposure 32, layers 8 and 9; 4.2 m)

Lithological description. Clay argillite-like in some areas, in others silty, platy, laminated, dark grayish brown, with subordinated intercalations of bluish gray fragmented clay.

Rounded concretions (0.1–0.2 m), often with ammonite shells in the center, found in the upper part of the member. The central part of the concretions is composed of calcareous phosphorite, the peripheral part of clayey siderite or limestone. Thin, (1–3 mm) lenslike intercalations of gray calcareous clays are confined to the lower part of the member, giving the rock a layered structure. There are three thin (0.02–0.03 m) intercalations of dark gray plastic clays with reticulate texture, pyrite concretions, and three rows of loaf-shaped concretions 0.1–0.3 x 0.5–1.5 m, less often to 4.0 m in size.

Shells of mollusks and foraminifers, remains of crustaceans, and pieces of mineralized wood are found in the clays and concretions.

Paleontological description. Ammonites: *Craspedites (Taimyroceras) canadensis candadensis* Jel., *C. (T.) canadensis pseudosubditus* Jel., *C. (T.) canadensis* aff. *pseudosubditus* Jel. According to Voronets (1962), *Subcraspedites* ex gr. *bidevexus* (Bogosl.), which should be referred to the Berriasian species *Subcraspedites (Ronkinites) rossicus* Schulg. n. sp., is confined to this member. Belemnites from exposure 32, layer 8: *Lagoni-*

belus (Lagonibelus) gustomesovi Sachs and Naln., layer 9: *Lagonibelus* (L.) *sibiricus* Sachs and Naln., *L. (Holcobeloides) sitnikovi* Sachs and Naln. Bivalves: *Buchia subinflata* (Pavl.), *B.* aff. *subinflata* (Pavl.), *B.* cf. *fischeriana* (d'Orb.), *Aequipecten arachnoideus* Sok. and Bodyl., *Lima (Limatula)* ind. sp., *Nucula* sp., Pectinidae. Crustacea: Decapoda. Many galleries of mud eaters. Foraminifera: *Ammodiscus veteranus* Kosyr., *Haplophragmoides emeljanzevi* Schl., *H. schleiferi* Schar., *H. fimbriatus* Schar., *Recurvoides* ex gr. *obskiensis* Rom., *Trochammina* ex gr. *rosaceaformis* Rom., *Orientalia (?) baccula* Schl., *Geinitzinita* cf. *arctocretacea* Gerke, *Marginulina pyramidalis* Koch, *M. subformosa* Bass., *Planularia pressula* Schl., *Saracenaria (?) vermis* (Gerke), *Lenticulina sossipatrovae* Gerke and E. Ivan., *L. modica* Schar., *L.* spp., *Dentalina (?) (Nubecularia ?)* sp.

Zone *Chetaites chetae*

Member VIII (exposure 33, layer 17; exposure 32, layer 10; 1.2 m)

Lithological description. Clay finely platy, thin-laminated, dark gray with a brownish tinge. The clay contains brownish plant remains and globules of pyrite. A thin (0.01–0.03 m) intercalation of gray plastic clays with oblate concretions of pyrite, on the weathered surfaces jarositized, yellow, occurs about 0.7 m from the base of the member.

In the lower part of the member are thin (1–3 mm) lenslike inclusions of light-gray calcareous clays. Two rows of small, ellipsoidal (0.05–0.08 x 0.15–0.50 m) laminated concretions of pelitomorphic calcareous phosphorite of brownish gray color are confined to the member. Mollusk and foraminifer shells and remains of crustaceans are encountered in the clays.

Paleontological description. Ammonites: *Ammonites* ind. gen. and sp., *Phylloceras* (?) sp. The taluses of members VI–VIII enclose finds of *Chetaites* cf. *chetae* Schulg., *Chetaites* sp. (? cf. *chetae* Schulg.), *Chetaites* (?) sp., *Craspedites (Craspedites)* sp. (cf. *okensis* d'Orb.), *Virgatosphinctes* (?) ind. sp. Bivalves: *Buchia* ex gr. *volgensis* (Lah.), *Aequipecten* (?) *arachnoideus* Sok. and Bodyl. (very many). Crustacea: Decapoda. Foraminifera: *Glomospirella intrita* Bass. (in litt.), *Haplophragmoides emeljanzevi* Schl., *H. schleiferi* Schar., *H. volossatovi* Schar., *Ammobaculites* sp., *Trochammina septentrionalis* Schar., *T.* ex gr. *rosaceaformis* Rom., *Gaudryina?* ex gr. *gerkei* Vass., *Marginulina subformosa* Bass., *Saracenaria? vermis* (Gerke), *Dentalina? (Nubecularia)* sp., *Lenticulina raritas* E. Ivan., *Eoguttulina* sp.

Taphonomy. The lower part of the layer reveals many Pectinidae and some *Buchia*. Crustaceans are found more frequently in the middle part of the layer, while Pectinidae are numerous only at the roof. Type of fossil cenosis: predominantly allochthonous fossil thanatocenosis with weak displacement prior to burial.

Zone *Chetaites sibiricus*

Member IX (exposure 33, layers 18–22; exposure 32, layers 11–15; 3.4 m)

Lithological description. Clay, in places argillite-like, with leptochlorite, dark gray, in fine plates, with subordinated intercalations of bluish gray fragmented clay. A number of thin (0.01–0.03 m) intercalations of platelike gray and dark gray clays, in places jarositized, yellow.

There are small loaf-shaped concretions (0.05–0.30 × 0.15–0.40 m) of calcareous phosphorite, phosphate limestone, and clayey siderite of fine-grained structure containing a considerable admixture of organic matter.

A thin sheet (0.03–0.05 m) of dense calcareous phosphorite is present near the base of the member, passing into phosphate limestone toward the roof and the base. The rock is brownish gray in the middle part of the layer and gray in the lower and upper parts. The change of color reflects the sequence of intercalations enriched in phosphatic, calcareous, or organic inclusions, which are oriented parallel to the bedding.

The boundary between the Jurassic and Cretaceous systems is drawn along this layer (Figure 5).

Paleontological description. Ammonites: *Craspedites (?Praetollia)* sp., *Praetollia maynci* Spath, *P. maynci* Spath var. *contigua* Spath, *Craspedites* (?) sp., *Chetaites* (?) sp.,

FIGURE 5. Layer of calcareous phosphorite at the base of member IX of the section near Cape Urdyuk-Khaya. Jurassic–Cretaceous boundary.

Subcraspedites (?) sp., *Subcraspedites* ind. sp. Possibly confined to this member is *Taimyroceras* (?) *bodylevskii* Voron., described by Voronets (1962), which we place in the genus *Subcraspedites (Ronkinites)*. Belemnites: *Lagonibelus (Lagonibelus) superelongatus* (Blüthg.) (layer 19, exposure 33). Exposure 32, layer 12 – *Cylindroteuthis (Arctoteuthis) porrectiformis* And., layer 13 – *Lagonibelus (Lagonibelus) elongatus* (Blüthg.). Bivalves: *Buchia* ex gr. *volgensis* (Lah.), *B.* cf. *volgensis* (Lah.), *B.* cf. *okensis* (Pavl.), *B.* cf. *terebratuloides* (Lah.), *Buchia* sp. juv., *Aequipecten* (?) *arachnoideus* Sok. and Bodyl., *Lima (Limatula)* sp., *Oxytoma (Oxytoma)* cf. *arcticostata* Zakh., *Nucula* sp. Crustacea: Decapoda. Foraminifera: *Recurvoides obskiensis* Rom., *Haplophragmoides emeljanzevi* Schl., *H. schleiferi* Schar., *H. fimbriatus* Schar., *Trochammina rosaceaformis* Rom., *T. parviloculata* Gerke (in litt.) (in the upper part of the zone); *T. septentrionalis* Schar., *T.* ex gr. *polymera* Dubr., *Recurvoides paucus* Dubr., *Geinitzinita* cf. *arctocretacea* Gerke, *Dentalina? (Nubecularia?)* sp., *Marginulina subformosa* Bass., *M. striatocostata* Reuss, *Saracenaria? vermis* (Gerke), *Lenticulina sossipatrovae* Gerke and E. Ivan., *L.* cf. *pseudoarctica* E. Ivan.

Taphonomy. In the 0.1–1.1-m interval the taphonomy is similar to that of member VII; in the 1.1–1.5-m interval there are many Pectinidae in the lower part, numerous *Buchia* in the middle, and abundant Crustacea in the upper part; the 1.5–2.4-m interval shows fewer *Buchia* and Pectinidae than in the preceding interval, and is characterized by small (dime-sized) Pectinidae; in the 2.4–3.6-m interval intercalations enriched with Pectinidae alternate with intercalations enriched with *Buchia* (coquina).

Zone *Hectoroceras kochi*

Member X (exposure 33, layers 23–27; exposure 32, layers 16–18; exposure 31, layers 1a–2 (bottom); 4.0 m)

Clay argillite-like, in places silty, fragmented, bluish gray, interbanded with fine plates of dark gray clay. The last type of clay predominates in the upper part of the member. Yellow jarositized areas are seen on the weathered surfaces.

Numerous small pyrite nodules are present in the rock and 3 rows of lenslike concretions (from 0.1–0.2 x 1–1.5 m to 2–3 m) of clayey siderite with a substantial admixture of phosphate material. Siderite fine-grained, in places pelitomorphic. Individual small concretions of clayey limestone found.

A thin intercalation (0.05–0.1 m) of gray plastic clays is traced in the upper part of the member.

The clay contains many shells of mollusks and foraminifers, and traces of the activity of mud eaters are discerned.

Paleontological description. Ammonites: *Hectoroceras kochi* Spath, *Praetollia maynci* Spath, *P.* aff. *maynci* Spath, *P. maynci* Spath var. *contigua* Spath, *Subcraspedites (Borealites)* sp. In rock taluses of members IX–X are found *Subcraspedites (? Borealites)* sp., *Praetollia* sp., *Surites (? Subcraspedites)* sp. Bivalves: *Buchia* cf. *unschensis* (Pavl.), *B.* cf. *okensis* (Pavl.), *Buchia* sp. (cf. *fischeriana* d'Orb.), *Buchia* cf. *terebratuloides* (Lah.), *B.*

sp. juv., *Aequipecten* (?) *arachnoideus* Sok. and Bodyl., *Lima* sp., *Oxytoma (Oxytoma)* cf. *arcticostata* Zakh., *Camptonectes (Camptonectes)* cf. *lens* (Sow.), *Nucula*. Apart from these, the following were collected in taluses from members IX–X: *Buchia volgensis* (Lah.), *B.* aff. *robusta* (Pavl.), *B.* aff. *uncitoides* (Pavl.). Crustacea: Decapoda (rare). Traces of life: galleries of mud eaters. Foraminifera: *Glomospirella intrita* Bass. (in litt.), *Recurvoides obskiensis* Rom., *Haplophragmoides* ex gr. *emeljanzevi* Schl., *H. schleiferi* Schar., *Trochammina parviloculata* Gerke (in litt.), *Gaudryina gerkei* Vass., *Marginulina pyramidalis* Koch, *Saracenaria ? vermis* Gerke (in litt.), *Lenticulina modica* Schar., *Lenticulina* spp.

Taphonomy. *Buchia* abundant, confined to particular intercalations (lenses), of which four are found in layer 1 of exposure 32. The specimens of *Buchia* are characterized by a thin shell and small size; other typical features: accumulations of young shells found together with adult shells and crushed valves together with well-preserved ones; *Buchia* found together with *Nucula*, many individuals with both valves; orientation parallel to the bedding, individual accumulations of 2–3 specimens or individual valves. Other bivalves rare but well preserved. Smooth Pectinidae and crustaceans become very rare starting from this layer and higher up in the section. The platelike dark argillites contain no fauna. Type of fossil cenosis: autochthonous fossil thanatocenosis.

Member XI (exposure 33, layer 28, exposure 31, layers 52 (top) and 3; 3.5 m)

Lithological description. Clay of finely plated structure, laminated, enriched with organic matter, dark gray with a brownish tinge.

Thin intercalations (0.01–0.05, more rarely 0.1 m) of plastic gray and dark gray clays with numerous oblate concretions of pyrite traced at levels of 1.5, 2.0, 2.4, and 2.8 m from the base of the member. Small nodules of pyrite and thin (1–2 mm) streaks of pyritized clayey limestone of a gray color discernible throughout the member.

Deformed mollusk shells, foraminifers, and remains of crustaceans found in the rock.

Paleontological description. Ammonites: *Subcraspedites (Subcraspedites)* sp. (cf. *anglicus* Schulg. n. sp.). Crustacea: Decapoda. Foraminifera: *Haplophragmoides emeljanzevi* Schl., *H. schleiferi* Schar., *H.* sp., *Recurvoides obskiensis* Rom.

Taphonomy. Numerous remains of flattened ammonite shells characteristic, occurring in groups of a few individuals. Size of shells from 2–3 to 6–7 cm. Fragments of Crustacea confined to definite levels. Type of fossil cenosis similar to an autochthonous fossil thanatocenosis.

Member XII (exposure 33, layers 29 and 30; exposure 31, layers 4 and 5; 2.7 m)

Lithological description. Clay bluish-grayish, fragmented, with conchoidal fracture, in the upper part with intercalations of dark gray, platy, laminated clay. In the lower part of the member there are two rows of small, loaf-shaped concretions (0.1–0.2 × 0.5 m) of clayey fine-grained limestone. The middle part of the member shows lenslike (0.1–0.2 × 2.0 m) concretions of zonal structure, which are represented by phosphatic limestone in the center and by clayey siderite on the periphery. Spindle-shaped and pear-shaped concretions of clayey limestone periodically encountered, oriented perpendicular to the bedding.

Paleontological description. Ammonites: *Praetollia* cf. *maynci* Spath, *Hectoroceras* cf. *kochi* Spath, *Subcraspedites (Subcraspedites)* cf. *anglicus* Schulg. n. sp. The taluses of members X–XII reveal *Surites* (?) sp. and *Subcraspedites* sp. Belemnites very rare. Bivalves: *Buchia* ex gr. *volgensis* (Lah.), *B. okensis* (Pavl.) *Camptonectes (Camptonectes)* ex gr. *lens* (Sow.), *Lima (Limatula)* ind. sp., *Parallelodon* sp. *Nucula* sp., *Oxytoma (Oxytoma)* sp. Brachiopoda: Terebratulidae. Foraminifera: *Glomospirella intrita* Bass. (in litt.), *Ammodiscus veteranus* Kosyr., *Haplophragmoides emeljanzevi* Schl., *H. schleiferi* Schar., *Trochammina parviloculata* Gerke (in litt.), *Gaudryina gerkei* Vass., *Orientalia ? baccula* Schl., *Saracenaria ? vermis* Gerke (in litt.), *Lenticulina* spp.

Taphonomy. The main fossil background is made up of shells of *Buchia*, which are found in accumulations (nests, lenses) of several or tens of specimens. Individual flattened valves predominate. *Nucula* represented as a rule by bivalve specimens and *Limatula* by isolated valves. Terebratulidae forming accumulations consisting of fragments of preapical parts and of shells. Ammonites frequent, brilliant nacreous layer preserved. Finds of belemnites very rare. Type of fossil cenosis: weakly displaced allochthonous thanatocenosis with elements of an autochthonous thanatocenosis.

Zone *Surites analogus*

Member XII (exposure 33, layers 31–36; 4.7 m)

Lithological description. Clay argillite-like, siltyish, in places silty, fragmented bluish gray, with subordinated interlayers of a brownish gray color. Numerous intercalations of lenslike concretions (0.05–0.2 x 0.3–1.5 m) of clayey limestone, plus spindle-shaped concretions of the same composition, oriented with the long axis perpendicular to the bedding. Shells of mollusks and foraminifers encountered.

Paleontological description. Ammonites: *Subcraspedites (Subcraspedites)* cf. *subpressulus* (Bogosl.), *Surites (Surites)* sp., *Surites* ind. sp.

More or less in these layers, in the area of the Uyutnyi stream, which enters the Laptev Sea about 150 m north of the fault from which exposure 33 begins, we find *Surites* sp. and *Subcraspedites* spp. Bivalves: *Buchia* cf. *volgensis* (Lah.), *B.* ex gr. *volgensis* (Lah.), *Buchia* sp., *Nucula* sp. Traces of life: galleries of mud eaters. Foraminifera: *Ammodiscus* sp., *Glomospirella intrita* Bass. (in litt.), *Recurvoides obskiensis* Rom., *Haplophragmoides emeljanzevi* Schl., *Ammobaculites gerkei* Schar., *Trochammina parviloculata* Gerke (in litt.), *T.* ex gr. *rosaceaformis* Rom., *Gaudryina gerkei* Vass., *Orientalia ? baccula* Schl., *Marginulina* ex gr. *robusta* Reuss, *M.* aff. *subformosa* Bass., *Lenticulina sossipatrovae* Gerke and E. Ivan., *L. gudinae* E. Ivan., *Geinitzinita arctocretacea intercolaris* Gerke.

Taphonomy. Numerous shells of *Buchia* typical of the member. Large individuals predominate in the upper part of layer 31; in layers 32 and 33 the *Buchia* shells form lenslike accumulations in which large and small specimens are entombed together; in layer 34 small shells predominate, while in layers 35 and 36 *Buchia* is not as frequent as in the underlying layers, and the shells are evenly distributed. *Buchia* dominates the intercalations of bluish clays. Type of fossil cenosis: allochthonous thanatocenosis with elements of an autochthonous thanatocenosis.

Zone *Bojarkia mesezhnikowi*

Member XIV (exposure 33, layers 37 and 38; 7.8 m)

Lithological description. Clay argillite-like, in places silty, fragmented, bluish gray, with intercalations (to 0.1 m) of fine-platy brownish gray clay. Three thin intercalations (0.01 m) of plastic gray clays noted in the member.

At the bottom and in the middle of the member are two thin (0.2–0.3 m) concretional intercalations of clayey sideritized limestone with nests of calcareous cryptocrystalline phosphorite. In addition, individual small concretions (to 0.1 x 0.2 m) of clayey limestone are found in the member.

Paleontological description. Ammonites: *Bojarkia* sp., *Surites* ind. sp., Belemnites: *Cylindroteuthis (Arctoteuthis) porrectiformis* And. Bivalves: *Buchia* ex gr. *volgensis* (Lah.)), *B.* sp. (? cf. *uncitoides* Pavl.), *B.* ind. sp., *Lima (Limatula)* sp., *Oxytoma (Oxytoma)* cf. *arcticostata* Zakh., *Plagiostoma* sp., smooth Pectinidae. Foraminifera: *Glomospirella intrita* Bass. (in litt.), *Recurvoides obskiensis* Rom., *Haplophragmoides* ex gr. *schleiferi* Schar., *Ammobaculites* spp., *A. gerkei* Schar., *Gaudryina gerkei* Vass., *Marginulina pyramidalis* Koch, *M. impropria* Bass., *Lenticulina sossipatrovae* Gerke and E. Ivan., *L.* cf. *gudinae* E. Ivan.

Taphonomy. At the level of 0.3 m from the base a noncontinuous thin intercalation of coquina composed of whole shells and individual valves of *Buchia* can be traced. Well preserved specimens clearly predominate. Thin intercalations, very rich in fauna, at the level of 2.0 m. Shells well preserved. In the upper part of the member (layer 38) there is an abundance of *Buchia* in intercalations of bluish gray clays; *Buchia* is more sparsely distributed in the brownish clays. Valves not crushed. Type of fossil cenosis close to an autochthonous fossil thanatocenosis.

Member XV (exposure 33, layers 39–44; 17 m)

Lithological description. Clay argillite-like, in the upper part of the member silty, consisting of alternating intercalations of two types: fragmentary bluish gray and platy brownish gray. Thin intercalations (0.05–0.1 m) of brown plastic clays occasionally encountered.

About 22 rows of concretions of various shape and size occur in the member. Most of them are loaf-shaped, 0.1–0.3 x 0.3–0.5 m, less often to 1.0–2.0 m. They are composed of clayey, sometimes sideritized gray limestone. Some of the rows of concretions have a zonal structure, the center filled with calcareous phosphorite, the peripheral part mainly with sideritic limestone.

Paleontological description. Ammonites: *Tollia* cf. *emeljanzevi* Voron., *T.* cf. *tolli* Pavl., *T. subtilis* Voron. Bivalves: *Buchia* ex gr. *volgensis* (Lah.), *B.* cf. *inflata* (Lah.), *Nucula* sp., *Oxytoma (Oxytoma) articostata* Zakh. Gastropoda: *Eulima* (?) sp. Traces of life: galleries of mud eaters. Foraminifera: *Ammodiscus* sp. (small), *Glomospirella intrita* Bass. (in litt.), *Recurvoides obskiensis* Rom., *Haplophragmoides* ex gr. *schleiferi* Schar., *Haplophragmoides* sp., *Ammobaculites* aff. *gerkei* Schar., *A.* spp., *Trochammina parviloculata* Gerke (in litt.), *Gaudryina gerkei* Vass., *Orientalia? baccula* Schl., *Marginulina pyramidalis* Koch, *M.* ex gr. *robusta* Reuss, *M. impropria* Bass., *Astacolus* aff. *trigonius* Bass., *Planularia pressula* Schl., *Lenticulina sossipatrovae* Gerke and E. Ivan., *L.* aff. *modica* Schar., *L. gudinae* E. Ivan., *Saracenaria* sp.

Taphonomy. As before, shells of *Buchia* constitute the main background among the fossils. There are fewer of them in layer 39 than in layer 38, but large and small forms reappear in abundance in the intercalations of bluish gray clays of layer 40. The shells are crushed, as in the preceding member, and the bulk of the fauna is confined to the intercalations of bluish gray clays. Layer 44 (upper 2 m of member XV) contains many small gastropods. Type of fossil cenosis similar to that of member XIV.

Member XVI (exposure 33, layers 45–51; 9.0 m)

Lithological description. Clays argillite-like, silty, fragmented, bluish gray and dark gray, with subordinated interlayers of brownish gray clays with a finely plated structure. In the upper part of the member the clay becomes more silty and poorly differentiated, dark gray; it contains an intercalation (0.03–0.1 m) of gray plastic clayey silts.

There are about 10 concretional intercalations of gray clayey limestones of loaflike (0.05–0.1 × 0.1–0.3 m) or flattened, almost oblate (0.05 × 0.1–0.2 m) form. Small spindle-shaped (0.02 × 0.1–0.2 m) vertically oriented concretions of clayey limestone are periodically found.

Paleontological description. Ammonites: *Tollia* cf. *tolmatschowi* Pavl., *T. subtilis* Voron., *T.* sp. (cf. *emeljanzevi* Voron.), *Bochianites* sp. According to Voronets (1962), finds of *Tollia tolli* Pavl. and *T. pakhsaensis* Voron. are confined to this part of the section. Bivalves: *Buchia inflata* (Lah.), *B.* cf. *bulloides* (Lah.), *B.* sp. (cf. *bulloides* Lah.), *Nucula* sp., *Lima (Limatula)* sp., *Oxytoma (Oxytoma) articostata* Zakh. Gastropoda: *Eulima* spp. Foraminifera: *Glomospirella gaultina* Berth., *Gl. intrita* Bass. (in litt.), *Recurvoides obskiensis* Rom., *Haplophragmoides* ex gr. *latidorsatus* Born., *H.* sp., *Gaudryina gerkei* Vass., *Ichthyolaria* ex gr. *tjumenica* Tylk., *Marginulina pyramidalis* Koch, *M.* ex gr. *robusta* Reuss, *Saracenaria* sp., *Lenticulina gudinae* E. Ivan. et al.

Taphonomy. The taphonomy is similar to that in the underlying member XV. Numerous intercalations, rich in gastropods, are characteristic. *Nucula* found as a rule in intercalations of brownish clays. Open bivalve specimens predominate, oriented parallel to the bedding.

VALANGINIAN STAGE. LOWER SUBSTAGE

Zone *Neotollia klimovskiensis*

Member XVII (exposure 33, layers 52–60; 13.6 m)

Lithological description. Clay argillite-like, in places silty, fragmented, in small areas fine-platy, gray and dark gray.

Five persistent concretional intercalations of clayey limestone are observed; they are of flattened lenslike (0.05–0.07 x 0.1–0.2 m) and loaflike (0.2–0.3 x 0.4–0.5 m) form. In addition, there are individual small oval and rounded concretions (0.02 x 0.04 m, less often 0.1 x 0.1 m) and also columnar concretions of the same composition.

Shells of mollusks, traces of detritus eaters, and foraminifers are occasionally encountered.

Paleontological description. Ammonites: *Tollia* (?) sp. Taluses of layers 52–60 contain *Neotollia* aff. *klimovskiensis* (Krimh.). Belemnites (layer 53): *Acroteuthis (Acroteuthis) arctica* Blüthg. Bivalves: *Buchia* ind. sp. (? cf. *bulloides* Lah.), *Nucula* sp., *Lima (Limatula)* sp., *Oxytoma (Oxytoma)* sp. Gastropoda: *Eulima* (?) sp. Traces of life: galleries of mud eaters. Foraminifera: *Ammodiscus* (small), *Glomospirella intrita* Bass., *Recurvoides obskiensis* Rom., *Haplophragmoides infracretaceous* Mjatl., *H.* ex gr. *latidorsatus* Born., H. sp., *Ammobaculites?* n. sp. (ex gr. *labythnangensis* Dain), *Gaudryina gerkei* Vass., *Orientalia? baccula* Schl., *Marginulina* ex gr. *pyramidalis* Koch, *Astacolus suspectus* Bass., *Lenticulina* spp., *Globulina chetensis* Bass., *Reinholdella (Pseudolamarckina) tatarica* Rom., and others.

Taphonomy. The distinctive feature of the member is the scarcity of *Buchia.* No specimens at all are found in some layers. *Nucula* is frequently encountered. Traces of life activity (galleries of mud eaters) abundant. Type of fossil cenosis throughout the member: autochthonous fossil thanatocenosis.

Zone *Polyptychites stubendorffi*

Member XVIII (exposure 33, layers 60–65; 9 m)

Silt clayey, consolidated, dark gray, with weakly expressed irregular lamination, passing into a detritus-type silty clay of a darker shade in the upper part of the member. Up to 10 rows of loaf-shaped and lenslike, more rarely rounded, concretions of clayey-silty limestone or clayey siderite are observed in the member. Silicified parts are discerned in the concretions, and grains of pyrite are detected. Size of calcareous concretions from 0.1 x 0.3 to 0.5 x 1.5 m. In addition, there are round or elongate small (0.1 x 0.1 m; 0.02 x 0.1 m) concretions of calcareous phosphorite.

Paleontological description. Ammonites: *Euryptychites* sp. (at the top of the member).

Saks and Shul'gina (Saks et al., 1963) report that *Polyptychites* ex gr. *keyserlingi* Neum. and Uhl., *P. conferticosta* Pavl., and *Tollia tolmatschowi* Pavl. are confined to this part of the section (to the top 9–10 m). Voronets (1962) mentions the presence of *Astieriptychites astieriptychus* Bodyl., *A. astieriformis* Voron., and *Polyptychites conferticosta* Pavl. in the top 10 m of the clays. Belemnites (very rare in the layer): *Acroteuthis (Boreioteuthis) freboldi* (Blüthg.), *A. (Acroteuthis) explanatoides polaris* Sachs and Naln. Bivalves: *Buchia* cf. *inflata* Lah., *B.* ex gr. *crassa* Pavl., *Buchia* sp., *Lima (Limatula) consobrina* d'Orb., *Thracia* (?) sp., *Nucula* sp. Traces of life: galleries of mud eaters. Foraminifera: *Ammodiscus* ex gr. *giganteus* Mjatl., *Glomospirella gaultina* Berth., *Gl. intrita* Bass. (in litt.), *Recurvoides obskiensis* Rom., *Haplophragomoides infracretaceous* Mjatl. *H.* ex gr. *latidorsatus* Born., *Ammobaculites?* n. sp. (ex gr. *labythnangensis* Dain), *Trochammina* sp., *Gaudryina gerkei* Vass., *G.* aff. *gerkei* Vass., *Marginulina pyramidalis* Koch, *M. striatocostata* Reuss, *Lenticulina gudinae* E. Ivan., *L.* cf. *arctica* Schl. (in litt.), and others.

Taphonomy. Faunal remains very rare. Main finds restricted to the concretions lying at the boundary of the layers. Specimens with both valves predominate among the *Buchia*.

CONDITIONS FOR SEDIMENTATION AND EXISTENCE OF FAUNA

The sections of the topmost strata of the Jurassic and lowermost strata of the Cretaceous of the Khatanga Depression are represented almost exclusively by terrigenous rocks: clays, silts, sands, and, occasionally, gritstones. Thin intercalations (from 0.05 to 0.3 m), composed primarily of carbonates, less often of carbonate phosphate formations with a marked admixture of terrigenous material, are found in a considerably lesser quantity.

The overall favorable marine conditions in the Khatanga basin – moderately warm water and a level of salinity normal for the time – promoted extensive development of pelagic and benthic organisms. In sediments formed in late Volgian and Berriasian time we find large numbers and many species of ammonites, belemnites, bivalve mollusks, brachiopods, gastropods, and foraminifers. Galleries and traces of life of *Arctichnus* and mud eaters, remains of echinoderms (stem joints of sea lilies, tests of sea urchins), crustaceans (higher Crustacea and Ostracoda), and Bryozoa are found frequently. Fragments of charred and mineralized wood, spores, pollen, and remains of algae (blue-green and brown) are also often encountered. Three main complexes of facies are identified in the Khatanga late Volgian and early Neocomian basin on the basis of the type of sediments and ecological features: littoral-marine shallow-water facies (upper sublittoral), facies of moderate depths (middle part of sublittoral), and facies of relatively deep waters (lower sublittoral).

LITTORAL-MARINE SHALLOW-WATER FACIES

Sections of the shallow-water littoral-marine Berriasian sediments were studied along the southern side of the Khatanga Depression in the basins of the Kheta, Boyarka, and Popigai rivers. The following facies are identified in this complex: 1) of sandy bottoms – upper part of the upper sublittoral; 2) of silty bottoms – lower part of the upper sublittoral.

Zone of development of the facies of sandy bottoms. Berriasian sediments on the Kheta River and upper Berriasian sediments on the Popigai River are represented by such facies. Evidence of the shallow-water littoral conditions for sedimentation are the finely sandy material, sometimes with an admixture of medium-grained material and the presence of gravel and small pebbles of traps, chalcedony, and silicon. Pieces of charred and pyritized wood and nodules of phosphorites (at the base of the section on the Kheta) and sometimes of pyrite are observed in the sandstones. Erosions are noted in the stratigraphic sections. The littoral-marine sediments are characterized by a cyclicity for the later stages of development of the basin (in the Valanginian) (Yudovnyi and Zakharov, 1965).

The benthic communities also bear witness to the shoaliness. The most characteristic are such rheophilic forms as smooth Ostreidae and large Pectinidae *(Boreionectes), Modiolus, Arctica, Tancredia, Astarte, Aguilerella, Pinna, Parallelodon, Entolium,* and others. Vertical tubes of lugworms (*Arctichnus arcticus* Zakh.), inhabitants of the shallow parts of the basin (Seilacher, 1967), are found. Frequent finds of *Lingula* indicate the closeness of the shoreline. The macrobenthos comprises all the ethological groups, but the oryctocenoses contain predominantly sessile (byssus, cemented, and anchored types) and embedded (burrowing type) invertebrates, that adapted to life in moving water. Almost all the forms encountered in the oryctocenoses belonged to the seston eaters. Mollusks and brachiopods have large, often thick-walled shells. Burial is of three main types: 1) coquina accumulations; 2) whole shells scattered through the layer; 3) group accumulations of mostly whole shells. The allochthonous fossil thanatocenosis is most typical for this type of facies.

Zone of development of the facies of muddy-silty bottoms. The upper Volgian sediments on the Kheta River and the upper Berriasian sediments on the Boyarka River are composed of such facies. The silty rocks of this zone are little differentiated: they contain a good deal of clayey particles and an admixture of fine sandy fraction. The greater distance from the shore and the calmer conditions for sedimentation as compared with the zone of sand deposits are confirmed by the predominance of grains of the epidote-zoisite group over grains of amphiboles in the 0.1–0.05 mm fraction. Intercalations of viscous greenish gray silty clay possibly point to the presence of breaks (pauses) in sedimentation.

The macrobenthos shows a distinct predominance of *Buchia* over other groups. Frequently found are *Nucula*, small (dwarf) *Pinna*, small *Astarte*, small gastropods, and among the Brachiopoda *Ligulina* and remains of higher crustaceans. Traces of mud eaters are numerous. Among the ethological groups a large role was played by the vagrant forms, which favored calm-water conditions. Sessile forms are represented by *Buchia*, which are euryfacial organisms, but are very widely distributed in relatively deepwater sediments. The greatest proportion among the ecological groups of bivalves, not counting *Buchia*, fell to the scavenging detritus eaters *(Nucula)*, and of the other invertebrates, the mud eaters, which swallow the soil. All these forms live in a loose substrate where the near-bottom currents are considerably weakened (Savilov, 1961).

In the zone of muddy bottoms in the lower part of the upper sublittoral, the principal types of entombment are sparse, evenly distributed valves and whole shells of small invertebrates and accumulations of *Buchia* shells. The autochthonous fossil thanatocenosis is widespread.

The foraminifer complexes of the zone of muddy bottoms show a predominance of benthic calcareous forms of the families Nodosariidae, Polymorphinidae, and Ceratobuliminidae, characteristic for the relatively shallow-water peripheral areas of the Berriasian sea of the Khatanga Depression.

The silty sediments of the zone under consideration were often formed near the lower boundary of the upper sublittoral, and therefore they bear some features of sediments of relatively deepwater zones. Examples are the layers of the Upper Jurassic (middle Volgian substage) and Lower Cretaceous (upper part of the *Hectoroceras kochi* zone) on the Boyarka River. These layers, and also the more deepwater sediments included between them, disclose many galleries of mud eaters; remains are found of Taxodonta, Cephalopoda, and *Buchia*, but along with these groups ground-burrowing *Pleuromya* is often found and brachipopods *(Lingula)* are encountered. On the other hand, in the well differentiated silty sediments, which were apparently laid down under the influence of a constant, weak wave action, we already find typically upper sublittoral forms, such as *Entolium, Pinna,* and *Dentalium,* but the shells of these mollusks are small (dwarf forms).

Such are the upper horizons of the upper Berriasian on the Boyarka River.

MARINE FACIES OF MODERATE DEPTHS (MIDDLE PART OF THE SUBLITTORAL)

The sediments of this zone can be seen in sections of upper Volgian and middle Berriasian deposits on the southern slope of the Khatanga Depression in the Boyarka basin. The section of the upper Berriasian on the Maimecha River was probably formed under similar conditions, but no special investigations have been conducted here.

The sediments of this zone are typically finely granular (clayey silts and clays above silts clearly predominate in the sections), and the sedimentation textures are monotonous and indistinct, indicating calm waters and some distance from the shoreline.

The rocks are relatively rich in remains of semipelagic forms: shells of ammonites and rostra of belemnites, found in different stages of ontogenesis. This implies that the cephalopods, which live in zones relatively far from the shore, were not transported prior to their burial.

The benthos is of homogeneous composition: the macrobenthos consists mainly of one species of small Astartidae (*Prorokia transitoria* Zakh.) and one or two species of *Buchia*; one foraminiferan, *Ammodiscus veteranus* Kosyr., dominates the microfauna (upper Volgian sediments). *Prorokia* is sometimes found in abundance, and *Buchia* is also plentiful in places. Small thin-shelled bivalves predominate. The paucity of species and the wealth of specimens, plus the small, thin shells are evidence of an anomalous influence of environmental factors, above all of a relative stagnation and of coldwater conditions related to the considerable depth of the basin. The fossil cenosis is in the main an autochthonous fossil thanatocenosis, although coquinas of *Buchia* and *Prorokia* shells are also found, indicating that the hydrodynamic regime underwent periodic activation.

Deepwater conditions reached their zenith at the very end of the upper Volgian, and right at the beginning of the Berriasian age the sea began to grow shallower, as we perceive from the fact that the forms which crept on the surface of the bottom were forced out of the benthic communities, and the detritus eaters were supplanted by byssus forms, seston eaters, which attached themselves more firmly to the bottom (see Table 2).

FACIES OF THE RELATIVELY DEEPWATER ZONE OF THE SEA (LOWER SUBLITTORAL)

The most complete uninterrupted section of sediments belonging to the relatively deepwater facies was described on the eastern shore of Paks Peninsula near Cape Urdyuk-Khaya. The following phenomena attest to the fact that these sediments were formed in the deepwater zone of the basin: the predominance of well-sorted (often more than 90% of the fraction > 0.001 mm) clayey sediments, the total absence of sand particles and the negligible amount of silt particles, the broad distribution of fine (to foliated) parallel lamination; the rich content of organic matter, phosphates, and iron sulfide, that characterize sediments of the central parts of sedimentation basins; the monotonous composition of the benthos (poor in species, rich in specimens), the abundance of forms readily tolerating an oxygen deficit and the considerable number of thin-shelled bivalves; the predominance, among the agglutinating foraminifers, of forms with a thin wall, composed of well-sorted, very fine-grained material; the wide distribution of autochthonous fossil thanatocenoses among the fossil cenoses.

The most deepwater part of the section corresponds to the upper Volgian stage and the lower half of the Berriasian stage. The sediments of this series have a good deal of clay and an extremely high organic content; the rock is silicified, pyritized, barite-containing. The concretions are mostly of zonal structure: phosphate in the center, limestone on the periphery. The mineral composition of the clays shows a minimum (as compared with other series) content of montmorillonites and mixed-layered formations for a similar content of hydromicas, chlorites, and chamosites. Finely laminate and foliate textures are widespread in the clayey rocks of this part of the section. Such textures, in combination with a high organic content and a large amount of pyrite, are a typical feature of deepwater sediments of recent marine basins with stagnant waters, such as the Black Sea, the Norwegian fjords, and bays off the coast of California (Shepard, 1963). This assumption is confirmed by observations on foraminifers, which in the part of the section under consideration are represented by sandy fine-grained forms (complex with *Haplophragmoides emeljanzevi*). The benthic communities of this series are characterized by an abundance of a few species: *Buchia*, small Pectinidae, and Decapoda. *Limatula, Oxytoma,* and *Nucula* are second-order members of the communities, while Gastropoda, *Parallelodon, Camptonectes,* and Brachiopoda occur incidentally. There are numerous semipelagic forms, ammonites predominating. The chief taphonomic characteristics are 1) the sequence of intercalations enriched some with *Buchia*, others with Pectinidae and remains of crustaceans, the *Buchia* clearly predominating in the bluish gray clays and the Pectinidae and Crustacea in the foliate, finely laminated argillite-like dark brown clays: 2) the joint burial of young, adult, and old specimens in all the oryctocenoses, showing that no transport occurred after death; 3) the extremely thin valves of the Pectinidae, present in various stages of ontogenesis, excellently preserved, dissociated and scattered in the bedding, another indication of very calm hydrodynamic conditions.

A detailed study of these strata reveals that there are typically frequent and quite appreciable fluctuations of various lithological-geochemical indexes: the composition of clay minerals, the content of organic carbon, bitumens, iron, and the ratio of its forms, the composition of absorbed cations, and the nature of the concretions (presence of calcitic, sideritic, carbonate, phosphate, and pyritic formations).

The middle part of the Berriasian stage was formed under similar conditions. However, the marked admixture (5–20%) of silt particles, the appearance of individual grains of leptochlorites, the predominance of calcareous concretions and the development of siderite and zonal phosphate-calcite siderite concretions with a slightly lesser content of phosphates and pyrite are possible indications of somewhat more shallow-water conditions of sedimentation.

Buchia dominates the benthic communities in these strata, but the distribution of the shells in the layers is far from uniform. Smooth Pectinidae and Crustacea become incidental. On the whole, the benthos is qualitatively more heterogeneous than in the preceding strata. Representatives of eight genera of bivalves and brachiopods are found here. The enrichment of the benthos may be associated with improved aeration of the near-bottom waters in connection with the presumed shoaling and the somewhat closer proximity of the shoreline. Among the foraminifers there is a decrease (especially in comparison with the preceding strata) of the number of sandy forms, but these still predominate over the calcareous forms: 8 genera of sandy and 3 genera of calcareous forms.

The sediments of the upper part of the Berriasian were formed under conditions similar to those of the preceding stage. The admixture of silt is negligible (5–10%), and the rocks are dense (argillites). The sodium content is high (to 50%) in the absorbed complex; chlorite and chamosite (60–70%) predominate among the clay minerals, while the remainder (30–40%) is shared almost equally between hydromicas and mixed-layered formations. Calcareous concretions are broadly distributed, and zonal, calcite-siderite, less often phosphate-calcite-siderite formations are present.

As before, the benthos consists mostly of *Buchia*, although its abundance is considerably diminished; smooth Pectinidae and Crustacea are virtually absent. The role of *Nucula* and mud eaters markedly increases in the biocenoses. The amount of sandy foraminifers declines, but these still predominate over the calcareous forms.

The strata of lower Valanginian sediments were formed under conditions which were very different from those for all the other strata of the deposits. The high content of silt particles, the presence of leptochlorite grains, the appearance of a large amount of vermiculite, the reduced content of organic matter, iron sulfide, and other sulfides, and the increased importance of Ca and Mg in the absorbed complex of rocks – all this points to shoaling of the area, the closer proximity of the shoreline, and a weakening of chemical erosion processes. Because of the permanently low organic content in the sediments, stable neutral and slightly reducing conditions arise. The amount of reduction is approximately 0.5% of the C_{org} consumed for the reduction of iron and sulfur.

Buchia still predominates in the benthic communities, but now in much smaller numbers, and the abundance of *Nucula* and small gastropods also drops. Among the foraminifers the proportion of calcareous forms diminishes and the number of sandy forms of shallow-water habit rises. Semipelagic forms are rare.

Hence, in the Khatanga marine basin at the end of the Jurassic and beginning of the Cretaceous we can identify three types of situations characterized by different conditions for sedimentation and the existence of fauna: littoral-marine shallow-water situations, marine situations of moderate depths, and relatively deepwater open sea situations. The various stages in the process of sedimentation and development of the fauna indicate that the conditions did not remain constant in each of these situations during this time.

Shallow-water conditions existed during the whole Berriasian and at the beginning of the Valanginian in the area of the middle reaches of the Kheta River. This area was near the shoreline. Terrigenous material arrived from the land as a result of the destruction of traps. Fine sandy and muddy-sandy bottoms predominated. Salinity was normal or close to normal for the time. Judging from the ecological characteristics of the generic groups of the contemporary benthic representatives (bivalves for the most part), the thermal regime was close to moderately warm. Aeration of the near-bottom waters was constantly normal.

All the hydrological features mentioned above promoted the development of an exceptionally varied and rich benthos, as well as a wealth of semipelagic forms, ammonites and belemnites, some species of which probably found it possible to live in the coastal shallows. Favorable conditions for the development of bottom fauna also existed in the zone of muddy bottoms in the upper sublittoral. The benthos (including microfauna) was heterogeneous, but forms with a large, heavy shell, typical for invertebrates of the zone of sandy and sandy-muddy bottoms, did not live here. Semipelagic forms are numerous and diverse.

The late Volgian and early Cretaceous was a time of maximally developed transgression in the north of Middle Siberia. Following the ingression of the sea, the deepwater facies approached the marginal parts of the Khatanga basin (basin of the Boyarka River). Owing to the proximity to the shoreline and to the Siberian Platform, however, relatively deepwater conditions did not persist here as long as in the area of Paks Peninsula. Combined lithological and biofacial analyses show that a marine situation with depths of the middle sublittoral existed in this area. The gas regime was close to normal, probably mainly on account of the vertical circulations, although there may have been periodic roiling of the sediment by wave activity and also oxygen starvation of the benthos in different periods. The bottoms were soft, clayey-muddy, possibly boggy. The sedimentation process was fairly stable, although at the beginning of the Berriasian small erosions or extremely slow sedimentation are noted. Starting from the beginning of the Berriasian to the late stages of development of the marine basin (early Hauterivian) the tempo of sedimentation progressively speeded up.

Salinity was normal at the end of the Volgian and in the Berriasian. It is hard to conjecture the temperature of the water. Indirect data, based on a comparison of the benthic communities in question with the more deepwater-littoral, very rich, certainly warmwater communities of the time, imply temperatures close to moderate. The unstable hydrodynamic regime plus, probably, the wide distribution of clayey-muddy biotopes were reflected in the composition of the benthos, which was very poor in species and rich in individuals: dominant among the bivalves were *Prorokia, Buchia,* and *Inoceramus,* and among the foraminifers one species, *Ammodiscus veteranus* Kosyr.

Very deepwater conditions in the lower part of the sublittoral and, possibly, at times even more deepwater conditions existed in the area of Paks Peninsula. Situated in the eastern part of the Khatanga sea-strait, this area was the middle part of the basin at its exit into the open sea. The considerable distance from the shoreline and from the mobile areas of land and coast contributed toward the stability of the marine situation holding sway there.

Combined lithological and biofacial analyses show the overall conditions for sedimentation and faunal existence to be the following. In the area in question marine conditions prevailed with depths of the order of 200 m, maybe more (for instance, during the formation of dark brown argillites devoid of benthic mollusks but rich in remains of higher Crustacea and small smooth Pectinidae, which may have lived on floating algae). Aeration of the near-bottom waters was at times very poor; vertical streams of water predominated, and wave action was not expressed. Organic detritus in the suspended state was present in the water in an amount sufficient to ensure the vital activity of the benthic filter feeders. The water was transparent, the light penetrating to great depths. Salinity was normal for the time. The temperature of the near-bottom waters was moderately low. Owing to the absence of erosions, conditions were right for uninterrupted sedimentation, and therefore, despite the slow rate at which the sediments were laid down, quite thick strata of clayey rocks managed to form. The rate of sedimentation apparently accelerated during the period between the lower Berriasian and the Valanginian due to steadily progressive, though slight shoaling of the area.

Although sedimentation conditions in the deepwater zone of the Khatanga basin were similar in late Volgian and early Cretaceous time, they were not constantly uniform. This is borne out by the above facial analysis, which enables us to distinguish several stages in sedimentation*:

3rd stage – late Volgian-early Berriasian (members VI–IX);

4th stage – late Berriasian (members X to the bottom of XV) with two substages: early (exposure 33, layers 23–37) and late (exposure 33, layers 38–42);

5th stage – end of Berriasian-early Valanginian (top of member XV to member XVIII) with two substages: end of Berriasian (exposure 53, layers 43–51) and early Valanginian (exposure 53, layers 52–65).

In a few cases the boundaries of these stages coincide with the boundaries of major stratigraphic units (stage, substage). For example, the boundary between the second and third stage coincides with the boundary between the middle Volgian and upper Volgian substages; the boundary between the fifth and sixth stages coincides with that between the Berriasian and the Valanginian stages. Sometimes, however, a stage of sedi-

* The first two stages cover upper Oxfordian-middle Volgian sediments and are not considered here (Basov et al., 1970).

mentation does not correspond to the volume of a stratigraphic unit. An example is the third stage, which encompasses the upper Volgian beds and the lower horizons of the Berriasian. Meanwhile, it should be noted that even though sedimentation conditions in these two consecutive stratigraphic units were extremely similar in the deep-water zone of the basin, a thin layer (0.02–0.03 m), composed of calcareous phosphate rock, passes very distinctly along their contact (between the zones *Chetaites chetae* and *Chetaites sibiricus*) and is not repeated anywhere else in the section. This layer bears witness to the marked (but apparently short-lived) change in the conditions of sedimentation.

STRATIGRAPHIC CONCLUSIONS

A zonal division of the Berriasian deposits of northern Siberia and the establishment of the lower and upper boundaries of the Berriasian are based on a detailed study of two types of section: the littoral silty-sandy facies of the Kheta and Boyarka rivers and the clayey facies of the open sea on Cape Urdyuk-Khaya (Paks Peninsula). In the first type of section the Jurassic-Cretaceous boundary, coinciding with the lower boundary of the Berriasian stage, was not observed directly in exposures. In the key section on the Boyarka, between outcrops of sediments of the *Craspedites originalis* subzone of the *Craspedites okensis* zone of the Volgian stage and the sediments of the Berriasian *Hectoroceras kochi* zone there is a break in the exposures which should include the zones *Craspedites taimyrensis* and *Chetaites chetae* of the Volgian stage and the zone *Chetaites sibiricus* at the base of the Berriasian. On the Kheta River, the section of the Volgian stage above the mouth of the Bukataya River ends with the zone *Chetaites chetae.* About 2 km below the mouth of the Bukataya, Mesozoic outcrops begin from the *Chetaites sibiricus* zone with a Berriasian complex of fauna: *Subcraspedites (Pronjaites) bidevexus* (Bogosl.) and *Surites (Surites)* cf. *tzikwinianus* (Bogosl.). However, no direct contact between Upper Jurassic and Lower Cretaceous strata is observed there. It may be assumed that the gap between the exposures is not large and that in the biostratigraphic respect the section is not interrupted, since representatives of the genus *Chetaites* are present in both cases. The drawing of the Jurassic-Cretaceous boundary between the *Chetaites chetae* and *Chetaites sibiricus* zones on the Kheta River is supported in the uninterrupted section on Cape Urdyuk-Khaya, despite the different sedimentation conditions in these two areas of the basin.

The Berriasian stage, represented by clays 53 m thick, is a continuation on Cape Urdyuk-Khaya of the clayey sediments of the Volgian stage without any apparent change in their composition, and it is only according to the replacement of Volgian by Berriasian ammonites that it is possible to draw the boundary between the two systems. A layer of dense calcareous phosphorite 3–5 cm thick is confined to this boundary. About 1.5 m below this layer *Craspedites (? Taimyroceras) canadensis* Jeletzky was found, and 0.3 m above this find *Chetaites* sp. (? cf. *chetae* Schulg.) of late Volgian age. About 30–40 cm above the layer (?) *Chetaites* sp. and *Praetollia maynci* Spath of Berriasian age were found, and still higher many specimens of *Praetollia,* which in higher strata are found together with *Subcraspedites* and *Hectoroceras.*

Consequently, in the north of Middle Siberia the Berriasian age differs from the Volgian in the disappearance of the genera *Craspedites, Garniericeras, Virgatosphinctes, Aulacosphinctes,* and *Berriasella* and in the appearance of the genera *Paracraspedites, Subcraspedites, Surites, Praetollia, Hectoroceras,* and *Argentiniceras?.* The genera *Bojarkia, Tollia,* and *Virgatoptychites* emerged on the scene somewhat later (Figure 6).

Each of the sections studied has its advantages and disadvantages. In terms of the abundance and state of preservation of the fauna, the Boyarka and Kheta sections have no equal in the Boreal Realm, yet, as we have already mentioned, on the Kheta River we did not observe any direct contact of Berriasian with Volgian and Valanginian sediments.

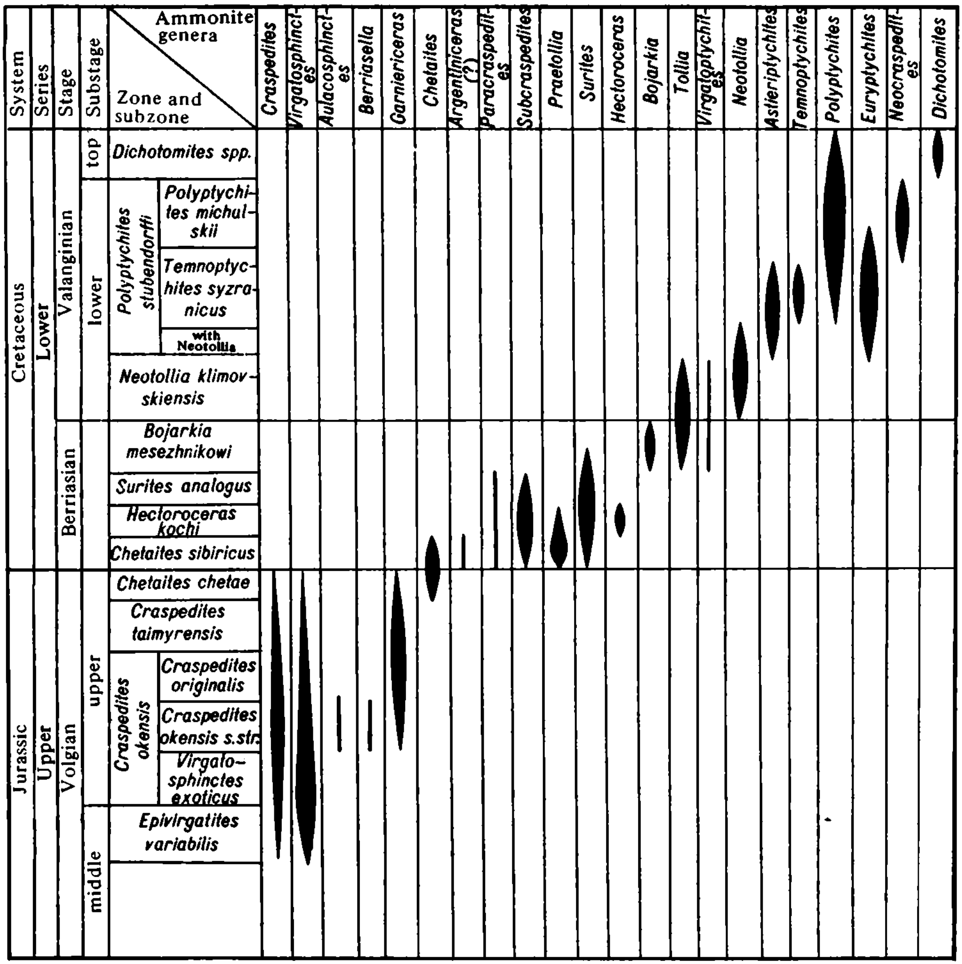


FIGURE 6. Stratigraphic distribution of genera of boreal ammonites

In the key section on the Boyarka, Berriasian sediments 61.3 m thick are admirably exposed, but the lower zone *Chetaites sibiricus*, identified on the Kheta, is absent there, and there is no contact with the Valanginian stage. Both boundaries of the Berriasian are traced in the uninterrupted section of clayey sediments on Paks Peninsula, but the fauna in the clays is poorly preserved (the shells are deformed and flattened, and they often disintegrate when extracted from the rock). Well-preserved ammonites are found only in concretions, but by no means do all the concretions contain ammonites. Only a study of all three sections made it possible to confirm our preconceptions on the position of the Jurassic-Cretaceous boundary. The volume and validity of the three lower zones of the Berriasian *(Chetaites sibiricus, Hectoroceras kochi,* and *Surites analogus)* have now been established, and changes have been introduced into the volume and name of the fourth upper zone of the Berriasian, *Bojarkia mesezhnikowi,* which was formerly called the *Tollia tolli* zone (Saks and Shul'gina, 1969). Earlier (Saks et al., 1965), the three lower zones were lumped together as a subzone in the zone *Surites spasskensis.* Yet each of these one-time subzones has its own specific ammonite complex, so that there is every reason to consider these subzones as separate zones.

In the *Chetaites sibiricus* zone, alongside *C. sibiricus* Schulg. we find *Praetollia,* from the Berriasellidae there is *Argentiniceras* (?), and finally, we have the first representatives of *Subcraspedites, Paracraspedites, Surites,* and *Hectoroceras.* Sediments of this zone are disclosed on the Kheta River, on Paks Peninsula, and on the east slope of the Cis-Polar Urals.

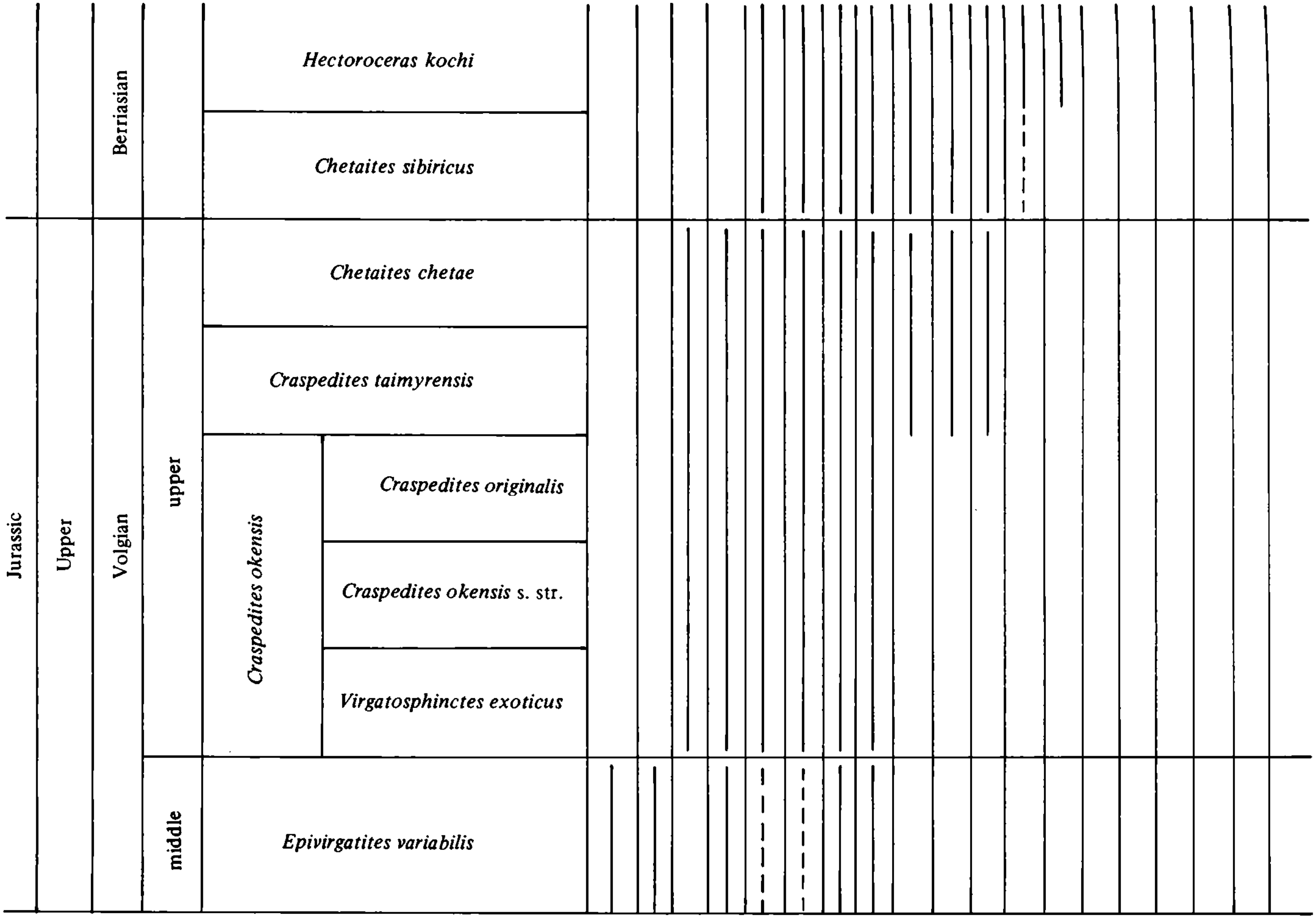
The *Hectoroceras kochi* zone is characterized by *Hectoroceras,* accompanied by *Praetollia, Surites,* and *Subcraspedites.* This zone has an extremely broad distribution in the Boreal Realm – in Siberia, England, Greenland, and Canada – and it may serve as a key horizon for identifying Berriasian sediments.

Finally, the *Surites analogus* zone is characterized by *Surites (Surites* ex gr. *analogus)* and other species of this genus plus *Subcraspedites.* The latter genus became extinct toward the end of the *"Surites analogus"* time. The *Surites analogus* zone or its analogue, the *Surites spasskensis* zone, has an even wider span in the Boreal Realm: Siberia, Eastern Europe, Poland, England, Greenland, Canada.

The upper *Tollia tolli* zone was formerly divided into beds with *Tollia* s. str. and *Tollia* sp. (Saks et al., 1965). The change in the facial composition of the sediments is confined to the beds with *Tollia* sp. on the Boyarka River, silts are replaced by sands with a totally different complex of belemnites and bivalves, and brachiopod genera unknown in the underlying layers appear for the first time. The ammonites from these layers differ from the typical representatives of *Tollia* and are described as the genus *Neotollia* (Saks and Shul'gina, 1969). On the Boyarka, Maimecha, Bol'shaya Romanikha, and Anabar rivers, *Neotollia* is found also higher up, together with such Valanginian ammonite genera as *Temnoptychites, Astieriptychites, Polyptychites,* and *Euryptychites.* We therefore believed it necessary to single out the former beds with *Tollia* sp. into a separate zone, *Neotollia klimovskiensis,* which we referred to the Valanginian stage. The former *Tollia tolli* zone thus shrank in volume. Along with representatives of *Tollia* and *Surites,* ammonites are encountered that are described under the name *Bojarkia* (Saks and Shul'gina, 1969); unlike *Tollia,* these do not pass into the Valanginian, and therefore we

TABLE 3. Distribution of *Buchia* species in Late Jurassic – Early Cretaceous time in northern Siberia

System	Series	Stage	Substage	Zone and subzone		*mosquensis*	*russiensis*	*tenuicollis*	*subinflata*	*terebratuloides*	*trigonoides*	*fischeriana*	*lahuseni*	*volgensis*	*okensis*	*andersoni*	*spasskensis*	*uncitoides*	*crassa*	*inflata*	*keyserlingi*	*sibirica*	*crassicollis*	*sublaevis*
Cretaceous	Lower	Hauterivian	lower	*Homolsomites bojarkensis*																				—
Cretaceous	Lower	Valanginian	upper	*Dichotomites*																			—	—
Cretaceous	Lower	Valanginian	lower	*Polyptychites stubendorffi*	*Polyptychites michalskii*														—	—	—	—	—	
Cretaceous	Lower	Valanginian	lower	*Polyptychites stubendorffi*	*Temnoptychites syzranicus*														—	—	—	—	— - -	
Cretaceous	Lower	Valanginian	lower	*Polyptychites stubendorffi*	with *Neotollia*													- -	—	—	—	— - -	- -	
Cretaceous	Lower	Valanginian	lower	*Neotollia klimovskiensis*														- -	—	—	—	- -		
Cretaceous	Lower	Berriasian		*Bojarkia mesezhnikowi*										—	- -		- -	—						
Cretaceous	Lower	Berriasian		*Surites analogus*						—	—	—	—	—	—	- -	—							
Cretaceous	Lower	Berriasian								—	—	—	—	—	—	- -	—							


Jurassic
Upper
Volgian
middle
upper
Berriasian
Epivirgatites variabilis
Craspedites okensis
Virgatosphinctes exoticus
Craspedites okensis s. str.
Craspedites originalis
Craspedites taimyrensis
Chetaites chetae
Chetaites sibiricus
Hectoroceras kochi

changed the name of the fourth, upper zone of the Berriasian to *Bojarkia mesezhnikowi.*

As we have already mentioned, the belemnite complex changes abruptly in the *Neotollia klimovskiensis* zone. Representatives of the genus *Acroteuthis* and of the subgenera *Acroteuthis* s. str. and *Boreioteuthis* become predominant. There are single species of *Cylindroteuthis (Arctoteuthis), Pachyteuthis (Pachyteuthis)* and *Lagonibelus (Lagonibelus),* which were characteristic for the Berriasian. *Pachyteuthis (Simobelus)* completely disappears. Of the bivalves, such Volgian-Berriasian species as *Buchia fischeriana* (d'Orb.), *B. terebratuloides* (Lah.), *B. trigonoides* (Lah.), *B. lahuseni,* (Pavl.), *B. okensis* (Pavl.), and *B. volgensis* (Lah.) disappear and do not appear at all in the *Neotollia klimovskiensis* zone (Table 3). This zone has a new complex of species that are typical for the Valanginian: *Buchia keyserlingi* (Lah.), *B. sibirica* (Sok.), *B. crassa* (Pavl.), *B. inflata* (Lah.), *Camptonectes (Boreionectes) imperialis asiaticus* Zakh., *Liostrea anabarensis* (Bodyl.), and others. The Brachiopoda encountered in the *Neotollia klimovskiensis* zone are also represented by species that are common with the Valanginian species. These are exclusively endemic forms: *Taimyrothyris humilis* Dagys, *Ptilorhynchia seducta* Dagys, and *Fusirhynchia* sp.

Hence, all the facts speak for the Valanginian age of the *Neotollia klimovskiensis* zone. In addition, in North America and Greenland representatives of *Neotollia* (*N. mutabilis* (Stant.) and *N. (?) paucicostata* (Don.)) are encountered together with or even higher than the typically Valanginian *Kilianella, Thurmanniceras, Polyptychites,* and *Temnoptychites.* In the northwestern part of West Germany in layers with Valanginian *Platylenticeras,* ammonites are found that evidently belong to the genus *Neotollia* (Kemper, 1964, Plate 1, Figure 3). Kemper named them *Tollia tolmatschowi* Pavl. It must be said that individual representatives of *Tollia* do enter Valanginian sediments in the *Neotollia klimovskiensis* zone, but the bulk of *Tollia* species are still typical for the Berriasian.

A monographic study of Berriasian ammonites, belemnites, bivalves, and foraminifers shows that they succeed the Volgian fauna. The ammonites differ from the Volgian complex more than all the other groups. Not counting *Phylloceras* and *Lytoceras,* there is only one common genus which is characteristic for the top of the Volgian stage and the bottom of the Berriasian *(Chetaites).* The other genera appear for the first time in the Berriasian of Siberia: *Paracraspedites, Subcraspedites, Praetollia, Argentiniceras (?), Hectoroceras, Surites, Bojarkia, Tollia, Virgatoptychites.* The last two genera continue into the Valanginian (Figure 6).

The belemnites display a similarity with the Volgian complex, but they are poorer in terms of the number of subgenera and species. The Berriasian features the genera and subgenera *Cylindroteuthis (Cylindroteuthis), C. (Arctoteuthis), Lagonibelus (Lagonibelus), Pachyteuthis (Pachyteuthis),* and *P. (Simobelus).*

The Berriasian bivalve mollusks have many genera and species that are common to the Volgian. Among the *Buchia* we have what is essentially a unique Volgian-Berriasian complex: *Buchia fischeriana* (d'Orb.), *B. terebratuloides* (Lah.), *B. trigonoides* (Lah.), *B. lahuseni* (Pavl.), *B. volgensis* (Lah.), and *B. okensis* (Pavl.), the last two species beginning to appear from the *Craspedites taimyrensis* zone of the Volgian stage. Zakharov concluded that three stages can be distinguished in the development of bivalves in sections of Volgian-early Neocomian age on Cape Urdyuk-Khaya. The late Volgian-early Berriasian complex embraces the zones *Craspedites okensis-Chetaites sibiricus*; the late Berriasian complex corresponds to the zones *Hectoroceras kochi-Bojarkia mesezhnikowi* (lowermost strata); the early Valanginian complex corresponds to the topmost strata of the *Bojarkia mesezhnikowi* zone to the *Polyptychites stubendorffi* zone. In Late Jurassic-Early Cretaceous sediments on the Boyarka River, Zakharov also identified three stages (disregarding the fourth, Hauterivian). The late Volgian-early Berriasian embraces the *Craspedites okensis-Hectoroceras kochi* zones, the later Berriasian corresponds to the *Surites analogus-Bojarkia mesezhnikowi* zones, and the Valanginian corresponds to the *Neotollia klimovskiensis-Polyptychites stubendorffi* zones. It may be noted that the boundaries of the stages drawn for two sections (moderate depths on the Boyarka and the deepwater section on Cape Urdyuk-Khaya) embrace the same epoch but are displaced in time.

Sections of the shallow-water littoral-marine deposits on the Kheta River present a different picture. The complexes of Berriasian bivalve species are clearly differentiated both from the upper Volgian and, partly, from the lower Valanginian complexes. Typical Early Cretaceous species, unknown in Upper Jurassic sediments, are already dominant in the layers with *Chetaites sibiricus*.

According to Basov, in the Jurassic-Cretaceous boundary layers of Siberia the foraminifers form three markedly different complexes. At the base of the Berriasian stage – in the *Chetaites sibiricus* zone, and in some sections also at the bottom of the *Hectoroceras kochi* zone – Volgian elements are preserved in considerable numbers. Higher up, in the *Hectoroceras kochi* and *Surites analogus* zones, typically Berriasian complexes appear. At the top of the Berriasian, in the *Bojarkia mesezhnikowi* zone (sometimes beginning from the *Surites analogus* zone), Berriasian species become particularly diverse, and the first Valanginian elements emerge. Hence, the Berriasian sediments contain a distinctive complex of foraminifers, differing both from the Volgian and from the Valanginian complexes. The foraminifer fauna is transitional between the Volgian and Early Cretaceous (Valanginian-Albian), although in the lower horizons of the Berriasian it is very similar to the Volgian.

Floristic data reveal a substantial difference between the Volgian and Berriasian complexes. Palynological investigations conducted by V.V. Pavlov (1969, 1970) showed a distinct difference in the composition of spore-pollen complexes of the upper substage of the Volgian stage and the Berriasian and also a similarity between the Berriasian and Valanginian complexes. Diverse spores of the genus *Lygodium* appear in the complexes of late Volgian time. In the Berriasian complexes, together with spores of *Lygodium* there are representatives of other genera of the family Shizaeaceae: *Pelletiera* and *Anemia*, spores of the family Gleicheniaceae, and well-differentiated pollen of conifers *Pinus* sp., *P.* subgen. *Haploxylon* sp., *P.* subgen. *Diploxylon* sp., and Taxodiaceae (Cupressaceae). Pavlov concluded that the presence of these spores in the Berriasian enables us to reliably differentiate between the Berriasian and Volgian complexes; where Berriasian and Valanginian sediments are concerned, it is not possible to establish their difference according to spore-pollen complexes.

CIS-POLAR TRANS-URALS

Sediments of the Upper Jurassic and Lower Cretaceous crop out in a number of exposures on rivers flowing down from the east slope of the Cis-Polar Urals. The upper horizons of the Jurassic, the Berriasian stage, and the overlying Valanginian sediments are laid bare in the basin of the Severnaya Sos'va River at a tributary of the Lyapin River (Yatriya River), at the tributaries of the Vol'ya River (Yany-Man'ya and Tol'ya rivers), and at a tributary of the Tol'ya River (Mauryn'ya River). These outcrops were known and studied back in the 1830s (Strazhevskii, 1833–1834; Fedorov, 1884–1897; Ilovaiskii, 1902–1904; Sirin and Shmakova, 1932–1935; and others). The same exposures were later investigated by Mikhailov (1957), Lider (1964), and other workers, and more recently, for specifically biostratigraphic purposes, by Vereninova and Nal'nyaeva (1962–1963), Klimova and Mesezhnikov (1957), and Zakharov, Klimova, Mesezhnikov, Saks, and Yudovnyi (1966). Finally, a most detailed biostratigraphic, paleoecological and lithological, layer-by-layer description of sections was undertaken in 1967–1969 by Gol'bert and Klimova.

YATRIYA RIVER

Exposure No. 1 is situated on the right bank of the Yatriya River about 2 km below the mouth of the Bol'shaya Lyul'ya (34 km from the mouth of the Yatriya). The area studied is composed of sediments of the upper Volgian substage (visible thickness 12 m) and of the Berriasian (thickness 12 m), Valanginian (thickness 54 m), and Hauterivian (thickness 29 m) stages. The rocks dip steeply (at an angle of 35–45°) west (dip azimuth 260–270°).

The zones *Kachpurites fulgens* and *Craspedites subditus* are identified in deposits of the upper substage of the Volgian stage. These are grayish green glauconite-quartz siltstones with sparse fine gravel and clay-leptochlorite cement. Ammonites: *Kachpurites* (?) ind. sp., *Craspedites* sp., *C.* cf. *leptus* Spath, *C. okensis* (d'Orb.), *Garniericeras* (?) ind. sp., *C.* cf. *leptus* Spath, *C. okensis* (d'Orb.), *Garniericeras* (?) ind. sp. (determination by Mesezhnikov). In the top three meters of the section of the upper Volgian substage only two poorly preserved fragments of ammonites were found: *Craspedites? (Taimyroceras?)* ind. sp. and *Ammonites (? Chetaites)* ind. sp.

The boundary between the Jurassic and Cretaceous sediments is a wavy surface of erosion overlain by rocks of the Berriasian stage, which begin with a bottom horizon of gravelly sandstones.

Zone *Hectoroceras kochi* (3.4 m)

Layer 1 (exposure 1; 1.2 m)

Lithological description. Sandstone inequigranular, silty, gravelly, leptochlorite-quartz with leptochlorite nodules and cement (0.5 m). In the upper part of the layer the sandstone is replaced by sandy leptochlorite-quartz siltstone with sparse grains of gravel and glauconite and with clayey-leptochloritic-calcareous cement (0.7 m). The rocks are grayish green with patches and sinters of brown hydrous ferric oxides, slightly consolidated, in places loose. Texture massive. Accumulations of small (to 2–3 cm) round pebbles, large pieces of mineralized wood, and small (1–1.5 cm in diameter) spherical concretions of phosphorite occur in places at the base of the layer. Here also are numerous fragments of shells and internal molds of ammonites, rostra of belemnites, and pieces of shells and internal molds of bivalves, among which representatives of the Jurassic fauna are occasionally noted; there are also small fragments of the underlying Jurassic rocks – glauconitic-quartzose siltstones with sparse flakes of micas and leptochloritic cement. Throughout the layer are encountered large carbonate ammonite-containing concretions, pieces of mineralized wood, remains of bivalves, fragments of shells and internal molds of ammonites, and belemnite rostra. They are more numerous in the siltstones in the upper part of the layer, the bivalve shells in places forming accumulations of dissociated valves and crushed shell.

It is seen under the microscope that the gravelly sandstones consist mainly of grains of sand size, with a predominance (15–20%) of fine sand (0.12–0.2 mm). Grains of coarse sand and gravel up to 10–12 mm in size are more or less evenly distributed in this mass. The proportion of coarse sand and gravel in the rock is around 20%, that of silt slightly less. The grains of gravel are as a rule angularly rounded or semirounded (less often angular), while the sand grains are angular or angularly rounded. They consist predominantly of quartz, and there are individual grains of potassic feldspars. Quartz also predominates among the siltstones, and there is a small admixture (about 1%) of feldspars and accessory minerals (epidote, hornblende, iron ores, zircon, garnet, etc.). Mica flakes account for about 2–3% in the sandstone; they are usually hydrated to some degree. About 10% of the bulk of the rock is made up of round, oval, or, more often, irregularly shaped nodules of leptochlorite from 0.15 to 1.2 mm in size. They are sometimes oxidized and acquire a yellowish or reddish brown color. The sandstone cement is leptochloritic, cryptocrystalline, with the low birefringence characteristic of chlorites. There is a negligible admixture of hydromica flakes. Type of cementation basal, more rarely porous.

Siltstone coarse-grained, with sparse grains (3–5%) of gravel, sandy. The main difference between this and the preceding rock is the higher content of silt and the lesser amount of sand and gravel. The marked increase in the amount of mica (to 15–20%) is also characteristic.

The heavy fraction 0.1–0.01 mm in size accounts for 4.9%. It is made up mostly

(78.5%) of the epidote-zoisite group of minerals. Hornblende is present in a small amount (11.0%), and in addition rutile (2.5%), garnet (about 1%), tourmaline, chlorite, sphene, fractions of a percent of iron ore minerals, zircon, anatase, leucoxene, apatite, spinel, and also metamorphic minerals. Authigenous minerals are represented in the heavy fraction by siderite. The light fraction is composed almost entirely of quartz, feldspars accounting for only some 2%.

Contact with the overlying siltstones of layer 2 indistinct, recognizable from the disappearance of pebbles and coarse gravel.

Paleontological description. Ammonites: *Hectoroceras tolijense* (Nik.), (very frequent), *H.* ind. sp. (very frequent), *Borealites fedorovi* Klim. (rare), *B. radialis* Klim. n. sp., *B. explicatus* Klim. n. sp. (rare), *B. mirus* Klim. n. sp. (very rare).* Belemnites (frequent): *Cylindroteuthis (Cylindroteuthis) lepida* Sachs and Naln., *C. (C.) luljensis* Sachs n. sp., *C. (Arctoteuthis) porrectiformis* And., *C. (A.) repentina* Sachs and Naln., *Lagonibelus (Lagonibelus) gustomesovi* Sachs and Naln. Bivalves: *Cyprina* ind. sp. (frequent), *Astarte (Astarte)* ind. sp. (rare), *Liostrea lyapinensis* Zakh. n. sp. (rare), *Plagiostoma incrassata* (Eichw.) (very rare), *Limatula consobrina* (d'Orb.) (very rare), *Entolium nummulare* (Fisch.) (rare), *Isognomon* cf. *triviale* Zakh. (very rare), *Pinna* cf. *romanikhaensis* Zakh. (very rare), *Oxytoma (Oxytoma) expansa* (Phill.), *Camptonectes (Boreionectes) breviauris* Zakh. (very rare, probably redeposited from upper Volgian sediments). Brachiopoda: *Fusirhynchia micropteryx* (Eichw.) (rare).

Ethology. Macrobenthos represented by various ethological types, none of which clearly predominates (Table 4).

Taphonomy. Most of the fossils are fragments of shells and rostra. Isolated valves are found only in the upper part of the layer. Finds of whole shells are very rare. There is a gradual enrichment of the rock in invertebrate remains from bottom to top through the layer. Pieces of thick-walled shells of bivalves are sparsely scattered in the rock at the base of the layer. The shell fragments are a little larger than gravel and pebble. Accumulations of shell detritus together with individual valves are present in the upper part of the layer. All fossils rounded. Type of fossil cenosis: allochthonous fossil thanatocenosis.

Layer 2 (exposure 1; 2.2 m)

Lithological description. Siltstone sandy, with sparse grains of fine gravel, leptochloritic-quartzose, micaceous, with glauconite and clay-leptochlorite cement. Color of rock dark bluish gray, green, brown or lilac in patches. Rock compact, in places slightly viscous. Texture massive, jointing coarse-lumpy. Small (10–15 cm) round carbonate concretions, often phosphatized, occur at the base of the layer. At a height of 1.2 m from the bottom

* In accordance with Klimova's view, in the sections described from the Cis-Polar Trans-Urals and the West Siberian Plain, *Borealites* is treated as an independent genus, while the species *payeri* is placed in the genus *Tollia.* In all the summarizing chapters, in accordance with Shul'gina's conclusion, *Borealites* is considered a subgenus of the genus *Subcraspedites,* and the species *payeri* included in the genus *Bojarkia.* (Editor.)

TABLE 4. Layer-by-layer ethological description of the macrobenthos from Berriasian and Valanginian sediments on the Yatriya River (exposure No. 1)

No. of layer		Sessile			Embedded			Free-lying		Vagrant		
		byssus	cemented	anchored	burrowing	boring (corroding)	silting-up	immobile	adhering by suction	creeping	flapping (swimming)	actively moving
1		13.4	13.4		20.0		6.6	6.6		13.4	26.6	
2 lower part of layer		15.4	6.8		68.4		0.7	0.7		2.0	6.0	
3		63.8	4.9	6.6	9.9		1.6	3.3		1.6	8.3	
5		20.0			37.0		8.6	25.7		8.7		
6	interval, m 0–0.8	11.1	11.1	11.1	14.8		7.4	33.4		7.4	3.7	
6	interval 8.0–13.0	9.7	16.1	6.5	28.9		9.7	6.5		6.5	16.1	
6	interval 14.0–22.0	5.8	5.8		36.2		23.2			11.6	17.4	
7					12.5	37.5	12.5			37.5		

of the layer, similar but slightly smaller concretions form a persistent horizon. The gravel is confined mainly to the lower part of the layer; farther up it gradually disappears and diminishes in size. Ammonites are frequent at the base of the layer; they are rare and poorly preserved in the middle, while 1.2 m from the bottom of the layer they are enclosed in concretions and are in a good state of preservation. Pieces of charred and mineralized wood, belemnite rostra, and bivalve shells are encountered throughout the layer.

The rock is composed mainly of fairly well-sorted fine-grained silt material (about 30–40%), mixed with about 8–10% fine sand and sparse grains of fine (2–3 mm) gravel. Mica flakes make up from 5 to 15% of the rock. Some of them are hydrated to a certain degree. An important element of the rock are segregations (grains) of authigenous minerals, predominantly leptochlorite (15%). The grains are round or of irregular form, and their size is about 0.4 mm. Their color is green or brown (if oxidized and replaced by hydrogoethite); birefringence very low, as is typical of chlorites. In a few (2–3%) grains of oval or kidney-shaped form, glauconite is also detected. The sand-gravel material is semirounded, more rarely angular-rounded, distributed more or less evenly in the rock and represented in the main by quartz. There are also many fragments of quartzites among the gravel grains. Cement leptochloritic, cryptocrystalline, with very low birefringence. Some areas in the main mass of cement show an abundance of finely dispersed clayey substance with numerous flakes of hydromicas and, possibly, montmorillonite. Type of cementation porous, in places pellicular.

The heavy fraction 0.1–0.01 mm in size accounts for 8.2–10.7%. Its composition is extremely constant and similar to that of the rocks of the underlying layer. Phosphates (dahlite) characteristically appear among the authigenous minerals.The light fraction is represented mostly by quartz grains and mica flakes, with a few feldspars. Fragments and grains of leptochlorite and glauconite predominate among the authigenous minerals.

Contact with the overlying siltstones of layer 3 indistinct, recognizable by the almost total disappearance of gravel, and also by the appearance, in layer 3, of numerous shells of *Buchia.*

Paleontological description. Ammonites (in the bottom 0.5 m of the layer): *Hectoroceras tolijense* (Nik.) (frequent), *H.* ind. sp. (frequent), *Borealites fedorovi* Klim. (rare), *B. radialis* Klim. n. sp. (rare), *B. explicatus* Klim. n. sp. (rare), *B. mirus* Klim. n. sp., (rare). In the upper part of the layer (rare): *B.* ind. sp., *B. (?) suritiformis* Klim. n. sp. (very rare), *B.* (?) aff. *suritiformis* Klim. n. sp. (very rare). Belemnites (frequent): the same as in layer 1. Bivalves (0–0.5 m interval): *Cyprina* sp. (abundance), *Liostrea lyapinensis* Zakh. n. sp. (many), *Isognomon triviale* Zakh. (very frequent), *Entolium nummulare* (Fisch.) (very frequent), *E. demissum* (Phill.) (rare), *Camptonectes (Camptonectes) lamellosus* (Sow.) (very frequent), *C. (C.)* aff. *vitreus* (Sow.) (frequent), *C. (Boreionectes)* cf. *imperialis* (Keys.) (very rare), *Aguilerella anabarensis* (Krimh.) (rare), *Cucullaea* sp. (very frequent), *Plagiostoma* cf. *incrassata* (Eichw.) (very rare), *Limatula* cf. *consobrina* (d'Orb.) (very rare), *Oxytoma (Oxytoma)* aff. *expansa* (Sow.) (rare), *Pinna* ind. sp. (very rare), *Inoceramus* (?) ind. sp. (very rare), *Pleuromya* sp. (rare), *Astarte* (?) sp. (rare). Gastropoda: *Turitella* (?) ind. sp. (very rare). Worms: *Serpula* sp. (very rare). In the 0.5–2.2 m interval: *Liostrea lyapinensis* Zakh. n. sp. (frequent), *Cyprina* ind. sp. (rare), *Astarte (Astarte)* ind. sp. (very rare), *Camptonectes (Camptonectes) lamellosus* (Sow.) (rare), *C. (Boreionectes)* ind. sp. (very rare), *Buchia* sp. (rare), *Pleuromya* sp. (very rare).

Ethology (0–0.5 m interval). Remains of macrobenthos clearly predominating over semipelagic forms. The greater part of the benthos (68%) is made up of burrowing bivalves; less numerous are byssus (15.4%) and cemented (6.8%) forms.

Taphonomy. There are many more of *Cyprina* than of any other fossil. Their valves are evenly distributed throughout the interval and lie parallel to the bedding, convex side up. Fragments of valves common, whole shells rare. Oysters as a rule represented by individual valves, generally the left (convex). Accumulations (nests) of several valves frequent. *Isognomon* usually found in the form of individual valves and large fragments of valves, but whole shells, oriented parallel to the bedding, are also often found. Valves of *Entolium* and *Camptonectes* generally dissociated, fragments occurring often. *Boreionectes* found in the form of rounded valve fragments. Whole shells and individual valves of *Cucullaea* were found in approximately equal amounts. The upper parts of *Pinna* shells are broken off. On the whole, the remains of bivalves are oriented parallel to the bedding. Belemnite remains represented by rostra and rounded fragments of rostra. Large-scale surveys of the orientation of belemnite rostra show that most of them lie northeast-southwest (according to 125 surveys) (Figure 7). Type of fossil cenosis: allochthonous fossil thanatocenosis with elements of an autochthonous thanatocenosis.

No ethological description is given for the 0.5–2.2 m interval.

Taphonomy. Oysters, *Cyprina,* and *Astarte* represented by individual valves scattered through the layer, oriented parallel to the bedding. Whole rostra of belemnites predominate, but there are also fragments. A multitude of voids from leached shells of bivalves. Type of fossil cenosis not determined.

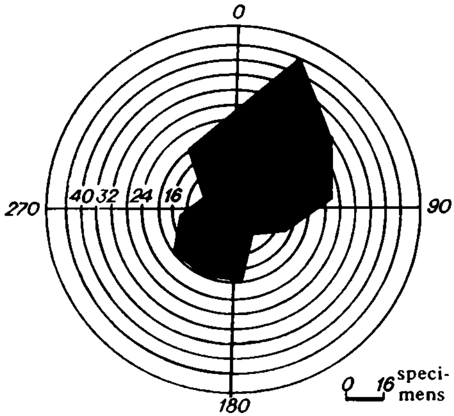


FIGURE 7. Orientation of belemnite rostra in Berriasian sediments on the Yatriya River (exposure 1, layer 2). Surveys by E. G. Yudovnyi.

Zone *Surites analogus* (6.2 m)

Layer 3 (exposure 1; 1.0 m)

Lithological description. Siltstone sandy, clayey, leptochlorite-glauconite-quartz, with clay-leptochlorite cement. Color of rock bluish gray, in places brown. Rock extremely compact, with massive texture. Jointing coarse-lumpy. This layer differs from the underlying deposits in the almost total absence of gravel grains (just a few grains not more than 2 mm in size are found), in the greater compactness of the rock, and, which is especially characteristic, in the large number of *Buchia* shells. Also encountered are shells of other bivalves, belemnite rostra, shells of small brachiopods (rare), and fragments of internal molds of ammonites. Pieces of charred wood, sometimes large, are occasionally found.

The microscope showed that fine silty quartz grains (35–45%), plus mica flakes (15%) are the main components of the rock. A few (1–2%) grains of fine sand and individual fragments of fine gravel (1–2 mm) are noted. The sand-gravel particles are semirounded or angularly rounded. Authigenous minerals are represented mainly by leptochlorite and glauconite in more or less equal amounts. The total content of their grains is 15–20%.

The heavy fraction 0.1–0.01 mm in size accounts for 13.7%. Its composition is similar to that of the underlying deposits. The light fraction is also made up mostly of quartz and micas, while authigenous minerals are represented by leptochlorite and glauconite.

The boundary with the overlying sediments is distinct and can be traced according to the replacement of the siltstones of the layer in question by clays and also according to the marked reduction in the number of *Buchia* shells.

Paleontological description. Ammonites: *Surites* cf. *spasskensis* (Nik.) (very rare), *Surites* ind. sp. (very rare). Belemnites (frequent), in addition to those in layers 1 and 2: *Cylindroteuthis (Arctoteuthis)* aff. *subconoidea* Sachs and Naln., *Lagonibelus (Lagonibelus) elongatus* (Blüthg.), *L. (L.) sibiricus* Sachs and Naln., *Pachyteuthis (Pachyteuthis) subrectangulata* (Blüthg.), *P. (Simobelus) curvula* Sachs and Naln. Bivalves (some of the specimens collected may belong to the base of layer 4): *Buchia volgensis* (Lah.), *B. okensis* (Pavl.), *B. fischeriana* (d'Orb.), *B. terebratuloides* (Lah.), *B. uncitoides* (Pavl.) (very many, an overall estimate), *Pleuromya uralensis* d'Orb. (very frequent), *Liostrea lyapinensis* Zakh. n. sp. (frequent), *Camptonectes (Camptonectes)* ind. sp. (frequent), *C. (Boreionectes)* ind. sp. (rare), *Pseudamussium* cf. *bojarkaensis* Zakh. (rare), *Entolium nummulare* (Fisch.) (rare), *Limatula* aff. *consobrina* (d'Orb.) (rare), *Plagiostoma* cf. *incrassata* (Eichw.) (very rare), *Modiolus* ind. sp. (very rare), *Oxytoma (Oxytoma) expansa* (Phill.) (very rare), *Astarte (Astarte)* ind. sp. (very rare), *Pholadomya* ind. sp. (very rare). Brachiopoda: *Siberiothyris* sp. (very rare), *Taimyrothyris bojarkaensis* Dagys (rare), *Uralorhynchia* sp. (very rare).

Ethology. Remains of macrobenthos considerably predominating over semipelagic forms. More than half of the benthos in the oryctocenosis belongs to the byssus type (63.8%). There are large numbers of burrowing (9.9%) and flapping (8.3%) forms.

Taphonomy. The taphonomic distinction of the oryctocenosis is the abundance of *Buchia*. Specimens with both valves predominate; they are usually flattened, and are evenly scattered in accumulations of several individuals. *Pleuromya* as a rule represented by whole shells, buried in situ. *Camptonectes* occurs in the form of bivalve shells or individual valves, lying parallel to the bedding. Relatively small (young?) forms predominate among the *Boreionectes*. The largest, reaching 100 mm in diameter, are in the form of fragments, very rarely individual valves. *Limatula* and Ostreidae generally represented by dissociated valves. Rostra of belemnites well preserved, very slightly rounded. Type of fossil cenosis for *Buchia* and *Pleuromya* determined as an autochthonous fossil thanatocenosis with elements of an allochthonous thanatocenosis. Type of cenosis not determined for the other invertebrates.

Layer 4 (exposure 1; 5.2 m)

Lithological description. Clay silty montmorillonite-hydromica-chlorite, micaceous, with glauconite. Rock bluish gray, as in the preceding layer, oxidized, ocher-colored at the surface and along the cleavage jointings. Its color becomes greenish brown and brown. Rock compact, weakly plastic, jointing coarse-lumpy, more rarely thick-platy. Texture massive. The layer is extremely poor in paleontological remains. Ammonites consist of poorly preserved fragments of clayey internal molds, primarily of inner whorls. Very large (up to 45 cm in diameter) but ill-preserved (disintegrating upon extraction) specimens are sometimes found. An internal mold of a large ammonite was discovered in the upper part of the layer. A few small fragments of charred wood are encountered throughout the layer.

As seen under the microscope, the bulk of the rock is composed of finely dispersed clayey substance, in places completely isotropic or in fine flakes, with the birefringence typical for hydromicas and montmorillonite. The main mass of the clay contains a good deal of colloform organic matter, and also much finely dispersed, jellified or, often, pyritized plant detritus. The terrigenous fraction is represented almost solely by grains of fine silt and flakes of mica. The content of both these is 30–40%, and the amount of mica in some places reaches 20%. The rare grains of quartz are up to 0.2 mm in size. The silty material is predominantly quartzose. The micas are almost exclusively muscovite; their flakes are generally hydrated. Authigenous minerals consist of small grains of glauconite and leptochlorite, the first of these generally predominating over the second. Their combined content is 5–25%. The size of the grains is 0.04–0.06 mm, and their form is usually irregular or oval.

The heavy fraction 0.1–0.01 mm in size accounts for between 2.1 and 12.2%. Its composition is similar to that of the underlying sediments, but there is just a slight increase in the amount of pyrite and epidote. Toward the top of the section there is a marked reduction in the role of authigenous minerals in the light fraction, especially of leptochlorite. The proportion of quartz also diminishes somewhat on account of the increased mica content.

The transition of the clays of the overlying layer is gradual. No lithological changes are observed near the boundary between the layers, and the next layer can be distinguished only according to paleontological data.

Paleontological description. Ammonites (rare): unidentifiable remains. Belemnites (frequent): along with species common to layers 1–3, *Acroteuthis* sp. appears. Bivalves: *Astarte (Astarte)* ind. sp. (rare), *Camptonectes* (?) ind. sp. (very rare).

In the spore-pollen complex the ratio of spores to pollen of gymnosperms is almost equal. The spores include many Gleicheniaceae (16.5%). Schizaeaceae are represented by individual specimens of the genus *Anemia* (1%). Spores of the genus *Coniopteris* constitute 4%, of the subgroup *Leiotriletes* 7.5%. The content of microphytoplanktonic forms is quite high (13%). Dominant among the gymnosperms are conifers of the family Pinaceae (genera *Picea, Protopicea, Pseudopicea, Pinus,* and to a lesser extent *Cedrus*), constituting 40%. Pollen of Taxodiaceae accounts for 1.5%, of the genus *Sciadopitys* 1.5%, and of the genus *Classopollis* 0.5%.

Ethological and taphonomic studies were not conducted on the macrobenthos because of the poor state of the shells.

Zone *Tollia payeri* (2.4 m)

Layer 5 (exposure 1; 2.4 m)

Lithological description. Clay silty, montmorillonite-hydromica-chlorite, with glauconite. External appearance, color, composition, and textural-structural features of the rock completely analogous to the clays of the underlying layer. In the middle part of the layer there are a few large (0.5 m in diameter) carbonate concretions with numerous remains of ammonites, belemnites, and bivalves. Sparsely scattered throughout the layer are rostra of belemnites and internal molds of bivalve shells.

Transition to rocks of layer above gradual. No lithological changes observed visually near the boundary between the layers, and the next layer higher up, which already belongs to the Valanginian stage, is identified only according to paleontological data. The glauconite is seen to abruptly disappear near the boundary.

Paleontological description. Ammonites (in concretions): *Tollia* cf. *payeri* (Toula) (very frequent). Belemnites (frequent): *Cylindroteuthis (Cylindroteuthis) lepida* Sachs and Naln., *C. (Arctoteuthis) repentina* Sachs and Naln., *Lagonibelus (Lagonibelus) gustomesovi* Sachs and Naln., *Acroteuthis (Acroteuthis) anabarensis* (Pavl.), *A. (A.) vnigri* Sachs and Naln. Bivalves: *Camptonectes (Boreionectes ?)* ind. sp. (many), *Pleuromya uralensis* d'Orb. (many), *Pinna* cf. *romanikhaensis* Zakh. (frequent), *Buchia* sp. (very frequent), *Astarte (Astarte) veneris veneris* d'Orb. (rare), *Cyprina* sp. (rare), *Musculus* cf. *strajeskianus* (d'Orb.) (rare), *Pholadomya* ind. sp. (very rare), *Goniomya* ind. sp. (very rare). Gastropoda: *Pleurotomaria* sp. (very rare).

Ethology. Semipelagic forms constitute a considerable part of the oryctocenosis (about 25%). Most representative among the benthos are burrowing (37%), immobile (25.7%), and bussus (20%) forms.

Taphonomy. *Boreionectes* relatively small, evenly scattered through the layer. More or less equal amounts of whole shells and individual valves, lying parallel to the bedding. The *Pleuromya* found with both valves in this layer are almost all in the original position, as is the case with the whole shells of *Pinna*. *Buchia* and *Astarte* in nestlike accumulations of several individuals represented, as a rule, by whole shells that are usually flattened. The *Cyprina* shells are characteristically entombed open, and they lie parallel to the bedding (Figure 8). Valves of *Musculus* also open. Type of fossil cenosis: weakly displaced allochthonous fossil thanatocenosis with elements of an autochthonous thanatocenosis.

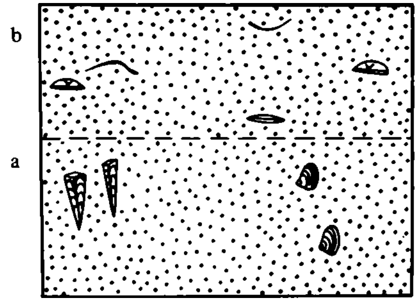


FIGURE 8. Types of burial of bivalves in Berriasian sediments on the Yatriya River (exposure 1, layer 5). Drawing by V.A. Zakharov. Scale 1:15.
a) *Pinna* and *Pleuromya* buried in situ; b) burials of *Boreionectes* shells.

Zone *Temnoptychites insolutus* (34.0 m)

Layer 6 (exposure 1; 34.0 m)

Lithological description. Clay silty, hydromicaceous-chloritic micaceous. Color of rock, as in the preceding layer, bluish gray, in places greenish brown with brown patches of hydrous ferric oxides. The rock is weakly compacted, plastic, jointing lumpy, in the weathered zone becoming loose (fine-lumpy). Texture massive, in some places in the lower part of the layer thinly lenticular-laminated. The greater part of the section of the layer is turfy. Judging from the appearance of the rocks in the strippings, the member is extremely monotonous and does not contain any organic or mineral inclusions that can be detected visually. Rostra of belemnites and fairly large pieces of charred wood are occasionally discovered. The lower part of the layer shows large, oblate (up to 4 m in size) and spherical (70 cm in diameter) carbonate concretions with ammonite shells. An internal mold of an ammonite shell was also found at the very top of the layer.

It was seen under the microscope that the bulk of the clay is finely dispersed substance which contains many brown flocculent clots of amorphous organic matter and finely dispersed plant detritus. In places of accumulation of organic life, there are frequent segregations of pulverized and globular pyrite. The terrigenous fraction is poorly sorted and represented by a mixture of inequigranular silty and pelitic material with an admixture of a few angular fine-sandy particles of quartz and a multitude of mica flakes (the content of these is 5–20%, in places 30%). The silty and coarse-pelitic material is evenly distributed, while the micas, as is seen in transverse microsections, are arranged parallel to the bedding. In longitudinal sections they are distributed haphazardly, but in places they form spiral-like "eddying structures." The even distribution of the heavier silty and coarse-pelitic quartz particles is meanwhile not destroyed. Also characteristic is the presence of traces, very numerous in places, of the movement of some very small mud-eating organisms. Authigenous minerals comprise pyrite and in the lower part of the layer isolated and very small, round grains of glauconite, whose content at the bottom of the layer does not exceed 1–2%, while higher up it disappears altogether.

The heavy fraction 0.1–0.01 mm in size accounts for 7.9–14.7%. Its composition is practically identical to that of the sediments of the Berriasian stage; just a certain increase in the amount of epidote is observed. Among the authigenous minerals pyrite is persistently present.

Paleontological description. Ammonites (in concretions in the lower part of the layer): *Temnoptychites grandis* Klim. n. sp. (in litt.) (very rare), *T. insolutus* Klim. n. sp. (in litt.) (very rare), *Neotollia venusta* Klim. n. sp. (rare). In the upper part of the layer *Neotollia densa* Klim. n. sp. (very rare). Belemnites (frequent): *Acroteuthis (Acroteuthis) anabarensis* (Pavl.), *A. (A.) vnigri* Sachs and Naln., *A. (A.) arctica* (Blüthg.), *A. (A.) chetae* Sachs and Naln., *A. (A.) explanatoides polaris* Sachs and Naln., *A. (Boreioteuthis) explorata* Sachs and Naln., *Cylindroteuthis (Arctoteuthis) repentina* Sachs and Naln., *Lagonibelus (Lagonibelus) elongatus,* (Blüthg.), *Pachyteuthis (Pachyteuthis) acuta* (Blüthg.). Bivalves:

Camptonectes (Boreionectes) imperialis (Keys.) (many), *Liostrea anabarensis* Bodyl. (frequent), *Cyprina* sp. (frequent), *Limatula consobrina* d'Orb. (frequent), *Astarte (Astarte) veneris* d'Orb. (rare), *Oxytoma (Oxytoma) expansa* (Phill.) (rare), *Entolium nummulare* (Fisch.) (very rare), *Buchia crassa* (Pavl.) (very rare), *Goniomya* sp. (rare), *Pleuromya uralensis* d'Orb. (frequent), *Homomya* sp. (very rare), *Pholadomya* ind. sp. (very rare), *Plagiostoma* aff. *incrassata* (Eichw.) (very rare), *Pinna* sp. (frequent), *Musculus* cf. *sibiricus* (Bodyl.) (very rare), *Musculus* sp. (frequent), *Lucina* (?) sp. (rare). Gastropoda: *Turitella* sp. (very rare). Brachiopoda: *Siberiothyris* sp. (rare), *Uralorhynchia* sp. (very rare). Composition of spore-pollen complex similar to that in the Berriasian deposits, except for the considerable species diversity of spores of Gleicheniaceae. Among the Schizaeaceae the genera *Pelletieria* and *Lygodium* are noted, accounting for 2%.

Ethology. The features of the macrobenthos show a regular pattern of change proceeding up the section of the layer. In the 0–8.0 m interval the macrobenthos consists largely of free-lying *Boreionectes* (33.4%). Sessile forms are represented by two ethological types: cemented and anchored (in equal amounts). Burrowing forms constitute 14.8%. In the 8.0–13.0 m interval the most representative group is the embedded: the burrowing type amounts to 18.9% and the silting-up type 9.7%. There are also many sessile forms: byssuses 9.7%, cemented 16.1%, and anchored forms 6.5%. In the upper part of the layer more than half the macrobenthos is composed of embedded bivalves (burrowing forms 36.2%, silting-up forms 23.2%). The other groups are not abundant. The predominant type of fossil cenosis is the weakly displaced allochthonous thanatocenosis with elements of an autochthonous thanatocenosis.

YANY-MAN'YA RIVER

Berriasian sediments, including the bottommost zone of the stage, crop out in a scarp on the right bank of the Yany-Man'ya River near the Parasoim stream (exposure No. 1 about 26 km from the river mouth).

The following are exposed in the scarp (from bottom to top): sediments of the Volgian stage, including its middle (*Laugeites vogulicus* zone, thickness 2 m) and upper (*Craspedites subditus* zone, thickness 3 m) substages (there was an interruption in sedimentation here at the time that the lower and, partly, the upper zones of the upper Volgian substage were formed), and also sediments of the Berriasian stage 16 m thick. The bedding is nearly horizontal. The Berriasian sediments are overlain by Quaternary loams.

The Volgian sediments are represented by grayish green or greenish brown (oxidized in the near-surface zone of the exposure) sandy-silty glauconites with sparse fine gravel, numerous nodular concretions of leptochloritic, leptochloritic-hydrogoethitic, or glauconitic-leptochloritic composition and with leptochlorite, in places leptochlorite-hydrogoethite, or, more rarely, carbonate cement. In the topmost horizons, near the contact with the Berriasian sediments, the glauconitites become poorer in glauconite and richer in nodules and grains of leptochloritic and leptochloritic-hydrogoethitic composition. Right by the find of the first Berriasian ammonite the amount of these markedly predominates over glauconite, and leptochlorite becomes the main mineral, whereby the upper Volgian glauconites pass into Berriasian chloritolites. The change of the rocks proceeds gradually, but rapidly at a distance of at most several tens of centimeters along the vertical.

The sediments contain numerous remains of bivalves (oysters, Pectinidae, *Pinna*, etc.), brachiopods, belemnites, and ammonites, usually in the form of clay molds, but the actual shell substance is occasionally preserved. Ammonites determined include *Laugeites* spp. and *Craspedites* cf. *subditus* (Traut.).

CRETACEOUS SYSTEM. LOWER SERIES. BERRIASIAN STAGE

Zone *Chetaites sibiricus* (3.0 m)

Layer 1 (exposure 1; 3.0 m)

Lithological description. Chloritolite nodular, silty-sandy, with sparse fine gravel, glauconitic (in strongly oxidized areas passing into rock of glauconite-leptochlorite-hydrogoethite composition). Color grayish green, in places dark green or greenish brown with patches and sinters of reddish brown hydrous ferric oxides and dark lilac manganese oxides. Rock compact, relatively heavy, its texture massive. Jointing in large blocks. Sparse organic remains observed in the layer (mainly internal molds of large bivalves and brachiopods), occasionally remains of ammonites and cylindrical apertures from dissolved belemnite rostra, plus fragments of charred wood.

It is seen under the microscope that the rock consists 50–60% of oval or rounded nodules 0.25–1.0 mm in size. About 15% is made up of glauconite grains which are often oxidized and replaced by hydrogoethite at the surface and along the syneresis jointings. Nodules composed primarily of hydrogoethite, which is formed upon the oxidation of leptochlorite. Nonoxidized or weakly oxidized leptochloritic or glauconitic-leptochloritic nodules are also encountered. The former consist of nuclei – leptochlorite grains of oval or irregular form with a colloform microaggregate (flaked) structure or in the form of lamellar mica-like aggregates. The nuclei are enclosed in thin shells of flaky leptochlorite belonging to a later generation. The shells sometimes have a distinctly concentric structure, like oölites. The glauconitic-leptochloritic nodules are grains of green or brownish oxidized glauconite of palmate or kidney-shaped form, regenerated by leptochlorite of a later generation and surrounded by sheaths of it. Terrigenous material is irregularly distributed in the rock and represented by comparatively sparse grains of quartz ranging in size from fine silt to coarse sand and by isolated grains of gravel. There are also a few mica flakes and small grains of feldspars and other minerals. Terrigenous material is absent in the nodules and grains of authigenous minerals. The rock cement is leptochloritic, in places replaced by hydrogoethite. Small areas of cement are sometimes composed of fine-grained siderite. Type of cementation porous, in places basal.

The proportion of heavy fraction 0.1–0.01 mm in size is extremely high (32.3%). Authigenous minerals represented by siderite. The terrigenous components are dominated by epidote, and there are grains of hornblende, rutile, zircon, tourmaline, garnet, iron ore minerals (magnetite, chromite, ilmenite), and other minerals. The light fraction consists mainly of quartz.

Paleontological description. Ammonites: *Chetaites* sp. (cf. *sibiricus*) Schulg. (very rare). Belemnites (rare): traces of dissolved rostra. Bivalves (very rare): *Astarte* ind. sp. *Modiolus* ind. sp., *Entolium* ind. sp., (?) *Corbicella* ind. sp., *Pinna* ind. sp. Brachiopoda: *Uralella* cf. *gigantea* Makridin (rare).

Ethology. Representatives of sessile (brachiopods) and flapping (Pectinidae) benthos predominate. Semipelagic forms rank second. Silting-up forms *(Pinna)* are sparsely represented.

Taphonomy. Shells of brachiopods and bivalves more or less evenly and sparsely scattered in the layer. Brachiopods usually buried apex down, the shells of Pectinidae generally entombed parallel to the bedding. Isolated *Pinna* shells buried almost vertically. Individual valves of shells and their fragments rare. Type of fossil cenosis: allochthonous fossil thanatocenosis with elements of an autochthonous thanatocenosis.

Zone *Hectoroceras kochi* (7.0 m)

Layer 2 (exposure 1; 1.5 m)

Lithological description. Chloritolite nodular, silty-sandy, gravelly, with glauconite. Color predominantly green, in places brownish green or yellowish green. Rock compact, of massive texture. The layer is characterized by the presence of a large amount (about 15%) of gravel and sparse small pebbles measuring up to 2–2.5 cm. The gravel-pebble material is very evenly scattered in the rock; just at the very base and near the surface of the layer does its content gradually but rapidly (at a distance of 5–10 cm along the vertical) decrease (until pebbles and coarse gravel disappear altogether) correspondingly near the bottom and roof of the layer. Organic inclusions very sparse. They consist of internal molds of shells of brachiopods and bivalves, internal molds of ammonites, and fragments of charred or mineralized wood.

Petrographic studies established that the rock underwent oxidation mainly while still in the process of diagenesis and consists of grains and nodules of leptochlorite, which are to some extent (often fully) replaced by hydrogoethite (30–40%), glauconite (2–10%), grains of terrigenous minerals (20–30%), and leptochlorite cement. Nodules mainly reddish brown hydrogoethitic and brownish green hydrogoethitic-leptochloritic. Their size is 0.2–0.8 mm and their form oval. Fragments of nodules are frequent, pointing to their erosion and redeposition at the site of formation. The shells of the nodules are composed mostly of nonoxidized or weakly oxidized yellowish green leptochlorite of colloform or flaky structure with a very low birefringence. Isolated round hydrogoethite oölites with distinct concentric structure are noted. Glauconite grains relatively rare, oval or reniform, yellowish green. The terrigenous material of the rock is representated in the main by angular grains the size of fine sand. There are considerably fewer grains of coarse silt and about 15% gravel and small pebbles. The sandy-gravelly material is not rounded and is evenly distributed in the rock. It consists mainly of quartz, plus fragments of quartzites and feldspathic-quartzose rocks. Small grains of feldspars (microcline, albite) and of femic minerals, and also sparse mica flakes (2–5%) are occasionally detected. The rock cement is leptochloritic colloform, with scarcely perceptible birefringence, in places finely flaky. Type of cementation basal, more rarely porous.

The proportion of heavy fraction 0.1–0.01 mm in size is low (1.4%). The authigenous minerals are here represented by siderite, the terrigenous by epidote, hornblende, garnet, rutile, iron ore minerals, and other minerals. The light fraction consists almost entirely of quartz.

The layer is connected to the underlying and overlying sediments by gradual, but rapid transitions and differs from them mainly in the presence of a large amount of coarse gravel and small pebble.

Paleontological description. Ammonites: *Hectoroceras* ind. sp. (very rare). Bivalves: *Astarte* sp. (very rare), undetermined Pectinidae and smooth-valved forms (very rare). Brachiopoda: *Uralorhynchia* sp. juv. (very rare), *U.* ind. sp. (very rare), *U.* n. sp. (very rare).

Ethology and taphonomy. The oryctocenosis is poor in fossils. Type of burial: shells unevenly and sparsely scattered. The benthos is represented mainly by sessile and creeping forms. Semipelagic forms (ammonites) are rarer. Pelecypods are buried in the form of dissociated valves, which are sometimes broken; whole shells rare. Large shells generally lie parallel to the bedding without definite orientation. Remains of ammonites in the form of internal molds, buried almost vertically or obliquely to the surface of the bedding (two finds). Type of fossil cenosis: allochthonous fossil thanatocenosis.

Layer 3 (exposure 1; 5.5 m)

Lithological description. Chloritolite nodular, sandy-silty, micaceous, with sparse fine gravel and glauconite. In places which have undergone intensive oxidation in the zone of recent weathering, the chloritolite passes into a nodular leptochlorite-hydrogoethite rock. Color of rock predominantly tobacco green, in places brownish green or brown. Texture massive. Jointing coarse-lumpy or thick-platy. Organic remains fairly abundant, including internal molds of Pectinidae, apertures from belemnite rostra, a few internal molds of brachiopods and ammonites, and pieces of charred and mineralized wood.

The microscope reveals that the rock is made up primarily of authigenous leptochlorite and hydrogoethite (oxidized leptochlorite) in the form of nodular grains and cement, sparse grains of glauconite, and also terrigenous minerals mostly the size of coarse silt. Rare grains of coarse sand and fine gravel are observed. The structure and composition of the segregations of authigenous minerals (grains, nodules) are similar to those in the rocks of layer 2, but the chloritolites in question usually contain less hydrogoethite (which is related to their lesser degree of oxidation in the stage of diagenesis also in the recent zone of weathering) and, what is particularly characteristic, much less glauconite (at most 5%). Along with this, the rocks of this layer show an increased terrigenous fraction (to 45%), the dimensionality of which is diminished (coarse-silty material predominates), while the mica content increases (10–15%). At the same time, proceeding up the section there is an ever increasing amount of finely dispersed particles of clay minerals, among which flakes of hydromicas are especially numerous. Cement (25–40%) leptochloritic (in places oxidized and replaced by hydrogoethite), for the most part colloform, almost isotropic or flaky. In some places the cement is composed of fine-grained siderite. Type of cementation basal or porous.

The yield of heavy fraction 0.1–0.01 mm in size is 5.7%. Its composition is similar to that of the underlying sediments. The light fraction is characterized by an increased content of micas (to 12%) and feldspars (to 6.2%). Authigenous light minerals represented mainly by leptochlorite.

Paleontological description. Ammonites: *Hectoroceras tolijense* (Nik.) (frequent), *H.* ind. sp. (frequent), *Borealites* ind. sp. (rare). Belemnites (frequent): traces of dissolved rostra. Bivalves: *Entolium nummulare* (Fisch.) (frequent), *Camptonectes* sp. (frequent), *Astarte* sp. (frequent). Brachiopoda: *Uralorhynchia* ind. sp. (frequent).

Ethology and taphonomy. Benthic forms rank first and semipelagic forms second in the oryctocenosis. The benthos is represented by two ethological groups: sessile and vagrant invertebrates, the latter group predominant. Remains of cephalopods (especially belemnites) numerous, but not as abundant as the benthos. Type of burial: evenly and sparsely scattered shells. Dissociated valves of pelecypod shells predominate, lying parallel to the bedding. Whole shells rare, sometimes found buried in situ. Ammonites found frequently, in some cases entombed almost vertically. Type of fosssil cenosis: allochthonous fossil thanatocenosis.

Zone *Surites analogus* (6.0 m)

Layer 4 (exposure 1; 6.0 m)

Lithological description. Chloritolite nodular, sandy-silty, clayey, micaceous, with sparse fine gravel and glauconite. In strongly weathered areas the chloritolite passes into leptochloritic-hydrogoethitic nodular rock. Color of rock tobacco green, brownish green, brown, reddish brown, with dark lilac patches. Texture predominantly massive, in places showing an indistinct fine or coarse lamination.

Rocks intensively jointed. Jointings filled with clayey material. Organic remains few, but at the base of the layer there is a bed about 0.5 m thick which is rich in internal molds of *Buchia*, Ostreidae, small *Pecten,* and brachiopods. Here too are numerous apertures from belemnite rostra. A similar intercalation is traced in the upper part of the layer, right near the contact with Quaternary sediments. According to Ilovaiskii (1903), *Surites* aff. *spasskensis* (Nik.) is found in the upper part of the layer. Externally the rocks of layer 4 are similar to the underlying sediments, but they are richer in iron, especially in the upper part. The layer is distinguished mostly by its characteristic complex of organisms, above all by the abundance of *Buchia.*

Petrographic studies established that these rocks have a composition and structure almost identical with those of the rocks of layer 3, especially with their strongly oxidized varieties. There is just some increase in the content of finely pelitic (clay) material, and also a reduction in the total amount of grains of terrigenous minerals (to 10–15%) in the upper horizons of the layer.

Quaternary loams from 0.5 to 1.5 m thick overlie the roof of layer 3 with erosion.

Paleontological description. Ammonites (towpath): *Surites* ind. sp. (very rare). Belemnites (frequent): traces of dissolved rostra. Bivalves: *Buchia* cf. *fischeriana* (d'Orb.) (rare), *B. volgensis* (Lah.) (very rare), *B.* cf. *okensis* (Pavl.) (very rare), *B.* sp. (rare),, *Liostrea* sp. (rare), *L.* cf. *lyapinensis* Zakh. n. sp. (rare), *Aguilerella* ind. sp. (very rare), *Pinna* ind. sp. (very rare), *Camptonectes* ind. sp. (rare). Brachiopoda: *Fusirhynchia* ind. sp. (rare).

Ethology. Traces of semipelagic mollusks – belemnites – predominate. Benthos very poor. Only in the lower and upper parts of the layer are there frequent occurrences of shells of *Buchia,* Ostreidae, small Pectinidae, and Brachiopoda. In these same places there is an abundance of apertures and molds of belemnite rostra. The benthos is represented mainly by a single ethological group: sessile invertebrates of all three ethological types. The byssus and cemented types are especially numerous.

Taphonomy. Fossils are exceptionally few in a large part of the layer (mainly apertures from belemnite rostra). The base and the upper part of the layer (each 0.5 m thick) contain many internal molds of bivalves and remains of belemnites. Type of burial: sparsely scattered small nestlike accumulations of internal molds of bivalves and casts of belemnite rostra. Molds of *Buchia* are predominant, Ostreidae less numerous. Orientation haphazard. Individual valves are found, buried parallel to the bedding. Type of fossil cenosis: allochthonous fossil thanatocenosis with elements of an autochthonous thanatocenosis.

The upper horizons of the Berriasian stage (*Tollia payeri* zone) and a large part of the Valanginian are not exposed on the Yany-Man'ya River.

TOL'YA RIVER

Exposure No. 1 is situated on the left bank of the Tol'ya about 2.5 km below the mouth of the Votsala-Alym''ya (some 27 km above the village of Tol'ya) and is a steep scarp about 20 m high and 225 m in extent. The same brown, ferruginous rocks are exposed in the scarp as on the Yany-Man'ya River. A large part of the exposure, approximately to a height of 10 m, is composed of sediments of the Upper Jurassic to the upper substage of the Volgian stage. The overlying externally similar Berriasian rocks (the *Hectoroceras kochi* zone, 5 m thick) begin as a transitional member 1 m thick (layer 1). At the roof of the Berriasian sediments with erosion lies a member of Quaternary sands and loams about 5 m thick. The Jurassic and Berriasian rocks dip gently to the east, with a dip azimuth of 90°, angle 4–5°.

The sediments of the upper Volgian substage are represented by grayish green, greenish brown, or brown (oxidized in the near-surface zone of the exposure) sandy-silty glauconites with sparse fine gravel, numerous nodules of leptochloritic, leptochloritic-hydrogoethitic or glauconitic-leptochloritic composition, and with leptochlorite, in places leptochlorite-hydrogoethite cement. The cement is primarily carbonate (calcitic or sideritic) in individual intercalations. Rocks massive, but in places (in the lower horizons) they show an indistinct oblique stratification of the littoral-marine type. The oblique series dip in the direction of the dip of the strata at an angle of 10–12°.

In the exposure the Jurassic-Cretaceous boundary coincides with the surface of the break in sedimentation. This is a practically even (in places slightly wavy) horizontal surface, scattered with fragments of mineralized wood (the pieces are flattened and lie flat), internal molds of bivalves, and gravel grains. The break in sedimentation apparently occurred under underwater conditions, since there are no traces whatsoever of subaerial weathering in the rocks of the upper horizons of the Jurassic, and the Berriasian sediments lying at the roof are very similar to them in lithological-facial composition. The break was apparently not accompanied by erosion of the underlying sediments, but it was quite prolonged, as the lower zone of the Berriasian section is missing altogether, and the Upper Jurassic rocks are overlain directly by the *Hectoroceras kochi* zone.

The rocks of the upper Volgian substage contain a fair number of paleontological remains, almost exclusively internal molds and imprints. Most numerous are molds of brachiopods and large bivalves and apertures from rostra of belemnites. Remains of Crinoidea and tubes of worms are found in abundance in individual intercalations. Ammonite remains are very scarce. They are of *Garniericeras* sp., *Kachpurites* ind. sp., and *Craspedites* sp.

CRETACEOUS SYSTEM. LOWER SERIES. BERRIASIAN STAGE

Zone *Hectoroceras kochi* (5.0 m)

Layer 1 (exposure 1; 1.0 m)

Lithological description. Glauconitic-leptochloritic nodular rock with a small admixture of sandy-silty material, isolated grains of gravel, with leptochlorite-siderite cement. Color tobacco green, greenish brown with patches and sinters of reddish brown hydrous ferric oxides and dark lilac manganese oxides. Rock compact, relatively heavy, the jointing clumpy, in places coarse-lumpy, the surface of the jointings intensively ferruginized. Texture of rock massive. In external appearance and textural features the rocks of this layer are indistinguishable from the underlying Jurassic sediments, but they are separated from them by a scarcely perceptible surface of a break in sedimentation. Very few organic inclusions are found in the layer. They include pieces of charred wood, internal molds of large bivalves, apertures from dissolved belemnite rostra, and very scarce remains of ammonites. At the base of the layer and especially right on the surface of the break there are more numerous fragments of charred wood, lying in the horizontal plane, and small accumulations of fine gravel (though pieces up to 1 cm in size are sometimes encountered) and of internal molds of bivalves. Fine gravel is sparsely scattered throughout the layer.

Petrographic studies established that the rock is composed chiefly of chemogenic ferrous alumosilicate minerals: leptochlorite and glauconite. Hydrogoethite, siderite, and calcite are found as an admixture, in places considerable, and mainly as secondary minerals. The main structural components are nodules and grains of leptochlorite and glauconite, in approximately equal numbers. The nodules are composed mostly of leptochlorite, but often of glauconite with a shell of leptochlorite. Their size is 0.2–1.5 mm, and their form oval or round. They are generally oxidized and replaced by hydrogoethite. The shells of the nodules occasionally have a concentric structure. The glauconite grains are reniform, palmate, or of irregular form. They are slightly smaller (0.25–1.0 mm). The syneresis jointings are often regenerated by leptochlorite. The total content of nodules and grains in the rock is about 50–60%, the number of leptochlorite nodules and glauconite grains (together with the leptochlorite-glauconite nodules) being approximately the same. The terrigenous material is unevenly distributed (only in the cement). It consists mainly of quartz grains ranging in size from fine silt to coarse sand. Grains of fine gravel are occasionally encountered. The material is poorly sorted, angular grains of fine sand and coarse silt predominating (totaling 20–30%). The pieces of gravel are also angular or semirounded. The sandy-silty material consists mostly of quartz (more than 90%). There are sparse grains of feldspars and accessory minerals (epidote, hornblende, garnet, tourmaline, iron ores, etc.). The mica content of the rock is 5–7%. Gravel is represented by quartz, more rarely by fragments of quartzites.

The cement in the rock is predominantly of leptochlorite, in places replaced by hydrogoethite. The structure of the cement is colloform or flaky. In places the cement is composed of fine-grained siderite, along which hydrogoethite or, less often, calcite develops. Type of cementation basal.

Contact with the overlying sediments distinct, almost even. It is marked by the surface of the break in sedimentation.

Paleontological description. Ammonites (rare): (?) *Hectoroceras* ind. sp. Belemnites (rare): *Cylindroteuthis* ind. sp. Bivalves: *Astarte* cf. *veneris* d'Orb. (very rare), *Entolium nummulare* (Fisch.) (very rare), *Mactromya* (?) ind. sp. (very rare), *Camptonectes (Camptonectes)* cf. *lamellosus* (Sow.) (very rare).

No ethological classifications have been made of the benthos for exposure 1, since the shells of the invertebrates are generally leached out of the rock and the true ratio of the groups has been destroyed. The taphonomy is not given for this reason.

Layer 2 (exposure 1; 4.0 m)

Lithological description. Chloritolite nodular, glauconitic, silty-sandy, with hydrogoethitic-leptochloritic or leptochloritic-sideritic cement. Color light tobacco green, in places brown. Rock weakly compact, relatively light. Jointing clumpy, texture massive. The layer is characterized by its lighter color, the relatively low specific gravity of the rocks, and their lesser density. At a distance of 0.7 m from the bottom of the layer there is a horizon of small (10–15 cm in diameter) ellipsoidal concretions with ammonites. Similar concretions are occasionally found higher up as well. Fine gravel is sparsely scattered throughout the layer.

Microscopic examination showed that the rock consists mainly of nodules and grains of authigenous ferruginized minerals. The nodules are made up mostly of a leptochlorite nucleus (sometimes oxidized and replaced by hydrogoethite), enclosed in a shell of leptochlorite. Such shells sometimes have a distinctly concentric structure. Grains of glauconite often make up the nuclei. Present in smaller amounts are grains of glauconite of the same form and size as in layer 1. But here they are much fewer (10–15% at the bottom of the layer, 1–3% at the top). A few hydrogoethitic-leptochloritic oölites, sometimes brittle, are observed. As in the underlying layer, the terrigenous material is weakly sorted and unevenly dispersed in the cementing mass of the rock. Its content is from 5–10 to 15–20%. It consists mainly of grains of coarse silt and pelite, plus coarse sand. Sparse particles of coarse sand and even of fine gravel up to 1.2 mm in size are observed. Composition: predominance of quartz (about 90%), 3–7% mica, sparse grains of feldspars, fragments of quartzites, and sometimes very fine grains of accessory minerals. The cement is composed of leptochlorite of colloform or finely flaky structure. In places it is replaced almost entirely by pelitomorphic or fine-grained siderite. A considerable admixture of finely dispersed clayey substance, including small flakes of hydromicas, appears in the upper part of the layer in the cementing mass.

The heavy fraction 0.1–0.01 mm in size accounts for up to 19.1%. Authigenous heavy minerals are represented by siderite, sometimes pyrite, and terrigenous minerals mainly by epidote (to 74.6%), and hornblende (about 10%). Magnetite, garnet, tourmaline, and rutile are present in an amount ranging from 1 to 3%, while other minerals account for fractions of a percent. The light fraction is dominated by quartz (about 90%); feldspars amount to 4% and micas to 5%.

At the roof of layer 2 with erosion lies a member of Quaternary sands and loams about 5 m thick.

Paleontological description. Ammonites: *Hectoroceras tolijense* (Nik.) (frequent), *Hectoroceras* ind. sp. (frequent), *Borealites* spp. (frequent). Bivalves: *Entolium* cf. *nummulare* (Fisch.) (very rare), *Astarte (Astarte)* ind. sp. (very rare), *Teredo* (rare). Brachiopoda: Brachiopoda gen. and ind. sp. (very rare).

In view of the paucity of paleontological remains and their poor state of preservation, no ethological or taphonomic studies were conducted.

Exposure No. 2 is situated about 200 m east of exposure 1, some 150 m north of the river bank. Bedrock was stripped at a height of 8–11 m above river level. Taking into account the gradient of the river, which is of about 1.5–2.0 m in the area between exposures 1 and 2, and the dip of the rocks, we may assume that the stripping uncovered that part of the section of the Berriasian stage which corresponds to a height of 18–21 m in exposure No.1.

Berriasian sediments in the stripping are revealed for a thickness of 3 m and are represented by clumpy, brown compact, ferruginized rocks with remains of ammonites of the *Surites analogus* zone. The lowermost strata of the member were not revealed, but at its roof with erosion lie light-gray clays with an abundance of plant detritus, which are provisionally referred to the Aptian-Albian.

Zone *Surites analogus* (visible thickness 3.0 m)

Layer 1 (exposure 2; visible thickness 3.0 m)

Lithological description. Chloritolite pelitomorphic, with nodules of leptochloritic or hydrogoethitic-leptochloritic composition; clayey sandy-silty, micaceous. Color brown (weathered varieties), tobacco green. A relict bluish gray color is preserved inside the lumps and clumps. Rock compact, relatively heavy, jointing clumpy, coarse-lumpy. Cracks filled with silt and clay material. Texture massive. In the near-surface zone, the rocks of the layer are heavily jointed and lumpy, strongly ferruginized and intermixed with silt. In a fresh section it is seen that the rocks are not laminated and contain a good number of fragments of charred and ferruginized wood (sometimes large pieces) and individual grains of fine gravel. There are small carbonate (siderite) clusters of concretions. Paleontological remains represented by internal molds of bivalves, very scarce internal molds of small brachiopods and ammonites, tubes of worms, and apertures from belemnite rostra.

Under the microscope it is seen that the bulk of the rock is made up of finely flaky leptochlorite. The chloritic finely dispersed mass is scattered (7–10%) with irregularly shaped fine grains of hydrogoethite, formed on account of the oxidation of siderite crystals. In places the leptochloritic main mass is oxidated and replaced by colloform clods of hydrous ferric oxides. The main mass of the rock contains numerous (15–20%) flakes of micas, in places a considerable admixture of finely dispersed clayey substance, and also fairly well-sorted sandy-silty material (to 25%). In the main these are grains of coarse silt with a few grains of fine sand. There is occasional fine gravel, up to 2 mm in size. The composition of the sandy-silty material is the same as that in the Berriasian rocks in exposure 1. Nodules of hydrogoethite-leptochlorite composition and of round, more often oval or angularly round form are distributed in nests in the rock. These are generally light-brown leptochlorite segregations oxidized to hydrogoethite, regenerated and surrounded by shells of yellowish green nonoxidated leptochlorite. The shells of the nodules are sometimes characterized by an indistinct fine-concentric structure. The size of the nodules is 1.5–2 mm, and their content about 5–7%. The rock also contains occasional grains of glauconite.

The yield of heavy fraction 0.1–0.01 mm in size is 15.4%. Authigenous minerals are hydrous ferric oxides and siderite (8–10% of the weight of the fraction), terrigenous minerals are epidote, hornblende, tourmaline, zircon, rutile, garnet, iron ores, and others in the same amount as in the Berriasian rocks in exposure 1. The light fraction is also represented mainly by quartz and micas (to 15–20% of the latter), the authigenous minerals by leptochlorite.

At the roof of the erosional layer occur light-gray, probably continental clays which are provisionally dated to the Aptian-Albian. The surface of erosion is distinct, gently wavy, and is emphasized by accumulations of charred plant remains.

Paleontological description. Ammonites: *Surites* ind. sp. (rare). Belemnites: *Acroteuthis (Acroteuthis)* ind. sp. (very rare). Bivalves: *Buchia okensis* (Pavl.) (rare), *B. volgensis* (Lah.) (rare).

Due to the weathering of the rocks and the poor state of preservation of the oryctocenosis, ethological and taphonomic observations were not conducted.

MAURYN'YA RIVER

Berriasian outcrops were observed by Zakharov and Mesezhnikov in 1966 on the right bank of the Mauryn'ya River, a right-hand tributary of the Tol'ya, about 8 km from the mouth as the crow flies. Exposure No. 52 is a scarp about 10 m high, the lower part of which is composed of rocks of Berriasian age rich in fauna. Exposure No. 53 consists of vysypki* of Berriasian rocks corresponding to layers 1–2 of exposure 52 and is situated on the slope of the right bank some 75–100 m downstream from exposure 52.

Layer 1. Thickness 0.20 m. Crops out in the river bed and a little above the waterline. Sand homogeneous, fine-grained, light-gray, with ammonites (determined by Mesezhnikov): *Hectoroceras* cf. *kochi* Spath, *H. tolijense* (Nik.), *H.* sp., *Surites* sp. juv. Belemnites: *Acroteuthis (Microbelus) mosquensis* (Pavl.). Bivalves: *Liostrea uralensis* Zakh. n. sp. (frequent), *Cucullaea* sp. (frequent).

Layer 2. Thickness 0.60 m. Sand fine-grained, brown. Ammonites: *Hectoroceras* cf. *kochi* Spath. Belemnites: *Acroteuthis (Microbelus) uralensis* Sachs and Naln., *A. (M.) mosquensis* (Pavl.), *Lagonibelus (Lagonibelus) gustomesovi* Sachs and Naln. Bivalves: *Liostrea uralensis* Zakh. n. sp. (very many), *L. lyapinensis* Zakh. n. sp. (frequent), *Camptonectes (Boreionectetes)* sp. juv. (very rare), *Pleuromya* sp. (very frequent), *Pinna* ind. sp. (very rare), *Cyprina* sp. (very frequent), *Isognomon* sp. (frequent), *Plagiostoma* sp. (very rare), *Panopaea* sp. (very frequent), *Modiolus* sp. (very rare). Brachiopoda: *Fusirhynchia micropteryx* (Eichw.), *Ptilorhynchia* aff. *seducta* Dagys.

Layer 3. Thickness 0.50 m. Sand brown. Bivalves: *Cucullaea* sp. (many), *Astarte (Astarte) veneris veneris* d'Orb. (very frequent), *Pleuromya* sp. (very frequent), *Cyprina* sp. (frequent), *Panopaea* sp. (frequent), *Liostrea uralensis* Zakh. n. sp. (frequent). Gastropoda: *Turritella* sp.

Layer 4. Thickness more than 2.7 m. Sandstone loose, brown. In the middle part of the layer there is a lens of dense calcareous sandstone with *Hectoroceras* cf. *kochi* Spath. Bivalves: *Liostrea lyapinensis* Zakh. n. sp. (frequent), *Pleuromya uralensis* d'Orb. (very rare), *Pinna* ind. sp. (very rare).

It is apparently from outcrops farther downstream that in 1962 Vereninova and Nal'nyaeva collected *Subcraspedites (Borealites)* ex gr. *suprasubditus* (Bogosl.) and a rich complex of belemnites: *Cylindroteuthis (Cylindroteuthis) lepida* Sachs and Naln., *C. (Arctoteuthis) porrectiformis* And., *C. (A.)* aff. *subconoidea* Sachs and Naln., *C. (A.) repentina* Sachs and Naln., *Lagonibelus (Lagonibelus) elongatus* (Blüthg.), *L. (L.) sibiricus* Sachs and Naln., *L. (L.) gustomesovi* Sachs and Naln., *Pachyteuthis (Pachyteuthis) acuta* (Blüthg.), *P. (P.) subrectangulata* (Blüthg.), *Acroteuthis (Microbelus) mosquensis* (Pavl.), *A. (M.) uralensis* Sachs and Naln., *A. (Boreioteuthis) explorata* Sachs and Naln.

* [Vysypka (plural, vysypki) is the Russian term for rock fragments scattered around showing the presence of bedrock.]

This complex more than any other characterizes the lower horizons of the Berriasian that are missing in the sections on the Yatriya and Tol'ya rivers (analogues of the *Chetaites sibiricus* zone).

In 1968, exposures along the Mauryn'ya River were investigated by Gol'bert and Klimova, who found there only Quaternary boulder loams that in places contain very numerous redeposited rostra of belemnites and concretions with Kimmeridgian, Berriasian, and Valanginian ammonites. It may be that the sandstone outcrops observed by previous geologists were buried under taluses or occurred in the form of detached masses in Quaternary strata and were washed out.

CONDITIONS FOR SEDIMENTATION AND EXISTENCE OF FAUNA

In the Cis-Polar Trans-Urals the Berriasian stage is made up of sediments of the upper part of the marine basin sublittoral. In the middle part of the region (sections of the Yany-Man'ya and Tol'ya rivers) these are essentially chemogenic rocks of a facies of nodular-oölitic iron ores – nodular chloritolites. In the north (Yatriya River) the Berriasian deposits are represented by rocks of the far-away zone in which the same facies peters out. They contain fewer chemogenic ore components and are rich in terrigenous material. The upper half of the section of the stage there is composed of more deepwater sediments: silty clays with nodules of leptochlorite and a relatively high glauconite content. In the south of the Cis-Polar Trans-Urals the Berriasian stage is also represented by a facies of nodular-oölitic iron ores, as is seen from borehole cores (Lider, 1964).

Lithological-facial and biofacial analyses attest to the formation of Berriasian sediments in a mobile hydrodynamic environment at depths from 10–20 m (layers enriched with pebble and coarse gravel in sections of the Yatriya and Yany-Man'ya rivers) to 30–50 m. On the Yatriya, the upper horizons of the Berriasian were formed under more deepwater conditions, apparently to 60–100 m. High up in the section the successive replacement of shallow-water by more deepwater facies is distinctly manifested everywhere, indicating that the basin became progressively deeper. On the Yatriya this is established from the replacement of gravelly sandstones by sandy siltstones with sparse fine gravel, then by siltstones, and, finally, by silty clays; in the sections of essentially chemogenic formations it is ascertained from the decrease in size and amount of gravel and sand grains, from the diminished content of leptochloritic nodules, and from the increased admixture of clayey material.

The shallow-water littoral origin of the layers enriched in gravel and pebble (Yatriya River, exposure 1, layer 1; Yany-Man'ya River, exposure 1, layer 2) is attested to by the accumulations of coarse clastic material, which is often very weakly rounded, the aggregations of fragments of stems and branches of land plants, the oxidation-reduction character of the environment in the upper layer of sediment (oxidation and replacement in diagenesis of the leptochlorite nodules by hydrogoethite, the absence of pyrite), and also by mixed nature of the displaced thanatocenoses. The fossils as a rule consist of fragments of shells that are often rounded and, subject to the laws of mechanical differentiation (in weight, size, and form), constitute a rock-forming component of the rock. A striking feature is the absence of semipelagic organisms (belemnites) together with the presence of a considerable number (in places even accumulations, Yatriya River) of ammonite remains.* All these facts together are better proof of the shallow-water and littoral origin of the sediments. Along with this, a depth of 10–20 m for the formation of rocks rich in gravel and small pebble must be considered minimal, since the mineral association of the sediments in question (leptochlorite, glauconite, phosphates) could not have arisen under oxidative conditions of the littoral. On the Yany-Man'ya River (exposure 1, layer 2) the hydrodynamic conditions were calmer, as is demonstrated by finds of vertically entombed shells of ammonites; this type of burial would have been impossible with vigorous roiling of the sediment.

Most of the Berriasian sediments were accumulated at depths of about 30–50 m (Yatriya River, exposure 1, layers 2 and 3; Yany-Man'ya River, exposure 1, layers 1, 3, and 4; Tol'ya River, exposure 1, layers 1 and 2). This is confirmed by the characteristics of the lithological composition of the rocks and by the nature of the paleontological remains included in them (numerous remains of semipelagic organisms, including rostra of belemnites, and the appearance of elements of autochthonous thanatocenoses). In the fossil communities the benthos is dominated by bussus forms, the *Buchia* characteristic for biotopes of relatively deep parts of water bodies. At the same time, the proportion of free-lying Pectinidae is increased (Table 4).

Maximum depths of sediment formation (60–100 m) are established for the upper horizons of the Berriasian on the Yatriya River (exposure 1, layers 4 and 5). The sediments are finely dispersed: silty micaceous clays with glauconite and sparse grains of leptochlorite. Pyrite is present in the form of phytomorphs on small plant remains, and there is also scattered (colloidal or dispersed) organic matter. The rocks are as a rule laminated, well sorted, and do not contain any coarse sandy material at all. The authigenous minerals characterize the oxidation-reduction situation in the upper layer of sediment, which becomes reducing in places of organic matter accumulation. Traces of oxidation of minerals not detected. The typical features of the benthos are the diminished number of byssus forms and the predominance of burrowing and free-lying bivalves (Table 4). Belemnite rostra occur frequently. Autochthonous fossil thanatocenoses are dominant in the oryctocenosis. All this points to a relatively calm hydrodynamic regime in the near-bottom part of the water body. Roiling of the mud took place only episodically, during storms. The wealth of benthos (Figure 9) and the presence of glauconite imply a normal gas regime near the bottom of the basin, well-aerated water, and predominantly oxidation-reduction conditions in the mud. The inflow of ferrous solutions from the nearby land which saturated the bottom mud was also a factor in the formation of the facies of nodular chloritolites. In the process of diagenesis, essentially chemogenic leptochloritic rocks, similar in composition and structure to oölitic iron ores, were also formed from this mud.

The Valanginian stage in the Cis-Polar Trans-Urals is composed of sediments of the middle sublittoral of the marine basin (depths 100–150 m). Only in the far south of the region are the lower Valanginian deposits still represented by the same facies as the

* As noted by Reyment (1958), accumulations of ammonite shells are often confined to littoral facies.

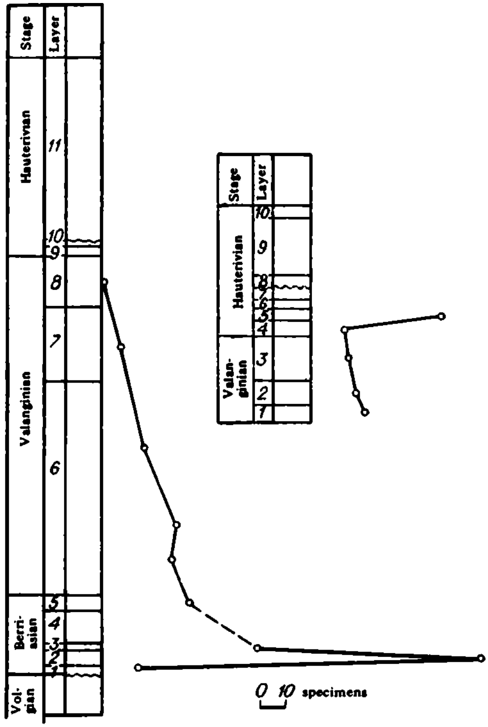


FIGURE 9. Quantitative distribution of benthos in Berriasian and Valanginian sediments on the Yatriya River

Berriasian (nodular-oölitic ferruginous rocks, stripped by a trench on the bank of the Severnaya Sos'va River opposite the village of Ust'-Man'ya). Bluish gray (in places dark-gray) silty micaceous clays are distributed over the remaining territory. The rocks are extremely well sorted (containing for the most part pelitic and fine-silty material); as a rule they are massive and saturated with colloidal and dispersed organic matter. Among the authigenous minerals, pyrite and, in places, siderite are widely developed. Glauconite practically disappears. The lower horizons still contain a few grains of it, as well as small nodules of leptochlorite which are sometimes of concentric structure. In the upper part of the *Temnoptychites insolutus* zone (Yatriya River, exposure 1, layer 6), the peculiar orientation of the mica flakes ("eddying structures") makes it possible to visualize extremely weak turbulence of the water at the bottom, capable of roiling only the lightest particles. The lithological data therefore point to the predominance of oxidation-reduction conditions in the near-bottom waters and of a reducing environment in the upper layer of sediment. The hydrodynamic regime is permanently calm.

The ecological characteristics of the benthos and its distribution in the section suggest a gradual deepening of the basin and deteriorating aeration of the near-bottom waters. At the base of the section of the Valanginian the benthos is still characterized by a considerable density and diversity of composition. Free-lying bivalves now dominate the fossil communities. The other ethological types are found in more or less equal proportions (Table 4). Higher up in the section and especially in the upper zone of the lower Valanginian (Yatriya River, exposure 1, layer 7) the benthos becomes poorer in abundance and diversity (Figure 9). It is made up mostly of creeping and boring types (Table 4). Autochthonous fossil thanatocenoses predominate.

This region used to be situated on the northwest fringe of the West Siberian Late Jurassic-Neocomian marine basin, which occupied almost the whole territory of the present-day West Siberian Plain. The sea was warm, with a normal salinity, and relatively deep in the central part. A relatively warm marine current flowed from north to south along its western shore apparently including and within the limits of the region under consideration. The climate in the northern regions of Western Siberia was warm (similar to that in the subtropics today) and humid (Gol'bert et al., 1968). At a distance of 25–50 km west of the region in question, in the place where the Urals are now, there was low land with a luxurious thermophilic and hygrophilic vegetation. This land served as the main alimentation region, as is shown by the association of terrigenous minerals in the Jurassic and Neocomian sediments (predominance of minerals typical for the Urals complex of rocks: chlorite, epidote, amphibole, micas, metamorphic minerals, and others). Farther to the east, at a distance of 150–200 km there was also land in the form of a large island (Berezovskii) or a group of islands on the structures of the Severnaya Sos'va arch. These pieces of land were separated from the West Siberian Sea by the basin of the Cis-Polar Trans-Urals, transforming it into a sea strait with a current running northeast-southwest. The stretches of land were situated near the western shore of the strait.

A marine basin, the Pechora, also existed in the Late Jurassic and Neocomian to the northeast of the Russian Plain. The Urals land was a narrow peninsula separating the basin from the West Siberian Sea. These basins intercommunicated north of Pai-Khoi. The Cis-Polar Urals and Pai-Khoi may have become flooded from time to time in the Late Jurassic and Neocomian and were transformed into an archipelago of islands separated by shallow straits connecting the Pechora and West Siberian seas.

The end of the Late Jurassic and beginning of the Early Cretaceous was marked in the Cis-Polar Trans-Urals by a certain shoaling of the marine basin, and this was reflected in the appearance of shallow-water facies (e.g. obliquely laminated littoral-marine sands in the upper Volgian sediments in the Tol'ya River section) and also in the appearance of breaks in sedimentation (or an extremely marked slowdown in its rate, even to complete stoppage – pauses) of various duration and character (Gol'bert and Klimova, 1969). However, the shoaling process did not cause the basin to dry up in any of the areas studied. The pauses in sedimentation occurred under the water in the sea shallows. For instance, on the Tol'ya River, judging from the omission of the lower zone of the Berriasian stage *(Chetaites sibiricus)* from the section and, probably, of the lower part of its second zone, we find a break in sedimentation that lasted longer than it took for the *Chetaites sibiricus* zone to be formed. In the exposure the break is registered in the form of a horizontal, gently sinuous or in places almost even surface of an ancient sea bottom that had become consolidated and buried in sediment. Below this surface occur sediments with fauna of the upper Volgian substage and directly above this sediments with the fauna of the Berriasian *Hectoroceras kochi* zone. On the Tol'ya River two pauses in sedimentation are additionally noted in the middle zone of the upper Volgian substage (Gol'bert, 1969). In none of the cases discussed above were the breaks in sedimentation accompanied by erosion of the sediments accumulated earlier.

The break in sedimentation on the Yatriya River section at the beginning of the Berriasian age was different. Here the siltstones of the upper Volgian substage are transgressively overlapped by sediments of the Berriasian stage, beginning as the basal gravelly sandstones of the *Hectoroceras kochi* zone. Totally missing from the section, therefore, are the lower zone of the Berriasian *(Chetaites sibiricus)* and, apparently, the lower horizons of the *Hectoroceras kochi* zone, while in the basal layers of the Berriasian are found small fragments of the underlying Upper Jurassic rocks and also shells of Jurassic bivalves. All this bears witness to the fact that the break in sedimentation was quite prolonged and was accompanied by erosion of the underlying sediments. As is clear in a comparison of the Yatriya, Yany-Man'ya, and Tol'ya sections, the erosion was not deep and took place in underwater conditions, as is proved by the absence of any trace of subaerial weathering (Gol'bert and Klimova, 1969).

Beginning with *"Hectoroceras kochi"* time, the main trend in the development of the marine basin in the Cis-Polar Trans-Urals during the Berriasian and Valanginian ages was a gradual deepening of the sea and receding of the shoreline.

A facial analysis shows that the upper Volgian and Berriasian sediments were formed in the shallow-water littoral zone of the marine basin at least 25–50 km from the shore (Gol'bert, 1966; Gol'bert and Klimova, 1969). At this time processes of chemical erosion were going on intensively on land, with the result that solutions of iron and other components entered the mass in the littoral part of the marine basin. Thus it became possible for the essentially ferruginous rocks composing the deposits of this age to be formed.

The early Valanginian saw a further development of the marine transgression with a peak in the middle. The areas under consideration were the bottom of a relatively deep sea, and the sediments which built up acquired a number of features of sediments of the pelagial (high degree of dispersion and sorting of the material, absence of stratification, the chloritic-hydromicaceous composition of the clays, the predominance of semipelagic over benthic organisms, etc.).

STRATIGRAPHIC CONCLUSIONS

The Berriasian sediments in the Cis-Polar Trans-Urals form an almost uninterrupted section and consist of marine facies that are characterized by a specific fauna, including ammonites. This permits them to be broken down into zones and allows for a correlation to be made with the corresponding subdivisions of adjacent regions and of the international scale. Another advantage is the fact that the Berriasian sediments form an uninterrupted section with the underlying sediments of the marine Upper Jurassic, owing to which the boundary between the Jurassic and Cretaceous can be established quite precisely according to paleontological data. In certain sections it is perceived by the changes in the lithological composition of the rocks: by the switch from glauconites to chloritolites, by the appearance of layers enriched in gravel, and in places by intraformational hiatuses.

Berriasian stage. Zone *Chetaites sibiricus.* This comprises 3.0 m thick nodular-sandy-silty chloritolites with sparse fine gravel on the Yany-Man'ya River. The chloritolites conformably overlie the glauconites of the upper part of the Volgian stage of the Upper Jurassic and are linked with them by a gradual transition. On the Yatriya and Tol'ya rivers there was a break in sedimentation at the time that this zone was formed.

There are few paleontological remains. Ammonites: *Chetaites* sp. (cf. *sibiricus* Schulg.). Bivalves: *Astarte* ind. sp., *Modiolus* ind. sp., *Entolium* ind. sp., (?) *Corbicella* ind. sp., *Pinna* ind. sp. Brachiopoda: *Uralella* cf. *gigantea* Makr.

In northern Siberia the *Chetaites sibiricus* zone is the lower zone of the Berriasian stage and corresponds to the *Praetollia maynci* zone in eastern Greenland.

The sediments of the *Hectoroceras kochi* zone are represented by gravelly quartz-leptochlorite sandstones, siltstones, and nodular chloritolites with gravel and small carbonate concretions.

On the Yany-Man'ya River the sediments of the zone in question conformably overlie the rocks of the *Chetaites sibiricus* zone. On the Yatriya and Tol'ya rivers there is a break in sedimentation at the base of the zone which in places (Yatriya River) was accompanied by erosion of the sediments formed earlier. The thickness of the *Hectoroceras kochi* zone is 7 m.

The zone has a rich faunal complex. Ammonites: *Hectoroceras tolijense* (Nik.), *H.* spp., *H.* ind. sp., *Borealites fedorovi* Klim., *B. radialis* Klim. n. sp., *B. explicatus* Klim. n. sp., *B. mirus* Klim. n. sp., *B. (?) surítiformis* Klim. n. sp., *B.* ind. sp. Belemnites: *Cylindroteuthis (Cylindroteuthis) lepida* Sachs and Naln., *C. (C.) luljensis* Sachs n. sp., *C. (Arctoteuthis) porrectiformis* And., *C. (A.) repentina* Sachs and Naln., *Lagonibelus (Lagonibelus) gustomesovi* Sachs and Naln. Bivalves: *Cyprina* ind. sp., *Astarte* cf. *veneris* d'Orb., *Astarte (Astarte)* ind. sp., *Liostrea lyapinensis* Zakh. n. sp., *Plagiostoma incrassata* Eichw., L. *Limatula consobrina* (d'Orb.), *Isognomon triviale* Zakh., *Entolium nummulare* (Fisch.), *E. demissum* (Phill.), *Camptonectes (Camptonectes) lamellosus* (Sow.), *C. (Boreionectes)* cf. *imperialis* (Keys.), *C. (B.) breviauris* Zakh., *Pinna* cf. *romanikhaensis* Zakh.., *Aguilerella anabarensis* (Krimh.), *Oxytoma (Oxytoma expansa* (Sow.), *Inoceramus* (?) ind. sp., *Pleuromya* sp., *Mactromya* (?) ind. sp., *Buchia* ind. sp. Brachiopoda: *Uralorhynchia* ind. sp., *U.* sp., Brachiopoda ind. gen and sp.

The *Hectoroceras kochi* zone was established on the basis of the presence of ammonites of the genus *Hectoroceras* that characterize an analogous zone in northern Siberia and eastern Greenland.

The *Surites analogus* zone is composed of nodular chloritolites, quartz-leptochlorite siltstones, and silty clays with glauconite. A complex section of the zone 6.2 m thick is revealed only on the Yatriya River (exposure 1). On the Yany-Man'ya River its uppermost strata are not exposed, and on the Tol'ya River only the middle part of the zone has been established in bedcrop outcrops.

The zone is characterized by a few remains of the ammonites *Surites* cf. *spasskensis* (Nik.) and *S.* ind. sp. and accumulations of *Buchia.* There are frequent finds of rostra of belemnites, among which the following were determined: *Cylindroteuthis (Cylindroteuthis) lepida* Sachs and Naln., *C. (C.) luljensis* Sachs, *C. (Arctoteuthis) porrectiformis* And., *C. (A.) repentina* Sachs and Naln., *Lagonibelus (Lagonibelus) gustomesovi* Sachs and Naln., *L. (L.) elongatus* (Blüthg.), *L. (L.) sibiricus* Sachs and Naln., *Pachyteuthis (Pachyteuthis) subrectangulata* (Blüthg.), *P. (Simobelus) curvula* Sachs and Naln. Bivalves: *Buchia volgensis* (Lah.), *B. okensis* (Pavl.), *B. fischeriana* (d'Orb.), *B. terebratuloides* (Lah.), *B. uncitoides* (Pavl.), *Pleuromya uralensis* d'Orb., *Liostrea lyapinensis* Zakh. n. sp., *Camptonectes (Camptonectes)* ind. sp., *C. (Boreionectes)* ind. sp., *Pseudamussium* aff. *bojarkaensis* Zakh., *Entolium nummulare* (Eichw.), *Limatula* aff. *consobrina* (d'Orb.), *Plagiostoma* cf. *incrassata* (Eichw.), *Modiolus* ind. sp., *Oxytoma (Oxytoma) expansa* (Phill.), *Astarte (Astarte)* ind. sp., *Cucullaea* ind. sp., *Pholadomya* ind. sp., *Aguilerella* ind. sp., *Pinna* ind. sp. Brachiopoda: *Siberiothyris* sp., *Taimyrothyris bojarkaensis* Dagys, *Uralorhynchia* sp., *Fusirhynchia* ind. sp.

The zone is identified according to the presence of ammonites of the genus *Surites* and is correlated with the analogous zone of the Berriasian in northern Siberia.

Natural outcrops of the *Tollia payeri* zone are present only on the Yatriya River (exposure No. 1), where the zone is composed of silty clays with glauconite 2.4 m thick.

The ammonite *Tollia* cf. *payeri* (Toula) is found in concretions from the middle part of the member of clays. The clays contain a few rostra of belemnites: *Cylindroteuthis (Cylindroteuthis) lepida* Sachs and Naln., *C. (Arctoteuthis) repentina* Sachs and Naln., *Lagonibelus (Lagonibelus) gustomesovi* Sachs and Naln., *Acroteuthis (Acroteuthis) anabarensis* Pavl.), *A. (A.) vnigri* Sachs and Naln. Bivalves: *Camptonectes (Boreionectes)* ind. sp., *Pleuromya uralensis* d'Orb.), *Cyprina* sp., *Musculus* cf. *strajeskianus* (d'Orb.), *Pholadomya* ind. sp., *Goniomya,* ind. sp., Gastropoda: *Pleurotomaria* ind. sp.

The zone is identified from finds of *Tollia* cf. *payeri* (Toula), a species of ammonite which characterizes the analogous zone of the Berriasian in eastern Greenland, and the zone is correlated with the *Bojarkia mesezhnikowi* zone in northern Siberia.

Valanginian stage. The *Temnoptychites insolutus* zone has a complete section on the Yatriya River (exposure No.1). The zone is made up of silty clays with sparse carbonate concretions. The thickness of the zone is 34 m.

Fauna was collected from the sediments. Ammonites: *Temnoptychites* aff. *syzranicus* Pavl., *T. grandis* Klim. n. sp., *T. insolutus* Klim. n. sp., *Neotollia venusta* Klim. n. sp., *Polyptychites* aff. *sphaericus* Koen. The clays in the upper part of the zone yielded *Neotollia densa* Klim. n. sp. Belemnites: *Acroteuthis (Acroteuthis) anabarensis* (Pavl.), *A. (A.) vnigri* Sachs and Naln., *A. (A.) arctica* (Blüthg.), *A. (A.) chetae* Sachs and Naln., *A. (Boreioteuthis) explorata* Sachs and Naln., *Cylindroteuthis (Arctoteuthis) repentina* Sachs and Naln., *Lagonibelus (Lagonibelus) elongatus* (Blüthg.), *Pachyteuthis (Pachyteuthis) acuta* (Blüthg.). Bivalves: *Camptonectes (Boreionectes) imperialis* (Keys.), *Liostrea anabarensis* Bodyl., *Cyprina* sp., *Astarte (Astarte) veneris* d'Orb., *Oxytoma (Oxytoma) expansa* (Phill,), *Entolium nummulare* (Fisch.), *Buchia crassa* (Pavl.), *Pleuromya uralensis* d'Orb., *Pholadomya* ind. sp., *Limatula consobrina* d'Orb., *Goniomya* sp., *Plagiostoma* aff. *incrassata* (Eichw.), *Musculus* cf. *sibiricus* (Bodyl.), *Pinna* ind. sp., *Lucina* (?) sp., *Inoceramus* sp. Gastropoda: *Turritella* sp. Brachiopoda: *Uralorhynchia* (?) sp.

The *Temnoptychites insolutus* zone is identified according to the presence of ammonites of the genus *Temnoptychites*, in particular, *T. insolutus* Klim. n. sp., and is correlated with the *Neotollia klimovskiensis* zone and the subzone *Temnoptychites syzranicus* of the *Polyptychites stubendorffi* zone in northern Siberia.

WEST SIBERIAN PLAIN

The Berriasian stage in its full volume is widely distributed in the platform mantle of the West Siberian platform. This is indicated by the continuity of the section of marine Upper Jurassic and Neocomian sediments on a large part of the platform, the presence of a complete section of the Berriasian stage in the marginal part of the West Siberian sedimentary basin (in the Cis-Polar Trans-Urals), and finally, by finds of Berriasian ammonites in borehole cores. Almost all over the West Siberian Plain the Berriasian stage is overlain by a thick series of younger deposits and occurs at depths of 1500–2600 m. A study of its rocks, their components, and of the paleontological remains contained in them is therefore possible only from cores of deep boreholes.

At least three zones of the Berriasian stage can be established with certainty according to ammonite finds: *Hectoroceras kochi*, *Surites analogus*, and *Tollia payeri*. The first zone is identified from ammonites of the genus *Hectoroceras* and possibly also the genus *Subcraspedites*, the second zone from ammonites of the genus *Surites* and possibly *Subcraspedites*, and the third zone from the fairly numerous finds of representatives of the genus *Tollia*, particularly individuals determined as *Tollia* cf. *payeri* (Toula). In view of the continuity of the section, the lower zone of the Berriasian stage is certainly present, even though it has not yet been confirmed by reliable finds of the ammonites characteristic for this zone. However, determination of the index species of the lower zone of the Siberian Berriasian, *Chetaites sibiricus* Schulg., requires well-preserved specimens because of the distinctive structure of its shell, and this is more or less ruled out in a core from boreholes of small diameter. It thus may well be that these ammonites were sometimes wrongly determined as Late Jurassic *Dorsoplanites* or *Laugeites*. The presence of the Berriasian stage on the West Siberian Plain is confirmed also by finds of bivalves and foraminifer complexes of Berriasian age. Examples of these bivalves are *Buchia volgensis* (Lah.), *B. okensis* (Pavl.), and *B. terebratuloides* (Lah.). Also typical are *Buchia* ind. sp. (*B.* cf. *stantoni* (Pavl.)), *B.* ind. sp. (*B.* cf. *andersoni* (Pavl.)), *B.* ind. sp. (*B.* cf. *lahuseni* (Pavl.)), *Entolium* cf. *nummulare* (Fisch), and *Astarte (Astarte)* cf. *veneris* d'Orb. Berriasian age has been established for the following foraminifer complexes of Western Siberia: *Haplophragmoides* (?) *fimbriatus*, *Trochammina rosaceaformis*, *Gaudryina gerkei*, *Ammobaculoides sibiricus*, *Trochammina polymera*, and *Reinholdella tatarica*.

Because ammonites, bivalves, and foraminifers are found episodically in borehole cores (and, moreover, as a rule not together) and sampling of the cores at intervals resulted in low percentage yield, there is insufficient evidence for dividing the Berriasian stage into zones and for defining the boundaries of both these and of the stage as a whole on the closed territory of the West Siberian Plain. In view of this, the thickness of the stage and of its zones can be only roughly estimated. In this survey we therefore confine ourselves to a brief description of those zones of the Berriasian stage that are more or less clearly identifiable. Data on the composition and thickness of the sediments in question are based on a lithological characterization of the corresponding regional stratigraphic units – suites and members whose Berriasian age is established according to ammonites, bivalves, and foraminifers.

Zone *Hectoroceras kochi.* Ammonites: *Hectoroceras* ind. sp. (northwest, Chuel'sk borehole 82-t*), (?) *Hectoroceras* ind. sp. (south, Bol'sherech'e borehole 1-t, depth 2522–2531 m, Sargatskoe borehole 2-t, depth 2521 m), *Subcraspedites* ind. sp. (northern Ob area, Lukashkin Yar borehole 1-t, depth 2142–2146 m), (?) *Subcraspedites* ind. sp. (Bol'sherech'e borehole 1-t, depth 2515–2522 m). Bivalves specific to this zone not established. In the lower part of the stage, apparently mainly in the *Hectoroceras kochi* zone, layers are distinguished with complexes of foraminifers that are named after the index species: *Haplophragmoides* (?) *fimbriatus* and *Trochammina rosaceaformis.* The first complex is distributed only in the extreme northeast of Western Siberia, in the Ust'-Yenisei depression. It is characterized by *Haplophragmoides* (?) *fimbriatus* Schar., *Trochammina rosaceaformis* Rom., *Crebrostomoides umbonatus minusculus* Bulyn. (in litt.), and *Ammobaculites gerkei* Schar. It should be noted that the earliest appearance of the first two of the above species was established by Basov (1969) in the north of Middle Siberia in the *Chetaites sibiricus* zone; in other words, both the lower zones of the Berriasian stage may characterize the given complex in Western Siberia. The *Trochammina rosaceaformis* complex is distributed to the south and southwest and also in the extreme northwest of the plain. It is characterized by an abundant content of the index species. Small numbers are also present of *Ammodiscus veteranus* Kosyr., *Cribrostomoides infracretaceous* (Mjatl.), *Recurvoides transitorius* Bulyn. (in litt.), *Verneuilinoides perexiguus* Dubr., *Gaudryina gerkei* (Vass.), and others.

Zone *Surites analogus.* Ammonites: (?) *Surites* ind. sp. (south, Omsk borehole 1-t, depth 2344–2345 m), (?) *Surites* (?*Borealites*) ind. sp. (southeast, Kolpashevo borehole 2-t, depth 2288 m), *Subcraspedites* ind. sp.((?) *subpressulus* (Bogosl.)) (middle Ob area, Nazina borehole 3-t, depth 2093–2098 m, Severo Vasyugan borehole 1-t, depth 2075–2080 m). Bivalves: *Buchia volgensis* (Lah.), *B. okensis* (Pavl.), and *B. terebratuloides* (Lah.). Foraminifer complexes: *Gaudryina gerkei, Ammobaculoides sibiricus,* and *Trochammina polymera.* In most sections the last complex characterizes younger deposits (*Tollia payeri* zone). The *Gaudryina gerkei* complex is known mainly in the Cis-Urals part of Western Siberia, in isolated sections in the southeast (region of the town of Kolpashevo), and also in the extreme northeast (Dudinka). Characteristic for the complex, apart from the index species, are: *Glomospirella multivoluta* (Rom.), *Cribrostomoides infracretaceous* (Mjatl.), *C. umbonatus umbonatus* (Rom.), *Ammobaculites praegoodlandensis* Bulyn. (in litt.), *A. gerkei* Schar., *Haplophragmium scabrum* Bulyn. (in litt.), *Gaudryina gerkei* (Vass.), *Marginulina robusta* (Reuss), *Reinholdella tatarica* (Rom.), and others. In the western regions, ranking second in the complex after the index species is *Ammobaculites praegoodlandensis* Bulyn.; to the northeast the complex becomes less heterogenous, and a number of species disappear. In the southern regions and in some places in the northwestern areas this complex is replaced by an *Ammobaculoides sibiricus*

* [The symbol t denotes a test borehole.]

complex which contains, apart from the index species, *Rheophax* spp., *Recurvoides obskiensis* (Rom.), *Ammobaculites praegoodlandensis* Bulyn. (in litt.), *A. gerkei* Schar., *Trochammina polymera* Dubr., *Verneuilinoides perexiguus* Dubr., *Marginulina zaspelovae* Rom., *Reinholdella tatarica* (Rom.), and others.

Zone *Tollia payeri.* Ammonites: *Tollia* cf. *payeri* (Toula) (south, Tatarskoe borehole 1-t, depth 2327–2334 m), (?) *Tollia* cf. *payeri* (Toula) (south, Tebis borehole 1-t, depth 2153–2165 m, Bol'sherech'e borehole 1-t, depth 2492–2500 m, Malinovka borehole 2-t, depth 2031–2037 m), *Tollia* ind. sp. (Bol'sherech'e borehole 1-t, depth 2423–2435 m, Shirotnoe Priob'e, Kursk borehole 1-t, depth 2253 m), *Tollia* ind. sp. ((?) *Borealites* ind. sp.) (Tarskoe Preirtysh'e, Novovasil'ev'ka borehole 1-t, depth 2404–2409 m). Bivalves characterizing this zone not established. Foraminifer complexes: *Trochammina polymera* and *Reinholdella tatarica.* In the northwest of Western Siberia *R. tatarica* is also found in the *Temnoptychites insolutus* zone of the lower Valanginian. Beds with a *Trochammina polymera* complex are distributed in the western regions of Western Siberia and overlie sediments containing complexes of *Gaudryina gerkei* and *Ammobaculoides sibiricus.* The composition of the complex is fairly homogeneous. Apart from rich populations of the index species, a few shells of *Recurvoides paucus paucus* Dubr., *Verneuilinoides perexiguus* Dubr., and *Ammodiscus* sp. are found. The beds with *Trochammina polymera* are overlain by sediments with a *Reinholdella tatarica* complex which are traced practically over the whole territory of the West Siberian Plain. In the south a *Reinholdella tatarica* complex is encountered together with *Tollia* cf. *payeri* (Toula), and in the northwest, above the beds with *Gaudryina gerkei* and *Trochammina polymera.* Apart from a few agglutinating foraminifers, *Cribrostomoides infracretaceous* (Mjatl.) and *Trochammina rosaceaformis* Rom., the complex contains an abundance of *Reinholdella tatarica* (Rom.), diverse Nodosariidae (genera *Lenticulina, Marginulina, and Saracenaria*) and Polymorphinidae. In the upper, apparently Valanginian part of the beds with the complex investigated, *Hoeglundina* sp. is present.

Over a large part of the West Siberian platform the Berriasian stage is composed of marine sediments: dark gray (in places nearly black), brownish black, or gray argillites (often bituminous), dark gray siltstones, and, more rarely, sandstones. On the edges of the platform and in the arch parts of the inner uplifts, the sections are dominated by sandy-silty rocks, clays, and argillites included in them in the form of relatively thin beds and members. In the depressions on the northwest side of the platform the Berriasian stage is composed almost completely of argillites. In the extreme southeast, in the Chulym-Yenisei region, a break in sedimentation and, possibly, the lowermost strata of the continental variegated clays of the index suite (Berriasian (?)–Aptian) corresponds to it according to the stratigraphic scheme.

The lithological composition, area of distribution, and even the nature of the paleontological remains of the Berriasian stage (especially its lower part) have much in common with the Volgian stage of the Upper Jurassic, with which it is linked by a gradual transition. The boundary between the Jurassic and Cretaceous, that is, between the Volgian and Berriasian stages, in most sections passes within lithologically homogeneous strata and can be established only from paleontological data. For example, over broad expanses it passes within the Bazhenov and Tutleima suites (correspondingly Volgian stage–Berriasian and Volgian stage–Valanginian), which are composed of chestnut-brown-black bituminous argillites. Finds of Late Jurassic ammonites are known in the lower parts of these suites and of Berriasian and Valanginian ammonites in the upper parts. No finds of any of these were made in any of the sections (at the corresponding stratigraphic levels). In view of this, it is important when dividing sections to correlate the sediments according to the logging and lithological data. The Berriasian age of the upper part of the series of primarily Upper Jurassic bituminous argillites is established from finds of ammonites, particularly for the topmost strata of the Bazhenov suite in the south, in the Bol'sherech'e and Sargaskoe areas (Gol'bert and Klimova, 1969). Finds of *Subcraspedites* sp. and foraminifer complexes have fixed the middle part of the bituminous argillites of the Shaima suite (upper Callovian–lower Hauterivian) to the west of the plain as being of Berriasian age. In the south of Western Siberia the bottom of the Berriasian stage is apparently extremely close to or coincident with the boundary of the Mar'yanov (upper Callovian–Volgian stage) and Kulomzin (Berriasian–Valanginian) suites. The boundary is quite accurately ascertained here from finds above the surface of the Mar'yanov suite of *Surites* ind. sp., *Buchia volgensis* (Lah.), and a *Trochammina rosaceaformis* foraminifer complex, while below it is fixed by finds of *Buchia mosquensis* (Buch) and a complex of Volgian foraminifers with *Ammodiscus veteranus* and *Arenoturrispaillia phiala.* It is true that all these remains are found scattered, in sections of different boreholes, but the paleontological data link up well here if layer-by-layer correlations are made.

Nor does the upper boundary of the Berriasian stage in Western Siberia as a rule coincide with the natural boundaries of actual sections (of suites and members). In the southern and central regions of the West Siberian Plain it passes in the upper part of the Kulomzin and Megion (Berriasian–Valanginian) suites and also in the lower horizons of the Akha suite (Berriasian–lower Hauterivian). But the position of the boundary is determined only approximately by correlating sections of boreholes containing remains of Berriasian and early Valanginian ammonites, bivalves, and foraminifers. In the northwestern regions of the West Siberian Plain the boundary between the Berriasian and Valanginian stages passes inside the bituminous argillites of the Shaima suite. The lower horizons of the dark gray nonbituminous argillites with intercalations of clayey limestones of the Frolov suite (Berriasian (?)–Aptian) and the lowermost strata of the middle series of the Yarrotin suite (Berriasian (?)–lower Hauterivian), composed of sandstones and siltstones with intercalations of argillites, are provisionally referred to the Berriasian stage.

In the northeast of Western Siberia, single finds of Berriasian ammonites, bivalves, and foraminifer complexes have placed in the Berriasian stage the upper horizons of argillites and siltstones of the Yanovstan suite (Kimmeridgian–Berriasian) and the lower parts of the Yurats (Berriasian–lower Hauterivian) and Nizhnekheta (Berriasian–lower Valanginian) suites, which are composed of gray siltstones and clays with subordinated intercalations of sandstones.

In the central and southern regions of the West Siberian Plain (Shirotnoe Priob'e, Ob-Irtysh interfluve) three lithologically differentiated parts are distinguished in the Berriasian stage (Trushkova, 1969).

The lower part, belonging to the Bazhenov suite, is made up of sediments of a relatively deepwater marine basin: chestnut-brown-black bituminous argillites with thin intercalations of black pelitomorphic limestones. The rocks are platy, in places massive, and crammed with remains of fish and hooks of belemnites. Mollusk shells occur frequently. The thickness of this part of the Berriasian stage is 10–15–35 m. In volume it apparently corresponds to the two lower zones of the Berriasian.

The middle part of the stage is represented by dark chestnut-brown-gray thinly laminated bituminous argillites, which were formerly identified as the upper Mar'yanov subsuite (Gurari, 1959, 1961). In the unified stratigraphic scheme of the West Siberian lowland published in 1967, these deposits were included in the Megion and Kulomzin suites. The rocks bear signs of shoaling of the marine basin. The fine lamination of the argillites is due to their thin beds of light-gray nonbituminous argillites and siltstones. In the Central Ob area on the Surgut and Nizhnevartovskoe arches the argillites are replaced by members of siltstones and sandstones up to 22 m thick. The age of this part of the Berriasian stage corresponds approximately to the time of formation of the *Surites analogus* zone and the lower part of the *Tollia payeri* zone. Its thickness is 20–40 m. This part of the stage is extremely rich in remains of mollusks. The following ammonites were determined: *Subcraspedites* ind. sp. (Lukashkin Yar borehole 1-t, depth 2142–2146 m), *Subcraspedites* ind. sp. ((?) *S. subpressulus* (Bogosl.)) (Nazina borehole 3-t, depth 2093–2098 m), (?) *Surites* ind. sp. (Omsk borehole 1-t, depth 2344–2345 m). A core sample of the Novovasil'ev'ka borehole 1-t (depth 2404–2409 m) yielded remains of *Tollia* ind. sp. (? *Borealites* ind. sp.), and on the Bol'sherech'e area (borehole 1-t, depth 2492–2500 m) (?) *Tollia* cf. *payeri* (Toula). In the Za'yalovo area we encountered *Buchia* cf. *terebratuloides* (Lah.), while in a core sample of the Uvat key borehole Mesezhnikov determined *B.* cf. *volgensis* (Lah.) (depth 2653–2656 m). Correlations of the sections by layers showed that the ammonites of the *Surites analogus* zone are usually found in the lower layers of the Kulomzin suite. Farther up were found ammonites of the *Tollia payeri* zone. The thickness of the *Surites analogus* zone in the central regions of West Siberia apparently does not exceed 15 m, judging from finds of fauna and layer-by-layer correlations of the sediments.

The upper part of the Berriasian stage in these regions is composed of shallow-water marine light-gray calcareous sandstones with intercalations of dark gray, often bituminous argillites (Achimov member). The thickness of this part of the stage is highly variable, from several meters to 120 m. In the southern and eastern directions the sandstones of the Achimov member gradually become enriched in clayey material and are replaced by greenish gray argillites of the Kulomzin suite. Paleontological remains are the most numerous in the zone of transition from Achimov member sandstones to argillites. Here are found *Tollia* ind. sp. (Bol'sherech'e borehole 1-t, depth 2423–2435 m) and *Tollia* cf. *payeri* (Toula) (Tatarskoe borehole 1-t, depth 2327–2334 m; Tebis borehole 1-t, depth 2153–2165 m; Malinovka borehole 1-t, depth 2031–2037 m).

Important for determining the upper boundary of the Berriasian stage are finds of bivalves, which are often encountered much higher up than ammonites. Among them we note *Buchia* cf. *okensis* (Pavl.) (Ust'-Sil'gina borehole 1-t, depth 2087–2095 m), *B.* sp. (cf. *terebratuloides* (Lah.)) in sections of the Sredne-Vasyugan borehole 3-t (depth 2055–2060 m) and Ust'-Sil'gina borehole 6-t (depth 2046 m), *B.* ind. sp. (cf. *volgensis*

(Lah.)) in the Pudino borehole 1-t (depth 2390–2395 m) and the Sen'kina borehole 7-t at a depth of 1994–2004 m. The species listed were found either in the topmost strata of the Kulomzin suite or in the lowermost strata of the Tarskaya suite (Berriasian–Valanginian), remembering that in this part of the plain the latter suite occupies the lowest position in the stratigraphic section and has the oldest age (Trushkova, 1969). All the finds mentioned without exception are situated above the sandstones of the Achimov member. The position of the upper boundary of the Berriasian stage is to some extent determined also by finds of early Valanginian ammonites, characterizing the *Temnoptychites insolutus* zone, at the top of the Kulomzin and Megion suites.

It follows from correlating the sections that the thickness of the Berriasian stage for the central regions of the West Siberian Plain is in the region of 150–200 m.

The lower zone of the Valanginian stage, *Temnoptychites insolutus,* contains: *Temnoptychites* ind. sp. (aff. *lgovensis* Nik.), *T.* ind. sp., *T. insolutus* Klim. n. sp. (in litt.), *Neotollia* cf. *densa* Klim. n. sp., *N.* ind. sp., *Buchia* ex gr. *crassicollis* (Keys.), *B.* cf. *terebratuloides* (Lah.), *Oxytoma (Oxytoma)* cf. *articostata* Zakh., *Entolium* cf. *demissum* (Phill.), *Astarte (Astarte)* cf. *veneriformis* Zakh. Foraminifer complexes: *Reinholdella tatarica* and large Lituolidae with *Cribrostomoides infracretaceous* (Mjatl.)

RUSSIAN PLAIN

In describing the sediments of the Ryazan horizon, Bogoslovskii (1897) did not mention which section he took as the stratotype. Sazonova (1965a, 1967) described a section on the Oka River which she proposed as the lectostratotype of the Ryazan horizon and the key section of the Berriasian of the Russian Plain. This section, situated on the right bank of the Oka below the mouth of the Pronya River between the villages of Nikitino and Chevkino, is discussed below. It was studied in 1966 by Sazonova and Sazonov with the collaboration of Saks, Shul'gina, Zakharov, and Pozhariskaya.

1. Upper Oxfordonian – clay dark-gray, almost black, rich, platy, calcareous, with *Amoeboceras alternans* (Buch).

2. Berriasian – *Riasanites rjasanensis* zone (lower stratum of Bogoslovskii's Ryazan horizon). Glauconitic sand, clayey, greenish gray, almost black, with sandy aggregates, with an inclusion of black phosphoritic nodules, containing an abundance of fauna.* Ammonites: *Riasanites rjasanensis* (Venez.), *R. subrjasanensis* (Nik.), *R. swistowianus* (Bogosl.), *Euthymiceras transfigurabile* (Bogosl.), *E. hospes* (Bogosl.), *E. micheicum* (Bogosl.), *E. inexploratum* (Bogosl.), *E.* ? aff. *progenitor* (Opp.), *Pronjaites* ex gr. *bidevexus* (Bogosl.),** *Neocomites* sp. Belemnites: *Acroteuthis (Microbelus) russiensis*

* Ammonites determined by Sazonova, belemnites by Saks, and bivalves by Pozhariskaya.

** The generic names of ammonites given by Sazonova (1971) are retained in the description of the sections on the Russian Plain. In all the summarizing chapters, in accordance with Shul'gina's view, the genus *Peregrinoceras* is referred to *Subcraspedites (Subcraspedites)*, the genus *Pronjaites* is considered a subgenus of the genus *Subcraspedites*, and the species *simplex* (Bogosl.) is included in the genus *Temnoptychites.* The genera *Bogoslovskia* and *Subpolyptychites* are hypothetically considered to be subgenera of the genus *Surites.* The species *analogus* (Bogosl.) is placed in *Surites (Surites)* and the species *suprasubditus* (Bogosl.) in *Subcraspedites (Borealites)*. (Editor.)

(d'Orb.), *A. (M.) uralensis* Sachs and Naln., *A. (M.) mosquensis* (Pavl.), *A. (Boreioteuthis) prolateralis* Gust. Bivalves: *Buchia volgensis* (Lah.), *B. fischeriana* (d'Orb.), *Trigonia (Clavotrigonia) scapha* Ay. Thickness 0.2 m.

3. Zone *Surites spasskensis*. Lower part of the middle layer of Bogoslovskii's Ryazan horizon. Sandstone nonuniformly clayey, in places phosphoritized, dark-green, filled with *Buchia* ("*Aucella* coquina" or "*Aucella* horizon") and with fewer ammonites, some of which are phosphoritized. Phosphoritic and sandy nodules are scattered in the lower part of the layer; in the phosphoritic nodules there are still isolated occurrences of redeposited rounded *Riasanites* sp., *Euthymiceras hospes* (Bogosl.), *E. transfigurabile* (Bogosl.), *E. inexploratum* (Bogosl.), and *E. progenitor* (Opp.).

The following were determined from here: *Surites (Caseyiceras) dorsorotundus* (Bogosl.), *S. (C.) analogus* (Bogosl.), *S. (Surites) kozakowianus* (Bogosl.), *S. (S.) spasskensis* (Nik.), *Externiceras solowaticum* (Bogosl.), *E. mostjae* (Bogosl.), *Pronjaites bidevexus* (Bogosl.), *Buchia volgensis* (Lah.), *B. terebratuloides* (Lah.), *B. dilatata* (Pavl.), *B. syzranensis* (Pavl.), *B. elliptica* (Pavl.), *Lima consobrina* d'Orb., *Camptonectes lamellosus* (Sow.), *Avicula russiensis* d'Orb. Thickness 0.15 m.

4. Upper part of the middle layer of the Ryazan horizon. Sandstone loose, in places more consolidated, phosphoritized, glauconitic, dark-green, ferruginized in patches, with phosphoritic black pebble and isolated phosphoritized fragments of fauna from the underlying layers. A large number of ammonites of the *Surites* group and a few *Buchia* are present, and in the sandstone many hiatuses are seen from leached-out rostra of belemnites and other fauna. Thickness 0.20 m.

5. Upper layer of Bogoslovskii's Ryazan horizon. Sandstone silty-clayey, rust-brown, in places phosphoritized (P_2O_5 to 4.1%), with glauconite, in places passing into inequigranular sand. Numerous representatives of the genus *Surites* and very few *Buchia* occur: *Surites (Surites) tzikwinianus* (Bogosl.), *S. (S.) spasskensis* (Nik.), *S. (S.) clementianus* (Bogosl.), *S. (S.) suprasubditus* (Bogosl.), *S. (S.) subtzikwinianus* (Bogosl.), *P. subpressulum* (Bogosl.), *Pronjaites bidevexus* (Bogosl.), *Externiceras solowaticum* (Bogosl.), *E. mostjae* (Bogosl.), *Acroteuthis (Microbelus) russiensis* (d'Orb.), *Buchia volgensis* (Lah.), *B. terebratuloides* (Lah.), *B. surensis* (Pavl.), *B. expansa* (Pavl.), *B. syzranensis* (Pavl.). Thickness 0.30 m.

6. Lower Valanginian–zone *Temnoptychites hoplitoides*. Conglomerate rust-brown, phosphoritized, consisting of lumps of sandstone and sand, cemented by ferruginous cement with occasional ammonites that are characterisitc for the lower Valanginian: *Temnoptychites hoplitoides* (Nik.), *T. ? lgowensis* (Nik.), *Menjaites glaber* (Nik.), *T. triptychiformis* (Nik.), *Polyptychites* cf. *keyserlingi* (Neum. and Uhl.). Thickness 0.15 m.

In the section examined the Berriasian with erosion is transgressively overlapped by sediments of the *Temnoptychites hoplitoides* zone. Near the town of Voskresensk in the Moscow Region, according to observations performed by Sazonova, Sazonov, Saks, Zakharov, Shul'gina, and Pozhariskaya in 1966, in quarries at various horizons of the upper Volgian substage (zones *Craspedites subditus* and *C. nodiger*) there occur Berriasian grayish green phosphoritic flagstones and glauconitic clayey sands with phosphorites 30–80 cm thick with *Riasanites rjasanensis* (Venez). According to the data of Gerasimov and Mikhailov (1966), also present here are *R. subrjasanensis* (Nik.), *R. swistowianus* (Nik.), *Euthymiceras micheicum* (Bogosl.), *Surites (Caseyiceras) analogus* (Bogosl.), *Pronjaites bidevexus* (Bogosl.), *Acroteuthis (Acroteuthis)* cf. *corpulenta* (Nil.), *A. (Microbelus) russiensis* (d'Orb.), *A. (M.) mosquensis* (Pavl.), *Camptonectes lamellosus* (Sow.), *Entolium nummulare* (Fisch.), *Ctenostreon* cf. *decemcostatum* (Traut.), *Isognomon biplicatum* Geras., *Lima subcostata* Geras., *Ostrea limaeformis* Geras., *Pleuromya peregrina* (d'Orb.), *P. tellina* Ag., *Protocardia concinna* (Buch), and *Stramentella ostaschovensis* Geras.

This layer is overlain by Valanginian (?) grayish yellow fine- and medium-grained sands without fauna.

In 1967–1969, Sazonova and Sazonov made a detailed study of sections in the basin of the Sura River that are mentioned in the works of Shirovskii, A. P. Pavlow, Sazonov, Rozanov, and others. Below we give a description of an exposure on the right bank of the Mena River opposite the northern end of the village of Mishukovo and north of the village of Pekhorka (near the local settlement "Abal"). The section on the Mena was examined in 1969 by Luppov, Saks, and Shul'gina together with Sazonova and Sazonov. Here at the base of the bank scarp, shearing an extensive landslide cirque, the following layers underlying Hauterivian clays are revealed:

1. Middle Volgian substage. Clays gray, calcareous, with *Lagonibelus (Holcobeloides) rosanovi* Gust. and *Acroteuthis (Boreioteuthis) niiga* Sachs and Naln., with intercalations of bituminous shales on the plates of which occur imprints of *Scuria maeotis* (Eichw.) and *Zaraiskites* sp. Visible thickness 2.0 m.

2. Berriasian. Zone *Riasanites rjasanensis.* Phosphoritic conglomerate, very solid, ferruginized, in places mineralized. In it are discovered phosphoritic nodules of two types. The first type are clayey, rounded, black, glossy, redeposited nodules 0.1–5–6 cm in size. They contain very sparse phosphoritized internal molds of middle Volgian ammonites. The second type are phosphoritic, sandy nodules, which have a rough surface and which contain fragments of *Riasanites* sp. Found in the cement are *Riasanites* sp., *Acroteuthis (Acroteuthis)* ind. sp., *A. (Microbelus uralensis* Sachs and Naln., *A. (M.) mosquensis* (Pavl.), and *Buchia* ex gr. *volgensis* (Lah.). This layer lies on the heavily eroded surface of the first layer, forming pockets in places. Thickness 0.2–0.4 m.

3. Zone *Surites spasskensis.* Sandstone clayey-silty, quartzose-glauconitic, calcareous, strongly ferruginized, rust-brown with greenish gray and pinkish patches. Contact with underlying phosphoritic conglomerate very uneven. A fine ferruginized brown incrustation of about 1–3 mm (remains of crust of weathering) is traced along the contact. Sandstone crammed with *Buchia,* but the accumulations are irregular. Numerous ammonites found here: *Surites (Surites) poreckoensis* Sazon., *S. (S.) kozakowianus* (Bogosl.), *S. (S.) tzikwinianus* (Bogosl.), *Bogoslovskia pseudostenomphala* I. Sason., *Chandomirovia ilekensis* Sason. Belemnites: *Acroteuthis (Acroteuthis explanatoides* (Pavl.), *A. (A.) anabarensis* (Pavl.), *A. (A.) lateralis* (Phill.), *A. (A.) arctica* Blüthg., *A. (Boreioteuthis) explorata* Sachs and Naln. Bivalves: *Buchia subokensis* (Pavl.), *B. surensis* (Pavl.), *B. elliptica* (Pavl.), *B. expansa* (Pavl.), *B. syzranensis* (Pavl.). This layer corresponds to the second layer of Bogoslovskii's Ryazan horizon and the third layer of the lectostratotype described by Sazonova. Thickness 0.3–0.45 m.

4. Clay greenish brown, rich, laminated. Thickness 0.1 m.

5. Sandstone oölitic, clayey-silty, calcareous. The rock contains many well-preserved shells of ammonites and sparse *Buchia* and ferruginized belemnites. In the sandstone occur mineralized oölitic concretions 5–10 cm in size, inside each of which there is usually a well-preserved ammonite. From this layer Sazonov (1951) described ammonites of the genus *Surites* and Sazonova determined the following: *Bogoslovskia pseudostenomphala* I. Sason., *Surites (Surites) poreckoensis* Sason., *S. (S.) spasskensis* (Nik.), *S. (S.) tzikwinianus* (Bogosl.), *S. (S.) clementianus* (Bogosl.), *S. (Caseyiceras) caseyi* I. Sason., *S. (C.) analogus* (Bogosl.), *Chandomirovia ilekensis* Sason., *Stchirowskiceras principale* I. Sason., *S. tumefactum* I. Sason., *Acroteuthis (Acroteuthis) arctica* Blüthg., *A. (A.) anabarensis* (Pavl.), *A. (Boreioteuthis) hauthali* (Blüthg.), *Buchia surensis* (Pavl.), *B. dilatata* (Pavl.), *B. terebratuloides* (Pavl.), *B. expansa* (Pavl.), *B. syzranensis* (Pavl.). Thickness 0.4–0.5 m.

6. Zone *Pseudogarnieria undulato-plicatilis.* Sandstone ferruginous, oölitic, with calcareous cement, platy, with an inclusion of gravelly grains of quartz up to 2–3 mm in size, containing a wealth of fauna: *Bogoslovskia pseudostenomphala* I. Sason., *Surites (Surites) simplex* (Bogosl.), *S.* ind. sp., *Chandomirovia* ind. sp., *Subpolyptychites distinctus* Sason., *S. orbicularis* I, Sason., *Menjaites imperceptus* I. Sason., *M. magnus* I. Sason., *M. fidus* I. Sason., *Stchirowskiceras principale* I. Sason., *S. tumefactum* I. Sason., *Pseudogarniera undulato-plicatilis* (Stchir.), *P. tuberculifera* (Stchir.), *P. securis* I. Sason., *P. alatyrensis* Kemper, *Proleopoldia kurmyschensis* (Stchir), *M. menensis* (Stchir.), *P. stchirowskii* I. Sason.,* *Acroteuthis (Acroteuthis) anabarensis* (Pavl.), *A. (A.) arctica* (Blüthg.), *A. (A.) vnigri* Sachs and Naln., *A. (A.) chetae* Sachs and Naln., *A. (A.) explanatoides* (Pavl.), *A. (A.) lateralis* (Phill.), *A. (Boreioteuthis) explorata* Sachs and Naln., *A. (B.) freboldi* Blüthg., *A. (B.) hauthali* Sachs and Naln., *Cylindroteuthis (Arctoteuthis) repentina* Sachs and Naln., *C. (A.)* ind. sp., *Buchia solida* (Lah.), *B. terebratuloides* (Pavl.), *B. regularis* (Pavl.), *B. trigonoides* (Lah.), *B. contorta* (Pavl.), *B. inflata* (Toula), *B. keyserlingi* (Lah.), *B.* cf. *nuciformis* (Pavl.), *B.* cf. *uncitoides* (Pavl.). Thickness 0.4–0.5 m.

7. Clayey-silty-sandy calcareous ferruginized rock, markedly disintegrated and deformed, containing more compact concretions of ferruginized marl with oölites. As a rule, the concretions contain ammonites with distinctly expressed polyptychic branching of the ribs and, very rarely, *Surites (Surites)* ex gr. *simplex* (Bogosl.), *Stchirowskiceras* sp., and *Buchia trigonoides* (Lah.). Thickness 0.50–0.60 m.

8. Lower Hauterivian. Clay dark-gray, calcareous, with sepataria of siderite in which *Simbirskites* sp. and *Speetoniceras* (?) sp. are found. Visible thickness 20 m.

Contact between layers 7 and 8 could not be established. The Hauterivian clays slide steeply down the slope and unevenly overlap layer 7.

On the right precipitous bank of the Volga near Kashpir (below the town of Syzran) the following are exposed:

* Shul'gina also determined from this zone *Surites (Surites) clementianus* (Bogosl.), *S. (S.) kozakowianus* (Bogosl.), *Subcraspedites (Subcraspedites) subpressulus* (Bogosl.), *Bojarkia* aff. *bodylevskii* Schulg., *Neotollia* (?) sp., and *Temnoptychites* sp. (Editor.)

1. Upper Volgian substage. Greenish gray glauconitic micaceous clayey silt with phosphoritized internal molds of ammonites. Determined were *Craspedites (Craspedites) kaschpuricus* (Traut.) – mass accumulation – and more rarely *C. (C.) parakaschpuricus* Geras., *C. kuznetzowi* (D. Sok.), and *C. (C.)* aff. *mosquensis* Geras., and sparse fragments of *Garniericeras* sp. Thickness 0.15 m.

2. Berriasian. Zone *Riasanites rjasanensis.* Sand fine-grained, glauconitic, micaceous, clayey, calcareous, with sparse sandy phosphoritic nodules, in which a rounded specimen of *Riasanites rjasanensis* (Venez.) was discovered; *Pachyteuthis* sp. and *Buchia* sp. were found in the sand. Thickness 0.10 m.

3. Bituminous shale, clayey, calcareous (layer 10 in the section described by Orlova in 1932). Thickness 0.10–0.25 m.

4. Sand fine-grained, glauconitic, micaceous, in places obliquely laminated. Thickness 0.20 m.

5. Nodules of sandy phosphorite, occurring as an extended chain at the base of the sandstone, which is compactly cemented, glauconitic, micaceous, fine-grained, calcareous. Thickness 0.50 m.

6. *Aucella* coquina. Sandstone calcareous, in places loose, glauconitic, micaceous, crammed with shells of *Buchia*, the internal molds of which are phosphoritized. The following are present: *Bogoslovskia pseudostenomphala* I. Sason., *Surites (Surites) spasskensis* (Nik.), *S. (S.) tzikwinianus* (Bogosl.), *Acroteuthis (Acroteuthis) lateralis* (Phill.), *Buchia volgensis* (Lah.), *B. keyserlingi* (Lah.). Milanovskii (1940) found *Riasanites rjasanensis* (Venez) in the lower part of the layer. Thickness 0.45 m.

7. Zone *Surites spasskensis.* Sandstone glauconitic, micaceous, with sparse phosphoritic nodules (gray, clayey), with mass accumulations of *Buchia* (this is the upper, more consolidated part of the shell rock), with *Surites (Surites) pechorensis* Sason., *S. (C.) analogus* (Bogosl.), *Acroteuthis (Acroteuthis) lateralis* (Phill.), *A. (A.) arctica* Blüthg., *Buchia terebratuloides* (Lah.), *B. pyriformis* (Lah.), *B. regularis* (Pavl.), *B. bulloides* (Lah.), *B. unzhensis* (Pavl.), *B. syzranensis* (Pavl.). Thickness 0.50 m.

8. Lower Valanginian. Sandstone silty, clayey, glauconitic, with phosphoritized sandy nodules at the base, with *Polyptychites keyserlingi* (Neum. and Uhl.) and *P. michalskii* (Bogosl.). Thickness 0.30 m.

9. Phosphoritic platform. Thickness 0.20 m.

In the Malyi gorge near the village of Mar'evka on the right bank of the Syzran River, the following are exposed:

1. Upper Volgian substage. Marl silty, micaceous, glauconitic, containing sparse chestnut-brown nodules of phosphorites with phosphoritized internal molds of *Craspedites kaschpuricus* (Traut.). Thickness 1.20 m.

2. Berriasian. Zone *Riasanites rjasanensis.* Conglomerate phosphoritized, calcareous, ferruginized; in places it is made up of displaced sandy phosphoritic nodules, occurring in a dark-green fine-grained micaceous glauconitic sand. A phosphoritic nodule yielded a founded specimen of *Riasanites rjasanensis* (Venez). Thickness 0.10 m.

3. Zone *Surites spasskensis.* Sandstone calcareous, silty-clayey, glauconitic, micaceous, in places fine-grained glauconitic sand with *Surites.* Thickness 0.40 m.

4. Sandstone silty-clayey, greenish gray, calcareous, crammed with *Buchia* ("*Aucella*

coquina"): *Buchia inflata* (Lah.), *B. spasskensis* (Pavl.), *B. surensis* (Pavl.). Belemnites: *Acroteuthis (Acroteuthis) lateralis* (Phill.). Sparse loose chestnut-brown phosphoritic nodules with a P_2O_5 content of up to 12% occurring in the sandstone. Thickness 0.5–1.5 m.

5. Lower Valanginian. Sandstone phosphoritized, silty, calcareous, containing sparse sandy phosphoritic nodules with *Polyptychites expansus* Bogosl. Thickness 0.15 m.

NORTHEASTERN USSR

Along the Pereval'naya River (Umkuveem depression in the Northeastern Kolyma area), the following are exposed, according to Paraketsov (1966), from the bottom upward in the section:

1. Interbanded conglomerates, gritstones, and variegated polymictic sandstones, from coarse- to fine-grained. Pebbles of conglomerates well rounded, sorted, consisting of underlying Paleozoic igneous and sedimentary rocks. Fragments of Upper Devonian andesites and liparites predominate. Pebble of sedimentary rocks represented mainly by Upper Permian black clayey limestones with fragments of prismatic layer of shells of *Kolyma.*

Farther up the section the number of intercalations of conglomerates and gritstones decreases while that of sandstones increases. The rocks contain remains of *Phylloceras* ? ind. sp., *Buchia stremouhovi* (Pavl.), *B. fischeriana* (d'Orb.), *B.* ex gr. *lahuseni* (Pavl.), and *Oxytoma* sp. Thickness 100 m.

2. Gray fine-grained tufogenic sandstones and silts with intercalations and lenses of tuffites, gritstones, and fine-pebble conglomerates. Organic remains from the lower part of the horizon: *Meleagrinella* sp., *Oxytoma* ind. sp., *Buchia* cf. *stremouhovi* (Pavl.), *B. fischeriana* (d'Orb.), *B. lahuseni* (Pavl.), *B.* cf. *krotovi* (Pavl.), *B.* cf. *okensis* (Pavl.), *Camptonectes* ex gr. *virdunensis* Buv., and others; in the middle: *Buchia* aff. *krotovi* (Pavl.), *B.* cf. *volgensis* (Lah.), *B.* cf. *spasskensis* (Pavl.), *B. unschensis* (Pavl.), and others; in the upper part: *Buchia lahuseni* (Pavl.), *B.* ex gr. *volgensis* (Lah.), *B. okensis* (Pavl.), *B.* cf. *spasskensis* (Pavl.), *B.* cf. *robusta* (Pavl.), *B.* cf. *jasikovi* (Pavl.), and others. Fragments of finely cristate ammonites of the family Phylloceratidae occur throughout the section. Thickness 360–380 m.

3. Gray fine- and medium-grained tufogenic sandstones with intercalations of siltstones, coarse-grained sandstones, gritstones, and argillites with remains of Valanginian *Buchia, Inoceramus,* and belemnites. Thickness 200–260 m.

A section in the upper reaches of the Chakhmatkyul and Golodnyi Klyuch rivers was described by Pokhialainen (1966).

In the upper reaches of the above rivers (Pontoteiskie mountains, Anadyr-Koryakskii Region) sediments of Middle Jurassic age are transgressively and nonconformably overlapped by rocks that Pokhialainen placed in the Berriasian. The following are exposed in the section from bottom to top:

1. Basal layer of nonpersistent thickness, represented by medium-pebbly conglomerates with intercalations (10–40 cm) of tuff breccias and massive tuff sandstones. Thickness 1–10 m.

2. Interbedded inequigranular tuff sandstones (beds to 2 m thick), siltstones alternating with tuffs (members up to 40–70 m thick) with *Buchia* aff. *okensis* (Pavl.), *B.* cf. *fischeriana* (d'Orb.), *B.* cf. *krotovi* (Pavl.), and *B.* cf. *volgensis* (Lah.) (the species of *Buchia* here and below were determined by Paraketsov). Thickness to 200 m.

3. Tuff sandstones coarse-grained, indistinctly platy, with fragments and gouges of green siltstones (5–7 m), tuff sandstones light in color, medium- and coarse-grained (0.3 m), tuff gritstones and fine-pebble tuff conglomerates (5–8 m) with large concretions of light-colored tuff sandstones. Fauna: *Lytoceras* sp., *Buchia* cf. *fischeriana* (d'Orb.), *B. okensis* (Pavl.), *B. elliptica* (Pavl.), gastropods. Thickness 20–25 m.

4. Tuff sandstones coarse-grained (to tuff breccias), siltstones, and tuffs with isolated *Buchia.* Thickness 50 m.

5. Coarse-grained sandstones with fragments of green siltstones (1–4 m), fine-grained platy sandstones (0.3–0.5 m), siltstones, sometimes with concretions of calcareous siltstones (0.5–2 m), and finely banded tuffs (0.1 m). Fauna: *Phylloceras* ind. sp., *Pleuromya* sp., *Astarte* sp., *Nucula* ind. sp., and *Turritella.* The following species of *Buchia* were determined: *B. terebratuloides* (Lah.), *B.* cf. *fischeriana* (d'Orb.), *B.* cf. *okensis* (Pavl.), *B. volgensis* (Lah.), *B. krotovi* (Pavl.), *B.* aff. *lahuseni* (Pavl.). Thickness 200 m.

6. Tuff siltstones with a few intercalations (5 m) of coarse-grained sandstones. Fauna: *Buchia terebratuloides* (Lah.), *B.* cf. *krotovi* (Pavl.), *B.* cf. *volgensis* (Lah), *B.* aff. *fischeriana* (d'Orb.). Thickness 75 m.

7. Tuff sandstones green and greenish gray with intercalations of green tuff siltstones with fauna: *Euthymiceras* n. sp., *Buchia* cf. *volgensis* (Lah.), *B.* cf. *okensis* (Pavl.), *B. terebratuloides* (Lah.), *B.* cf. *fischeriana* (d'Orb.). Thickness 150 m.

The total thickness of the sediments included in the Berriasian in the Pontoteiskie mountains is 700 m.

The Berriasian section in the upper reaches of the Chakhmatkyul and Golodnyi Klyuch rivers is interesting in that here, together with species of *Buchia,* an ammonite occurs which has a sculpture similar to that of the Berriasian Berriasellidae of European Russia. Another interesting point is that the large-shelled *B. okensis* (Pavl.) from the middle part of the Berriasian section in other regions is generally found in early Valanginian strata or in the topmost strata of the Berriasian.

The Valanginian rocks of the Pontoteiskie mountains, conformably overlapping the Berriasian (siltstone-sandstone layers), are characterized by the same set of *Buchia* species as are the same-aged formations of other areas.

According to Terekhova (1966), in the Mainskie mountains formations of the Volgian stage are represented by dark-gray tuffite siltstones, tuff sandstones, and tuffs of the basic composition with *Buchia* cf. *mosquensis* (Buch), *B.* cf. *rugosa* (Fisch.), and *Meleagrinella* ind. sp. The total thickness of the rocks of the Volgian stage on the shore of the Main River is 270 m.

Along the Main River, near the spit of Voennye Moryaki, sediments of the Volgian stage are observed, conformably overlapped by rocks of the Berriasian (from bottom to top in the section):

1. Tuffite siltstones with intercalations of tuff sandstones, concretions, and lenses of

pelitomorphic and silty carbonate. Fauna: *Phylloceras* sp., *Buchia krotovi* (Pavl.), *B. fischeriana* (d'Orb.), *B. okensis* (Pavl.), *B. volgensis* (Lah.), Thickness 60 m.

2. Sandy tuffite siltstones and tuff sandstones with scattered pebble and gravel. Fauna: *Buchia okensis* (Pavl.), *B. volgensis* (Lah.), *B.* cf. *lahuseni* (Pavl.). Thickness 160–170 m.

Terekhova estimated the total thickness of the Berriasian of the Mainskie mountains at around 200 m.

The formations examined are conformably overlain by siltstones and tuff sandstones with a fauna of Valanginian species of *Buchia.*

Chapter III.

DISTRIBUTION OF THE BERRIASIAN STAGE IN THE BOREAL REALM

As seen from Table 5, marine facies of the Berriasian stage are very widely distributed within the Boreal Realm of the northern hemisphere. They are known in Northwestern and Eastern Europe (Great Britain, Spitsbergen, Poland, Russian Plain, possibly in the northern part of West Germany and on the Lofoten Islands), are well represented in Siberia (on the West Siberian Plain, including the east slope of the Urals, in the North Siberian lowland, on Taimyr), and can be identified in the extreme Northeast and Far East of the USSR (Kolyma area, basins of the Anadyr and Penzhina rivers, Koryakskii Mountain Range, shore of the sea of Okhotsk, region of Sikhote Alin). Marine Berriasian deposits are also developed in the northern part of North America (Alaska, Canadian Archipelago, northern and western Canada) and, finally, in eastern Greenland. We have already examined the key sections of the Berriasian in the north of Middle Siberia, on the east slope of the Cis-Polar Urals, in Western Siberia, in the middle part of the Russian Plain, and in the Far Northeast of the USSR. We begin our survey of the other regions where the Boreal Realm is developed with Europe, after which we will move from west to east. In drawing up our survey we were greatly aided by a number of summaries which provide specific data on the stratigraphy of the Berriasian in different parts of the Boreal Realm: Gerasimov et al. (1962) and Sazonov and Sazonova (1967) (Russian Plain), Saks et al. (1963) (Northern USSR and non-Soviet Arctic), Avdeiko (1968) (northern part of the Pacific Region), Jeletzky (1971) (Canada), and Donovan (1957, 1964) (eastern Greenland). However, in discussing the Berriasian in different regions, we must take into account that in many cases the biostratigraphic conclusions are based on determinations of fauna, primarily ammonites, that investigators have identified variously. These determinations are often preliminary and made from poorly preserved material, so that a number of the conclusions presented below concerning age problems may eventually have to be revised.

WESTERN EUROPE

Berriasian sediments of the Boreal type are known from the studies of Pavlow and Lamplugh (1892) in northeastern and central eastern England: Yorkshire (section of Speeton clays) and Lincolnshire (section of Spilsby sandstones). Pavlow was inclined to place the lower part of the Spilsby sandstones and beds D4–D8 of the Speeton clays at the top of the Jurassic (Aquilonian), and he correlated them with the upper Volgian stage of the Russian Plain.

The fauna of these sections was studied in greater detail by Spath (1924), Swinnerton (1934, 1935–1955), Neale (1962), and Casey (1962). Spath showed that the lower part of the Spilsby sandstones and Speeton beds D4–D8 contain infra-Valanginian (Berriasian) ammonites: *Subcraspedites* similar to *S. (S.)* ex gr. *pressulus* (Bogosl.) and *Surites* (= *Paracraspedites* Swinnerton) ex gr. *spasskensis* (Nik.). At the base of bed D8 is a coprolite layer about 0.1 m thick that directly overlies the Kimmeridgian. The Spilsby sandstones are also underlain by Kimmeridgian clays (Swinnerton, 1934).

However, Casey once again referred the lower part of the Spilsby sandstones to the upper Volgian substage on the basis of finds of *Craspedites* similar to the Russian upper Volgian representatives of this genus. Unfortunately, Casey has still not given descriptions or drawings of the ammonites according to which he revised Spath's views, so that his conclusions are rather unreliable. It should be remembered that a typically Neocomian complex of belemnites (with *Acroteuthis* s. str.) is observed at the bottom of the Spilsby sandstones, and this complex is still older than that found in Speeton beds D6–D8 (4 m thick), which all investigators, following Spath, acknowledge to be of Berriasian age. There are many reasons to agree with Jeletzky (1965), who contends that the English *Subcraspedites* and *Paracraspedites* are similar to the *Subcraspedites* and *Surites* of the Russian Plain, which are known to be Berriasian. In the present study, Shul'gina has shown that *Subcraspedites (Subcraspedites) plicomphalus* Sow. and *Paracraspedites stenomphaloides* Swinn. occur in Berriasian beds in Siberia. At present, therefore, it is more correct to date the lower part (0.7 m) of the Spilsby sandstones with *Paracraspedites stenomphaloides* Swinn., *P. bifurcatus* Swinn., *Subcraspedites (Subcraspedites)* aff. *subpressulus* (Bogosl.), *S. (Ronkinites) primitivus* Swinn., *S. (Swinnertonia) preplicomphalus* Swinn., *S. (Sw.) undulatus* Swinn., *Acroteuthis* s. str., and others to the early Berriasian. This may be an analogue of zones *Chetaites sibiricus* (where there is also *Paracraspedites stenomphaloides* Swinn.) and *Hectoroceras kochi.* Representatives of the genus *Hectoroceras* in England are found in the Sandringham sands in Norfolk (Casey, 1961), above *Paracraspedites* and *Subcraspedites* (Casey, 1971).

The superjacent beds of the Spilsby sandstones (about 20 m) and beds D6B–D8 of the Speeton clays (about 3.5 m) with *Paracraspedites stenomphaloides* Swinn., *Surites (Surites) subtzikwinianus* (Bogosl.), *Subcraspedites (Swinnertonia) preplicomphalus* Spath, *Tollia wrighti* Neale, and others correspond to higher horizons of the Siberian Berriasian (zones *Surites analogus* and *Bojarkia mesezhnikowi*). Speeton layer D6A (0.5 m) with *Supcraspedites (Swinnertonia) preplicomphalus* Swinn., *S.* sp., *Surites (Bogoslovskia) stenomphalus* (Sow.), *Tollia pseudotolli* Neale, *T.* cf. *tolmatschowi* Pavl., and *T.* sp. may correspond to the very top of the Berriasian. The ammonites that Nealę describes are unfortunately in a poor stage of preservation, making a precise diagnosis difficult. The overlying Speeton beds (D4) contain *Polyptychites* spp. and without question belong to the lower Valanginian.

In southern England, the northern part of West Germany, and in Holland the Jurassic-Cretaceous boundary layers are represented by a series of freshwater and brackish-water sediments of the Wealden and Purbeckian. According to Rayner (1967), in England the

System	Series	Stage	Substage	Southeastern France	Northeastern England	Northern part of West Germany	Northern Poland (Kujawy)	Spitsbergen	Russian Plain	Cis-Polar Trans-Urals	Northern Siberia	Northeast Asia	Far East	Alaska	Northern Canada	Western Canada	Western USA	Eastern Greenland	Caucasus	Japan	Mexico	Argentina
Cretaceous	Lower	Valanginian	lower	Kilianella roubaudiana Kilianella lucensis	*Polyptychites* spp. *Tollia* cf. *tolmatschowi*	*Polyptychites* spp. Platylenticeras involutum Platylenticeras heteropleurum (with *Tollia* and *Neotollia*) Tolypeceras marcouisianum	*Platylenticeras* sp., *Neocomites neocomiensis premolica*	*Polyptychites* spp.	Polyptychites michalsii Temnoptychites hoplitoides Pseudogarnieria undulato-plicatilis	Polyptychites michalskii Temnoptychites insolutus	Polyptychites stubendorffi: Polyptychites michalskii; Temnoptychites syzranicus Neotollia klimovskiensis	*Polyptychites*? sp., *Buchia crassa*, *B. inflata*, *B. bulloides*	*Buchia keyserlingi*, *B. inflata*: *Polyptychites* sp.; *Neohoploceras* sp., *Olcostephanus* sp., *Neocomites* sp.	*Buchia keyserlingi*, *B. inflata*	*Buchia inflata*, *B.* aff. *inflata*, *B. keyserlingi*: *Polyptychites stubendorffi*; *Neotollia (?) anabarensis*, *Polyptychites*; *Thorsteinssonoceras ellesmerense*; *Temnoptychites elegans*, *Tollia tolli*	? *Buchia inflata*, *Tollia* sp. *Buchia pacifica*, *Neocomites* cf. *rota*	*Neocraspedites giganteus*, *Buchia keyserlingi* *Buchia pacifica*: *Neotollia mutabilis*; *Kilianella crassiplicata*; *Thurmanniceras*	*Polyptychites* spp. *Temnoptychites* spp. *Neotollia (?) paucicostata*	Thurmanniceras thurmanni, Kilianella roubaudiana	*Thurmanniceras* sp., *Olcostephanus* sp.	*Thurmanniceras* sp., *Polyptychites* sp. *Kilianella* aff. *pexiptycha*	Neocomites wichmanni, Thurmanniceras pertransiens
		Berriasian	e	Berriasella boissieri	*Bojarkia* cf. *payeri*		Berriasella boissieri: *Surites* spp.	*Tollia* sp.	Surites spasskensis	Bojarkia payeri	Bojarkia mesezhnikowi	*Buchia volgensis*	*Subcraspedites* aff. *bidevexus*	*Buchia okensis*, *B. subokensis*	*Buchia* sp. n. aff. *volgensis*, *Surites* cf. *spasskensis*, *Subcraspedites* sp.	*Buchia tolmatschowi*, *Tollia* sp., *Surites* cf. *tzikwinianus*	*Buchia* aff. *tolmatschowi*	Bojarkia payeri	Berriasella boissieri, Riasanites rjasanensis	*Berriasella* ex gr. *berthei* *Spiticeras* cf. *binodiger*	*Berriasella densistriata*, *Spiticeras uhligi*	Spiticeras damesi, Cuyaniceras transgrediens
			d		*Surites stenomphalus*			*Surites* sp. *Subcraspedites* sp.		Surites analogus	Surites analogus		*Buchia volgensis* *Neocomites* aff. *retowskyi*, *Berriasella* sp.			*Buchia uncitoides*, *Spiticeras* cf. *scriptum*, *Protacanthodiscus* sp.	*Negreliceras stonyense*, *Neocosmoceras* spp., *Buchia uncitoides*	Surites spp.				
			c		*Hectoroceras* sp.	*Riasanites*?	*Riasanites rjasanensis*		Riasanites rjasanensis	Hectoroceras kochi	Hectoroceras kochi	*Euthymiceras* sp.			*Hectoroceras* aff. *kochi*			Hectoroceras kochi				
			b		*Paracraspedites stenomphaloides*			*Chetaites* cf. *sibiricus*		Chetaites sibiricus	Chetaites sibiricus	*Surites* sp., *Buchia okensis*			*Buchia okensis*, *Subcraspedites* cf. *suprasubditus*, *S.* ex gr. *plicomphalus*	*Buchia okensis*, *Pseudargentiniceras* aff. *gallicum*, *Subcraspedites* cf. *suprasubditus*		Praetollia maynci	Berriasella pontica		*Berriasella tenochi*, *Spiticeras zirkeli*	Argentiniceras noduliferum, Neocosmoceras egregium
			a	Berriasella grandis											*Buchia* ex gr. *uncitoides*, *Subcraspedites* sp. n.			*Subcraspedites* aff. *preplicomphalus*				
Jurassic	Upper	Tithonian (Volgian)	upper	Beriasella chaperi		Wealden fauna	Wealden fauna	*Chetaites*? sp. *Craspedites* ex gr. *nodiger*	Craspedites nodiger	Taimyroceras (?) sp.	Chetaites chetae Craspedites taimyrensis	*Chetaites* sp. *Buchia tenuicollis* *B. fischeriana*	*Chetaites*? *Buchia fischeriana*, *B. terebratuloides*, *Berriasella* sp.		*Buchia unschensis*, *B. terebratuloides*, *Craspedites canadensis*	*Buchia terebratuloides*, *Paradontoceras callistoides*	*Substeueroceras stantoni*, *Proniceras*, *Buchia* aff. *okensis*	*Craspedites ferrugineus* *Laugeites* spp.	Lemencia richteri	*Substeueroceras* sp., *Spiticeras* cf. *eucomphalum*	*Substeueroceras* cf. *koeneni*, *Proniceras*	Substeueroceras koeneni
				Berriasella delphinensis				*Craspedites*, *Virgatosphinctes*	Craspedites subditus Kachpurites fulgens	Craspedites subditus Kachpurites fulgens	Craspedites okensis: Craspedites originalis; Craspedites okensis; Virgatosphinctes exoticus				*Buchia fischeriana* *Buchia richardsonensis*	*Buchia fischeriana* *Buchia* cf. *blanfordiana*, *Substeueroceras stantoni*	*Parodontoceras*, *Buchia fischeriana* *Kossmatia*, *Buchia eldernensis*			*Corongoceras* sp.	*Kossmatia*, *Durangites*, *Corongoceras*	Corongoceras alternans

Purbeckian clays, limestones, marls, and sandstones totaling up to 120 m in thickness contain intercalations of marine sediments with oysters and *Hemicidaris*, and can be divided into three zones on the basis of the ostracod fauna (from bottom to top): *Cypris purbeckensis, Cypridea granulosa, and Pseudocypridina setina.* The Hastings beds – sands, silts, and clays of delta or lake origin (to 240 m thick) – belong to the bottom of the Cretaceous. Neale (1967) demonstrated a similarity between the ostracod complexes of the middle Purbeckian and those of the Berriasian stage in southeastern France.

In the northern part of West Germany marine Portlandian sediments are overlain by Münder marls with *Cypris purbeckensis* (to 400 m), above these with erosion occur freshwater limestones, serpulites, with *Serpula coacertata* Blum (70 m), and still higher there are Wealden clays and argillites to 500 m thick which are classified into six zones according to the ostracod fauna. The lower zones (Wealden 1, 2, and partly 3) correspond to the upper Purbeckian of England, while the upper zones (part of 3, 4, 5, and 6) correspond to the Hastings beds and the Berriasian stage of England. Wealden 1 and 2 are purely freshwater sediments, 3 and 4 chiefly freshwater but with occasional intercalations of brackish-water and marine sediments, and Wealden 5 and 6 are brackish-water sediments.

In the northern part of West Germany and in Holland the marine deposits of the Neocomian begin with argillites 20–25 m thick that belong to the bottom of the Valanginian. In the lower part the argillites contain *Tolypeceras marcouisianum* (d'Orb.), *Platylenticeras robustum* Kemp., higher up in the section *P. heteropleurum* Neum. and Uhl., *Neotollia* (?) sp. (*"Tollia tolmatschowi"* Kemper non Pavl.), *Tollia pseudotolli* Neale, *T.*, (?) *pumilis* (Vog.), *Polyptychites (Polyptychites)* spp., *P. (Propolyptychites) quadrifidus* Koen., *P. (Propolyptychites) emslandensis* Kemp., *Neocraspedites semilaevis* (Koen.), *Euryptychites* sp., *Acroteuthis (Acroteuthis) arctica* Blüthg., *Exogyra couloni* Defr., *Thracia phillipsi* Roem., and others (section in the Bentheim region, described by Kemper, 1968). Finds of *Platylenticeras involutum* Kemp. originate from the sandstones at the very top of the *Platylenticeras* beds. Still higher occur sandstones about 100 m thick with *Polyptychites* spp.

The early Valanginian age of the beds with *Platylenticeras* is proved by the fact that *Tolypeceras marcouisianum* (d'Orb.) and *Platylenticeras heteropleurum* Neum. and Uhl. in the Mediterranean Region are confined to the lower part of the *Kilianella roubaudiana* zone, which is the lower zone of the stratotypic section of the Valanginian. As for the Wealden deposits, they must correspond (though probably only in their middle and upper parts) to the Berriasian. Further confirmation of this is a find in the Wealden, evidently in one of the marine intercalations, of an ammonite which Riedel (1939) determined as *Blanfordiceras* but which Kemper (1964) believed to be rather *Riasanites* or *Tollia.*

In Demark, Berriasian sediments cannot be reliably identified from fauna, but the Volgian deposits in Haldager borehole No.1 (Sorgenfrei and Buch, 1964) apparently contain also upper Volgian or Berriasian sandstones with clay interlayers with a fauna that photographs show to be represented by *Buchia* ex gr. *volgensis* (Lah.) of the late Volgian or Berriasian type (pl. 7, fig. 72), *Lagonibelus* sp. (? cf. *sibiricus* Sachs and Naln.), and *Acroteuthis (Microbelus)* sp. (? cf. *uralensis* Sachs and Naln.).

Farther to the east, in northern Poland and Kujawy, Berriasian sediments overlie freshwater and brackish-water Purbeckian marls and shales (to 128 m) containing a fauna of *Cyrena* and ostracods. At the base of the Berriasian there also occur brackish-water siltstones and marls with interlayers of sandstones up to 45 m thick. This member contains intercalations of marine sediments with *Ammobaculites subcretaceus* Cush., *Haplophragmoides* sp., *Lenticulina subalata* (Reuss), *Eoguttulina witoldi* Sztejn, *Palaeocytheridea, Cytherella, Klieana, Cypridea,* and others. Marek (1967) broke down the marine Berriasian into two zones. The lower *Riasanites rjasanensis* zone consists of shales, marls, siltstones, and sandstones up to 57 m thick with *Riasanites rjasanensis* (Venez.), *R.* cf. *rjasanensis* (Venez.), *R.* sp., *Protacanthodiscus* sp., *Berriasella* cf. *lorioli* (Zitt.), *B.* cf. *euxina* (Ret.), *B.* sp. cf. *pontica* (Ret.), *B. (Subthurmannia)* sp. cf. *boissieri* (Pict.), *Himalayites* cf. *kortazari* (Kil.), *Neocomites* sp. (? *occitanicus* Pict.), and *Praetollia* cf. *maynci* Spath. The upper zone, which Marek proposes, by analogy with the by now outdated stratigraphic scheme of the Russian Plain, to name the "*Surites stenomphalus*" zone, consists of shales about 55 m thick containing *Riasanites rjasanensis* (Venez.), *Surites (Surites)* cf. *spasskensis* (Nik.), *S. (S.) subtzikwinianus* (Bogosl.), *S. (S.)* cf. *kozakowianus* (Bogosl.), *S.* sp., *Tollia* (?) sp., *Neocosmoceras* aff. *sayni* (Sim.), *N.* cf. *platicostatum* (Sayn), *Euthymiceras* cf. *euthymi* (Pict.), and *Berriasella (Subthurmannia)* cf. *boissieri* (Pict.).

We must assume that both Marek's zones correspond to the *Berriasella boissieri* zone in the Mediterranean Region, while on the Russian Plain, judging from the distribution of *Riasanites rjasanensis* (Venez.), they correspond to the zone with this name, although Marek himself admits that *Riasanites* may have persisted longer in Poland and that the "*Surites stenomphalus*" zone is correlated in Russia with the *Surites spasskensis* zone. It has to be pointed out that the ammonites illustrated by Marek are in a very poor state of preservation, so that it is difficult to determine the genus let alone the species. Nevertheless, the presence of boreal *Craspedites* in the Berriasian of Poland remains an indisputable fact.

The marine Berriasian of Kujawy is on the whole characterized by a complex of bivalves with *Astarte similis* Münst., *A. subdentata* Roem., *Leda scapha* d'Orb., *Exogyra sinuata* (Sow.), *Pinna depressa* Münst., and others. There are gastropods and brachiopods and a complex of foraminifers and ostracods with *Protocythere propria emslandensis* Bart., *P. praetriplicata infravalanginiensis* Sztejn, *Ammobaculites subcretaceus* Cush., *Trochammina keyniensis* Sztejn, *Eoguttulina witoldi* Szetjn, *Epistomina caracolla anterior* Bart., *Lenticulina humilis* (Reuss), *L. subalata* (Reuss), and others (Sztejn, 1967, 1969). Dembowska (1964) mentions in addition *Riasanites* cf. *subrjasanensis* (Nik.), *Berriasella* sp. (ex gr. *malbosi* Pict.), *B.* sp. (ex gr. *richteri* Opp.), *Subcraspedites (Swinnertonia)* cf. *undulatus* Swinn., *Praetollia* sp., and *Craspedites* sp.

Above the Berriasian without any visible break occur shales and siltstones of the lower Valanginian up to 50 m thick with *Platylenticeras* sp., *Polyptychites* cf. *gravidus* Koen., *Nikitinoceras* ? (=*Temnoptychites*?), *Neocomites neocomiensis premolica* Sayn, *Oxyteuthis primus* Blasz., *Exogyra sinuata* (Sow.), *Pinna, Astarte,* and *Natica laevigata* d'Orb. (Marek, 1969). The foraminifer and ostracod complex remains for the most part the same as in the Berriasian (Sztejn, 1969).

The Berriasian is also present (Orvig, 1953) on the Lofoten Islands, judging from finds on Hinnöy Island of *Buchia volgensis* (Lah.) in light-colored sandstones of the upper part of the Ramsaa series. Higher up in the same sandstones occurs a Valanginian fauna (*Bochianites, Buchia keyserlingi* (Lah.)) and lower down a middle Volgian fauna (*Epivirgatites nikitini* Mich., *Buchia mosquensis* (Buch)). Sokolov (1912) also mentions a find of Volgian *"Virgatosphinctes"* (= *Chetaites*?) sp. on Andöy Island. There are no data for ascertaining the completeness of the section.

On western Spitsbergen Pchelina (1965) places the weakly bituminous gray and dark-gray argillites with carbonate concretions that occur on the shores of Isfjord and contain the characteristically Berriasian *Buchia volgensis* (Lah.), *B. okensis* (Pavl.), and *B. terebratuloides* (Lah.) in the Berriasian. Pchelina does not mention the thickness of the Berriasian but gives the combined thickness of the Berriasian and Valanginian (160–285 m). According to Ershova, *Surites* sp. and *Subcraspedites* sp. are found here. Frebold (1929b) additionally mentions *Subcraspedites (Subcraspedites)* cf. *pressulus* (Bogosl.) and *S. (S.)* cf. *subpressulus* (Bogosl.) from the shores of this fjord. In accordance with Shul'gina's conclusion, *Chetaites* cf. *sibiricus* Schulg. was described from Isfjord by Sokolov and Bodylevsky (1931, pl. 9, fig. 3) as *Perisphinctes* sp. A. Forms of the genus *Subcraspedites (Borealites)* sp. were described by Frebold (1929a) as *Polyptychites perovalis* Koen. (pl. 1, fig. 1 and pl. 3, fig. 1) and by Sokolov and Bodylevsky (1931) as *P.* aff. *quadrifidus* Koen. and *P.* sp. A. In the same work Frebold described *Paracraspedites* cf. *stenomphaloides* Swinn. under the name *Polyptychites hoeli* Freb. (pl. 2, fig. 3).

Off the southern tip of western Spitsbergen (Sörkapp Land) Pchelina (1967) observed that Berriasian greenish gray argillites with concretions of siderite have a thickness of the order of 50 m and in the lower part contain *Surites* (?) sp., *Buchia okensis* (Pavl.), *B.* ind. sp. (cf. *volgensis* (Lah.)), *Aequipecten* aff. *arachnoideus* Bodyl., and higher up the section *Tollia* sp. juv., *Buchia terebratuloides* (Lah.), *B. volgensis* (Lah.), *B.* cf. *sibirica* (Sok.), *Lima* aff. *consobrina* d'Orb., and *Oxytoma inaequivalvis expansa* (Phill.).

On the eastern shore of the island (Ågård Bay) there is a 8-m-thick Berriasian member of greenish gray argillites with glauconite and siderite, with concretions of clayey limestone and phosphorite with *Buchia volgensis* (Lah.) and *B. okensis* (Pavl.) and in the upper part with a typically Berriasian foraminifer complex: *Haplophragmoides* sp. (ex gr. *umbonatus* Rom.), *Ammobaculites* ex gr. *gerkei* Schar., *Recurvoides obskiensis* Rom., *Gaudryina gerkei* Vass., *Lenticulina sossipatrovae* Gerke and E. Ivan., *L.* ex gr. *münsteri* (Roem.), *L. novella* Vass., *Marginulina striatocostata* Reuss, and others. From the Ågård Bay region Zhirmunskii (1927) determined *Tolypeceras marcouisianum* (d'Orb.) and *Temnoptychites* cf. *simplex* Bogosl., that characterize the bottommost strata of the Valanginian, and together with them Berriasian *Subcraspedites* aff. *pressulus* (Bogosl.), *S.* aff. *subpressulus* (Bogosl.), and *Riasanites* ? cf. *rjasanensis* (Venez.). However, not all of these determinations are reliable (see Sokolov and Bodylevsky, 1931).

Everywhere on western Spitsbergen the Berriasian argillites come to be replaced continuously downward by argillites of the upper Volgian substage. Reported from the latter by Pchelina (1967), Shul'gina (1968), and Ershova (1969) are *Chetaites* (?) ind. sp., *Craspedites (Craspedites)* cf. *pseudonodiger* Schulg., *C. (C.)* ex gr. *nodiger* (Eichw.), *C. (C.) bodylevskii* Ersch., and *C. (Taimyroceras) agardensis* Ersch., attesting to the presence of the uppermost zones of the upper Volgian substage of the Russian Plain and

Siberia (*Craspedites nodiger, C. taimyrensis, Chetaites chetae*). *Virgatosphinctes* (?) ind. sp. (? aff. *tenuicostatus* Schulg.) also occur in Volgian sediments on western Spitsbergen (Shul'gina, 1967). Shul'gina concluded that *Perisphinctes* sp. B (Sokolov and Bodylevsky, 1931, pl. 14, fig. 1) refers to *Virgatosphinctes* sp. All this paves the way for a more minute study of the position of the Jurassic-Cretaceous boundary in Spitsbergen sections.

The Berriasian may also be present on Kong Karls Land. From here Blüthgen (1936) described a large number of species of Neocomian belemnites and *Buchia* from taluses of marls and sandy limestones on Kongsöya and Svensköya Islands. Among the *Buchia,* alongside the forms known to be Valanginian (*B. crassicollis* (Keys.), *B. keyserlingi* (Lah.), and others), there are species that are characteristic for the Berriasian (*B. terebratuloides* (Lah.)). The most prominent of the belemnites is *Lagonibelus (Lagonibelus) superelongatus* (Blüthg.), which in Siberia does not occur above the Berriasian.

EASTERN EUROPE

Marine Lower Cretaceous, including Berriasian, sediments are known on Franz Josef Land.

On the Russian Plain there is quite a wide distribution of Berriasian deposits, but they consist of a thinnish phosphorite-bearing horizon and occur everywhere with erosion on various horizons of the Upper Jurassic: from the Callovian and Oxfordian on the Oka River to the *Craspedites nodiger* zone of the upper Volgian substage near Voskresensk and on the Volga near Kashpir. A break is also observed almost everywhere at the roof of the Berriasian.

The upper Volgian sediments of the central part of the Russian Plain were described in detail by Gerasimov (1969), and therefore we shall not dwell on them. Sections of the Berriasian and bottom of the Valanginian on the Oka, Menya, and Volga rivers near Syzran are described below. The following are clearly established in them:

Berriasian. Zone *Riasanites rjasanensis* with *Riasanites* spp., *Euthymiceras* spp., *Neocomites* sp., *Subcraspedites (Pronjaites) bidevexus* (Bogosl.), *Surites (Surites) spasskensis* (Nik.), *S. (S.) tzikwinianus* (Bogosl.), *S. (S.) analogus* (Bogosl.), *S. (Bogoslovskia) pseudostenomphalus* I. Sason., *Acroteuthis (Microbelus)* spp., including *A. (M.) uralensis* Sachs and Naln., *A. (A.) lateralis* (Phill.), and *A. (Boreioteuthis) prolateralis* Gust., and *Buchia volgensis* (Lah.).

Zone *Surites spasskensis* with *Surites (Surites)* spp., *S. (Caseyiceras) caseyi* I. Sason., *Subcraspedites (Subcraspedites)* spp., *Externiceras* spp., and *Chandomirovia ilekensis* Sason. In the lower part of the zone there is also *Euthymiceras,* while in the upper horizons *Stchirowskiceras* spp. appear. Belemnites represented only by *Acroteuthis (Acroteuthis)* spp. and *A. (Boreioteuthis)* spp. *Buchia* very numerous: *B. volgensis* (Lah.), *B. dilatata* (Pavl.), *B. syzranensis* (Pavl.), *B. elliptica* (Pavl.), *B. andersoni* (Pavl.), *B. terebratuloides* (Lah.), *B. surensis* (Pavl.), *B. expansa* (Pavl.), *B. subokensis* (Pavl.).

Lower Valanginian. Zone *Pseudogarnieria undulato-plicatilis* with *Pseudogarnieria* spp., *Proleopoldia* spp., *Menjaites* spp., *Surites (Bogoslovskia) pseudostenomphalus* I. Sason., *S. (S.) clementianus* (Bogosl.), *S. (S.),* cf. *analogus* (Bogosl.), *S. (Subpolyptychites) dis-*

tinctus I. Sason., *S. Subpolyptychites) orbicularis* I. Sason., *Subcraspedites (Subcraspedites) supbressulus* Bogosl., *Chandomirovia* ind. sp., *Bojarkia* aff. *bodylevskii* Schulg. n. sp., *Stchirowskiceras* spp., *Neotollia* (?) sp., *Temnoptychites simplex* (Bogosl.), *T.* sp., *Acroteuthis (Acroteuthis)* spp., *A. (Boreioteuthis)* spp., *Cylindroteuthis (Arctoteuthis) repentina* Sachs and Naln., *Buchia solida* (Lah.), *B. terebratuloides* (Pavl.), *B. regularis* (Pavl.), *B. trigonoides* (Lah.), *B. contorta* (Pavl.), *B. inflata* (Toula), *B. keyserlingi* (Lah.), *B. subinflata* (Pavl.).

The beds with *Riasanites* and *Euthymiceras* can be fairly definitely correlated only with the *Berriasella boissieri* zone of the Mediterranean Region. The *Surites spasskensis* zone probably corresponds basically to the *Surites analogus* zone of northern Siberia (obviously, these two zones may not have the same bulk). It is still not clear to what extent the *Surites spasskensis* zone may include the Siberian zone *Bojarkia mesezhnikowi.* Beds with *Pseudogarnieria* have been established only in the basin of the Sura River, on the Menya River, and the Oka basin, on the Neplozha River (Zonov, 1938). Fauna was studied from a section on the Menya which according to Saks and Shul'gina is a block displaced by a landslide. There is still the danger that representatives of other age complexes of fauna may have entered the layers with *Pseudogarnieria* to some degree. The faunal collections available occupy a position intermediate between the Berriasian and Valanginian. Predominant among the ammonites are endemic genera that are not encountered outside the Russian Plain *(Pseudogarnieria, Menjaites, Stchirowskiceras).* The presence of *Surites, Subcraspedites, Chandomirovia,* and *Bojarkia* brings this complex close to the Berriasian, while the appearance of *Temnoptychites, Menjaites,* and *Neotollia?* and the Valanginian habit of the *Buchia* and belemnites bring it close to the Valanginian. Still, it must be remembered that the belemnite complex on the Russian Plain acquires a similar appearance already in the *Surites spasskensis* zone.

Meanwhile, in the *Pseudogarnieria undulato-plicatilis* zone there are none of the Polyptychitidae, *Platylenticeras,* or *Tolypeceras* that are typical of the Valanginian of Western Europe. Shchirovskii's reports of finding *Platylenticeras gevrilianum* (d'Orb.) and *Tolypeceras marcouisianum* (d'Orb.) along with *Pseudogarnieria* and *Proleopoldia* on the Menya River were refuted by Spath (1947), who referred both these forms to *Pseudogarnieria.* Shchirovskii's *"marcouisianum"* specimen was later renamed *Pseudogarnieria alatyrensis* by Kemper (1961). All the same, the appearance of numerous forms of *Menjaites* (on the Oka River this genus is found together with *Temnoptychites* and on the Izhma River together with *Temnoptychites* and *Polyptychites*) and of less numerous *Temnoptychites* in the *Pseudogarnieria undulato-plicatilis* zone compels us, following Sazonov and Sazonova (1967), to place this zone in the bottom strata of the Valanginian.

On the Russian Plain marine Berriasian sediments are traced in the Urals-Emba Region and in the basins of the Volga, Oka, Moskva, and Vyatka rivers. In a number of areas they are eroded and all that have been preserved are redoposited (usually in phosphorites) faunal remains.

South of the Russian Plain the Berriasian is discovered with a boreal fauna beyond the border of Eastern Europe on Mangyshlak. Here the Berriasian transgressively overlaps various horizons of the Jurassic to lower Volgian (?) sediments inclusive. Upper Volgian sediments are absent. The Berriasian is represented by sandstones, sands, limestones, and clays 12–40 m thick with *Riasanites rjasanensis* (Venez.), *Euthymiceras euthymi* (Pict.), *Surites (Surites) kozakowianus* (Bogosl.), *Subcraspedites (Subcraspedites)* cf. *subpressulus* (Bogosl.), *Buchia volgensis* (Lah.), *B. okensis* (Pavl.), *Lopha rectangularis* (Roem.), *Trigonia carinata caspia* Savel., and others. These layers are conformably overlain by lower Valanginian limestones with intercalations of sands and sandstones (40 m) with *Echinopygus rostratus* Ag., *Buchia keyserlingi* (Lah.), *Diceras* sp., and others (Savel'ev and Vasilenko, 1963). From the Berriasian of Mangyshlak Bobkova (1958) mentions in addition *Protacanthodiscus transcaspius* (Lupp.), Sazonov and Sazonova (1967) report *Neocomites* aff. *occitanicus* Pict. and *Riasanites* cf. *subrjasanensis* (Nik.), and Luppov (1932) records *Blanfordiceras.*

In a phosphorite conglomerate underlying Hauterivian deposits in the Yaroslavl Volga area in the northern part of the Russian Plain, Aristov (1966) found dense, black phosphorite nodules with *Riasanites rjasanensis* (Venez.), *R.* aff. *subrjasanensis* (Nik.), and *R.* sp., characterizing the *R. rjasanensis* zone, and loose, whitish phosphorite nodules with *Surites (Caseyiceras) dorsorotundus* (Bogosl.), *S. (S.) spasskensis* (Nik.), *S. (S.) kozakowianus* (Bogosl.), *Subcraspedites (Subcraspedites)* aff. *subpressulus* (Bogosl.), and *S.(Pronjaites) bidevexus* (Bogosl.), that belong to the *Surites spasskensis* zone. The lower Valanginian cannot be identified here according to the fauna.

According to Dubeikovskii (1969), in the upper reaches of the Vyatka and Kama rivers quartz-glauconite green sands with phosphorite nodules 3.2 m thick with *Riasanites rjasanensis* (Venez.), *R. subrjasanensis* (Nik.), *Acroteuthis (Acroteuthis) lateralis* (Phill.), *A. (A.) arctica* Blüthg., *A. (Microbelus) russiensis* (d'Orb.), and *Buchia fischeriana* (d'Orb.) belong to the *Riasanites rjasanensis* zone. The sands transgressively overlap clays of the middle part of the upper Volgian substage (with *Craspedites (Craspedites)* cf. *okensis* (d'Orb.) and *C. (C.)* cf. *fragilis* (Terq.)). The *Surites spasskensis* zone may also be present, since in phosphorites at the base of the Lower Cretaceous there have been finds of *S. (S.)* aff. *analogus* (Bogosl.), *S. (S.)* cf. *tzikwinianus* (Bogosl.), *S. (S.)* sp. (aff. *subtzikwinianus* Bogosl.), *S. (Bogoslovskia) stenomphalus* (Pavl.), *Externiceras* cf. *solowaticum* (Bogosl.), *Subcraspedites (Borealites) suprasubditus* (Bogosl.), *Buchia volgensis* (Lah.), *B. fischeriana* (d'Orb.), and others (Dubeikovskii, 1969; Dubeikovskii and Tamoikin, 1967).

The beds with *Riasanites* do not extend north of the Vyatka-Kama region. In the basin of the Sysola River is a possibly Berriasian phosphorite conglomerate 5–45 cm thick at the base of Cretaceous sediments; the conglomerate contains *Buchia trigonoides* (Lah.), *B. stantoni* (Pavl.), and *B. fischeriana* (d'Orb.) in the phosphorites and skeletons of radiolarians (*Consphaera, Litocampe, Dicolocapsa, Stichocapsa, Tricolocapsa,* and others) and undetermined remains of ammonites and *Buchia* in the cement (Khudyaev, 1936).

According to the observations performed by A. P. Pavlow (1902) and Bodylevskii, (1963), and also those conducted by Kravets, Saks, Shul'gina, Gol'bert, Zakharov, and Klimov in 1970, on the Izhma River in the Pechora basin above Volgian sediments there is a break in the exposures in the Kush-Shchel'e scarp, after which appear gray silty clays and silts with lenses of sandstone and concretions of phosphorites of 6.4 m visible thickness with *Surites (Surites) kozakowianus* (Bogosl.), *S. (S.)* ex gr. *spasskensis* (Nik.), *Subcraspedites (Borealites) suprasubditus* (Bogosl.), *S. (Pronjaites) bidevexus* (Bogosl.), *S. (S.) pressulus* (Bogosl.), *Acroteuthis* spp., *Buchia terebratuloides* (Lah.), *B. volgensis* (Lah.), *B.* aff. *volgensis* (Lah.), *B. lahuseni* (Pavl.), *B.* cf. *unschensis* (Pavl.), *B.* cf. *okensis* (Pavl.), and *B.* cf. *subokensis* (Pavl.). Judging from the presence of *Surites* spp., *Subcraspedites* spp., and *Acroteuthis* s. str., these beds correspond to the *Surites spasskensis* zone in the Volga basin and, judging from a find of *Pachyteuthis (Simobleus) curvula* Sachs and Naln., they also correspond to the *Surites analogus* zone in Siberia. The clays with Siberian forms of *Lagonibelus* and *Acroteuthis (Boreioteuthis) prolateralis* Gust., which are situated at the base of the Berriasian section, may be still older (*Hectoroceras kochi* zone?).

The 5.5-m-thick (visible thickness) greenish gray silts occurring stratigraphically higher in the Parusy-Shchel'e scarp contain *Tollia* (? *Bojarkia*) ind. sp., *Acroteuthis* spp., *Buchia volgensis* (Lah.), and *B.* cf. *lahuseni* (Pavl.) and correspond to the Siberian *Bojarkia mesezhnikowi* zone. These rocks are overlain by gray and, higher up, variegated silts and siltstones with *Temnoptychites* spp., *Menjaites glaber* (Nik.), *Russanovia diptycha* (Keys.), *Polyptychites* sp., *Acroteuthis* spp., *Buchia inflata* (Toula), *B. syzranensis* (Pavl.), *B.* cf. *terebratuloides* (Lah.), *B.* cf. *keyserlingi* (Lah.), and *B. crassa* (Pavl.) belonging to the bottom strata of the lower Valanginian.

North of the Izhma River along the Pechora the Jurassic-Cretaceous boundary layers are represented in boreholes exclusively by clays in which upper Volgian and Berriasian layers cannot be identified because of the absence of fauna. The thickness of the Berriasian in the boreholes is around 25 m.

On the southern island of Novaya Zemlya, Dibner (1962) and Bodylevskii (1967) on several occasions found boulders and redeposited concretions of calcareous sandstones with a Berriasian fauna, indicating that the corresponding sediments developed in the past on the periphery of the island and in its southern part. From the area of Matochkin shar Bodylevskii mentions *Surites (Surites)* cf. *spasskensis* (Nik.) and *S. (Bogoslovskia) stenomphalus* (Pavl.), while Dibner reports (from determinations performed by Spath) *Tollia groenlandica* (Spath), *T.* aff. *tolmatschowi* Pavl., and *Surites (Bogoslovskia)* aff. *stenomphalus* (Pavl.). On the western shore of the southern island are also found boulders (concretions, rather) of bituminous limestones with upper Volgian *Craspedites (Craspedites)* cf. *fragilis* (Trautsch.), *C. (C.)* cf. *jugensis* Prig., *Buchia obliqua* (Tullb.), *B. terebratuloides* (Lah.), *B. subuncitoides* (Bodyl.), *B. subinflata* (Pavl.), *B. andersoni* (Pavl.), and others (Bodylevskii, 1967). Belonging to the bottom of the lower Valanginian are boulders of sandstones from Pan'kova Land with *Platylenticeras* (?) cf. *gevrilianum* (d'Orb.), *Buchia keyserlingi* (Lah.), *B. unschensis* (Pavl.), and *Oxytoma inaequivalvis* Sow. The finds mentioned by Bodylevskii (1967) of *Tollia* and *Temnoptychites* in boulders of the same rocks can easily be explained by the fact that *Tollia* existed also at the beginning of the Valanginian. In the southern part of the southern island Dibner reported finds of boulders of siderites and sandstones with Berriasian *Buchia volgensis* (Lah.), *B. lahuseni* (Pavl.), and *B. terebratuloides* (Lah.).

On the northern island of Novaya Zemlya and on Pai-Khoi a Berriasian fauna has not been found even in boulders.

Sections of the Berriasian at the foot of the east slope of the Cis-Polar Urals on the Yatriya, Yany-Man'ya, Tol'ya, and Mauryn'ya rivers in the basin of the Severnaya Sos'va and in the West Siberian Plain are described below.

In the upper Volgian sediments we identify *Kachpurites fulgens* and *Craspedites subditus* zones with ammonites and belemnites *Acroteuthis (Microbelus)* spp. that are characteristic for the Russian Plain. The upper horizons of the Volgian stage contain undetermined ammonites that are similar to *Craspedites (Taimyroceras)* and *Chetaites* and belemnites (*Lagonibelus* spp.) endemic to Siberia. Higher up occurs the Berriasian, with erosion in places on the east slope of the Urals. The following zones are established.

Zone *Chetaites sibiricus* with *Ch.* sp. (cf. *sibiricus* Schulg.). Possibly belonging to this zone are the layers with *Subcraspedites (Borealites)* ex gr. *suprasubditus* (Bogosl.) and a complex of belemnites that unite the East European *Acroteuthis (Microbelus)* and *A. (Boreioteuthis)* with the Siberian *Cylindroteuthis* and *Lagonibelus*.

Zone *Hectoroceras kochi* with *H. tolijense* (Nik.), *H. kochi* Spath, *Subcraspedites (Borealites)* spp., *Cylindroteuthis* spp., and *Lagonibelus* spp.

Zone *Surites analogus* with *S. (S.)* cf. *spasskensis* (Nik.), *S.* sp., *Cylindroteuthis, Lagonibelus, Pachyteuthis (Simobelus) curvula* Sachs and Naln., *Buchia volgensis* (Lah.), and others.

Zone *Bojarkia payeri* with *B.* cf. *payeri* (Toula), *Cylindroteuthis, Lagonibelus,* and the first *Acroteuthis* s. str.

The lower Valanginian begins with the zone *Temnoptychites insolutus* with *Temnoptychites* spp. and *Neotollia* spp. and the upper part with the first *Polyptychites* (*P.* aff. *sphaericus* Koen.). *Acroteuthis* s. str. predominates among the belemnites. Above this is the zone *Polyptychites michalskii* with *Polyptychites* spp.

In boreholes in the lower reaches of the Ob a member of silty clays and siltstones includes *Praetollia* sp. characteristic for the bottom of the Berriasian, and higher up is replaced by a member of compact clays of the lower Valanginian with *Polyptychites* cf. *sibiricus* (Sok.) (Mikhailov, 1957).

Kartseva (1969) maintains that the upper horizons (about 50–100 m) of the series of black clays and siltstones in the lower reaches of the Yenisei, which Saks and Ronkina (1957) earlier included in the upper Volgian substage, should be referred to the Berriasian. They contain ? *Surites (Surites)* cf. *spasskensis* (Nik.), *Craspedites* (? *Paracraspedites* or ?*Subcraspedites*) juv. ind. sp., *Onychites, Modiolus* cf. *sibiricus* Bodyl., *Buchia* aff. *tolli* (Sok.), and others. Among the foraminifers Sharovskaya determined 16 species, half of which (*Haplophragmoides fimbriatus* Schar., *H.* (?) *schleiferi* Schar., *Recurvoides* ex gr. *obskiensis* Rom., *Trochammina* ex gr. *rosaceaformis* Rom., *Ammobaculites* ex gr. *fontinensis* Terq., *Marginulina striatocostata* Reuss, *M. zaspelovae* Rom., and *Globulina chetaensis berriasica* Bass.) are common with the Volgian species. The young elements include: *Hyperammina aptica* Damp. and Dain, *Haplophragmoides* (?) *infracretaceous* Mjatl., *Recurvoides obskiensis* Rom., *Ammobaculites gerkei* Schar., *Gaudryina gerkei* Vass., *Marginulina gracilissima* (Reuss), and *Saracenaria elegans* Schl. Bondarenko identified a spore-pollen complex containing mainly pollen of Gymnospermae (63.2–78.8%).

Dominant among the spores are Schizaeaceae (6–9%) and *Coniopteris* spp. (9.7%). There are negligible amounts of *Selaginella* (2.3%), Osmundaceae (1%), Gleicheniacae (2.2%), and Polypodiaceae (to 1–2%). Most of the pollen is from Coniferae and especially Pinaceae (61.9%), followed by Podocarpaceae (5.1%), Bennettitales (0.5%), Gingkoaceae (1.5%), and others. Bondarenko concluded that this complex characterizes sediments of the Lower Cretaceous. It differs from the Jurassic complexes in the much larger proportion of various spores of Schizaeaceae and in the less distinct predominance of pollen of gymnosperms, from which *Classopollis* spp., characterisitc for the Upper Jurassic, disappear almost totally.

In the lower reaches of the Yenisei, as in the central part of the West Siberian Plain, the boundary between the Volgian stage and the Berriasian passes inside a homogeneous series of clays. The underlying beds of clay, belonging to the upper Volgian substage, are characterized by *Craspedites (Taimyroceras) laevigatus* Bodyl., *C. (T.)* sp. and a foraminifer complex with *Ammodiscus veteranus* Kosyr., *Haplophragmoides emeljanzevi* Schl., and others.

Overlying the black clays of the Volgian stage and bottom of the Berriasian and on arches of structures overlying the lower horizons of the Upper and Middle Jurassic with erosion is a series of light greenish gray siltstones, silts, and clays with sandstone intercalations. The lower part of the series 16–33 m thick, preserved only on the submerged parts of structures, has a Berriasian fauna: *Subcraspedites* ind. sp., *S.* (?) ind. sp., *Craspedites (Surites?)* ind. sp., *Tollia* (?) ind. sp., *Buchia terebratuloides* (Lah.), *B.* cf. *volgensis* (Lah.), *B.* cf. *okensis* (Pavl.), *B.* cf. *trigonoides* (Lah.). Higher up in the section appear typically Valanginian *Buchia* (*B.* cf. *keyserlingi* (Lah.), *B.* aff. *crassa* (Pavl.), and others) characterizing a horizon 20–35 m thick, and it is from this horizon, which can be traced in all the boreholes on the Malokhet arch, that the lower Valanginian should be considered to begin.

The foraminifer complex remains quite constant in the series of gray siltstones and clays. *Haplophragmoides infracretaceous* Mjatl. predominates quantitatively and also present are *H. niveus* Schar., *Ammobaculites gerkei* Schar., *Rhabdammina aptica* Damp. and Dain, *Lenticulina novella* Vass., *L.* aff. *subalata* Reuss, *Marginulina robusta* Reuss, *Globulina guttaeformis* Schl. (in litt.), *Epistomina* aff. *reticulata* Reuss, and others.

It is very likely that the erosion present inside the Berriasian of the Ust'-Yenisei depression corresponds in time to the formation of the Achimov series on the West Siberian Plain.

In the Anabar-Khatanga region the sections on the Kheta and Boyarka rivers and on Paks Peninsula that have been studied in depth in recent years and were described above make it possible to ascertain the following zones in the Jurassic-Cretaceous boundary layers (in the Paks Peninsula section upper Volgian, Berriasian, and lower Valanginian sediments form a single series of clays without breaks in sedimentation).

Upper Volgian substage. Zone *Craspedites okensis* with subzones *Virgatosphinctes exoticus, Craspedites okensis* s. str., and *Craspedites originalis.*

Zone *Craspedites taimyrensis* with *C. (Taimyroceras)* spp., *C. (C.) planus* Schulg., *Garniericeras margaritae* Schulg., *Virgatosphinctes exoticus* Schulg., and *Chetaites* sp.

Zone *Chetaites chetae* with *Ch. chetae* Schulg. *Craspedites (Taimyroceras) singularis*

Schulg., *Garniericeras margaritae* Schulg., and *Virgatosphinctes tenuicostatus* Schulg.

Berriasian. Zone *Chetaites sibiricus* with *Ch. sibiricus* Schulg., *Praetollia maynci* Spath, *Hectoroceras* sp., *Paracraspedites stenomphaloides* Swinn., *Subcraspedites (Pronjaites) bidevexus* (Bogosl.), *Surites (Surites)* cf. *tzikwinianus* (Bogosl.), *Argentiniceras* (?) n. sp. *Subcraspedites (Ronkinites) rossicus* Schulg. n. sp., and *S. (Borealites) suprasubditus* (Bogosl.).

Zone *Hectoroceras kochi* with *Hectoroceras kochi* Spath, *Praetollia maynci* Spath, *Subcraspedites (Subcraspedites)* spp., *Surites (Surites)* spp., *S. (Bogoslovskia)* ex gr. *stenomphalus* (Pavl.).

Zone *Surites analogus* with *Surites (Surites)* spp., *Subcraspedites (Subcraspedites)* spp., and *S. (Ronkinites)* aff. *primitivus* Swinn.

Zone *Bojarkia mesezhnikowi* with *Bojarkia* spp., *Tollia* spp., *Surites (Surites)* sp., and *Bochianites* sp.

Lower Valinginian. Zone *Neotollia klimovskiensis* with *Neotollia* spp. and *Tollia* sp.

Zone *Polyptychites stubendorffi* with subzones *Temnoptychites syzranicus* and *Polyptychites michalskii. Neotollia* and *Tollia* are still encountered in the lower horizons of the first subzone, but the subzone's ammonite complex is basically composed of *Polyptychites, Euryptychites, Astieriptychites, Russanovia,* and in the upper part, *Temnoptychites.*

Berriasian sediments are uncovered in a number of other areas in the Anabar-Khatanga region.

According to observations made by Zakharov, Mesezhnikov, and Yudovnyi in 1963 and 1964, on the Bol'shaya Romanikha River sections of the Neocomian begin with compact sands with calcareous concretions, the sands containing *Neotollia klimovskiensis* (Krimh.) and *N. maimetschensis* Schulg. n. sp. and belonging to the bottom of the lower Valanginian. The Berriasian does not crop out onto the surface. Only in the upper reaches of the Bol'shaya Romanikha, in the West Siberian upland, did Safronov (1959) find blocks of Berriasian sandstones with *Surites (Surites)* cf. *spasskensis* (Nik.) above traps.

On the left bank of the Maimecha River, 6–7 km above the mouth of the Gula River, according to Basov, Ronkina, and Shul'gina (1964), above middle Volgian glauconite-leptochlorite sandstones with concretions with *Epivirgatites variabilis* Schulg., *Pachyteuthis (Pachyteuthis) apiculata* Sachs and Naln., *Acroteuthis (Microbelus) russiensis* (d'Orb.), *Buchia mosquensis* (Buch), *B. russiensis* (Pavl.), and others, after a break in the section of about 1 m there are outcrops of greenish brown and grayish green glauconite-leptochlorite siltstones and silts with phosphorite nodules, above with calcareous concretions, 22 m thick with *Surites (Surites) subanalogus* Schulg. n. sp., *Paracraspedites* cf. *stenomphaloides* Swinn., *Subcraspedites* sp., *Lytoceras* sp., and *Cylindroteuthis (Arctoteuthis) porrectiformis* And., *C. (A.) repentina* Sachs and Naln., *Buchia volgensis* (Lah.), *B.* cf. *terebratuloides* (Lah.), *Inoceramus* sp., and *Prorokia* sp. Foraminifers: *Ammodiscus veteranus* Kosyr., *Marginulina* ex gr. *zaspelovae* Rom., *M. integra* Bass., *Marginulinopsis borealis majmetschensis* Bass., *Lenticulina saracenaeformis* E. Ivan and others. In the upper 6.5 m of the section *Ammodiscus veteranus* Kosyr. disappears, while *Nodosaria subhispida* Gerke, *N. incomes* Gerke and Schl., *Astacolus suspectus* Bass., *Lenticulina pseudoarctica* E. Ivan., and others appear. Judging from the ammonites, these silty rocks may correspond to the *Surites analogus* zone, but judging from the foraminifers, in the lower 15.5 m there is a correlation rather with the *Hectoroceras kochi* zone.

Above the beds described on the right bank of the Maimecha occur greenish gray silts and silty clays with calcareous concretions 2.8 m thick with *Surites* sp., *S. (?Tollia)* sp., *Phylloceras* sp., *Buchia volgensis* (Lah.), *Pleuromya uralensis* d'Orb., *Inoceramus* sp. Foraminifers: *Lenticulina pseudoarctica* E. Ivan., *Nodosaria incomes.* Gerke and Schl., *Marginulina* ex gr. *zaspelovae* Rom., *M. secta* Bass., *Astacolus trigonius* Bass., *Frondicularia* ex gr. *tjumenica* Tylk. and others (possibly an analogue of the *Bojarkia mesezhnikowi* zone).

About 3 km downstream near the mouth of the Gula the lower Valanginian appears – the *Neotollia klimovskiensis* zone – bluish gray silty sands with calcareous concretions, visible thickness 3.6 m, with *Neotollia klimovskiensis* (Krimh.), *N. maimetschensis* Schulg. n. sp., *Buchia* ex gr. *keyserlingi* (Lah.), *Liostrea anabarensis* Bodyl., *Modiolus sibiricus* Bodyl., *Cucullaea arctica* Bodyl., and others. Overlying these are fine sands with *Temnoptychites, Astieriptytchites, Neotollia* aff. *anabarensis* (Pavl.), and others (subzone *Temnoptychites syzranicus* of the zone *Polyptychites stubendorffi*).

East of the Maimecha along the southern rim of the Khatanga Depression are isolated outcrops of sandstones, sands, and clays with a fauna that in part can be related to the Berriasian (Saks et al., 1959). On the Sabyda and Dal'din these are beds with *Tollia (T. tollia* Pavl., *T.* aff. *tolli* Pavl., *T. tolmatschowi* Pavl., *T.* ind. sp.), *Acroteuthis (Acroteuthis) anabarensis* Pavl., *Buchia okensis* (Pavl.), *B.* sp. aff. *obliqua* (Tullb.), *B. sibirica* (Sok.), *Liostrea anabarensis* Bodyl., and others which may relate either to the top of the Berriasian (*Bojarkia mesezhnikowi* zone) or to the bottom of the lower Valanginian (*Neotollia klimovskiensis* zone).

In the lower reaches of the Polovinnaya River, a left-hand tributary of the Popigai, and on the Popigai River, below the mouth of the Polovinnaya, Shul'gina, Basov, Zakharov, and Yudovnyi (1968) observed outcrops of sediments of the *Surites analogus* zone: gritstones (0.3–0.4 m) oölitic sandstones (12–15 m), and clays (10 m) containing *Surites (Surites)* ex gr. *spasskensis* (Nik.), *S. (S.)* cf. *tzikwinianus* (Bogosl.), *S.* sp., *Cylindroteuthis* sp., *Buchia volgensis* (Lah.), *B. okensis* (Pavl.), *B. terebratuloides* (Lah.), *B. robusta* (Pavl.), *B. spasskensis* (Pavl.), and others. A faunal complex appears in the sandstones and clays that is transitional to the Valanginian, with *Tollia* cf. *tolli* Pavl., *T.* aff. *tolli* Pavl., *Neotollia* aff. *klimovskiensis* (Krimh.), *N.* sp., *Phylloceras* sp., *Acroteuthis (Acroteuthis) anabarensis* (Pavl.), *A. (A.) lateralis* (Phill.), *Buchia inflata* (Toula), *B. keyserlingi* (Lah.), *B. sibirica* (Sok.), *B. bulloides* (Lah.), and others.

Near the northern edge of the Siberian Platform Berriasian outcrops continue in a direction eastward from the Popigai River. On the Dulgan River in gray clayey sands and sandstones 90 m thick finds of fauna have been made that seem to match closest the *Surites analogus* zone: *S. (S.) kozakowianus* Bogosl., *S. (S.)* aff. *tzikwinianus* Bogosl., and *Buchia volgensis* (Lah.). South of Lake Lapa there are beds with *Tollia tolmatschowi* Pavl., *Buchia terebratuloides* (Lah.), *B. volgensis* (Lah.), and others (possibly the *Bojarkia mesezhnikowi* zone).

In the Nordvik area the Berriasian enters into the composition of a series of gray and dark-gray clays with intercalations of limestones and calcareous sandstones up to 150–250 m thick which also includes the whole of the Valanginian and has been stripped by boreholes in many drilling areas (Uryung-Tumus Peninsula, Il'ino–Kozhevnikovskaya and Yuzhno-Tigyanskaya structures, Syndasko). In exposures on the Tigyan River Berzin (1939) collected from these clays *Surites (Surites)* aff. *clementianus* Bogosl., *S. (S.)* aff. *analogus* Bogosl., *Buchia spasskensis* (Pavl.), *B. subokensis* (Pavl.), *B.* cf. *okensis* (Pavl.), *B. volgensis* (Lah.), and *B.* cf. *terebratuloides* (Lah.) (possibly the *Surites analogus* zone). Bodylevskii's collections from the Tigyan River (contributions by Berzin) also includes a lower Valanginian *Neotollia*.

Along the northern edge of the Khatanga Depression the presence of the Berriasian can be assumed between the mouths of the Aprelevka and Osip rivers, on the Aprelevka, and in the upper reaches of the Osip. Here we have sands, sandstones, and silts with coal beds containing *Buchia elliptica* (Pavl.), *B.* cf. *fischeriana* (d'Orb.), *B.* cf. *unschensis* (Pavl.), *B.* cf. *subokensis* (Pavl.), *B. tenuicollis* (Pavl.), *B. terebratuloides* (Lah.), *B. lahuseni* (Pavl.), and others. Outcrops of clays with *Tollia* (?) ind. sp. are also observed.

On the Muruptuma-tari River Dibner described clays and siltstones with *Tollia* ind. sp., *Protocardium concinnum* Buch, and others and farther north conglomerates (0.2–0.3 m) with *Buchia lahuseni* (Pavl.), sandstones (13 m) with *Tollia* cf. *latelobata* Pavl., *Neotollia* (?) *anabarensis* Pavl., and *Acroteuthis (Acroteuthis)* sp., and clays with intercalations of siltstones and limestones with concretions (30.5 m) with *Tollia* (?) ind. sp., *Buchia volgensis* (Lah.), *B.* cf. *inflata* (Lah.), *B. keyserlingi* (Lah.), *B. surensis* (Pavl.), *B.* cf. *tolli* (Pavl.), and others. It may be that these rocks, totally or in part, belong to the bottom of the Valanginian.

On the left shore of the Verkhnyaya Taimyra River on the Goluboi stream that empties into the Dyabaka-tari River, near outcrops of upper Volgian rocks, a specimen of *Subcraspedites* sp. was found in a talus, suggesting that the Berriasian is developed here too (Saks et al., 1965).

In northern Taimyr in the lower reaches of the Kamennaya and Zhdanov rivers (basin of the Leningradskaya River), Basov, Zakharov, Mesezhnikov, and Yudovnyi (1965) observed outcrops of Berriasian sands and sandstones with *Subcraspedites* (?) sp., *Tollia* sp., *Buchia* spp., and the foraminifer *Haplophragmoides latidorsatus* Born. According to Dibner and Ageev (1960), Valanginian sandstones and clays with *Buchia inflata* (Toula) and other species crop out on Severnaya Zemlya and on Bol'shevik Island. There are no definite data on the presence of the Berriasian here.

On the Anabar River and its tributaries, above the Volgian clays, silts, glauconitic sandstones, and gritstones there is, without any visible break, a member of dark-gray sandy clays with pyrite nodules and siderite concretions, at the top with loaf-shaped siltstones 5–30 m thick with *Paracraspedites* aff. *bifurcatus* Swinn., *P.* ind. sp. (? cf. *bifurcatus* Swinn.), *P. (Surites ?)* ind. sp., *Buchia* cf. *fischeriana* (d'Orb.), *B.* cf. *volgensis* (Lah.), *B.* cf. *okensis* (Pavl.), *B. terebratuloides* (Lah.), *B.* cf. *uncitoides* (Pavl.), *B. trigonoides* (Lah.), and others. There is a complex of foraminifers with *Ammodiscus veteranus* Kosyr., *Haplophragmoides infracretaceouss* Mjatl., and *Trochammina rosaceaformis* Rom. (Saks et al., 1963). Judging from the composition of the foraminifers and taking into account the find of *Hectoroceras* sp on the right-hand tributaries of the Anabar River, we should opt for placing these clays in the *Hectoroceras kochi* zone. The presence of the *Chetaites sibiricus* zone has not been proved, but in the gritstones underlying the clay on the Buolkalakh River Zhukov found *Chetaites chetae* Schulg., a zonal species of the upper zone of the upper Volgian substage.

Above the clays on the Anabar River occur greenish yellow fine-grained sands with loaf-shaped concretions and lenses of calcareous sandstones and intercalations of silts at least 16 m thick with *Surites (Surites) subanalogus* Schulg. n. sp., *S.* ind. sp., *Lytoceras* sp., *Cylindroteuthis (Arctoteuthis)* cf. *baculus* Crickmay, *Buchia fischeriana* (d'Orb.), *B. trigonoides* (Lah.), *B. lahuseni* (Pavl.), *B. uncitoides* (Pavl.), *B. okensis* (Pavl.), *B. volgensis* (Lah.), *B. andersoni* (Pavl.), *B. inflata* (Toula), *B.* aff. *inflata* (Toula), *B. terebratuloides* (Lah.), *B.* aff. *crassa* (Pavl.) and *B.* n. sp. Schulg. (aff. *uncitoides* Pavl.). Foraminifera encountered were *Globulina lacrima* Reuss and *Saracenaria digna* Schleif. This is evidently the *Surites analogus* zone.

On the right-hand tributaries of the Anabar in a sand-silt series specimens were found of *Bojarkia mesezhnikowi* Schulg., implying that the upper zone of the Berriasian is also present in the Anabar basin.

Belonging to the *Neotollia klimovskiensis* zone, which begins the section of the Valanginian, is a member of silts (in the lower 7–8 m grayish green glauconitic, in the upper 26 m dark-gray clayey with loaves and lenses of calcareous siltstone) in exposures on the Anabar, particularly in the Klimovskii bluff. Collected from the glauconitic silts were *Tollia tolli* Pavl., *T. latelobata* Pavl., *T.* cf. *vai* Krimh., *T.* sp., *Neotollia klimovskiensis* (Krimh.), *N. klimovskiana* Bodyl. and Schulg. n. sp., *Phylloceras* sp., *Acroteuthis (Acroteuthis) anabarensis* (Pavl.), *A. (A.) arctica* Blüthg., *Buchia crassa* (Pavl.), *B.* cf. *crassa* (Pavl.), *B. crassicollis americana* (Sok.), *B. inflata* (Lah.), *B. keyserlingi* (Lah.), *B. robusta* (Pavl.), *B. sibirica* (Sok.), *B. bulloides* (Pavl.), *Liostrea anabarensis* Bodyl., *Cucullaea arctica* Bodyl., *Pleuromya anabarensis* Bodyl., *P.* cf. *uralensis* d'Orb., *Modiolus sibiricus* and others. The clayey silts yielded *Tollia* ind. sp., *Plylloceras* sp., *Acroteuthis (Acroteuthis) anabarensis* (Pavl.), *A. (A.)* cf. *arctica* Blüthg., *A. (A.) explanatoides polaris* Sachs and Naln., *A. (Boreioteuthis) hauthalt* Blüthg., *Buchia volgensis* (Lah.), *B.* ex gr. *keyserlingi* (Lah.), *B.* cf. *uncitoides* (Pavl.), *Pleuromya anabarensis* Bodyl., and others, plus foraminifers: *Haplophragmoides infracretaceous* Mjatl., *Gaudryina gerkei* Vass., *Marginulina* aff. *robusta* Reuss, *Reinholdella* aff. *tatarica* Rom., *Globulina lacrima* Reuss, and others.

Above this occur alternating gray coarse and fine silts with calcareous concretions, loaves, and lenses of calcareous siltstone 18–24 m thick with *Polyptychites, Temnoptychites, Astieriptychites, Euryptychites, Neotollia,* etc. (subzone *Temnoptychites syzranicus* of the zone *Polyptychites stubendorffi* of the lower Valanginian).

In a creek valley on the left slope of the valley of the Saibalakh Vtoroi River on the west shore of Anabar Bay black-gray fragmental clays were revealed with loaves of calcareous siltstone and large calcareous concretions 8 m in visible thickness, in the lower part with *Tollia* ind. sp., *Surites* (?) ind. sp., *Buchia fischeriana* (d'Orb.), *B.* cf. *trigonoides* (Pavl.), and *B.* cf. *volgensis* (Lah.), in the middle horizons with *Tollia* cf. *tolli* Pavl. and *Buchia fischeriana* (d'Orb.), and in the upper part with *Tollia* cf. *tolli* Pavl., *T.* sp., and *Polyptychites* (?) ind. sp. Obviously present here are the *Bojarkia mesezhnikowi* zone of the top of the Berriasian and the *Neotollia klimovskiensis* zone of the bottom of the Valanginian.

On the east shore of Anabar Bay the section of the Neocomian begins with *Polyptychites* layers of the lower Valanginian that are exposed after a break in the section above Callovian outcrops. Still farther east, in the Pronchishcheva ridge Emel'yantsev found *Tollia tolli* Pavl., *T. latelobata* Pavl., and *Neotollia* (?) *anabarensis* (Pavl.) in clays with lenses and concretions of limestone (Saks et al., 1963), indicating that the top of the Berriasian and bottom of the Valanginian are present here.

In the Olenek River basin Berriasian rocks overlie, without any visible break, argillites with a fauna of the upper Volgian substage and, possibly, the bottom of the Berriasian: *Craspedites* (?) ind. sp., *C. (Paracraspedites ?)* ind. sp., *Phylloceras* sp. ?, *Lagonibelus (Lagonibelus)* aff. *superelongatus* (Blüthg.), *Buchia volgensis* (Lah.), *B. fischeriana* (d'Orb.), *B. okensis* (Pavl.), *B.* cf. *spasskensis* (Pavl.), and *B. orbicularis* (Hyatt). The data of Sorokov et al. show the Berriasian to consist of a member of argillites 25–40 m thick with a fauna closest to that of the *Surites analogus* zone: *S. (S.)* ex gr. *spasskensis* (Nik.), *S. (S.)* aff. *kozakowianus* (Bogosl.), *S.* (?) sp., *Paracraspedites olenekensis* Ersch. n. sp. (in litt.), *Subcraspedites (Borealites)* aff. *suprasubditus* (Bogosl.), *S. (S.)* ex gr. *subpressulus* (Bogosl.), *Buchia fischeriana* (d'Orb.), *B. volgensis* (Lah), *B. trigonoides* (Lah.), *B. okensis* (Pavl.). Appearing at the top of the argillites are *Tollia tolmatschowi* Pavl. and *T.* aff. *latelobata* Pavl.

Above this lies a member of alternating sandstones, siltstones, and argillites 75–80 m thick with *Buchia volgensis* (Lah.), *B. okensis* (Pavl.), and *B.* aff. *inflata* (Toula). Here are probably sediments of the *Bojarkia mesezhnikowi* and *Neotollia klimovskiensis* zones.

An analogous section is observed, according to Sorokov et al., in the lower reaches of the Lena, on the Bulkursk and Chekurovsk anticlines (Saks et al., 1963). An argillite member 24–30 m thick contains *Surites* sp., *Phylloceras* ind. sp., *Buchia fischeriana* (d'Orb.), *B. volgensis* (Lah.), *B.* ex gr. *volgensis* (Lah.), *B. okensis* (Pavl.), and *B. terebratuloides* (Lah.). Higher up, in a series of interbanded sandstones and siltstones 170–370 m thick, the following were collected: in the lower part *Tollia tolli* Pavl., *T.* (?) ind. sp., *Lytoceras sutile* Opp., *Phylloceras* ind. sp., and *Buchia* ex gr. *volgensis* (Lah.); higher up the section *Subcraspedites (Borealites)* aff. *suprasubditus* (Bogosl.) and *Buchia inflata* (Toula).

Up the Lena River Berriasian marine sediments are traced as far as the Molodo and Besyuke rivers. *Surites* sp. and *Tollia* sp. are found in siltstones and sandstones on these rivers (Saks et al., 1963). It may well be that the Berriasian stage (especially its lower horizons) is included in the series of siltstones and sandstones of mainly Volgian age, in which Koshelkina noted a number of finds of fauna on the Molodo and Usunku rivers that is either encountered both in the upper Volgian substage and in the Berriasian or is even Berriasian rather than late Volgian: *Chetaites* (?) sp., *Lagonibelus (Lagonibelus) elongatus* (Blüthg.), *Buchia volgensis* (Lah.), *B.* ex gr. *surensis* (Pavl.), *B.* cf. *lahuseni* (Pavl.), *B. fischeriana* (d'Orb.), *B. terebratuloides* (Lah.), *B.* cf. *keyserlingi* (Lah.), *B.* cf. *subokensis* (Pavl.), *B.* ex gr. *crassicollis* (Keys.), *B. krotovi* (Pavl.).

To the east of the lower reaches of the Lena the Marine Berriasian disappears, to reappear only in the extreme northeastern part of Asia, east of the lower reaches of the Kolyma. Sandstone outcrops with *Buchia fischeriana* (d'Orb.), *B. russiensis* (Pavl.), *B. terebratuloides* (Lah.), *B. obliqua* Tullb., *B. jasikovi* (Pavl.), *B.* ex gr. *volgensis* (Lah.), and *B.* ex gr. *keyserlingi* (Lah.), known in the Tas-Khayakhtakh ridge on the Taskan and Omolon rivers, still belong to the upper Volgian substage (Tuchkov, 1959; Saks et al., 1963).

NORTHEAST ASIA

Buchia remains are chiefly used for the purpose of identifying and zoning the Volgian and Berriasian stages in the Northeast of the USSR. Remains of other mollusks, including ammonites and *Inoceramus,* have recently been found in Jurassic-Cretaceous boundary layers. The number of such finds will no doubt increase, and then it will be possible to assess the age of the series containing them with a greater degree of certainty.

The Volgian stage was very clearly identified by Parakestov (Efimova et al., 1968) in the basin of the Bol'shoi Anyui River, where it is represented by an igneous-sedimentary series 1000–1100 m thick and is arbitrarily divided into three substages. The boundary between the Volgian stage and the Kimmeridgian is drawn in this area according to the appearance of *Buchia piochii* (Gabb.). Encountered together with this species in the lower substage of the Volgian stage are *B. mosquensis* (Buch), *B. rugosa* (Fisch.), and *B. orbicularis* (Hyatt). Apart from *Buchia, Subplanites* ? ind. sp., *Lima borealis* Pcel., and *Modiolus* aff. *molodonensis* Voron. are recorded from here. The boundary between the lower and middle substages of the Volgian is fixed according to the appearance of *Buchia fischeriana* (d'Orb.). Also appearing in the middle substage are *B. flexuosa* (Parak.) and *B. circula* (Parak.), plus, less often, *B. mosquensis, B. rugosa,* and *B. orbicularis.* A find of *Dorsoplanites* ind. sp. has been recorded. In the upper Volgian substage there is an abundance of *B. tenuicollis* (Pavl.), *B. krotovi* (Pavl.), *B. jasikovi* (Pavl.), and *B. terebratuloides* (Lah.). The boundary with the middle substage is drawn according to the appearance of *B. tenuicollis.* Remains of *Chetaites* ind. sp. are found in addition to *Buchia.*

In the middle reaches of the Kolyma and Indigirka rivers the Volgian stage, composed of siltstones, argillites, and sandstones, has a thickness of 1000–2000 m. The upper part is formed of continental deposits with *Cladophlebis aldanensis* Vachr., *Cl. haiburnensis* (L. and H.) Brongn., *Raphaelia diamensis* Sew., and others. In the lower reaches of the Kolyma the Volgian stage consists of a series of sedimentary rocks interbanded with tuffs, less often lavas of basalts, andesites, and sometimes liparites, the thickness of which is 700–1200 m.

In the Anadyr-Koryakskii folded region sediments containing Volgian–Berriasian *Buchia* are widely distributed. Ammonites are found very rarely here, and in many cases it is impossible to determine the age of the sediments. For instance, in the Murgal'sk uplift the very lowest parts of the Murgal'sk series with *Buchia* ex gr. *mosquensis* (Buch) might be placed in the Volgian stage (Vasetskii, 1963). According tô a number of investigators (Eliseev, Terekhova, and others), in the Mainskie Mountains Berriasian sediments conformably overlie sandy-silty beds with *B.* cf. *mosquensis* (Buch), *B.* cf. *rugosa* (Fisch.), and *Meleagrinella* ind. sp. which can be placed in the Volgian stage. Perhaps still belonging to the Upper Jurassic is the lower part of the igneous-siliceous series, characterized exclusively by remains of radiolarians, on northwestern Kamchatka. In the Pontoteiskie

Mountains in deposits unconformably overlying Middle Jurassic layers, *Buchia okensis* Pavl. was collected from the bottommost horizons containing forms of the genus. It is not clear whether the basal strata of the series in question belong to the Berriasian or to the upper Volgian.

Everywhere in the Northeast of the USSR the boundary between the Jurassic and Cretaceous is drawn arbitrarily along the base of the beds with *B. okensis* (Pavl.) and *B. volgensis* (Lah.) (in the Khatanga basin both species are present at the top of the upper Volgian substage as well).

In the Kolyma area (Paraketsov, 1966) the Berriasian consists primarily of terrigenous formations 320–600 m thick. The lower part of the section yields remains of *B. volgensis* (Lah.), *B. okensis* (Pavl.), *B. spasskensis* (Pavl.), *B. jasikovi* (Pavl.), *B. unschensis* (Pavl.), *B. fischeriana* (d'Orb.), *B. lahuseni* (Pavl.), *B. tenuicollis* (Pavl.), *B. krotovi* (Pavl.), and *B. terebratuloides* (Lah.). Also occurring here are remains of *Surites* (?) ind. sp. (Efimova et al., 1968). In the higher horizons, transitional to the Valanginian, *Buchia fischeriana, B. lahuseni, B. tenuicollis, B. krotovi,* and *B. terebratuloides* disappear, and *B. elliptica* (Pavl.), *B. keyserlingi* (Lah.), *B. sibirica* (Sok.), and *B. visingensis* (Sok.) appear. Together with these on the Rauchua River are remains of *Tollia* sp. (Vereshchagin et al., 1965). Apart from *Buchia,* the following are reported by Paraketsov (1966) from the Berriasian of the Kolyma area: *Phylloceras* (?) ind. sp., *Camptonectes* ex gr. *virgunensis* Buv., *Paleodictyon* sp., and *Oxytoma* sp.

The boundary between the Berriasian and Valanginian stages is drawn according to the disappearance of *Buchia volgensis* and *B. okensis* and the appearance of *B. bulloides* (Pavl.) and *B. inflata* (Toula). Also widespread in the lower Valanginian are *B. keyserlingi* (Lah.), *B. sibirica* (Sok.), and *B. visingensis* (Sok.). In the opinion of a number of investigators of the Northeastern USSR (Vereshchagin, Avdeiko, Pokhialainen), the species listed occur in the upper Berriasian as well. However, these species are absent in the beds with Berriasian ammonites in the well-stratified sections of northern Middle Siberia.

The following faunal complexes characterize the Berriasian stage of the Murgal'sk uplift (Anadyr-Koryakskii Region). Older complex: *B. volgensis* (Lah.), *B. okensis* (Pavl.), *B. terebratuloides* (Lah.), *B. krotovi* (Pavl.), *B. paradoxa* (Sok.), and *B. lahuseni* (Pavl.). The higher strata of the Berriasian or, possibly, the bottom of the Valanginian contain, together with *B. okensis* (Pavl.), *B. keyserlingi* (Lah.) and *B. visingensis* (Sok.). Present here too are *Inoceramus (Taenioceramus) pronatus* Poch. and *I. (Anopaea) mandibulaformis* Poch. A series of sandstones and siltstones 300–350 m thick belongs to the Berriasian. In addition to *Buchia and Inoceramus,* remains of *Amphidonta* n. sp., *Meleagrinella* aff. *ovalis* (Phill.), and *Oxytoma* aff. *aucta* Zakh. have been collected from the Berriasian in the Murgal'sk uplift.

On Taigonos Peninsula, Avdeiko (1968) arbitrarily referred to the Berriasian tufogenic-sedimentary rocks 200 m thick with *Buchia volgensis* (Lah.), *B.* cf. *keyserlingi* (Lah.), *B.* cf. *lahuseni* (Pavl.), *B.* cf. *fischeriana* (d'Orb.), *B.* cf. *unschensis* (Pavl.), and others.

In the Pontoteiskie Mountains Berriasian age is attributed to a series of tuff sandstones, siltstones, and tuffs up to 700 m thick. The fossil remains are distributed in the following order in the section, proceeding from the bottom:

1. *Buchia* aff. *okensis* (Pavl.), *B.* cf. *fischeriana* (d'Orb), *B.* cf. *tenuicollis* (Pavl.), *B.* cf. *krotovi* (Pavl.), *B.* cf. *volgensis* (Lah.).

2. *B.* cf. *fischeriana* (d'Orb.), *B. okensis* (Pavl.), *B. keyserlingi* (Lah.), *B. elliptica* (Pavl.), *Lytoceras* sp.

3. *B. tenuicollis* (Pavl.), *B. terebratuloides* (Lah.), *B. krotovi* (Pavl.), *B.* aff. *lahuseni* (Pavl.), *B.* cf. *fischeriana* (d'Orb.), *B.* cf. *okensis* (Pavl.) *B. volgensis* (Lah.), *Phylloceras* ind. sp., *Pleuromya* sp., *Astarte* sp., *Nucula* ind. sp., gastropods.

4. *B. terebratuloides* (Lah.), *B.* cf. *krotovi* (Pavl.), *B.* cf. *volgensis* (Lah.), *B.* aff. *fischeriana* (d'Orb.).

5. *B.* cf. *volgensis* (Lah.), *B.* cf. *okensis* Pavl., *B. terebratuloides* (Lah.), *B.* cf. *fischeriana* (d'Orb.), *B. tenuicollis* (Pavl.), *Euthymiceras* n. sp., *Belemnites* sp.

Some forms of the second complex, which in other areas occupy the highest position in the Berriasian sections, in the Pontoteiskie Mountains are encountered among forms of *Buchia* characteristic for the lower half of the Berriasian.

Pokhialainen (1967) places in the Berriasian some of the igneous-siliceous rocks of the Talovka Mountains with the radiolarians *Canosphaera* ? sp., *Dicolocapsa* ind. sp., *Tricolocapsa* sp., *Dictiomitra* sp., *Lithostrobus* sp., *Lithomitra* aff. *capito* Rüst., *L.* aff. *capitoidea* Zham., *Eucyrtidium* cf. *khabakovi* Zham., and *Stichocorys* cf. *korjakensis* Zham.

In cases where the igneous-siliceous series of the Berriasian are replaced along the strike by terrigenous formations, these contain *Buchia okensis* (Pavl.), *B. volgensis* (Lah.), *B.* cf. *terebratuloides* (Pavl.), *B. krotovi* (Pavl.), and *B. fischeriana* (d'Orb.).

Terekhova's data show that in the Mainskie Mountains the Berriasian stage conformably overlies sediments of the Volgian stage with *B.* cf. *mosquensis* Buch and is represented by a series of interbanded siltstones and sandstones 200 m thick. In the lower horizons the Berriasian contains *B. krotovi* (Pavl.), *B. fischeriana* (d'Orb.), *B. okensis* (Pavl.), *B. volgensis* (Lah.), and *Phylloceras* sp. Found higher up are *B. okensis* (Pavl.), *B. volgensis* (Lah.), and *B.* cf. *lahuseni* (Pavl.). The presence of the Berriasian in the Pekul'nei Range is attested to by finds of *B.* ex gr. *okensis* (Pavl.) and *B.* cf. *terebratuloides* (Lah.).

In the Velikaya River basin we might place the siliceous rocks and limestones with *B.* cf. *volgensis* (Lah.), *B. obliqua* (Tullb.), *B.* cf. *contorta* (Pavl.), *B.* cf. *keyserlingi* (Lah.), and *B.* aff *fischeriana* (d'Orb.) in the Berriasian. In addition to *Buchia*, Dundo and Zhamoida (1963) report from here the radiolarians *Cenosphaera sphaerozoica* Zham., *C.* sp. 1, *C.* sp. 2, *Stylosphaera* sp., *Saturhalis* (?) sp., *Trisphaera* (?) sp., *Dicolocapsa* sp., *Lithostrobus* sp., *Dictiomitra* sp. 1, *D.* sp. 2, *Lithomitra* aff. *capito* Rüst., *Eucyrtidium khabakovi* Zham., *Stichocorys korjakensis* Zham., *Siphocampe* aff. *rostra* Chab., *Lithocampe* sp. A, *L.* sp. B, *Stichocapsa* cf. *piriformis* Tan Sin Hok. In the Ugol'naya Bay area Terekhova notes that the Berriasian is represented by sandstones with *Buchia* cf. *okensis* (Pavl.), *B.* ex gr. *volgensis* (Lah.), *B.* cf. *krotovi* (Pavl.), and others.

Finds of *B.* cf. *fischeriana* (d'Orb.), *B.* cf. *lahuseni* (Pavl.), *B.* cf. *volgensis* (Lah.), and *B. russiensis* (Pavl.) attest to the presence of the Berriasian in the Khatyrka basin (Rusakov and Egiazarov, 1959; Gladenkov, 1963).

In fixing the boundary between the Berriasian and the Valanginian in the Anadyr-Koryakskii Region we have to go according to the change in the *Buchia* complexes in the sections. The transitional Volgian-Berriasian *B. lahuseni, B. fischeriana,* and *B. tenuicollis* are no longer found in the lower Valanginian. *B. okensis* and *B. volgensis* drop out of the complex. On the other hand, such forms as *B. piriformis, B. sibirica, B. inflata,* and *B. uncitoides* appear and flourish.

In view of the absence of any other sound criteria, the principle of identifying the Berriasian according to the appearance of *B. okensis* and *B. volgensis* is as yet the only one for separating the Jurassic and Cretaceous in the Northeastern USSR. In a number of cases, when typical Berriasian *Buchia* and ammonites are absent in a complex, it is hard to decide whether the beds with middle-of-the-road *Buchia* are Volgian or Berriasian.

The upper boundary of the Berriasian stage in the Northeast of the USSR can be hypothetically drawn according to the change in the *Buchia* complexes – the disappearance of *B. okensis* (Pavl.) and *B. volgensis* (Lah.), usual for the Berriasian, and the appearance and spread of such typically Valanginian forms as *B. sibirica* (Sok.), *B. inflata* (Toula), *B. piriformis* (Lah.), and *B. bulloides* (Pavl.).

The Berriasian stage in the Northeastern USSR cannot yet be broken down into zones because the data on the distribution of the *Buchia* complexes inside the stage are contradictory and there are hardly any ammonites. All that can be done is to speak in each specific case of layers that contain distinctive associations of fossil faunas and that are confined to a certain part of the Berriasian.

The *Buchia* complex that characterizes the Berriasian stage of the northeast is represented by the following forms: *Buchia volgensis* (Lah.), *B. okensis* (Pavl.), *B. terebratuloides* (Lah.), *B. lahuseni* (Pavl.), *B. subokensis* (Pavl.), *B. fischeriana* (d'Orb.), *B. paradoxa* (Sok.), *B. elliptica* (Pavl.), *B. visingensis* (Sok.), *B. obliqua* (Tullb.), *B. contorta* (Pavl.), *B. jasikovi* (Pavl.). The Berriasian forms of the genus *Inoceramus* are *I. (Taenioceramus) pronatus* Poch., *I. (Anopaea) mandibulaformis* Poch., and *Retroceramus* ind. sp. The ammonites determined were *Phylloceras* sp., *Lytoceras* sp., *Euthymiceras* n. sp., *Surites* (?) ind. sp., and *Tollia* sp. Such forms as *Buchia keyserlingi* (Lah.), *B. visingensis* (Sok.), and *Tollia* sp. quite possibly originate from lower Valanginian sediments.

Apart from *Buchia, Inoceramus,* and ammonites, the Berriasian of the Northeastern part of the USSR yields remains of various as yet scarcely studied bivalve mollusks, gastropods, Crinoidea, and belemnites.

FAR EAST

Finds of Valanginian *Tollia* cf. *tolli* Pavl. and *Polyptychites* sp. cf. *keyserlingi* Neum. and Uhl. in a series of sandstones, shales, and tuffites are reported by Springis (1958) from Melkovodnaya Bay on the northern shore of the Sea of Okhotsk. According to Lebedev (1969), to the south of Udskaya Gulf on the western shore of the sea, sandstones with intercalations of siltstones 350–400 m thick with middle Volgian *Buchia* cf. *mosquensis* (Buch), *B.* aff. *rugosa* (Fisch.), *B. circula* (Parak.), *B.* cf. *flexuosa* (Parak.), and *B.* cf. *tenuicollis* (Pavl.) are overlain by sandstones with intercalations of siltstones and argillites about 200 m thick with plant remains and in the lower horizons with gravel. Flora:

Coniopteris ex gr. *arctica* Pryn., *Encephalartites* sp., *Butefia burejensis* Pryn., *Ctenis burejensis* Pryn., *Aldania umanskii* Vachr. and Leb., *Tyrmia polynovii* Pryn., *Nilssoniopteris* aff. *ovalis* Samyl., and others. The sandstones with flora are overlain by siltstones (about 30 m) with brackish-water *Corbicula tetoriensis* Kob. and Suz., *Exogyra* cf. *ryosekiensis* Kob. and Suz., and *Gervillia* cf. *schinanoensis* Yabe and Nag. Above this are sandstones (about 70 m) with *Subcraspedites (Pronjaites)* aff. *bidevexus* Bogosl., *Buchia sibirica* (Sok.), *B. uncitoides* (Pavl.), *B. keyserlingi* (Lah.), *B. volgensis* (Lah.), *B. okensis* (Pavl.), *B.* cf. *bulloides* (Lah.), and *B.* cf. *robusta* (Pavl.) of Berriasian, possibly some of early Valanginian, age. The sandstones with flora are thus designated early Berriasian or late Volgian. Above the sandstones with *Buchia* are sandstones with lenses of siltstones about 100 m thick with plant remains *(Lobifolia, Sagenopteris, Pityophllum)*; farther up these rocks are again replaced by sandstones (50–100 m) with lower Valanginian *Buchia nuciformis* (Pavl.), *B.* cf. *inflata* (Toula), *B. uncitoides* (Pavl.), *B. sibirica* (Sok.), and others.

The Berriasian and Valanginian are not separated by Vereshchagin and Potapova (1966) in the northern and central parts of Sikhote Alin. They are represented by a thick (2000–3000 m) flysch series of sandstones, siltstones, and clayey and siliceous-clayey shales, sometimes with some proportion of gritstones and conglomerates with *Buchia* that suggest the presence of the Berriasian. For instance, in the lower part of the Pionera suite in the lower reaches of the Amur River, *Buchia* cf. *volgensis fenestellata* (Pavl.), *B.* cf. *volgensis* (Lah.), *B.* cf. *bulloides* (Lah.), *B.* cf. *terebratuloides* (Lah.), *B.* cf. *crassicollis* (Keys.), and *Inoceramus* cf. *wolloswitchi* Sok. were collected. In the Pivana suite higher up the section occur Valanginian *Buchia keyserlingi* (Lah.), *B. crassicollis* (Keys.), *B. inflata* (Toula), and *Polyptychites* ind. sp.

In the southern part of Sikhote Alin Konovalov (1970) found remains of a Berriasian fauna of the Tethyan type in the lower and middle subsuites of the Taukhin suite of siltstones with intercalations of sandstones and conglomerates totaling 2600 m in thickness: *Neocomites* aff. *retowskyi* Sar. and Schlond., *N. ussuriensis* Voron., *N.* sp., *Berriasella* sp., *Nautilus* ind. sp., *Iotrigonia tauchiana* Konov., *Myophorella (Myophorella) nottica* Konov., and also boreal forms: *Buchia volgensis* (Lah.), *B. expansa* (Pavl.), *B. keyserlingi regularis* (Pavl.),, *B.* cf. *elgaensis* (Psel.), *B. lahuseni* (Pavl.), *B. russiensis* (Pavl.), *B.* cf. *fischeriana* (d'Orb.), *B. okensis* (Pavl.), *B. subfischeriana* (Konov.), *B. vereshagiana* (Konov.), and others. Forms transitional to the Valanginian occurring in the upper Taukhina subsuite are *Neohoploceras* sp., *Olcostephanus* sp., and *Neocomites* sp., and with them *Buchia keyserlingi* (Lah.), *B. inflata* (Toula), *B. bulloides* (Lah.), *B. uncitoides* (Pavl.), *B. sibirica* (Sok.), *B. volgensis* (Lah.), *B. gracilis* (Lah.), *B. solida* (Lah.). etc.

In the overlying lower subsuite of the Klyuchi suite of sandstones, conglomerates, and siltstones (thickness of suite to 2300 m) there are records of the characteristically Berriasian *Buchia terebratuloides* (Lah.), *B. volgensis* (Lah.), *B. uncitoides* (Pavl.), and *B. bulloides* (Lah.). Collected along with these from the same suite are the Valanginian *Buchia keyserlingi* (Lah.), *B. inflata* (Toula), *B. crassa* (Pavl.), *B. crassicollis* (Keys.), *B. syzranensis* (Pavl.), *B. visingensis* (Sok.), *Polyptychites* sp., and others. From the Valanginian of the Suchan area Bodylevskii mentions species that are characteristic for the Berriasian and

Valanginian of Japan: *Corbicula* sp., *Exogyra ryosekensis* Kob. and Suz., *Ostrea* cf. *yoshimoensis* Kob. and Suz., and *Astarte sacawana* Yabe and Nag.

According to Krasilov (1967), Berriasian sediments of the Southern Maritime Territory contain plant remains: *Alsophilites nipponensis* (Oishi), *Coniopteris burejensis* Sew., *Onychiopsis psilotoides* Ward, *Sphenopteris nitidula* Oishi, *Zamiophyllum buchianum* Nath., *Nilssonia schaumburgensis* Dunk., and others. The Volgian sediments underlying the Lower Cretaceous on Sikhote Alin consist of a series of sandstones, siltstones, and shales 500–2500 m thick with ammonites of the Tithonian type *(Berriasella, Virgatosphinctes, Aulacosphinctes, Primoryites, Chetaites)*, and *Cylindroteuthis, Buchia mosquensis* (Buch), *B. terebratuloides* (Lah.), *B. russiensis* (Pavl.), *B. fischeriana* (d'Orb.), and *B. stantoni* (Pavl.). Judging from the species of *Buchia* and *Chetaites*, the upper Volgian substage is also present here. The break at the base of the Cretaceous is apparently manifested by no means everywhere.

NORTH AMERICA

In Alaska, Berriasian and Valanginian sediments can be distinguished only according to the species of *Buchia;* judging from finds of these, the Berriasian stage is certainly not represented in all sections of the Neocomian, and Jurassic and older rocks are often overlain directly by the Valanginian with *Buchia crassicollis* (Keys.), *B. sublaevis* (Keys.), and other species. Berriasian clay shales with *B. subokensis* Pavl. are known in the Alexander Archipelago in southeast Alaska, where the break at the base of the Cretaceous may be absent (Imlay and Reeside, 1954). On the Yukon River shales and greywackes with *Buchia okensis* (Pavl.) (Kandik formation) unconformably overlie the Triassic.

In northern Alaska, in the Okpikruak formation, consisting of a thick (to 900 m) series of argillites, siltstones, and greywackes, plus sandstones and conglomerates at the base, Imlay (1961) identified the *Buchia okensis* and *B. subokensis* zone (Berriasian) and above this the zones *B. sublaevis* and *B. crassicollis* (Valanginian, possibly also the bottom of the Hauterivian). The Okpikruak formation lies with erosion on various horizons of the Jurassic.

In northwestern Canada to the west of the lower reaches of the Mackenzie River in the Richardson Mountains, Jeletzky (1958, 1964) identifies a lower series of shales and siltstones (to 380 m thick) the lower horizons of which are characterized by a middle Volgian fauna of *Buchia mosquensis* (Buch) and other species. Above this are horizons with an upper Volgian and Berriasian fauna. Jeletzky distinguishes two zones in the upper Volgian sediments: *Buchia piochii* (lower) and *B. fischeriana* and *B. trigonoides* (upper). After a break in the upper part of the series come the zones of the Berriasian: lower – *B. okensis* with *Subcraspedites (Borealites)* cf. *suprasubditus* (Bogosl.), *Buchia elliptica* (Pavl.), *B. canadiana* (Crickmay), *B. terebratuloides* (Lah.), *B.* aff. *volgensis* (Lah.) and upper – *Tollia* cf. *payeri* [=*Subcraspedites (Borealites)* sp.]* and *Buchia volgensis* with

* Here and below we give in brackets redeterminations that were made from photographs by Shul'gina for ammonites and by Saks for belemnites.

Tollia cf. *tolli* (Pavl.), *Tollia (Praetollia?)* n. sp., [=*Surites (Surites)* cf. *spasskensis* (Nik.)], *Buchia* ex gr. *terebratuloides* (Lah.).

Above lies the lower series of sandstones 30 m thick with, in the lower horizons *Tollia* cf. *tolli* Pavl., *T.* ind. sp. *Surites* aff. *analogus* (Bogosl.) [=*S. (S.)* cf. *spasskensis* (Nik.)], *Buchia uncitoides* (Pavl.) and *B. volgensis* (Lah.), and in the upper horizons with *Euryptychites* n. sp., ex gr. *latissimus* Neum. and Uhl., *E. globulosus* Koen., *Neotollia (?) anabarensis* (Pavl.) var., and *Buchia volgensis* (Lah.) (bottom of the Valanginian).

The Deer Bay formation, black shales up to 850 m thick, in the Canadian Archipelago belongs to the top of the Jurassic and bottom of the Cretaceous. Finds of fauna from here were studied by Jeletzky (1964, 1966, 1971), who singled out in the upper Volgian substage layers with *Buchia richardsonensis* Jel., layers with *B. fischeriana* (d'Orb.) and Dorsoplanitidae (*Dorsoplanites* cf. *gracilis* Spath, *D.* n. sp. aff. *crassus* Spath, *D.* ind. sp. ex gr. *panderi* Mich., *Laugeites* ? ind. sp.), and layers with *Craspedites (Taimyroceras?) canadensis* Jel. and *Buchia unschensis* (Pavl.). The boundary layers between the Volgian and Berriasian stages are usually missing from the section; only on Axel Heiberg Island are the bottommost strata of the Berriasian characterized by as yet undescribed Craspeditidae (*Subcraspedites* n. sp.) and *Buchia* ex gr. *uncitoides* (Pavl.).

Belonging to the Berriasian are the beds with *Paracraspedites* (?) aff. *hoeli* Freb. [=*Surites (Surites)* ex gr. *spasskensis* (Nik.), *Subcraspedites (Borealites)* sp.], S. (*Borealites)* aff. *suprasubditus* (Bogosl.) [=*S. (S.)* ex gr. *plicomphalus* (Sow.)], *Surites (Surites)* aff. *spasskensis* (Nik.) [=*Subcraspedites (Subcraspedites)* n. sp.?], *Buchia okensis* (Pavl.), the beds with *B. uncitoides* (Pavl.) s. l., and the beds with *B.* n. sp. aff. *volgensis* (Lah.) and *Tollia* cf. *payeri* (Toula) [=? *Subcraspedites* sp.]. Corresponding to the bottom of the Valanginian are the beds with *Tollia latelobata* Pavl. [=*T. tolli* Pavl.], *T. novosemelica* Sok [= *Temnoptychites elegans* Bodyl., *Tollia* sp.], *Temnoptychites simplex* (Bogosl.), and *Buchia keyserlingi* (Lah.) s. l., overlain by beds with *Thorsteinssonoceras ellesmerense* Jel. and higher up with *Tollia mutabilis* (Stant.) [=? *Tollia* sp.] and *Polyptychites keyserlingi* (Neum. and Uhl.). Wiedmann (1968) also reports finding *Hectoroceras* aff. *kochi* Spath in Canada, an ammonite which is known to be exclusive to the Berriasian zone of the same name in Siberia and Greenland.

To the east of the Rocky Mountains, in the basin of the Peace River, Jeletzky (1968) identifies the following zones at the top of the Jurassic and bottom of the Cretaceous: belonging to the upper Volgian stage are the *Buchia piochii* zone with *Spiticeras (Notostephanus)* cf. *kurdistanensis* Spath and the *Buchia fischeriana* and *B. trigonoides* zone; of Berriasian age are the *B. okensis* zone and the *Tollia* cf. *payeri* and *Buchia volgensis* zone. The zone *Euryptychites* n. sp. aff. *latissimus* and *Neotollia (?) anabarensis* corresponds to the bottom of the Valanginian.

Determined from the Berriasian were *Surites* cf. *stenomphalus* (Pavl.) [=*Subcraspedites (Borealites)* sp.], *Subcraspedites (Borealites)* cf. *suprasubditus* (Bogosl.), *Tollia* aff. *groenlandica* Spath, *T.* cf. *tolli* Pavl., and others, and from the lower Valanginian *Polyptychites* aff. *keyserlingi* Neum. and Uhl., *P.* cf. *keyserlingi* Neum and Uhl., *Neocomites* aff. *indomontanus* Uhl., and others (Jeletzky, 1964).

On Vancouver Island in layers with *Buchia* cf. *blanfordiana* (Stol.) that belong to the top of the middle Volgian or bottom of the upper Volgian, ammonites are found which are reminiscent of the upper Tithonian *Substueroceras stantoni* And. and *Gymnodiscoceras* sp. and also the belemnite *Cylindroteuthis* aff. *subobeliscoides* (Pavl.) [=*C. (C.) jacutica* Sachs and Naln.]. From beds with *Buchia uncitoides* (Pavl.) on Vancouver Island the Tethyan ammonites *Spiticeras (Spiticeras)* cf. *scriptum* (Strachey), *S. (S.)* cf. *mojavari* Uhl., *S. (S.)* ind. sp., *S. (Gloebericeras)* ind sp. (?), *Protacanthodiscus* n. sp. aff. *micheicus* (Bogosl.), and *Neocomites* n. sp. were determined, indicating that the enclosing beds belong to the upper Berriasian (the *Berriasella boissieri* zone in Southern Europe and the *Spiticeras damesi* zone in Argentina) (Jeletzky, 1965). The overlying beds with *Buchia tolmatschowi* (Sok.) yield the boreal ammonites *Tollia paucicostata* (Don.) [=*Tollia* sp.; in Jeletzky's pl. 13, fig. 9 and pl. 14, fig. 4 – *Subcraspedites (? Borealites)* sp.] and *Temnoptychites* aff. *simplex* (Bogosl.) [= *Surites (Surites)* cf. *tzikwinianus* (Bogosl.)]. Proceeding on the basis of these ammonites, the *Buchia tolmatschowi* zone belongs to the topmost strata of the Berriasian. The overlying zones *Buchia pacifica* and *B. inflata* are characterized by *Tollia mutabilis* (Stant.) [=*Tollia* sp.] and *Neocomites (Parandiceras)* cf. *rota* Spath and should be placed in the lower Valanginian.

In the southwestern part of British Columbia Jeletzky and Tipper (1968) described the Raleigh Mountain Bay group made up of silt shales, siltstones with limestones intercalations, greywackes, and sandstones up to 250 m thick, in the lower part with an upper Volgian fauna. *Buchia* species enable two zones to be distinguished here: lower – *Buchia fischeriana* s.l. with late forms *B. lahuseni* (Pavl.), *B. lahuseni tenuicollis* (Pavl.), and *B.* aff. *terebratuloides* (Lah.) s. l., and upper – *B. terebratuloides* s. l. with var. *subuncitoides* (Bodyl.), var. *subinflata* (Pavl.), var. *occidentalis* (And.) and early forms *B. okensis* (Pavl.) s. l. and *B.* aff. *fischeriana* (d'Orb.).

The zones of the Berriasian are identified above: lower – *B. okensis* s. l. and *B. uncitoides* s.l. together with which are found *Berriasella (Pseudargentiniceras)* n. sp. aff. *gallica* Maz., *B. (Mazenoticeras)* aff. *broussei* Maz., *B.* (s.l.) ind. sp., and *B.* (?) ind. sp., and upper zone – *Buchia uncitoides* s.l. with *Spiticeras (Spiticeras)* ind. sp., *Cylindroteuthis (Arctoteuthis)* cf. *baculus* Crickmay, *Camptonectes* cf. *praecinctus* Spath, and others. The zone *Buchia tolmatschowi* s.l. should be placed at the top of the Berriasian and the zone *Buchia pacifica* s.l. in the lower Valanginian. Present in the upper part of the latter is *Homolsomites* cf. *giganteus* (Imlay).

In the State of Washington in the northwest of the USA a series of clay shales belonging to the Berriasian, with *Buchia* aff. *okensis* (Pavl.) and *B.* aff. *volgensis* (Lah.) can be identified. In recent works published by Imlay, Jones, and Bailey (Jones et al., 1969; Imlay and Jones, 1970) in Oregon and California the *Buchia* aff. *okensis* zone with *B. terebratuloides* (Lah.), *B. trigonoides* (Lah.), *B. okensis* (Pavl.), *Substeueroceras stantoni* And., *Blanfordiceras, Proniceras, Paradontoceras reedi* And., *Spiticeras (Spiticeras)* cf. *obliquenodosum* Ret., *Cylindroteuthis (Arctoteuthis) tehamaensis* Stant., and others was referred to the top of the Jurassic. The *Buchia uncitoides* zone with sparse *B. okensis* (Pavl.) and also *Spiticeras (Spiticeras), S. (Negreliceras) stonyense* Iml. and Jon., *S. (Kilianiceras ?), Neocosmoceras,* and others corresponds to the Berriasian. At the boundary with the Valanginian are beds with *Buchia* aff. *tolmatschowi* (Sok.). Of lower (bottom) Valanginian age is the *B. pacifica* and *B. inflata* zone with ammonites: lower part – *Thurmanniceras stippi* And., middle part – *Th. californicum* (Stant.) and *Kilianella crassi-*

plicata (Stant.); upper part – *Tollia mutabilis* (Stant.) [=Neotollia in Imlay and Jones, pl. 7, figs. 4–9, including the lectotype in fig. 9 and pl. 8, figs. 4–10 and *Tollia* sp. in pl. 7, figs. 1, 2, 10–12, and pl. 8, figs. 1–3].

GREENLAND

The most complete section of the Berriasian on the eastern shore of Greenland was described by Maync (1949) on the slope of Nisen Mountain on Wollaston Peninsula. The fauna from here was studied, albeit incompletely, by Spath (1947, 1952) and Donovan (1964). At the base of the section occur sandy shales with intercalations of sandstone about 60 m thick, including Volgian forms of *Buchia, Laugeites* cf. *intermedius* Dond., and *L.* cf. *parvus* Don. Above are coarse sandstones with thick intercalations and lenses of conglomerates 120 m thick, in which only species of *Buchia* are found on the slope of Nisen Mountain. But some 12–15 km north of Kuhn Island such sandstones yield Berriasian *Subcraspedites (Swinnertonia)* aff. *preplicomphalus* Swinn. and *Surites (Surites)* aff. *spasskensis* (Nik.); actually, according to Maync (1947), these forms are found together with *Laugeites groenlandicus* Spath, *Praetollia aberrans* Spath, and *Buchia volgensis* (Lah.). Present in the lower 60 m are *Hectoroceras kochi* Spath, *Praetollia maynci* Spath, *Surites (Surites) spasskensis* (Nik.), *S. (S.) tzikwinianus* (Bogosl.), and *S.* ind. sp.; above these are found *Subcraspedites* sp., *Surites (Surites) spasskensis* (Nik.), and *Bojarkia payeri* (Toula), 60 m higher *Praetollia* (?) and *Surites* ind. sp., and at the roof of the series *Bojarkia payeri* (Toula) and *Subcraspedites* (?) sp. (according to Donovan, also *Praetollia maynci* Spath). Still higher, in a thick (more than 200 m) series of sandstones with intercalations of gritstones and lenses of limestones *Polyptychites* spp. (*P.* cf. *eoumphalus* Koen. and others) were collected. In a series of alternating shales, sandstones, and conglomerates on Kuhn Island finds were made of upper Volgian *Laugeites groenlandicus* Spath, *L.* aff. *groenlandicus* Spath, *L. intermedia* Don., *L. jamesoni* Don., *L. parvus* Don., *Acuticostites* (?) sp., *Dorsoplanites* (?) sp., *Glaucolithites* (?) spp., *Virgatosphinctes* (?) sp., and also *Praetollia* (?) and, possibly, higher up the section the above-mentioned Berriasian species *Subcraspedites* and *Surites.* Also obtained from Kuhn Island were *Hectoroceras* n. sp. (?) and *Bojarkia payeri* (Toula) (Spath, 1947, 1952; Donovan, 1964). All this points to the presence of the Berriasian on the island, overlain by Valanginian limestones with *Polyptychites* and *Buchia.*

South of Wollaston Peninsula, on Traill Island, Donovan (1953) places a series of dark micaceous shales 50 m thick with *Buchia crassicollis* (Keys.) and *Acroteuthis (Acroteuthis) bojarkae* Sachs and Naln. ("*Pachyteuthis* aff. *partneyi*" Donovan) in the Berriasian. Judging from the fauna, however, this seems rather to the bottom of the Valanginian. Belonging to the Valanginian are limestones with *Polyptychites, Euryptychites, Temnoptychites, Neotollia (?) paucicostata* (Don.), and others.

On Milne Land the lower part of the Harzfield sandstones, with a total thickness of 330 m, belongs to the Volgian stage. About 75–90 m from the bottom of the sandstones is a bed with *Lingula, Laugeites groenlandicus* Spath, and *Craspedites ferrugineus* Spath. Some 20–40 m above this *Craspedites leptus* Spath, *Subcraspeditetes (Pronjaites) bide-*

vexus (Bogosl.), and *Tollia groenlandica* (Spath) were collected. Still higher is a thick series of sandstones with plant remains (Donovan, 1957, 1964).

On Jameson Land, in a member of sandstones and sandy shales 85 m thick, corresponding to the Berriasian of Milne Land, finds were made of *Hectoroceras kochi* Spath, *Subcraspedites* (?) n. sp., *Subcraspedites* (?*Paracraspedites*) ind. sp., *Acroteuthis (Acroteuthis) (?) arctica* Blüthg., *Buchia* cf. *terebratuloides* (Lah.), *B. volgensis* (Lah.), and others (Spath, 1947). This member is underlain by coarse and fine-grained sandstones with *Tancredia* (100 m) and overlain by sandy shales with pyrite concretions and remains of plants (70 m).

Judging from the absence of *Hectoroceras,* the layers with *Praetollia manynci* in Greenland and the layers with *Subcraspedites* and *Surites* beneath them seem above all to correspond in Siberia to the *Chetaites sibiricus* zone, in which *Praetollia maynci* Spath is encountered on Paks Peninsula. The *Hectoroceras kochi* zone is common to Siberia and Greenland, the beds with *Surites spasskensis* may parallel the *Surites analogus* zone, and, finally, the beds with *Bojarkia payeri* may correlate with the *Bojarkia mesezhnikowi* zone (*Bojarkia payeri* zone in Western Siberia).

Chapter IV

THE BERRIASIAN MARINE FAUNA

SURVEY OF AMMONITES OF THE BOREAL REALM

In the literature on the Berriasian boreal ammonites we find a wealth of different interpretations of the size of various genera and confusion as to which species belong to which genera. No one seems to agree whether to place the majority of the species in the genera *Paracraspedites, Subcraspedites, Surites,* or *Tollia*. Doubts have been expressed about the existence of the genus *Praetollia* (this genus is mentioned with a question mark as a synonym of the genus *Paracraspedites* in Fundamentals of Paleontology, 1958) and about the validity of the genus *Subcraspedites*. Jeletzky (1965) and Arkell (1957) consider *Subcraspedites* as a subgenus of *Tollia*. Nor is there any consensus on the age of the representatives of *Paracraspedites* and *Subcraspedites*. Formerly these genera were universally recognized to be of Berriasian age, but once the article by Casey had appeared (1962), and this specialist had visited the Soviet Union, where he examined the collections from the Ryazan horizon of the Russian Plain and the Berriasian of northern Siberia, the majority of investigators took up his proposal to date these genera to the Volgian and to distribute the forms previously assigned to the genera *Paracraspedites* and *Subcraspedites* among the genera *Surites* and *Tollia*. A study of Berriasian ammonites in northern Siberia showed that representatives of *Paracraspedites* and *Subcraspedites* do in fact occur together with *Chetaites* and *Hectoroceras*, which everyone agrees to be of Berriasian age. The reasons for this chaotic state of affairs in the systematics are, first, that the diagnoses of almost all the above genera either had been in existence for a long time, so that only the type species of newly instituted genera were mentioned, or they had been given very sketchily, so that it was difficult to determine forms according to them. Second, the specimens from which genera and species were described were often in an unsatisfactory state of preservation. There were not enough specimens for it to be possible to ascertain the size and limits of a particular genus or species, and what is more, studies were conducted without taking into account the ontogenesis of the shells. Third, there was intensive formation of new genera and species during Berriasian time in the Boreal Realm, with the result that transitional forms are encountered which are often hard to define systematically. Examples of such ambiguous forms are the species *stenomphalus, suprasubditus, solowaticus, bidevexus,* and *anabarensis,* which have been bandied around from genus to genus by various authors, and even by the same authors at different times. More on these forms below.

Eight families (Craspeditidae, Berriasellidae, Olcostephanidae, Neocomitidae, Protancyloceratidae, Perisphinctidae, Phylloceratidae, Lytoceratidae) are known at present in the Boreal Berriasian. Three subfamilies are known in the family Craspeditidae (Craspeditinae, Tolliinae, Garniericeratinae).* Among the Berriasian ammonites *Paracraspedites, Surites, Praetollia, Subcraspedites,* and, apparently, *Externiceras* I. Sasonova n. g. and *Stchirowskiceras* I. Sasonova n. g. belong to the subfamily Craspeditinae, *Bojarkia, Tollia, Virgatoptychites,* and *Chandomirovia*** to the subfamily Tolliinae, and *Hectoroceras* to the subfamily Garniericeratinae. Spath (1952) placed *Hectoroceras* in the family Craspeditidae, subfamily Tolliinae, although in the general form of the shell and suture line it is much closer to the Garniericeratinae; hence, we assign it to this subfamily. One genus in the Arctic Berriasian, *Chetaites,* belongs to the family Perisphinctidae, subfamily Dorsoplanitinae, whose members were distributed for the most part in the Volgian.

One genus in Siberia, represented, unfortunately, by only a single specimen, belongs to the Tethyan family Berriasellidae. This form has a few tubercles on the periphery of the lateral sides, which is totally uncharacteristic of the northern groups and, on the other hand, quite typical for the southern forms. In the sculpture and general form of the shell this ammonite resembles most of all the South American genus *Argentiniceras,* but it has a different arrangement of the tubercles and is therefore determined provisionally as *Argentiniceras* (?) n. sp. The families Phylloceratidae and Lytoceratidae are found in small numbers (in comparison with the Craspeditidae) in the Arctic Berriasian.

In other regions of the Boreal Realm – Northern Urals, Russian Plain, Poland, England, Greenland, Spitsbergen, and also in the northern part of the Pacific Basin (Arctic Canada) – the majority of forms occurring belong to the family Craspeditidae *(Surites, Subcraspedites, Praetollia, Tollia, Paracraspedites, Bojarkia).* Only a small number of genera belong to the families Berriasellidae, subfamily Berriasellinae *(Berriasella, Riasanites, Protacanthodiscus),* Neocomitidae *(Neocomites, Euthymiceras, Neocosmoceras),* and Olcostephanidae *(Spiticeras).* The number and distribution of the ammonite genera in these regions are given in Table 6 (compiled from published data).

Not all the ammonites occurring in Greenland have been described monographically. Such forms as *Paracraspedites* and *Chetaites* may be present there, since in general the fauna of Siberia and Greenland was very similar in late Jurassic and early Cretaceous time. But even if the number of genera in other regions is eventually augmented, we find a striking diversity of ammonites in the north of Siberia, hardly inferior to the generic diversity in the Mediterranean Region. For instance, 8 genera are known in the Crimea, 14 in the Caucasus, 12 in Algeria, 16 in southeastern France, and 14 in northern Siberia. All in all, it is possible to count up to 24 ammonite genera in the Boreal Realm, including the forms of southern origin.

A large number of southern forms occur in Canada (5 genera: *Berriasella, Spiticeras, Neocomites, Protacanthodiscus, Pseudargentiniceras*); 3 southern genera occur on the

* Sazonova suggests, without sufficient grounds, raising the Garniericeratinae to the status of a family and isolating the family Suritidae from the Craspeditidae.

** *Chandomirovia* should be considered rather as being included in the genus *Temnoptychites* (Bodylevskii, 1967).

TABLE 6. Number and distribution of ammonite genera in the Boreal Berriasian

Northern Siberia	Russian Plain	Poland	England	Greenland	Spitsbergen	Canada
Surites	*Surites*	*Surites*	*Surites*	*Surites*	*Surites*	*Surites*
Subcraspedites	*Subcraspedites*	*Subcraspedites*	*Subcraspedites*	*Subcraspedites*	*Subcraspedites*	*Subcraspedites*
Paracraspedites	–	–	*Paracraspedites*	–	*Paracraspedites*	–
Praetollia	–	*Praetollia (?)*	–	*Praetollia*	–	–
Tollia	–	*Tollia (?)*	*Tollia*	*Tollia*	–	–
Bojarkia	*Bojarkia*	–	–	*Bojarkia*	–	–
Virgatoptychites	–	–	–	–	–	–
Chetaites	–	–	–	–	–	–
Hectoroceras	–	–	*Hectoroceras*	*Hectoroceras*	–	*Hectoroceras (?)*
Argentiniceras (?)	–	–	–	–	–	–
Lytoceras	–	–	–	–	–	–
Phylloceras	–	–	–	–	–	–
–	*Externiceras*	–	–	–	–	–
–	*Chandomirovia*	–	–	–	–	–
–	*Riasanites*	*Riasanites*	–	–	–	–
–	*Euthymiceras*	*Euthymiceras*	–	–	–	–
–	*Neocomites*	*Neocomites*	–	–	–	*Neocomites*
–	–	*Berriasella*	–	–	–	*Berriasella*
–	–	*Protacanthodiscus*	–	–	–	*Protacanthodiscus*
–	–	*Neocosmoceras*	–	–	–	*Spiticeras*
–	–	*Himalayites*	–	–	–	*Pseudargentiniceras*

Russian Plain *(Riasanites, Euthymiceras, Neocomites)*, and two genera in Siberia *(Bochianites* and *Argentiniceras ?)*, not counting the Phylloceratidae and Lytoceratidae, which are apparently cosmopolitan. Seven southern genera are known in Poland *(Berriasella, Neocosmoceras, Riasanites, Euthymiceras, Himalayites, Neocomites, Protacanthodiscus)*.*

We will now discuss each boreal genus of ammonite separately, because the systematic history, size, and geographic and stratigraphic distribution of the genera are interpreted differently by almost all investigators.

FAMILY CRASPEDITIDAE SPATH, 1924

Subfamily Craspeditinae Spath, 1952

Genus *Subcraspedites* Spath, 1924

Originally, Spath (1924, p. 17) instituted the genus *Subcraspedites* without giving a diagnosis, just with a mention of the type species, which he took to be *Ammonites plicomphalus*, that had been illustrated by Sowerby (1823, pl. 404). Sowerby (1822, 1823) presented two specimens of what he believed to be this species (pls. 359 and 404), considering the smaller of them to be simply a juvenile form or the inner whorl of the larger specimen. Following Brown (1837), Spath suggested that these two forms presented by Sowerby belong to different species; he named the larger one *ptychomphalus* at the suggestion of Brown (Spath, 1947) and the smaller one *Subcraspedites sowerbyi* on his own initiative (Spath, 1952). The name *Ammonites plicomphalus* thus fell out of usage altogether.

In many of his publications Spath continued to consider as the type of the genus *Subcraspedites* a finely ribbed form (pl. 404), which he believed could not have become a large tuberous form (pl. 359). However, after being the first to give a diagnosis of the genus, Spath made the mistake in 1947, twenty-three years after the genus had been instituted, of saying that the name *ptychomphalus* was incorrectly assigned by Brown to the form appearing in pl. 359 under the name *plicomphalus*, since this name was first given in fact to the single specimen published by Sowerby in 1822, not to the other one shown a year later in pl. 404. The first specimen should therefore be the holotype of the species and the type of the genus.

Casey (1962), noting that there was too much confusion surrounding the question of the type species of the genus *Subcraspedites*, decided to appeal to the International Committee on Zoological Nomenclature to establish *Subcraspedites sowerbyi* Spath (*Ammonites plicomphalus* Sowerby, 1823, non 1822) as the type of *Subcraspedites*.

The present author has had the opportunity to study a large number of representatives of the genus *Subcraspedites* both from personal collections in northern Siberia and from

* The ammonites described from Poland are unfortunately for the most part poorly preserved, so that a form cannot always be assigned to a specific genus with certainty.

other collections in the Ryazan horizon of the Russian Plain, as well as casts of English forms of *Subcraspedites,* kindly sent by Casey to the author at the Chernyshev museum. After careful scrutiny and comparison, and after uncoiling large forms with a diameter going from 250–200 to 50 mm and shells with a diameter going from 60–50 to 10 mm in order to trace the changes related to the growth of the shell, I reached the conclusion that Sowerby was probably right in thinking both his specimens belonged to the same species. As he stated, the smaller of the specimens may well correspond to the inner whorl of the larger one. All juvenile specimens of true (*Subcraspedites* s. str.) have fine, dense ribbing, the ribs being slightly inflated in the region of the umbilicus. As the shell grows, the umbilical ribs become thicker and sparser, acquiring the form of tubercles, while the peripheral ribs gradually smooth out. Even if the form in Sowerby's pl. 404 is not the inner whorl of *S. plicomphalus* in pl. 359, this still seems to be the same species, and it should indeed be considered the type of the genus *Subcraspedites.*

The age of *Subcraspedites* is a topic worthy of special attention. Since the genus was instituted until recently there was no agreement concerning the Early Cretaceous (Berriasian) age of this group of ammonites, until the publication of a work by Casey (1962) in which the author reviewed the age of the Spilsby sandstones, noting that their lower part, which contains the ammonites *Paracraspedites* and *Subcraspedites,* should be dated to the Volgian age. Casey claims that the *Paracraspedites* ammonites do not belong to the Craspeditidae but are similar to the Portlandian Pavloviinae and to the Portlandian *Titanites*; in other words, they are of Volgian age. He believes the forms of *Subcraspedites* to be close to the Volgian species *Craspedites nodiger,* and therefore suggests that they are late Volgian. The Berriasian ammonites formerly placed (Spath, 1947) in the genus *Subcraspedites* (*S. pressulus* Bogosl., *S. subpressulus* Bogosl.) are referred by Casey to the genus *Tollia. Olcostephanus stenomphalus* Pavl., which Spath originally placed in *Subcraspedites* (1924), is included by Casey in *Surites.*

Having studied numerous sections of Upper Jurassic and Lower Cretaceous deposits in northern Siberia and visited sections on the Russian Plain (in the Ryazan Region and in the Sura basin), I have come to the conclusion that most of the representatives of *Subcraspedites* are confined to the *Hectoroceras kochi* zone in Siberia and to the *Surites spasskensis* zone on the Russian Plain, although certain species may have appeared earlier. The specimen of *Subcraspedites* sp. pictured on pl. 30, fig. 3 of Gerasimov's 1969 publication, from Volgian sediments in Kashpir, probably belongs rather to the genus *Epivirgatites.* The two specimens described by this author under the name *Craspedites* (?) *arcticus* Schulg. from the *Craspedites originalis* subzone of the Volgian stage (Key section of Upper Jurassic deposits of the Kheta basin, 1969) may belong to *Subcraspedites.* Here, as in other cases, we are confronted with forms that are hard to fit into the framework of any one specific genus. This particular form has characters of both *Craspedites* and *Subcraspedites,* but it is more similar to the latter. The species *bidevexus* and *suprasubditus,* the first appearing earlier than the many other forms of *Subcraspedites* in the *Chetaites sibiricus* zone, and the second appearing in the lower strata of the *Hectoroceras kochi* zone, occupy a rather special position. *Olcostephanus bidevexus* Bogosl. differs from all the other representatives of *Subcraspedites* in the more constricted middle part of the venter and in the accordingly narrower cross section, which proved to be the motive for placing this species in the genus *Tollia* (Gerasimov, 1962; Casey, 1962). Sazonova (1971) isolates *bidevexus* into a new genus, *Pronjaites.* Although this genus at first glance is indeed similar to *Tollia,* it resembles many members of the genus *Subcraspedites* in the suture line and type of development of the sculpture, and therefore we consider *Pronjaites* to be a subgenus of the genus *Subcraspedites.*

Olcostephanus suprasubditus Bogosl. has characters of two genera – *Subcraspedites* and *Surites,* – but it is more similar to the first of these in the type of development of the sculpture and in the suture line.

Klimova (1969) instituted the genus *Borealites* for species from the Northern Urals that are similar to *suprasubditus*; however, this genus should be considered a subgenus of *Subcraspedites,* because there are only minor differences between *Subcraspedites* s. str. and *Borealites.* All one can do in this case is to refer to the original description of the Ryazan ammonites given by the eminent Bogoslovskii (1895). In describing the species *pressulus* and *subpressulus,* which indisputably belong to *Subcraspedites* s. str., Bogoslovskii observes that they show a closer similarity to the species *suprasubditus* than any other of the Ryazan forms. The species *suprasubditus* and related forms occupy the same position relative to *Subcraspedites* as do the Volgian *Taimyroceras* relative to *Craspedites,* that is, the similarities between them override the differences; this gave Jeletzky (1966) the idea, when describing Canadian forms of *Craspedites* similar to *Taimyroceras,* of transferring these forms to the subgenus with a question mark. I consider *Taimyroceras* as a subgenus of the genus *Craspedites* (Shul'gina, 1969).

Spath (1947) placed the species *suprasubditus* in *Subcraspedites.* Bodylevskii (1949) thought that it should be placed in *Craspedites.* Gerasimov (1962) referred it to *Craspedites (Subcraspedites),* while Casey (1962) proposed transferring it to *Surites.*

If we faithfully follow the diagnosis of the genus *Subcraspedites* given by Spath (1947), the only forms that should be placed in this group are the few in which the umbilical tubercles remain on the adult whorls, while the rest of the sculpture, namely the fine ribs on the sides and on the venter, gradually fade out, so that at the end of the adult whorl the venter becomes smooth. In this sense Casey (1962) is right in saying that *Subcraspedites plicomphalus* (Sow.) resembles the Volgian *Craspedites nodiger* (Eichw.), on the adult whorls of which the only sculpture that remains consists of the umbilical tubercles, the ribs on the sides and venter disappearing. But here the similarity ends. The form of the shell, the sculpture of the inner and middle whorls, and the suture line in *Subcraspedites plicomphalus* are different from those in *Craspedites nodiger.*

Hence, we should place in *Subcraspedites* the ammonites that resemble *Subcraspedites plicomphalus* (Sow.). However, there are many forms which in many characters (general form of shell, sculpture of inner whorls, suture line) are almost indistinguishable from *Subcraspedites* ex gr. *plicomphalus* but do show the differences in the sculpture of the adult and sometimes also of the middle whorls. There are forms that are practically identical where the ornament is concerned but differ in the form of the cross section or in some other characters (more strongly projecting umbilical tubercles, more evolute shell, different details in the pattern of the suture line). These forms should also be considered as subgenera within the genus *Subcraspedites.*

Among the forms of *Subcraspedites,* apart from the above-mentioned subgenera

Pronjaites and *Borealites,* we find three very distinct groups of species that are united by a common type of change of the major characters with growth of the shell.

The first group includes *Subcraspedites (Subcraspedites) plicomphalus* (Sow.), *S. (S.) pressulus* (Bogosl.), *S. (S.) subpressulus* (Bogosl.),* and *S. (S.) anglicus* Schulg. n. sp. All these forms perfectly fit the diagnosis given by Spath for the genus *Subcraspedites,* that is, fine, many-branched fascicles predominate in the juvenile stages, while on the adult whorls the umbilical tubercles remain and the peripheral ribs gradually disappear. This group is mostly confined to the *Hectoroceras kochi* zone, but isolated individuals are found in the *Surites analogus* zone.

The second group comprises the subgenus *Ronkinites* n. subgen. and includes the species *Subcraspedites (Ronkinites) rossicus* Schulg. n. sp. and *S. (R.) primitivus* Swinn. These species do not have sharply expressed umbilical tubercles and the ribs are coarser and less densely distributed. Stratigraphically, this group occupies the same position as *Subcraspedites* s. str.

The third group is singled out for the English forms described by Swinnerton (1934) as *Subcraspedites*; it consists of the subgenus *Subcraspedites (Swinnertonia)* n. subgen., with the following species: *S. (Sw.) undulatus* Swinn., *S. (Sw.) subundulatus* Swinn., *S. (Sw.) parundulatus* Swinn., *S. (Sw.) cristatus* Swinn., and *S. (Sw.) precristatus* Swinn.

These species are characterized by very high and sharp umbilical tubercles, whereas in *Subcraspedites* s. str. the tubercles are more gently sloped and blunt; also they do not project as strongly, even on much larger specimens. In general, the species belonging to *Subcraspedites (Swinnertonia)* do not attain large dimensions, and this may be why the ribs on the peripheral side of the shell do not become very much smoothed. In addition, all the forms listed have a more evolute shell than *Subcraspedites* s. str. As far as the sculpture is concerned, *Subcraspedites preplicomphalus* Swinn. is indistinguishable from *Subcraspedites* s. str., but according to the evoluteness of the shell it is more closely related to *S. (Swinnertonia).* These species do not occur in Siberia.

As noted above, the species *suprasubditus* and the related new Urals species described by Klimova should be placed in a fourth group, *Subcraspedites (Borealites),* which is intermediate between *Subcraspedites* s. str. and *S. (Ronkinites)* on the one hand and *Surites* on the other. The representatives of *Borealites* differ from *Subcraspedites* s. str. in the later appearance of the many-branched fascicles, the greater thickness of these, and in the later obliteration of the peripheral ribs on the adult, large whorls; there are also fewer accessory ribs. Ershova believes that the subgenus *Borealites* should include the Spitsbergen specimens illustrated by Frebold (1929) on pl.I, fig. 1 under the name *Polyptychites perovalis* Koenen and on pl.III, fig. 1 under the name *P.* cf. *perovalis* Koenen. A new name, *Subcraspedites (Borealites) freboldi* Schulgina and Erschowa n. sp., is proposed for these forms. *Polyptychites hoeli* Freb., described in the same publication (p. 13, pl.III, fig. 3) refers to *Paracraspedites stenomphaloides* Swinn.

Finally, the species *bidevexus,* differing from the representatives of *Subcraspedites* in the form of the cross section, is placed rather arbitrarily as the subgenus *Pronjaites* in the

* Sazonova (1971) unjustifiably instituted a new genus, *Peregrinoceras,* for the species *pressulus* Bogosl. and *subpressulus* Bogosl.

genus *Subcraspedites*. In my opinion, not enough material has been accumulated to be able to isolate this as an independent genus: still unknown are the very youngest inner whorls of *bidevexus*, the large whorls with the body chamber, and its species variability.

The majority of the forms of *Subcraspedites*, primarily *Subcraspedites (Subcraspedites) plicomphalus* (Sow.) and related species, are distributed in the *Hectoroceras kochi* zone. *S. (Ronkinites)* is also confined to this zone. *S. (Pronjaites) bidevexus*, a more ancient species, occurs in the *Chetaites sibiricus* zone. *S. (Borealites) suprasubditus* is confined to the lower strata of the *Hectoroceras kochi* zone. No forms of *Subcraspedites* have been found at all above the bottom layer of the *Surites analogus* zone (layer 6 in the key section on the Boyarka River). The total number of species belonging to the genus *Subcraspedites* is 20, eight of which occur in northern Siberia. *Subcraspedites* is a specifically boreal species, even arctic-boreal though isolated forms have reached the region of Mangyshlak, where they occur together with the Middle Russian *Riasanites* and *Euthymiceras* and the southern genera *Protacanthodiscus* and *Blanfordiceras* (Luppov, 1932; Bobkova, 1958). From Poland (Dembowska, 1964) comes *Subcraspedites (Swinnertonia) undulatus* Swinn.

Genus *Surites* Sasonov, 1951

The genus was instituted in 1951 by Sazonov, with the type species *pechorensis*, for a group of ammonites (the species *tzikwinianus, subtzikwinianus*, etc.) described by Bogoslovskii (1897, 1902) from the Ryazan horizon in the composition of the genus *Olcostephanus*. Until recently, the genus *Surites* was not used in either the Soviet or the world literature, because back in the 1920s, Spath (1923, 1924, 1947, 1952) had placed some of the ammonites from the Ryazan horizon in the genus *Subcraspedites* (Spath, 1924) and some later in the genus *Paracraspedites*, instituted by Swinnerton (1934) for the English ammonites similar to the species *stenomphalus*. The species referred by Spath (1947, 1952) to *Paracraspedites* were *tzikwinianus, kozakowianus, stenomphalus*, and *spasskensis* (the last species differs very little from the type species of *Surites, S. pechorensis*). Spath's point of view was accepted by Soviet paleontologists.

In 1962 appeared the above-mentioned article by Casey, in which the ammonites of the genus *Paracraspedites* were recognized to resemble the Portlandian genera *Pavlovia* and *Titanites*. On this basis Casey determined the age of *Paracraspedites* as Upper Jurassic. After Casey's visits to the Soviet Union (1963, 1967), his suggestion to accept the genus *Surites* for many Ryazan species came into force and found expression in the literature (Saks and Shul'gina, 1964; Bodylevskii, 1967; Saks et al., 1965). Most of the species formerly placed in *Paracraspedites* were now renamed *Surites*. However, investigations showed that Berriasian deposits in northern Siberia contain forms that unquestionably belong to *Paracraspedites*. The only appreciable difference between *Paracraspedites* and *Surites* is that in *Surites* the ribs are curved anteriorly on the periphery of the sides and on the venter. Unfortunately, the suture line of *Paracraspedites* has not yet been studied.

The species *stenomphalus* should also be placed in *Surites*. For it Sazonova (1965) created the genus *Bogoslovskia,* which we consider a subgenus of the genus *Surites.*

The history of this ill-starred species, which was repeatedly fabricated into a zonal species on the Russian Plain and which has been tossed around from genus to genus, is as follows. Originally, Pavlow (1889) described two forms: Russian (from the region of Simbirsk) and English (from Lincolnshire) under the name *Olcostephanus stenomphalus;* in his view, they were very close to *Olcostephanus spasskensis* Nik. Then, having established the Siberian genus *Tollia,* Pavlow (1913) transferred *stenomphalus* to *Tollia.* Spath (1924) included *stenomphalus* in the genus *Subcraspedites,* but later he had doubts about the correctness of this decision and suggested that it would be better to place it in *Paracraspedites* (Spath, 1947). Casey (1962) considers *stenomphalus* to belong to *Surites.* There has thus been a long dispute as to which genus this species belongs. The trouble is simply that *stenomphalus* has characters relating it on the one hand to *Surites* (the species very closely resembles *Surites spasskensis*) and on the other to *Tollia* and, to some extent, *Subcraspedites.*

It is a pity that the specimen from the former Simbirsk Province, presented by Pavlow on pl. 3, fig. 10, has been lost, so that it is only from the drawing that we can get an idea of its features. It was just this lost specimen that Sazonova took as the type species of the genus *Bogoslovskia,* although she should have used the English form, which is deposited at the Museum of Cambridge and a cast of which was kindly sent by Casey to the Soviet Union. The English specimen was chosen by Spath (1947) as the lectotype of the species *stenomphalus.* In Pavlow's work the English form is shown in pl. 3, fig. 1. If we compare the English specimen with the Russian one, we perceive a number of differences that permit us to separate these forms into two independent species. The shell of the English specimen is more flattened than the Russian form, the cross section is more elongate and narrower, and the umbilicus is wider. The width of the umbilicus constitutes 25% of the shell diameter in the English form, 20% in the Simbirsk. Moreover, in the English specimen there is a surprisingly regular alternation of double and triple ribs (2:3:2:3:2:3:2:3:2:3, then a constriction 3:2:3:2, again a constriction 1:3:2, another constriction 1:2:3:2:3, and a constriction 3), in other words in places where there are no constrictions, a very distinct alternation of double and triple ribs is observed. There are 25 umbilical ribs in all. In the Simbirsk specimen, judging from the figure, there are 24 umbilical ribs, and they show the following sequence, starting from the aperture: 3:2:2:3:2:3:2:2:2:3:2:3:3:3:2:3:2:2:2:2, that is, there is no regular alternation of double and triple ribs. Hence, these are different species, and the English specimen, with its many constrictions, flatter shell, and elongate cross section, is closer to the genus *Tollia,* while the Simbirsk specimen with its thicker shell and absence of constrictions is closer to *Surites.*

Since Spath (1947, p. 23) took the English specimen depicted on pl. III, fig. 1 as the lectotype of the species, the Simbirsk specimen should be given a new name. In describing the new genus *Bogoslovskia,* Sazonova (1965) wrongly chose the Simbirsk specimen of *Olcostephanus stenomphalus* as the type of the species, and accordingly of the genus, while considering the English form as a new species. In her publication of 1971, Sazonova corrected her mistake and bestowed a new name, *pseudostenomphalus,* on the Simbirsk specimen.

Let us examine on what grounds we place both forms in the genus *Surites* and propose the genus *Bogoslovskia* as a subgenus of *Surites*. Both forms differ from *Subcraspedites* s. str. in the relatively widely spaced double and triple ribs; representatives of *Subcraspedites* of the same size have numerous fine secondary irregularly branching ribs, on the average 4–5 per main rib. Apart from this, in these specimens the ribs curve strongly forward on the venter, a feature that is characteristic of *Surites* but not of *Subcraspedites*.

The species *stenomphalus* and *pseudostenomphalus* differ from the representatives of the genus *Tollia* in the presence of only double ribs on the inner whorls, this being characteristic for *Surites* and *Subcraspedites* but not for *Tollia*, and in the absence of ribs with four branches. Furthermore, in *Tollia* the ribs in the middle of the lateral surface are slightly planed, while the peripheral and umbilical ribs do not project as strongly as in the forms compared. The cross section of *Tollia* is markedly drawn out in height.

Both forms show a marked resemblance to *Surites*. The species *stenomphalus* differs from the type species *Surites pechorensis* Sason. in having a flatter shell and an earlier appearance of triple ribs (at a diameter of around 50 mm); in *Surites pechorensis* double ribs are present at the same diameter, and the triple ribs appear somewhat later.

The species *pseudostenomphalus* I. Sasonova differs from *Surites pechorensis* Sason. in the narrower umbilicus, the slightly more inflated sides of the shell, and in the earlier appearance of trifurcate ribs. These distinguishing signs are sufficient only for isolating a subgenus.

In the present work Sazonova isolates from the genus *Surites* the subgenus *Caseyiceras* (in the 1971 publication this was a subgenus), with the type species *Surites (Caseyiceras) caseyi* I. Sason. n. sp., for forms which differ from *Surites* s. str. in having a strongly inflated shell and a less pronounced bend of the ribs on the venter. Sazonova includes here the species *Surites dorsorotundus* (Bogosl.) and *Surites analogus* (Bogosl.). But the latter species should be placed in the subgenus *Surites* s. str., because the curve of the ribs on the venter is strongly pronounced. In general it is very difficult, sometimes impossible, to define the boundary between these two subgenera.

Among the new forms described by Sazonova there is the genus *Subpolyptychites* with the type species *distinctus*, represented by one specimen, and the species *orbicularis*, also represented by a single individual. In our opinion, these forms should be placed in the genus *Surites*, possibly in the subgenus *Caseyiceras* in accordance with the thickness of the shell, or to a separate subgenus, which will be characterized by a thick shell and a narrow umbilicus. In any case, the nature of development of the sculpture in the above forms is typical of *Surites*. The appearance of several or a few three- or four-branched fascicles that are not of polyptychitic structure (though Sazonova writes that typically polyptychitic branching appears on the adult whorls) cannot serve as a basis for instituting a new genus. In the specimen of *Subpolyptychites orbicularis* I. Sason., shown in pl. VII, fig. 4, the inner whorl (figs. 4c, 4d) is indistinguishable from that in *Surites*; the middle whorl (figs. 4a, 4b) with a diameter of 47 mm in the last third has a ribbing characteristic for several species of *Tollia* or *Subcraspedites*. The suture line and the sculpture of the body chamber of this species are unfortunately unknown. In the specimen of *Subpolyptychites distinctus* I. Sason., shown in pl. VI, fig. 4, the inner and middle whorls have a typically suritic structure. On the whorl of 50 mm diameter, on a background of double suritic ribs, a single trifurcate rib appears with two points of branching, but it is not of polyptychitic structure as Sazonova states but highly anomalous, such as commonly occurs also in representatives of *Surites (Bogoslovskia)*. The suture line and sculpture of the body chamber are also unknown for this species. It seems on the whole that there are not enough reasons or material for instituting this genus; the specimens presented are easily confused with *Surites*.

In Lower Cretaceous deposits of Siberia the first representatives of *Surites* appear in the *Chetaites sibiricus* zone (*Surites (Surites) tzikwinianus* (Bogosl.), *S. (S.) subtzikwinianus* (Bogosl.), *S. (S.)* ex gr. *spasskensis* (Nik.)). However, the greatest species diversity and abundance of *Surites* are confined to the higher horizons, i.e. to the upper part of the *Hectoroceras kochi* zone and to the *Surites analogus* zone. The last single finds of *Surites* are known from the topmost zone of the Siberian Berriasian *(Bojarkia mesezhnikowi)*. No representatives of *Surites* are found in Valanginian sediments, in the *Neotollia klimovskiensis* zone.

In all, 13 species of *Surites* are known, most of them described from the Ryazan horizon of the Russian Plain. These species are *Surites (Surites) pechorensis* Sasonov (=*S. poreckoensis* Sasonov), *S. (S.) spasskensis* (Nik.) (non Bogosl.), *S. (S.) spasskensoides* Schulg. n. sp. (= *S. spasskensis* Bogosl.), *S. (S.) kozakowianus* (Bogosl.), *S. (S.) clementianus* (Bogosl.) [= *S.* cf. *tzikwinianus* (Bogosl.)] (Bogoslovskii, 1902, pl. V, fig. 1), *S. (S.) subclementianus* Bodyl., *S. (S.) tzikwinianus* (Bogosl.), *S. (S.) subtzikwinianus* (Bogosl.), *S. (S.) analogus* (Bogosl.), *S. (S.) simplex* (Bogosl.), and *S. (Bogoslovskia) stenomphalus* (Pavl.). One new species, *Surites subanalogus* Schulg. n. sp., is described from Siberia. From the Russian Plain Sazonova describes the new species *S. (S.) pervulgatus* I. Sason, n. sp., *S. (Caseyiceras) caseyi* I. Sason. n. sp., *S. (Subpolyptychites, ? Caseyiceras) orbicularis* I. Sason. n. sp., *S. (Subpolyptychites, ? Caseyiceras) distinctus* I. Sason. n. sp., and *S. (Bogoslovskia) pseudostenomphalus* I. Sason, n. sp.

The representatives of *Surites* are typically boreal forms and (as shown in the table) distributed, apart from on the Russian Plain and in Siberia, in Greenland, England, Poland, Arctic and western Canada, and on Spitsbergen. *Surites* is also present on Mangyshlak in the Northern Urals (Luppov, 1932).

Genus *Paracraspedites* Swinnerton, 1934

The representatives of the genus *Paracraspedites* are closely related to *Surites*, and almost all the species formerly named *Paracraspedites* are now placed in *Surites*.

In describing the genus, Swinnerton (1934) chose as the type species a form which he believed to be very similar to the species *stenomphalus*, and he called it *stenomphaloides*. He compares it with the Ryazan species *subtzikwinianus* and writes, on p. 41: "The Lincolnshire and Riasan areas evidently derived their faunas from the same northern source." We must assume that this common source was northern Siberia, where the majority of the boreal ammonites originated. The difference between *Paracraspedites stenomphaloides* and *P. stenomphalus*, according to Swinnerton, consists in the more strongly projecting peripheral ribs and the absence of curvature of the ribs on the venter in *stenomphaloides*.

In short, the close relationship between *Paracraspedites* and many of the Ryazan forms is obvious, and Spath (1947) placed the species *stenomphalus, spasskensis, kozakowianus,* and *tzikwinianus* in the genus *Paracraspedites*. In all these species the ribs bend strongly on the venter, and therefore, having accepted the genus *Surites*, we should place them in it. *Paracraspedites* differs from *Surites* in that the ribs do not bend forward on the venter.

Paracraspedites should be considered to be of Berriasian age, although isolated representatives may have appeared still earlier, in the Volgian. However, no forms of *Paracraspedites* have been found in Upper Jurassic deposits of northern Siberia or the Russian Plain. On the other hand, in the Berriasian of Siberia, rare representatives of this genus have been discovered in sediments of the *Chetaites sibiricus* and *Surites analogus* zones: on the Kheta River, *Paracraspedites stenomphaloides* Swinn.; on the Anabar River, *P.* aff. *bifurcatus* Swinn.; on the Maimecha River, *P.* cf. *stenomphaloides* Swinn. Ershova's collections, coming from the Olenek River area, include *P. olenekensis* Erschowa n. sp. (in litt.), taken from the same layers as *Subcraspedites*. In comparison with *Subcraspedites* and *Surites*, hundreds of specimens of which occur in Siberia, *Paracraspedites* is rare. Only four species are known: *P. stenomphaloides* Swinn., *P. bifurcatus* Swinn., *P.* ? *trifurcatus* Swinn. (it is not clear whether this species belongs to the genus), and a fourth species, described by Ershova from northern Siberia, but not published – *P. olenekensis* Erschowa, n. sp.

Genus *Praetollia* Spath, 1952

The genus *Praetollia* is not recognized by all investigators, apparently for two reasons: 1) its representatives occur rarely, and 2) the specimens illustrated by Spath were flattened, and the general form of the shell remained unknown.

Donovan (1952) considers *Praetollia* to be a younger synonym of *Tollia*. Bodylevskii (Fundamentals of Paleontology, 1958) includes this genus in *Paracraspedites* with a question mark. In fact, *Praetollia* is a valid genus that is not to be confused with the genera *Tollia, Paracraspedites,* or *Surites* and this is genetically most closely related to *Subcraspedites,* though it does show a number of differences from this genus.

According to Spath (1952), the genus *Tollia* differs from *Praetollia* mainly in that *Tollia* has more sigmoidal ribs with thickenings in the umbilical part, and the main ribs are arranged farther apart. In the collection of north Siberian ammonites most of the *Praetollia* shells are crushed (this also applies to the Greenland forms), but there is one specimen in which part of the venter is preserved without deformation. We may therefore add to the diagnosis of the genus that the form of the cross section of the shell is quite different in *Praetollia* from that in *Tollia*: a very high oval in *Tollia*, subquadrate in *Praetollia*. The venter is constricted in *Tollia,* smoothly rounded with a slight flattening in the middle in *Praetollia*. The ribs in *Tollia* pass over the lateral surface and venter with a marked forward bend whereas in *Praetollia* they at first slope slightly forward, and then in the middle of the lateral sides the branches often incline backward, running across the venter almost in a straight line. The suture line of *Praetollia* differs from that of *Tollia* in its being a little simpler, less incised.

On Paks Peninsula in northern Siberia forms are found that are identical to the Greenland forms, i.e. *Praetollia maynci* Spath with its varieties and *P. aberrans* Spath; they are, however, to be considered older than as indicated by Spath. Representatives of *Praetollia* are found directly above the boundary between Jurassic and Cretaceous deposits and are distributed in the *Chetaites sibiricus* zone and at the bottom of the *Hectoroceras kochi* zone.

There are reports that *Praetollia* occurs in the Berriasian of Poland (Dembowska, 1964; Marek, 1967), but the degree of preservation of the specimens is not such that we can say with certainty that they belong to this genus. From Arctic Canada Jeletzky (1964, pl. 4, fig. 8) presents a form under the name *Praetollia* n. sp., which is in fact *Surites (Surites)* cf. *spasskensis* Nik.

Genus *Bojarkia* Schulgina, 1970

This new genus combines characters of *Surites* and *Tollia* and at the same time shows individual features that are absent in the related groups. The representatives of this genus appeared almost at the same time as *Tollia* (a little earlier); their juvenile whorls with fine, predominantly triple ribs are no different from those in *Tollia*. It is to be assumed that both had common ancestors in the "person" of *Surites*. Features characteristic of *Surites* are manifested in the middle stages of growth in *Bojarkia*. This genus resembles *Tollia* in the sculpture and in the overall appearance of the adult whorls. But the suture line of *Tollia*, despite a similarity to that of *Bojarkia*, has a more complicated frilling. Thus, whereas *Bojarkia* shows features of the ancestral forms, *Tollia* went further in its development and little resembles *Surites*.

The genus *Bojarkia* is of Berriasian age. Finds are confined to strata directly overlying beds with a mass distribution of *Surites* (*Surites analogus* zone). In the present work the former *Tollia tolli* zone is replaced by the *Bojarkia mesezhnikowi* zone; at the bottom of this zone occasional representatives of *Surites* occur. *Tollia* spp. appear together with *Bojarkia*, but not at the same level (a little higher). *Bojarkia* then disappears without crossing the Berriasian-Valanginian border, while *Tollia* persists into the early Valanginian.

Two species are described from Berriasian sediments in northern Siberia *(Bojarkia mesezhnikowi* and *B. bodylevskii)*. We found one specimen, probably of *B. bodylevskii*, on the Russian Plain in summer 1969 on the Menya River. In the nature of the ribbing and general form of the shell, especially in the shape of the cross section, the species "*Perisphinctes payeri* Toula" from eastern Greenland, which Spath (1936) placed in the genus *Tollia*, should be considered to belong to *Bojarkia*. The same species was indicated by Jeletzky, with the sign cf., for Arctic Canada. However, the form illustrated by Jeletzky (1964, pl. 4, fig. 11) belongs to *Subcraspedites (Borealites)*.

Genus *Externiceras* I. Sasonova, 1971

Sazonova instituted this genus for two species described by Bogoslovskii (1897) from the

Ryazan horizon under the name *Perisphinctes solowaticus* Bogosl. and *Olcostephanus mostjae* Bogosl. The species *solowaticus* is taken as the type, although in our opinion, *mostjae* has more characters distinguishing it from the known boreal genera of ammonites. In neither species do the ribs show a marked curve on the venter; this differentiates them from *Surites* and brings them close to *Paracraspedites*, from which, however, they differ in the finer and denser ribbing. The species *mostjae* differs from *Surites* and *Paracraspedites* in the presence of trifurcate ribs and sparsely distributed bidichotomous ribs at a shell size of about 35–40 mm, whereas in *Surites* and *Paracraspedites* only double ribs are observed. With subsequent development the ribbing becomes only double with a high point of branching. In *solowaticus*, the pattern of rib branching is unknown at a size of 35–40 mm, but at a size of about 50 mm bifurcation predominates, although there are a few triple ribs. *Externiceras* differs from *Subcraspedites* in the absence of many-branched fascicles in the middle stages of growth. Where the suture line and form of the shell are concerned, the new genus fits in best with the subfamily Craspeditinae. Representatives of *E. solowaticum* (Bogosl.) occur in Berriasian deposits in northern Siberia.

Genus *Stchirowskiceras* I. Sasonova, 1971

Sazonova established this genus for peculiar ammonites that have a rather long suritic stage of development with double, relatively sidely spaced coarse ribs that bend forward as they cross the venter. On the adult, large whorls the representatives of *Stchirowskiceras* resemble *Subcraspedites*, particularly *Subcraspedites (Borealites)*, owing to the formation of umbilical tubercles and the planing of the ribbing on the sides of the shell. But differences are the later appearance of three- and four-branched fascicles and the earlier obliteration of the ribs on the sides. In Plate XXI, Figure 16 we show a photograph of a specimen viewed from the side of the aperture. It is seen that the ribs in the middle of the venter are smoothed out just as in *Temnoptychites*. Is the photograph a poor one, or do the representatives of the new genus actually show a tendency toward obliteration of the ribs on the venter? The suture line of *Stchirowskiceras* is typically craspeditan and, judging from the other characters mentioned above, the genus should apparently be placed in the subfamily Craspeditinae. No forms of this genus are found in Lower Cretaceous deposits in Siberia.

Genus *Menjaites* I. Sasonova, 1971

In describing this genus, Sazonova mentions that it is distributed in the lower strata of the Valanginian, in the *Pseudogarnieria undulato-plicatilis* zone. Some specimens referred to *Menjaites* are very similar to, even indistinguishable from, *Temnoptychites glaber* (Nik.), which occurs in beds with other Valanginian forms of *Temnoptychites*. There are forms of *Menjaites* that closely resemble *Craspedites* externally. The deep and frequent constrictions observed on the juvenile whorls in one species of *Menjaites* are characteristic of such species as *Craspedites (Craspedites) nodiger* (Eichw.) and *C. (C.) kaschpuricus*

(Traut.), but in these species the shell is thicker than in *Menjaites*. The suture line of *Menjaites* is exactly as in the typical Volgian forms of *Craspedites*: little incised, with quite broad, short lobes and three or four accessory lobes that decrease markedly in size toward the umbilical margin. Further research is thus required to justify the institution of the genus *Menjaites*, in order that more characters may be found which distinguish it from *Craspedites* and *Temnoptychites*. The species *Mejaites (? Temnoptychites) glaber* Nik. occurs, apart from on the Russian Plain, on the Izhma River in beds with species of *Temnoptychites*.

Subfamily Tolliinae Spath, 1952

Genus *Tollia* Pavlow, 1913

It is thought that Pavlow instituted this genus in 1914, since the huge edition of the book "Jurassic and Lower Cretaceous Cephalopoda of Northern Siberia" was published in that year. In Leningrad, however, Voronets had an author's copy of the same work that had been issued in 1913, and therefore we should take 1913 to be the year that the genus was established. This is not so important where *Tollia* is concerned, because no one tried to rename this genus. But for *Temnoptychites,* described by Pavlow in the same book, the date is of great significance. In 1913 Sokolov proposed the name *Nikitinoceras* for four groups of ammonites. As rightly noted by Bodylevskii (1967), Sokolov did not mention the type species of this genus and, moreover, according to recent concepts, it should embrace the genera *Craspedites, Surites, Temnoptychites,* and *Dichotomites*. This is why the name *Nikitinoceras* was not taken up in the Russian literature.

Pavlow described three species: *Tollia tolli* Pavl., *T. tolmatschowi* Pavl., and *T. latelobata* Pavl. The type was not mentioned, but since *T. tolli* was described first, it was this form that became the type. It must be pointed out that *T. tolli* and *T. tolmatschowi* are very similar, as even their author admits; in fact, they scarcely differ and should have been considered one species if it were not for the long-standing tradition and the differences that may actually be reduced to intraspecific variability. The species *T. latelobata* was described from a large specimen in which the individual characteristics of the species were lost; for this reason, in collections this species is as a rule not distinguished.

For many years the only species of *Tollia* that were known were the three described from the Klimovskii ravine on the Anabar River, if we discount the species *bidevexus* and *stenomphalus* from the Russian Platform, which were unjustifiably placed in the genus. Then Spath (1936) included in *Tollia* the species "*Perisphinctes payeri* Toula" from eastern Greenland, whose resemblance to the forms of this genus had been noted by Pavlow. At present we place this species in the genus *Bojarkia*. In 1953 Krymgol'ts (Krymgol'ts, Petrova, and Pchelintseva, 1953) described two new species from the Klimovskii ravine in Siberia: *Tollia klimovskiensis* and *T. vai,* the first of which was isolated by Shul'gina (1969) into a new genus, *Neotollia*, on the basis of a number of signs. In 1962, in a monograph on the Cephalopoda of the Lena-Anabar region, Voronets described three more new species: *Tollia emeljanzevi* Voron., *T. pakhsaensis* Voron., and

T. profundoumbilicata Voron., and one new variety of the species *T. kordikovi* Bodyl., that had been named but not described or published by Bodylevskii; this is *T. kordikovi* Bodyl. var. *subtilis* Voron., which is here considered as the species *T. subtilis* Voron. In 1960 Shul'gina described from Lower Cretaceous deposits in Western Siberia the species *T. sibirica* Klimova, which should be placed in the genus *Neotollia*. Certain species of *Tollia* were recorded from Lower Cretaceous deposits in the Cis-Polar Urals (*Tollia* aff. *tolli* Pavl.), the northeastern USSR (*Tollia* cf. *tolli* Pavl.), and northern Canada (*Tollia tolli* Pavl.) (Saks et al., 1963, 1965, Jeletzky, 1964, 1965).

All these finds were confined to Arctic regions. In 1962 appeared a work by Neale on the Berriasian ammonites of the Speeton clays in England, in which two new species of *Tollia* are described: *Tollia wrighti* Neale and *T. pseudotolli* Neale, in addition to *"Tollia"* cf. *payeri* Toula, *T.* cf. *tolmatschowi* Pavl., *"Tollia" stenomphala* Pavl., and *T.* sp. Earlier the author had been skeptical about the presence of these species in England in view of their poor degree of preservation (Saks and Shul'gina, 1964), but now, after careful study of this genus, the above forms (except for *T,* cf. *tolmatschowi, "T." stenomphala,* and *T. payeri*, which are not preserved well enough for the genus to be determined, let alone the species) are considered by us to belong to *Tollia*. In 1964 representatives of *Tollia* were discovered and described in the northwestern part of West Germany (Kemper, 1964): *T. tolmatschowi* Pavl., which belongs rather to the genus *Neotollia,* and *T. pseudotolli* Neale, which is a true species of *Tollia*. Kemper also places the species *pumilo*, described by Vogel (1959) as *Polyptychites pumilo* Vog., in the genus *Tollia*. This form is intermediate between *Tollia* and *Polyptychites* and should be isolated into a separate genus or subgenus.

After species of *Tollia* had been found in England and West Germany, the absence of the genus on the Russian Plain came under doubt. Although Pavlow (1913) had mentioned in describing forms of the genus that many species are present in lower Neocomian sediments in European Russia, nobody found any there. It is still a matter of uncertainty whether true *Tollia* and not simply related forms are present on the Russian Plain. The collection made by the author together with Sazonova in the summer of 1969 on the Menya River includes forms that are very reminiscent of *Tollia*. However, their degree of preservation is not such that their generic affiliation can be determined for sure.

Another species that should be placed in *Tollia* is the one identified by Spath (1936) as *Subcraspedites groenlandicus* according to the fine triple ribs and ribs with four branches in the young stages of growth (pl. 38, fig. 3a) and the marked smoothing of the ribbing in the middle of the sides in adult forms (pl. 36, fig. 3a). The Novaya Zemlya species *Olcostephanus sosnovskii* Sokolov (Sokolov, 1913) is placed in *Tollia* according to the same characters plus the absence of a break in the ribbing on the venter. Spath compared this form to *S. groenlandicus* as its closest relative. Recently in the publications by Jeletzky (1965) and Imlay and Jones (1970), species formerly placed in *Dichotomites* and *Homolsomites* have been considered to belong to *Tollia (mutabilis, burgeri, paucicostata, tehamaensis, crassicostata)*. In our view, some of the forms from western Canada and California do indeed belong to *Tollia,* while others are of the genus *Neotollia* (including the lectotype *mutabilis*).

There are thus 16 species, 8 of which are described from northern Siberia (*T. tolli*

Pavl., *T. tolmatschowi* Pavl., *T. latelobata* Pavl., *T. vai* Krimh., *T. emeljanzevi* Voron., *T. subtilis* Voron., *T. pakhsaensis* Voron., *T. profundoumbilicata* Voron.), two species described from England (*T. pseudotolli* Neale and *T. wrighti* Neale), one species from eastern Greenland (*T. groenlandica* Spath), one species from Novaya Zemlya (*T. sosnovskii* Sokolov), and four species known from California and western Canada (*T. crassicostata* Imlay, *T. burgeri* And., *T. tehamaensis* And., and *T. paucicostata* Don.).

From data collected from numerous sections in Lower Cretaceous deposits in northern Siberia the age of *Tollia* proved to be only Berriasian (or lower Valanginian in the former understanding). In fact, finds of *Tollia* are confined in most cases to the upper part of the Berriasian, to strata occurring above the *Surites analogus* zone. However, a monographic study of this group and accurate stratigraphic allocation showed that in Siberia representatives of the genus are found still higher, in strata belonging to the Valanginian, together with *Astieriptychites* and *Temnoptychites*. In the northwestern part of West Germany *Tollia pseudotolli* Neale is confined to the beds with *Platylenticeras* that in Europe belong to the bottom of the lower Valanginian; in California forms of *Tollia* are distributed in the upper strata of the Berriasian and in the lower Valanginian. We have therefore abolished the *Tollia tolli* zone, which has existed for many years in stratigraphic schemes of Western Siberia, and have replaced it with the zones *Bojarkia mesezhnikowi* and *Neotollia klimovskiensis.*

Genus *Neotollia* Schulgina, 1969

From the many representatives of the genus *Tollia* the author has picked out forms that differ in certain characters from the typical representatives *Tollia tolli* and *T. tolmatschowi* and that occupy a higher stratigraphic position than these. In earlier publications (Saks et al., 1965, 1968) we isolated on this basis separate beds with *Tollia* sp. in the upper part of the *Tollia tolli* zone. In studying the changes in the characteristic features of the shell with growth, the author became convinced that the forms in question should be isolated into a separate genus. *Neotollia* differs as a rule from *Tollia* in the thicker shell, greater involuteness, broader and lower cross section, and in the presence of double ribs in the juvenile and middle stages of growth.

For the type of the genus we propose the species *klimovskiensis,* already described by Krymgol'ts (Krymgol'ts et al., 1953). Very similar to this species is *Polyptychites anabarensis* Pavl., which was earlier placed in the genus *Tollia* (Shul'gina, 1965). According to a number of characters this species could be assigned to either genus, in other words, this is a transitional form, as is the case with *stenomphalus, bidevexus,* and *suprasubditus,* which show characters of several genera and at the same time do not have clear-cut individual features enabling them to be made independent genera.

The species *anabarensis* is extremely similar to *Neotollia* according to the involuteness of the shell, the form of the cross section, and the general habitus. In the sculpture, that is, in the predominance of trifurcate fascicles at a shell diameter of 50–60 mm, the species resembles *Tollia.* It differs from *Polyptychites* in the absence of the typical polyptychitic branching of the ribs. It is placed in *Neotollia* with some reservations.

Also to be placed in *Neotollia* is *Tollia sibirica* Klimova, described from boreholes in the West Siberian lowland.

Bodylevskii's collection contains a number of specimens belonging to *Neotollia*. One of them, from the collection of Kiselev (1936, No. 185) under the name *Tollia klimovskiana* n. sp., is described in the present work within the genus *Neotollia*.

Possibly belonging to the genus *Neotollia*, but not to the species *klimovskiensis*, is a form from West Germany described by Kemper (1964) as *Tollia tolmatschowi* Pavl. Representatives of *Neotollia* are also present in the Northern Urals (Klimova's collection). In California and western Canada forms of *Neotollia* occur among specimens named *Tollia*. These are *Neotollia crassicostata* Imlay, *N. mutabilis* Stant., *N. burgeri* And., *N. ? paucicostata* Don. (Imlay and Jones, 1970, pl. 8, figs. 4, 5; pl. 7, figs. 4, 7–9).

From Greenland Donovan (1953, pl. 23, fig. 2) described an ammonite under the name *Dichotomites gregerseni* And. var. *paucicostatus* Don., which seems to belong rather to *Neotollia*; yet, without knowing the sculpture of the inner whorls, it is hard to be sure of this.

The age of *Neotollia* is early Valanginian. The former beds with *Tollia* sp. are isolated by us into the *Neotollia klimovskiensis* zone, the bottommost zone of the Valanginian. Higher up in the *Polyptychites stubendorffi* zone, representatives of *Neotollia* are encountered in beds with *Russanovia diptycha* (Keys.), *Astieriptychites*, and *Temnoptychites*.

Genus *Virgatoptychites* Voronez, 1958

Voronets instituted the genus *Virgatoptychites* with the type species *V. changalassensis*, placing it in the family Polyptychitidae Spath, 1924, and determined its age as late Valanginian on the basis of a find in the same sample of a shell of *Ostrea anabarensis* Bodyl., a species considered upper Valanginian. Recent investigations (Saks et al., 1965; Zakharov, 1966) have shown that *Ostrea anabarensis* Bodyl. is characteristic for the top of the Berriasian and for the whole Valanginian stage, so that age determination cannot be made on the basis of this form. We found two representatives of *Virgatoptychites* on the Boyarka River in the *Bojarkia mesezhnikowi* (top of the Berriasian) and *Neotollia klimovskiensis* (lower Valanginian) zones.

The genus *Virgatoptychites* is to be placed in the family Craspeditidae, subfamily Tolliinae, not the family Polyptychitidae. The suture line of *Virgatoptychites* is typically craspeditan, little incised and with a greater number of auxiliary lobes (five, which are raised in the direction of the umbilicus) than in the Polyptychitidae. In pattern, number of elements and their distribution, the suture line is similar to that of *Tollia, Neotollia,* and *Bojarkia*, differing mainly in having narrower second and first auxiliary lobes. The most closely related genus is *Tollia*.

In contrast to *Tollia*, judging from the specimen presented by Voronets in pl. I, fig. 3, *Virgatoptychites* does not have tripartite ribs on the small whorls, but has typically virgatic sculpture on the middle whorls that does not disappear in the middle of the sides (in *Tollia* only isolated ribs have virgatic or bidichotomous structure and the sculpture in the middle of the sides is obliterated). The whorls of *Virgatoptychites* are much thicker than those of *Tollia*, and therefore the form of the cross section is different, not a high but a low, broad oval, narrower toward the top. In the general form of the shell and the presence of umbilical ribbed thickenings on the middle and large whorls, the forms of *Virgatoptychites* could be confused with *Polyptychites* (as admitted by the author; see Saks et al., 1958). However, the nature of the suture line and the characteristic sculpture allow for a clear distinction between these two genera. There is some similarity to the representatives of *Neotollia*, in which the form of the shell resembles that of *Virgatoptychites* and in which some virgatic ribs are present, but in *Neotollia* there are no umbilical tubercles or regular virgatic ribs, and the suture line is more complicated.

The new genus differs from the Volgian genus *Virgatites,* which has a similar sculpture of the middle and large whorls, in the totally different suture line, the thick, inflated shell, and the presence of umbilical tubercles. The regressive development of the sculpture in *Virgatoptychites,* identical to the development shown by the Volgian *Virgatites,* once again stresses the fact that the Craspeditidae originated from the Perisphinctidae.

Two species have been reliably recorded from the north of Siberia: *Virgatoptychites changalassensis* Voron. and *V. trifurcatus* Schulg. n. sp. A third species, *V. pakhsaensis* Voron., is placed in the genus with a question mark. Jeletzky (1971) mentions the presence of *Virgatoptychites* in Canada.

Genus *Chandomirovia* Sasonov, 1951

This genus, with the single species *Chandomirovia ilekensis* Sason., is unfortunately represented only by two small specimens (35 and 40 mm) in which the typical characters of the genus are not manifested. In the form of the shell, its involuteness, and particularly in the nature of the sculpture these specimens closely resemble *Temnoptychites lgowensis* (Nik.), with which in fact Sazonov compares this new genus (Sazonov, 1951). Bodylevskii (1967) includes *Chandomirovia ilekensis* Sason. in the synonymy of the species *Temnoptychites hoplitoides* (Nik.) with a question mark. *Temnoptychites* is characterized by a weakening or disappearance of the ribbing on the venter on the middle and large whorls, but this character is manifested at different shell sizes in different species. For instance, in *T. grandiosus* the weakening of the ribs on the venter begins to appear only from a shell diameter of 43–45 mm, and the ribs disappear completely only from a diameter of 55 mm. In the case in question it may be that the shells did not reach a size at which the weakening or disappearance of the ribs on the venter could be manifested, or at which some other characters present in the known boreal genera of ammonites could present themselves. In the involuteness and form of the shell *Ch. ilekensis* resembles some species of *Tollia* and *Neotollia*, but in typical representatives of *Tollia* the third rib as a rule remains free (in *Ch. ilekensis* the third rib is usually attached, sometimes forming a polyptychitic bundle, as is typical of *Temnoptychites*), and in *Neotollia* at a size of 35–45 mm only double ribs are present as a rule. The validity of this genus therefore raises doubts and we should question whether it does not belong to *Temnoptychites*, all the more so that the sculpture, the form of the shell, and the width of the umbilicus do

TABLE 7. Characteristic features of Berriasian ammonites

Genus	Form of shell	Whorl section	Ribs on venter	Ribs on inner whorls	Ribs on middle whorls	Ribs on outer whorls	Senile stages
Paracraspe-dites	Flattened, umbilicus wide	Oval or subrectan-gular	Without forward bend	Not known	Double, strong, projecting	Double and triple, coarse	Not known
Surites	Flattened or in-flated, umbilicus moderately broad or wide	Oval, rounded, transverse-oval, or subquadrate	With a marked or not very marked forward bend	Double, relatively coarse	Double and triple	Double and triple and with a fourth branch, strong	Ribs tuberous near the umbilicus, smoothed out in the middle, 3–4 outer ribs per main rib
Subcraspe-dites	Flattened or slightly inflated, umbilicus mod-erately narrow or moderately wide	Oval, subrec-tangular, or subquadrate	With a slight forward bend	Double, fine	From 3–8 ac-cessory ribs per main rib, relative-ly fine	Umbilical infla-tions, smoothed out in the middle	Smooth, often with umbilical tubercles
Praetollia	Flattened, um-bilicus narrow	Oval or sub-quadrate	Without forward bend	Double, fine	Double and triple, relatively fine	Double and triple, relatively fine	Not known

Bojarkia	Flattened, umbilicus moderately narrow	Oval or subrectangular	With forward bend	Double and triple, fine	Either double or triple predominating, very prominent	Double and triple, with a fourth and fifth branch, prominent near the umbilicus and on the periphery, smoothed out in the middle	Umbilical tubercles and smoothed outer ribs
Tollia	Flattened, umbilicus moderately narrow	Oval, drawn out in height or subrectangular	With marked forward bend	Double and triple, fine	Two, three, or four branches per main rib	Three and four branches, prominent near the umbilicus and on the periphery, smoothed out in the middle	Smooth
Neotollia	Flattened or inflated, umbilicus narrow	Oval or in the form of a high trapezium	With forward bend	Double, relatively fine	Double, with the appearance of a third branch	Double and triple, sometimes with a fourth and fifth branch	Smooth, sometimes with umbilical thickenings, sometimes with peripheral ribs
Hectoroceras	Markedly flattened, umbilicus very narrow	Sagittate	Ribs absent	Double, relatively fine	Double and triple	Double and triple	Smooth

not differ from those in many representatives of this genus at a size of 35–40 mm.

The age of *Chandomirovia* (Sazonova, 1965) is set at Berriasian (middle and upper strata of the Ryazan horizon). According to Sazonova, *Chandomirovia* occurs in later deposits only in redeposited form. Judging from earlier data of Sazonov (1951), *Ch. ilekenis* is characteristic for the *Temnoptychites hoplitoides* zone in the lower Valanginian. In view of the close resemblance that *Chandomirovia* bears to *Temnoptychites* and *Tollia*, this genus should be placed in the subfamilly Tolliinae.

Subfamily Garniericeratinae Spath, 1952

Genus *Hectoroceras* Spath, 1947

In describing this genus, Spath (1947) placed it in the family Craspeditidae, but later (Spath, 1952) he mentions that the species of *Hectoroceras* may be descendants of the Oppeliidae. In the same work Spath instituted two more subfamilies in the family Craspeditidae: Tolliinae and Garniericeratinae. In the first of these he placed the genera *Praetollia, Tollia,* and, hypothetically, *Hectoroceras.* It would, of course, have been better to place *Hectoroceras* in the subfamily Garniericeratinae, especially since Spath considered the representatives of *Garniericeras* (particularly the species *G. tolijense* (Nik.)) as very similar to *Hectoroceras*. There is no doubt as to the kinship between *Garniericeras* and *Hectoroceras*. They both have a similar form of shell; their suture lines, with numerous auxiliary lobes and shortened saddles and lobes are very similar – at any rate, the two genera resemble each other more than they resemble any other genus of the family Craspeditidae. We therefore propose placing *Hectoroceras* in the Garniericeratinae. Spath described *H. kochi* from eastern Greenland, positioning it between the beds with *Praetollia* and those with *Tollia*. The same species is massively distributed in northern Siberia, also more or less between beds with *Praetollia* and *Tollia*. However, since the zonal stratigraphy of northern Siberia has been worked out in much greater detail than that of Greenland, we now have a much better idea of the stratigraphic position of the species of *Hectoroceras*, which is between the *Chetaites sibiricus* zone (in which *Praetollia* and the first *Hectoroceras* appear) and the *Surites analogus* zone (in which *Hectoroceras* is no longer found). Hence, between the last *Hectoroceras* and the first *Tollia* there was a time gap equal to one zone. We isolate a *Hectoroceras kochi* zone, that can be traced in many sections in Siberia, in the Northern Urals, and in Greenland. Representatives of *Hectoroceras*, apart from those indicated for the northern regions, are known from England without allocation to a section (Casey, 1962). In a table of zone correlations for Canada Wiedmann (1968) gives *H.* aff. *kochi* Spath, but Jeletzky does not mention that *Hectoroceras* is present in Canada.

For easy comparison of the genera studied by the author we present Table 7 (pp.142–143), showing all the main characteristic features of the shells. Genera which were not studied personally by us are not included in the table.

AMMONITES OF THE NORTH OF MIDDLE SIBERIA*

FAMILY CRASPEDITIDAE SPATH, 1924

Subfamily Craspeditinae Spath, 1924

Genus *Subcraspedites* Spath, 1924, emend. Schulgina, 1969

Type species: *Ammonites plicomphalus* J. Sowerby, 1822, p. 82, pl. 359. Lower Cretaceous (Berriasian) of England. Lincolnshire, Spilsby sandstone.

Diagnosis. Shell flattened or slightly inflated, of average thickness. Cross section oval, subrectangular, or subquadrate. Umbilicus moderately wide or wide. Sculpture of inner, juvenile whorls consisting of bipartite, fine or not very fine ribs. On the middle whorls the ribs are fine or not so fine, irregularly branched, elevated in the region of the umbilicus. From 3 to 8 secondary ribs per main rib. On the adult whorls the umbilical ribs have tuberous inflations *(Subcraspedites* s. str., *Subcraspedites (Swinnertonia), Subcraspedites (Borealites))* or are without these *(Subcraspedites (Ronkinites)* and *Subcraspedites (Pronjaites)).*

The suture line has a fairly broad outer lobe and a first lateral lobe of the same width and length as the outer lobe or a little narrower and shorter than it, rarely just slightly longer. Second lateral lobe just over half as long and as wide as the first. There are 4 or 5 auxiliary lobes** arranged in a straight line on the lateral side or descending near the umbilical margin.

Species composition. Twenty species, of which 8 occur in northern Siberia.

Comparison. The most closely related genera are *Tollia* and *Surites.* Forms of *Subcraspedites* have often been wrongly included in these genera.

The chief signs distinguishing *Subcraspedites* from *Tollia* are: 1) the less flattened sides of the shell; 2) the wider cross section (the first two characters differentiate all representatives of *Subcraspedites* from *Tollia* with the exception of *Subcraspedites (Pronjaites) bidevexus)*; 3) the wider umbilicus; 4) the weaker bend of the ribs on the venter; 5) bipartite ribs on the juvenile whorls (triple and double in *Tollia*); 6) the less regular branching of the ribs on the middle whorls with a large number of accessory ribs in *Subcraspedites* s. str. per main rib. The suture line is similar in the two genera. On the large whorls the suture line is more incised in *Tollia* than in *Subcraspedites*.

The representatives of *Subcraspedites* differ from the genus *Surites* as follows: 1) the lesser curvature of the ribs on the venter; 2) the presence of many secondary ribs with tuberous thickenings on the umbilical ribs of the middle whorls (except in the subgenera *Ronkinites* and *Pronjaites*); 3) the smooth shell with more or less prominent umbilical tubercles on the adult, large whorls; 4) the presence of constrictions.

The suture lines of *Subcraspedites* and *Surites* are very similar, in fact almost identical,

* The collection is deposited at the F. N. Chernyshev Central Geological Museum, Leningrad, item No. 10118.

** Here and in the following, middle whorls about 50 mm in diameter are meant.

and at the same time they closely resemble those of *Craspedites (Taimyroceras)*, only as a rule with a larger number of auxiliary elements. *Craspedites (Taimyroceras) taimyrensis* Bodyl. and *C. (T.) singularis* Schulg. have 3–4 auxiliary lobes, *Surites* and *Subcraspedites* 4–5.

Remarks. The author understands the genus *Subcraspedites* in a broader sense than indicated by Spath in the short diagnosis he gave 23 years after the genus had been published (Spath, 1947). Five subgenera are established.

The first subgenus, *Subcraspedites* s. str., corresponds to what Spath understood as the genus *Subcraspedites*, with the type species *Subcraspedites (Subcraspedites) plicomphalus* Sow.

The second subgenus was isolated for the English species described by Swinnerton (1934) under the name *Subcraspedites* but differing from the representatives of *Subcraspedites* s. str. in the more evolute shell, the somewhat different suture line, and the sharper and higher umbilical tubercles (except for the species *S. primitivus* Swinn., which falls into a third subgenus). This subgenus is named *Subcraspedites (Swinnertonia)* n. subgen. with the type species *S. (Sw.) cristatus* Swinn.

The third subgenus is established for forms differing slightly from the typical *Subcraspedites* in development. They do not have distinctly expressed umbilical tubercles, and the secondary ribs are few; however, the nature of the changes of the sculpture with growth of the shell is the same as in *Subcraspedites* s. str., that is, from double ribs in the juvenile stages to fascicles with four branches in the adult stages of growth. These forms are included in the subgenus *Subcraspedites (Ronkinites)* n. subgen. with the type species *S. (R.) rossicus* Schulg. n. sp.

The fourth subgenus comprises the forms included by Klimova (1969) in the genus *Borealites* with the type species *Subcraspedites (Borealites) fedorovi* Klim. This group is extremely closely related to the representatives of *Subcraspedites* s. str, differing as a rule in the later appearance of the many-branched fascicles with a number of secondary ribs not exceeding 4–5 per umbilical rib, in the greater coarseness of the ribs, and in the less projecting umbilical tubercles.

The fifth group, *Subcraspedites (Pronjaites)*, isolated by Sazonova for one species, *bidevexus*, into the genus *Pronjaites*, is distinctive. Actually there is no group, but just the one species *bidevexus*, which differs from all the other forms of *Subcraspedites* in the more flattened sides of the shell, the narrower venter, and, as a consequence of this, the narrower and higher cross section. Sculpture development is of the same type as in the other *Subcraspedites* except that since the large whorls with the body chamber are not known, it is not certain whether umbilical tubercles are formed or not at these stages.

Age and distribution. Berriasian of the Boreal Realm. England, Russian Plain, Poland. In Arctic regions known from Greenland, Spitsbergen, Canada, and Western and northern Siberia. A few species have reached Mangyshlak.

Subgenus *Subcraspedites* s. str.

Type species: *Subcraspedites (Subcraspedites) plicomphalus* J. Sowerby, 1822, p. 82, pl. 359. Lower Cretaceous (Berriasian) of England. Lincolnshire, Spilsby sandstone.

Diagnosis. Fine bipartite ribs on inner whorls; numerous fine ribs (from 4 to 8 accessory) on the middle whorls; ribs sometimes smoothed out in middle of sides; umbilical tubercles and obliterated or partly obliterated ribs on the sides and venter. The representatives of this subgenus sometimes attain large dimensions (to 200–250 mm in diameter).

Species composition. Five species, 4 of which occur in northern Siberia.

Comparison. A comparison with the other groups placed by the author in *Subcraspedites* was given above in the description of the genus.

Age and distribution. Berriasian of the Boreal Realm. England, Russian Plain. In Arctic regions known from Greenland, Spitsbergen, Canada, and Siberia. Occasional species found on Mangyshlak.

*Subcraspedites (Subcraspedites) anglicus** Schulgina n. sp.
Plate I, Figures 1, 2; Plate II, Figure 2; Plate III, Figure 1; Plate IV, Figure 1;
Figure 10, *3, 4;* Figure 11, *9, 10;* Figure 12, *13*

Holotype. Specimen No. 1/10118, Plate I, Figure 1. Boyarka River. Berriasian stage. *Hectoroceras kochi* zone.

Material. Sixteen specimens, most of them excellently preserved. It was possible to uncoil many of the specimens to the inner whorls.

Description. Shell of medium thickness (thickness 29–40% of the shell diameter), sides slightly flattened; venter sometimes slightly compressed. Width of umbilicus, sculpture, and to a lesser degree the cross section of the whorls change with growth of the shell.

On the inner whorls the form of the cross section is an oval drawn out in height, on the large whorls, a wide oval. Whorls increasing moderately in height (on the inner and middle whorls the height increases over half a whorl by a factor of 1.5–1.6, on the large whorls by a factor of 1.3). The degree of involuteness of the shell decreases with age. Young whorls enclose the preceding by 3/4 to 4/5, adult whorls by 2/3. Width of umbilicus on inner and middle whorls moderate, 28–33% of the shell diameter; on adult, large whorls the width of the umbilicus constitutes 34–41%, in other words, the umbilicus becomes wide. Umbilicus shallow, cup-shaped, its walls gently sloped. Thickness of shell diminishing with growth (see dimensions).

Sculpture of inner whorls at a diameter of 15–25 mm consisting of fine, dense ribs numbering 38–40–50 per complete whorl.** The ribs begin some distance from the umbilical suture, so that there is a smooth interval between the suture and the beginning of the ribbing. This is characteristic for all stages of growth. The ribs divide in the middle of the lateral surface or slightly lower (at a distance of 1/3 from the umbilical margin). They slope forward slightly as they cross the side and venter. Triple ribs appear at a shell diameter above 30 mm.

* The name is given in view of the similarity to the English species.

** A triple rib sometimes appears as an anomaly.

In the middle stages of growth the sculpture consists of elevated umbilical ribs that split up into a multitude of fine secondary ribs at 1/3 of the distance from the umbilical margin or almost in the middle of the lateral surface; the second, rarely the third, rib becomes attached to the umbilical rib, the others remaining intermediaries. In some cases only intermediaries predominate; the number of accessory ribs per main rib varies from 5 to 8. The number of umbilical ribs at a shell diameter of 50–60 mm is 22–26. At a shell diameter of 75–85 mm the umbilical ribs become more massive and fewer. They assume the form of tubercles, and the accessory ribs in the middle of the sides smooth out. The number of umbilical ribs on the adult whorls is reduced to 16–18. On large whorls 100–120 mm in diameter all that is usually left of the sculpture are a few umbilical tubercles, which may be developed to varying degrees; however, peripheral ribs are sometimes also detected. Only umbilical tubercles (9–13) are preserved on large specimens 150–200 mm in diameter (Plate IV, Figure 1). Individuals of this species are characterized by constrictions that are seen particularly distinctly on the middle whorls; they number 2–3 per whorl. The body chamber occupies a complete or almost a complete whorl. On the body chamber of small specimens (at a diameter of 55 mm) and also in adult, large forms the sculpture changes uniformly, that is, the umbilical ribs become fewer and thicker and the accessory ribs are smoothed out.

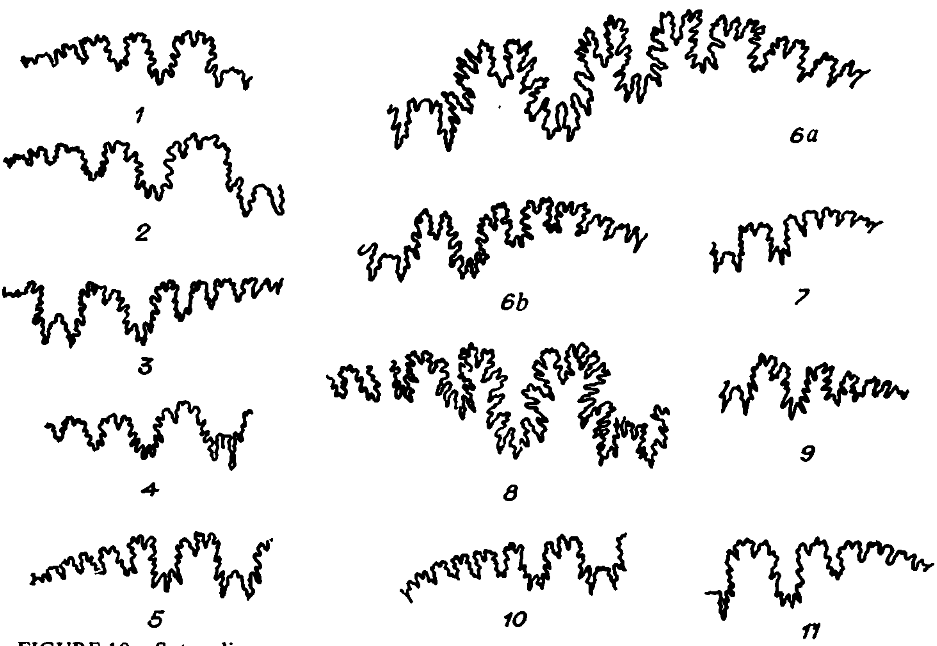


FIGURE 10. Suture lines:
1) *Subcraspedites (Subcraspedites)* cf. *subpressulus* Bogosl.; 2) *Subcraspedites (Ronkinites) rossicus* Schulg. n. sp.; 3, 4) *Subcraspedites (Subcraspedites) anglicus* Schulg. n. sp.; 5) *Subcraspedites (Borealites) suprasubditus* (Bogosl.); 6, a, b) *Neotollia maimetschensis* Schulg. n. sp. (a: middle whorl, b: large whorl); 7, 10) *Neotollia klimovskiensis* (Krimh.); 8) *Tollia tolli* Pavl.; 9) *Surites (Surites) subanalogus* Schulg. n. sp.; 11) *Subcraspedites (Pronjaites) bidevexus* (Bogosl.). (× 3.5.)

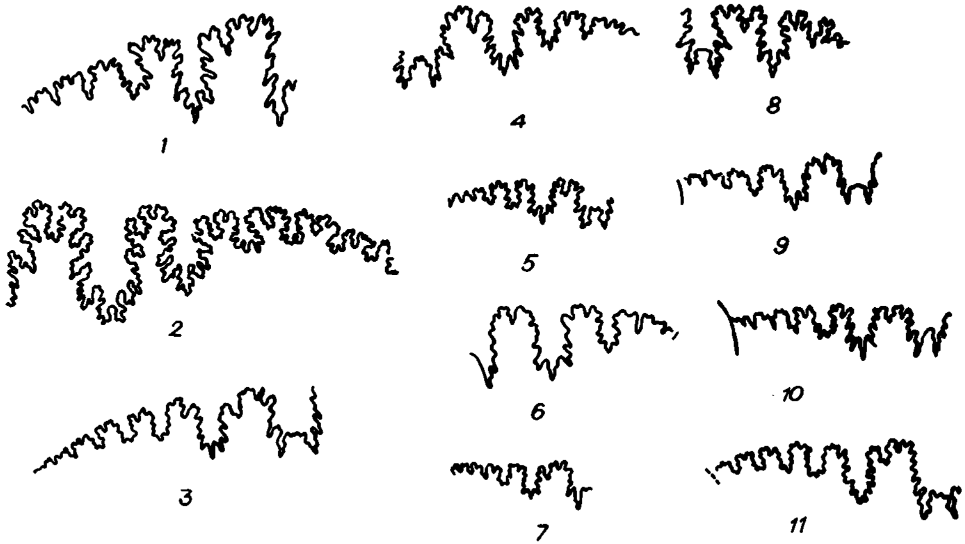


FIGURE 11. Suture lines:
1, 4) *Tollia tolli* Pavl.; 2) *Hectoroceras kochi* Spath; 3) *Neotollia klimovskiana* Bodyl. and Schulg. n. sp.; 5) *Subcraspedites (Subcraspedites) plicomphalus* (Sow.); 6) *Surites (Bogoslovskia)* sp. (× 2.5); 7) *Surites (Surites)* sp.; 8) *Argentiniceras* (?) n. sp.; 9, 10) *Subcraspedites (Subcraspedites) anglicus* Schulg. n. sp.; 11) *Neotollia* sp.

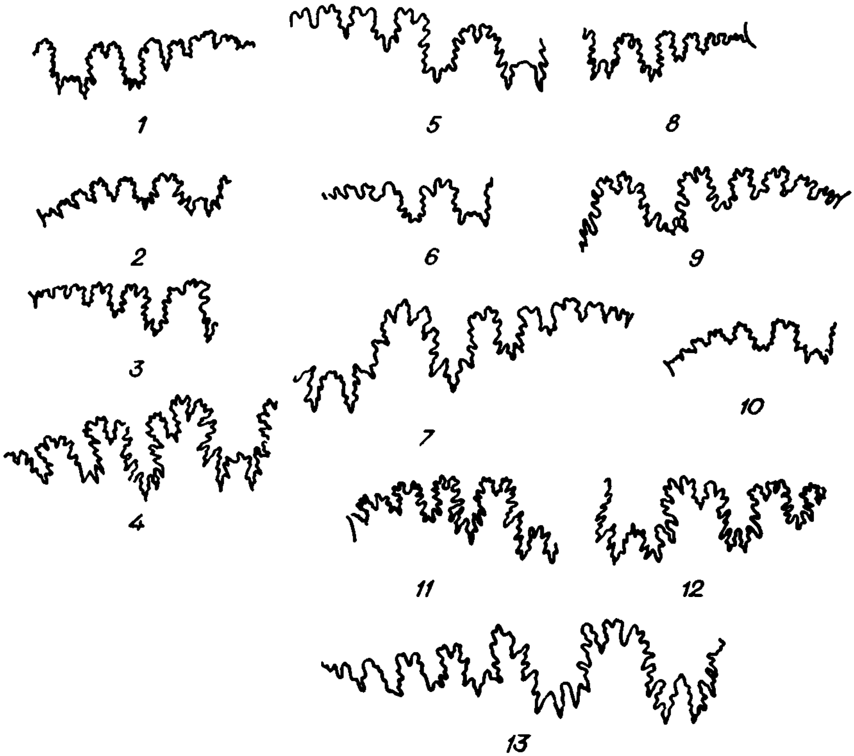


FIGURE 12. Suture lines:
1) *Virgatoptychites trifurcatus* Schulg. n. sp.; 2, 9) *Neotollia* (? *Propolyptychites*) sp.; 3) *Subcraspedites (Borealites) suprasubditus* (Bogosl.); 4, 11, 12) *Tollia tolli* Pavl.; 5) *Praetollia maynci* Spath; 6) *Neotollia* juv. sp. (× 5); 7) *Bojarkia mesezhnikowi* Schulg.; 8) *Surites (Surites)* sp.; 10 *Neotollia* sp.; 13) *Subcraspedites (Subcraspedites) anglicus* Schulg. n. sp. (suture of holotype, drawn from a large whorl).

The suture line has, apart from a ventral and two main lateral lobes, four auxiliary lobes on the lateral surface and sometimes a small fifth auxiliary lobe on the umbilical wall. The first lateral lobe is the same length as the ventral lobe (or even just a little longer), but it is slightly narrower (Figure 10, *3, 4*; Figure 11, *9, 10*; Figure 12, *13*). The second lateral lobe is just over half as long as the first; the first lateral saddle is wide, the second much narrower than the first. In general the suture follows a straight line, not rising or falling as it approaches the umbilical suture.

Variability. The species variability consists in the different number of accessory ribs per umbilical rib (5, 6, 7, or 8) and in that these ribs may be thicker or thinner at uniform shell dimensions. The constrictions may sharp or hardly perceptible. The venter varies slightly in its degree of constriction.

The umbilical tubercles may be wider or narrower, shorter or longer, and their direction may be radial or slightly forward-sloped. The ribs on the sides and venter are markedly smoothed in some specimens, less so in others.

Comparison and remarks. In the general form of the shell and sculpture, the representatives of *Subcraspedites (Subcraspedites) anglicus* closely resemble *S. (S.) plicomphalus* (Sow.), described below; they also differ little from *S. (S.) pressulus* (Bogosl.) and very little from *S. (S.) subpressulus* (Bogosl.).

The forms described differ from *S. (S.) plicomphalus* (Sow.) (Sowerby, 1822, pl. 359) in having a more evolute shell. At a shell diameter of 90 mm the width of the umbilicus in the English specimen of *S. plicomphalus* constitutes 28% if measured according to the drawing, 25% if measured from the photograph of the holotype of *S. (S.) plicomphalus*, presented by Donovan (1964). At the same dimensions the width of the umbilicus of *S. (S.) anglicus* occupies from 30 to 40% of the shell diameter. In addition, *S. (S.) plicomphalus* (Sow.) has 10 or 11 umbilical tubercles (according to Sowerby's pl 359); in *S. (S.) anglicus* there are at least 15 or 16 umbilical tubercles at the same or a similar shell size as in the English specimen. Unfortunately, the inner and middle whorls of the holotype of *S. (S.) plicomphalus* are unknown, and it is only by comparing adult whorls that one can surmise whether a specimen belongs to this or that species. The collection of Siberian ammonites contains two specimens that differ from *S. (S.) anglicus* in the same characters as *S. (S.) plicomphalus* does, and therefore they are referred to *plicomphalus*. From *S. (S.) pressulus* (Bogosl.) the new species differs in the wider umbilicus (23% in the Ryazan form and 28–30% at the same size in *S. anglicus*), the larger number of umbilical tubercles, the more prominent ribs, and the less marked flattening of the sides. *S. (S.) anglicus* differs from *S. (S.) subpressulus* (Bogosl.) in the more prominent ribs and their less considerable smoothing in the middle of the sides.

Briefly, the characters distinguishing all the species mentioned above from each other (including *S. (S.) sowerbyi* Spath, which differs from *anglicus* just in having finer and denser ribbing) are not marked, and it may well be that they should all be made synonyms of *S. (S.) plicomphalus*; we cannot, however, do this, as the English and Ryazan forms are badly preserved and because a comparison cannot be made for all stages of growth.

Occurrence. Khatanga basin, Boyarka River (at the confluence between the Levaya and Pravaya Boyarka). Exposure 16, layers 1–6 of the key section. Paks Peninsula (Cape Urdyuk-Khaya), members XI–XII.

Age and distribution. Berriasian stage. *Hectoroceras kochi* zone in northern Siberia.

Subcraspedites (Subcraspedites) plicomphalus (Sowerby)
Plate II, Figure 1; Figure 11, *5*

1822. *Ammonites plicomphalus* J. Sowerby, p. 82, pl. 359.

Holotype. *Ammonites plicomphalus* Sowerby, 1822, p. 82, pl. 359. Berriasian of England, Lincolnshire, Spilsby sandstone.

As mentioned above, two specimens were referred to the species *plicomphalus* on the grounds that the Siberian and English specimens are indistinguishable at the same shell size. As far as the inner and middle whorls are concerned, the description given for *S. (S.) anglicus* n. sp. applies equally to *S. (S.) plicomphalus*, only the adult whorls of these

TABLE 8. Shell dimensions, mm

	Specimen 1 (holotype)			Specimen 2	Specimen 6					
	Plate I, Figure 1			Plate II, Figure 2	Plate IV, Figure 1					
D	52	88	146	34	115	58	149	103	195	65
W. u.	16,5(0.31)	29(0.33)	50(0.34)	9.5(0.28)	40(0.34)	16(0.28)	50(0.33)	34(0.33)	80(0.41)	20(0.30)
L. h.	10(0.38)	30(0.34)	48(0.33)	13(0.40)	38(0.35)	21(0.36)	56(0.39)	39(0.37)	65(0.33)	25(0.30)
I. h.	14(0.27)	18(0.20)	32(0.22)	9(0.27)	21(0.18)	–	–	27(0.26)	43(0.22)	17(0.20)
T	21(0.40)	31.5(0.36)	48(0.33)	12(0.35)	40(0.34)	20(0.34)	48(0.32)	34(0.33)	57(0.29)	22.5(0.34)
C. b.	4.5	7.3	–	2.2	6.2	5.0	–	6.6	–	5.6

Note. Here and in the following, D stands for the shell diameter, W. u. for the width of the umbilicus, L. h. for the lateral height, I. h. for the internal height of the whorl, T for the thickness of the outer whorl, and C. b. for the coefficient of branching of the ribs, i.e. the number of secondary ribs per umbilical rib. The relative (to the diameter) dimensions are given in parentheses.

species showing differentiating characters. For example, at a shell diameter of 88–90 mm *S. (S.) plicomphalus* has a narrower umbilicus (28% instead of 30–33%) and fewer umbilical tubercles (11–12) than *S. (S.) anglicus* (16–18). The suture lines of the two species are practically identical (Figure 11, *5*). Measurements, mm:

	Specimen 3 Plate II, Figure 1	Specimen 3a	Holotype (after Sowerby)
D	90	88	90
W. u.	25(0.28)	25(0.28)	25(0.28)
L. h.	33(0.36)	30(0.34)	33(0.36)
I. h.	19(0.21)	20(0.22)	–
T	33(0.36)	–	–
C. b.	6.0–8.3	5.7–8.4	–

The specimens described do not differ from the holotype in the outer form of the shell, size, width of umbilicus, number and form of umbilical tubercles, or in the form of the whorl section. The only differences may be the presence of one or two constrictions in the Siberian specimens, about which Sowerby says nothing, and the more distinct ribbing, especially in specimen 3a, which was not included in the plates. In specimen 3 (Plate II, Figure 1a) bands can be seen running parallel to the siphuncle and arranged on the left side of the shell exactly as in the holotype.

Occurrence. Khatanga basin, Boyarka River. Exposure 16, layers 5–6 of the key section.

Age and distribution. Berriasian stage, *Hectoroceras kochi* zone of northern Siberia. Berriasian of England. Forms known from Arctic Canada are *Subcraspedites (Subcraspedites)* ex gr. *plicomphalus* Sow. (Jeletzky, 1964; pl. 2, figs. 1a–c; pl. 3, figs. 2a–d). Jeletzky determined these forms as *Tollia (Subcraspedites)* aff. *suprasubditus* (Bogosl.).

Subgenus *Borealites* Klimova, 1969

1969. *Borealites* Klimova, p. 70.

Type species: *Subcraspedites (Borealites) fedorovi* Klimova, 1969, p. 129, pl. I, fig. 1. Berriasian of the Cis-Polar Trans-Urals.

Diagnosis. Shells ranging from small to large, with moderately flattened sides, or else shells slightly inflated. Cross section oval. Sculpture of juvenile whorls consisting of double ribs. Many-branched thickish fascicles of 3–5 secondary ribs on the middle whorls. On the large whorls the ribs are smoothed out in the middle of the sides, while in the part near the umbilicus they form thickenings. Suture line as in *Subcraspedites* s. str.

Species composition. Four species, one occurring in northern Siberia: *S. (B.) suprasubditus* (Bogosl.).

Comparison. Differs from *Subcraspedites* s. str. in the later appearance of many-branched fascicles, the fewer secondary ribs, the greater thickness of these, and in the less massive umbilical tubercles on the adult whorls.

Frebold (1929, pl. 1, figs. 1a, b) showed a specimen under the name *Polyptychites perovalis* Koenen and another specimen (pl. 3, fig. 1) under the name *Polyptychites* cf. *perovalis*; these, in the opinion of Shul'gina and Ershova, should be referred to the new species *Subcraspedites (Borealites) freboldi* n. sp. Schulgina and Erschowa. Also to be placed in the subgenus *Borealites* are the Spitsbergen specimens illustrated on pl. 10, figs. 1, 2, 3 in the work by Bodylevskii and Sokolov (Sokolov and Bodylevsky, 1931) under the name *Polyptychites* aff. *quadrifidus* Koen. and *Polyptychites* sp. A. The Canadian forms shown by Jeletzky (1964) in pl. 1, fig. 2 under the name *Tollia (Subcraspedites)* cf. *stenomphalus* Pavl. and on pl. 3, figs. 1,3 under the name *Tollia (Subcraspedites)* aff. *hoeli* Freb. belong to the same subgenus.

Age and distribution. Berriasian of the Boreal Realm. Northern and Western Siberia, Russian Plain, Canada, Spitsbergen.

Subcraspedites (Borealites) suprasubditus (Bogoslovsky)
Plate V, Figures 1, 2; Plate VI, Figures 3, 4, 5, 6; Figure 10, *5;* Figure 12, *3*

1895. *Olcostephanus suprasubditus* Bogoslovskii, p. 47, pl. 1, figs. 1–4.
1949. *Craspedites suprasubditus* Bodylevskii, pp. 40, 197, pl. 3, figs. 1–2; fig. 19.

Lectotype chosen by the author: *Olcostephanus suprasubditus* Bogoslovskii, 1895, pl. 1, fig. 1, F. N. Chernyshev Central Geological Museum, Leningrad. Village of Shatrishchi on the Oka River. Berriasian stage (Ryazan horizon).

Material. More than thirty well-preserved specimens, as a rule found in round concretions.

Description. Shell of medium thickness (31–38% of the diameter), showing various degrees of lateral flattening, with a rounded venter. The lateral sides descend from the umbilical part to the shell margins. Cross section oval, narrower at the top on juvenile whorls and in the form of a slightly drawn-out oval on the outer whorls (sometimes subrectangular with rounded corners). Whorls moderately increasing in height (height of whorl increasing over half a whorl by a factor of 1.4–1.6). The whorls embrace the preceding ones for 2/3 or 3/4. Umbilicus from moderately narrow to moderately wide, constituting on the average 24–29% of the diameter. Walls of umbilicus gently sloped on the inner whorls, becoming steeper on the adult whorls. Sculpture of young whorls 10–12 mm in diameter consisting of fine, dense double and rare single ribs. Bifurcation of main ribs occurs near the umbilical margin. As the shell grows, the point of branching shifts toward the middle of the sides, the ribs become somewhat coarser, and the number of main ribs decreases. Thus, at shell diameters of 12, 25, 42, 60, 70, 90, and 104 mm the number of main ribs is respectively 32, 30, 32, 28–25, 23–22, 19, and 18. The ribs originate on the umbilical bend not right at the suture, so that the lowêr part of the umbilical wall remains smooth. The primary ribs on the middle and large whorls curve slightly backward as they cross the lower part of the shell, and then slope markedly forward, in this fashion passing over the sides and venter. As the shell grows, the number of accessory ribs increases from two to five, while on the average the coefficient of branching is 3.5–4. A triple branch begins to appear at a size of about 40 mm. At

TABLE 9. Shell dimensions, mm

		Specimen 7	Specimen 10			Specimen 11			Specimen 8	Specimen drawn by Bogoslovskii
		Plate V, Figure 1	Plate VI, Figure 3			Plate VI, Figure 4			Plate V, Figure 2	
D	104	90	70	63	60	42	25	12	66	127
W. u.	30(0.38)	25(0.27)	17(0.24)	18(0.28)	17(0.28)	12(0.28)	5(0.20)	3(0.25)	17(0.25)	0.29
L. h.	41(0.39)	35(0.39)	29(0.40)	25(0.40)	25(0.41)	17.5(0.41)	11(0.44)	5(0.41)	27(0.40)	0.35
I. h.									16(0.24)	0.20
T									25(0.38)	0.31)
C. b.	4.6	3.8	4.1	3.7	3.7	2.0	2.0	1.8–1.9	3.8	4.3 on 1/3 of the last whorl

diameters of 60–70 mm the umbilical ribs take on the form of elongate tubercles, the accessory third rib often becomes attached to the primary rib, but at large diameters the connection between the primary and accessory ribs is broken owing to the obliteration of the ribs in the middle of the lateral surfaces. On the body chamber at a diameter of 90 mm the sculpture is smoothed out (Plate V, Figure 1), but at the same time a specimen 104 mm in size still has distinct tuberous umbilical ribs and poorly marked peripheral ribs, though not on the body chamber but on the phragmocone. The body chamber occupies almost a complete whorl.

In the lectotype the number of secondary ribs reaches 5–7, and at a diameter of 127 mm both the umbilical tubercles and the peripheral ribs are still clearly distinguishable, but not on the body chamber. However, on a body chamber remaining from a large specimen (Bogoslovskii, 1895, pl. 1, fig. 3) the tuberous ribs descend and are smoothed out, and of the secondary ribs barely perceptible traces remain, as is characteristic for typical *Subcraspedites*.

The suture line of the lectotype drawn by Bogoslovskii is damaged and therefore cannot give a correct idea of its pattern. In Figure 10, *5* and Figure 12, *3* we show two suture lines of Siberian specimens of *S. (B.) suprasubditus.* Both lines consist of a fairly broad ventral lobe, a slightly projecting first saddle, a first lateral saddle that is almost twice as long and as wide as the second lateral lobe, and five auxiliary lobes. The second and third auxiliary lobes are almost of the same size. The fifth auxiliary lobe is very small and is situated on the wall of the umbilicus. The suture line either runs in a straight line or descends toward the margin of the umbilicus.

Variability. The species variability consists in the finer or coarser ribs on the inner and middle whorls, the greater or smaller number of accessory ribs, the slightly earlier or later appearance of these ribs, and the type of direction of the suture line.

Comparison and remarks. The species *suprasubditus* occupies an intermediate position in the genus *Subcraspedites*, on the one hand between *Subcraspedites* s. str. (*S. plicomphalus, S. anglicus, S. pressulus,* etc.) and *Subcraspedites (Ronkinites)* and on the other between *Subcraspedites* s. l. and *Surites.* Bogoslovskii (1895) noted a relationship between the species and the Volgian *Craspedites (Craspedites) subditus* Trautsch. It is this triple character of the species that caused different investigators to place it in the genera *Subcraspedites, Craspedites, Surites,* and *Borealites.* We believe that the species *suprasubditus* closely resembles *Subcraspedites* s. str. and belongs to the subgenus *Borealites.*

The Siberian forms scarcely differ from the specimens described by Bogoslovskii.

S. (B.) suprasubditus differs from *S. (S.) pressulus* (Bogosl.) and *S. (S.) subpressulus* (Bogosl.) in the fewer secondary ribs and the slightly different nature of the umbilical ribs. The species *suprasubditus* shows a marked resemblance to *S. (S.) plicomphalus* Sow. and *S. (S.) anglicus* n. sp., differing from them in the coarser ribs on the inner, juvenile whorls, the later appearance of triple ribs, the coarser and less frequent secondary ribs and the absence of strong, distinctly expressed tubercles on the body chamber. It differs further from *S. (S.) anglicus* in the narrower umbilicus. The representatives of *S. (Ronkinites)* also shows very similar characters, especially in the initial stages of growth, to those of the species described. *S. (B.) suprasubditus* differs from *S. (R.) rossicus* n. sp. in the presence of prominent umbilical tubercles on the middle and large whorls and the smoothed-out ribbing on the body chamber. The inner juvenile whorls up to a shell diameter of 40–45 mm scarcely differ from those of representatives of *Surites*, and at this age they are easily confused with these. Still, in general appearance, though not in each individual case, *S. (Borealites) suprasubditus* differs from *Surites* in having a narrower umbilicus, a lesser curvature of the ribs on the venter, and an earlier appearance of trifurcate fascicles. The suture line of *S. (B.) suprasubditus* is extremely similar to that of *S. (S.) anglicus, S. (S.) plicomphalus*, and *Surites*. In the genus *Surites* the closest to the forms of *Subcraspedites* in general and to *S. (B.) suprasubditus* in particular are such species as *Surites (Surites) tzikwinianus* (Bogosl.) and *S. (S.) subtzikwinianus* (Bogosl.), which differ only in the later appearance of the trifurcation, the somewhat coarser secondary ribs, and the marked forward bend of the ribs on the venter. In the period of trifurcate fascicles *S. (B.) suprasubditus* hardly differs from *Surites (Surites) tzikwinianus* and *S. (S.) subtzikwinianus*, although it is true that fourth, fifth, and sixth branches appear in *suprasubditus* with growth of the shell. At any rate, the species named are those extreme elements in the genus *Surites* which cause the boundaries between the two closely related genera *Surites* and *Subcraspedites* to be obliterated. Only the distinct forward bend of the ribs on the venter in *Surites* serves as a reliable sign differentiating this genus from *Subcraspedites*. Where age is concerned, *S. (B.) suprasubditus* (Bogosl.) together with *S. (Pronjaites) bidevexus* (Bogosl.) are older than the other representatives of the genus *Subcraspedites*.

Subgenus *Ronkinites** Schulgina n. subgen.

Type species: *Subcraspedites (Ronkinites) rossicus* Schulgina n. sp. Berriasian of northern Siberia.

Diagnosis. Shell flattened. Cross section from oval to subquadrate. Ribs in early stages double, in later stages triple with an intercalatory fourth branch, slightly elevated in the umbilical part. Small forms, not more than 70–80 mm in diameter. Constrictions are typical.

Species composition. One species known from northern Siberia; the English species *primitivus* is hypothetically placed in *Subcraspedites (Ronkinites)*.

Comparison. Differs from *Subcraspedites* s. str. in the coarser ribs of the inner whorls, the absence of many-branched fascicles on the middle whorls and of distinct umbilical tubercles at the adult stages, in the smaller shell sizes, and in the lesser forward bend of the ribs on the venter.

The subgenus *Ronkinites* differs from *Subcraspedites (Swinnertonia)* n. subgen. in the more involute shell, the absence of projecting umbilical tubercles on the adult whorls, and the fewer secondary ribs.

Remarks. *Subcraspedites (Ronkinites)* is most closely related genetically to *S. (Borealites) suprasubditus*. Having diverged in their development from true *Subcraspedites* (*S.* s. str.), the representatives of the new subgenus have come close to *Surites* in

* Named after the geologist Z. Z. Ronkina.

certain characters through the transitional form *S. (B.) suprasubditus*. Still, such distinguishing characters as the virtual absence of curved ribbing on the venter, the earlier appearance of triple ribs, and the abundance of constrictions do not allow us to place them in *Surites*; on the contrary, they must be considered within *Subcraspedites*, though as highly divergent forms.

It is to the new subgenus that we should preferably refer the English species *S. (R.) primitivus* Swinn., which differs from *S. (R.) rossicus* n. sp. in the denser arrangement of the ribs; the other characters are the same.

Frebold (1929, pl. 2, fig. 1) shows a specimen under the name *Polyptychites* cf. *petschorensis* Bogosl., which resembles most closely *Subcraspedites (Ronkinites) primitivus* Swinn.

Age and distribution. Berriasian of the Boreal Realm. Northern Siberia, England, Spitsbergen.

Subcraspedites (Ronkinites) rossicus Schulgina n. sp.
Plate VI, Figure 2; Plate VII, Figures 1–3; Figure 10, *2*

Holotype. Specimen No. 16/10118. F. N. Chernyshev Central Geological Museum, Leningrad. Plate VII, Figure 3. Boyarka River, Berriasian stage, *Hectoroceras kochi* zone.

Material. Fourteen very well-preserved specimens.

Description. Shell flattened, of medium thickness: 30–34% of the diameter on the middle whorls and 36–37% on the younger ones. Cross section oval in the early stages of growth, subquadrate in the adult stages. Venter rounded, slightly constricted in the central part, but flattened at the end of the adult whorls, so that the form of the cross section also changes. Width of umbilicus increasing with growth of the shell: at shell diameters of around 22–45 mm the width of the umbilicus is 27–29%, and at diameters of 69–70 mm 34%. The whorls moderately increase in height (height of whorl increasing over half one coil by a factor of 1.30–1.36). Juvenile whorls enclose preceding whorls for 4/5–5/6, adult whorls for 2/3. Umbilicus cup-shaped, with sheer walls on the early whorls and with gently sloped walls on the later ones. Lateral flattening occurs with growth of the shell. The sculpture at a diameter of about 10 mm consists of single and double ribs that are scarcely distinguishable, especially on the periphery of the sides. They look more like wrinkles than ribs. At a diameter of 20–25 mm the shell is covered with coarse ribs that bifurcate in the middle of the lateral surface. The ribs originate near the umbilical suture and pass evenly over the whole shell, bending very slightly forward on the venter. The number of main ribs per whorl is 32 at the size indicated. As the shell grows, the number of umbilical ribs somewhat decreases. Double ribs are present up to a diameter of 30–35 mm, after which a triple branch appears which either attaches to the main rib or, more often, remains free. With further growth a fourth branch may appear; this always remains free. There are usually 2–3 quite deep and wide constrictions on the middle whorls.

On the body chamber, which occupies 7/8 of the whorl, the number of constrictions increases to 4–5, destroying the regular pattern of branching of the ribbing. The sculpture on the body chamber consists of prominent, slightly elevated umbilical ribs (22–28) and slightly less prominent accessory ribs, 2–3 per main rib. There is commonly a fourth accessory branch. The constrictions occupy a large area. They become wider at the end than at the beginning of the whorl or at the preceding stages of growth. At the very end of the body chamber the distance between the ribs slightly increases, and single ribs appear.

The suture line of *S. (R.) rossicus* n. sp. has the same form and pattern as that of *S. (S.) anglicus* n. sp. It consists of a fairly broad ventral lobe, a first lateral lobe which is smaller than the ventral lobe, a second lateral lobe which is half as long and as wide as the first lateral lobe, and four auxiliary lobes, the last of which is situated on the umbilical wall. The suture is rectilinear. Measurements, mm:

	Specimen 16 (holotype)		Specimen 9	
	Plate VII, Figure 3a	Plate VII, Figure 3c	Plate VI, Figure 2a	Plate VI, Figure 2b
D	60	44	63	22
W. u.	21(0.35)	13(0.29)	23(0.36)	6(0.27)
L. h.	20.5(0.34)	17(0.39)	22(0.35)	8.5(0.38)
I. h.	14(0.23)	9.5(0.21)	–	5(0.22)
T	20.5(0.34)	16.5(0.37)	–	8(0.36)
C. b.	2.7	2.6	2.7	2.0

Variability. The species variability consists in the degree of lateral flattening in the adult stages of growth, the number of constrictions, the degree of prominence of the ribs on the body chamber, and the number of these ribs.

Comparison and remarks. *S. (Ronkinites) rossicus* is most similar, as already noted, to *S. (Borealites) suprasubditus* (Bogosl.). It does not reach the size attained by *S. (B.) suprasubditus* or *S. (S.) anglicus*. At any rate, the maximum size in our collection is 70–80 mm. The new species differs from *S. (B.) suprasubditus* (Bogosl.) in the less constricted venter, the greater lateral flattening on the middle and adult whorls, the abundance of wide, deep constrictions, the absence of distinct tuberous umbilical ribs on the adult whorls, the smaller number of secondary ribs per main rib, and the lesser curvature of the ribs on the venter.

The feature distinguishing the species from *S. (R.) primitivus* Swinn., which we hypothetically place in the same subgenus, is the sparser and coarser ribs in *S. (S.) rossicus* n. sp.

Occurrence. Khatanga basin, Boyarka River. Exposure 16, layers 4–6 of the key section.

Age and distribution. Berriasian stage, *Hectoroceras kochi* zone and bottom of the *Surites analogus* zone in northern Siberia.

Genus *Surites* Sasonov, 1951

1965. *Bogoslovskia* I. Sasonova, p. 103.

1971. *Subpolyptychites* I. Sasonova, n. gen. (see p. 88).

Type species: *Surites pechorensis* Sasonov, 1951, p. 59, pl. I, Fig. 3. Berriasian of the Russian Plain, village of Poretskoe on the Sura River.

Diagnosis. Shells from flattened to inflated, small and large, reaching 35 cm. Width of umbilicus constituting 30–40% of the shell diameter. Cross section oval, round, transverse-oval, or subquadrate. Venter constricted or smoothly rounded. Ribs double in early stages of growth, primarily double with the appearance of a third branch in the middle stages, triple with a fourth branch, that usually remains free, in the adult stages. The ribs cross the venter with a varying degree (but usually considerable) of forward bending. Suture line consisting of 7 or 8 elements. The line is not very frilled and runs either in a straight line or with a slope downward toward the umbilical margin. The first lateral lobe is the same length as or shorter than the ventral lobe; the second lateral lobe is just over half as large as the first; 4 or 5 auxiliary lobes gradually decrease in size toward the umbilicus.

Species composition. Thirteen species. Almost all the species described for the Russian Plain occur in northern Siberia, and there are new ones, a description of one of which is given below.

Comparison. Related genera are *Paracraspedites* and *Subcraspedites*. The genus *Surites* differs from *Paracraspedites* in the forward bend of the ribs on the venter. It differs from *Subcraspedites* s. l. in the somewhat less densely distributed ribs with a higher point of their branching on the inner, juvenile whorls and in the later appearance of the third accessory rib; *Surites* differs from *Subcraspedites* s. str. in the absence of many-branched fascicles on the middle whorls, the presence of peripheral ribs on the adult whorls, and in the considerable forward bend of the ribs on the venter.

Remarks. The wealth of new genera established by Sazonova made it necessary to reexamine the size of the genus *Surites*. Sazonova placed representatives of *Surites* with an inflated shell, wide umbilicus, and less curved ribs on the venter in the subgenus *Caseyiceras* with the type *C. caseyi*. We also consider the genus *Bogoslovskia* I. Sasonova, 1965 as a subgenus of *Surites* in view of the minor differences from *Surites* s. str. The new genus isolated by Sazonova under the name *Subpolyptychites* (with the type *S. distinctus*) is also included by us in the genus *Surites* because of the close resemblance it bears to this genus.

Hence, at present the genus *Surites* is in any case divided into 3 subgenera: *Surites* s. str., *Surites (Bogoslovskia)*, and *Surites (Caseyiceras)*.

Age and distribution. Berriasian of the Boreal Realm. Russian Plain, Poland, England, Western and northern Siberia, Greenland, Spitsbergen, Canada.

Subgenus *Surites* s. str.

Type species: *Surites (Surites) pechorensis* Sasonov, 1951, p. 59, pl. I, fig. 3. Berriasian of the Russian Plain.

Diagnosis. Shells from small to large, more or less laterally flattened. Umbilicus moderately narrow or moderately wide. Form of cross section oval or subquadrate. Ribs primarily double in the early stages, with third and fourth intercalatory ribs in the adult stages, the latter ribs smoothing out in the middle of the sides but not disappearing on the periphery. The ribs bend forward as they cross the venter.

Species composition. Up to 17 species, 10 of which occur in northern Siberia.

Comparison. Differs from *Surites (Bogoslovskia)* in the wider umbilicus, the later appearance of third ribs, and the different shape of the cross section. Differences from *Surites (Caseyiceras)* are the more flattened shell and the stronger bend of the ribs on the venter.

Age and distribution. Berriasian of the Boreal Realm. England, Russian Plain, Greenland, Spitsbergen, Canada, Western and northern Siberia.

Surites (Surites) spasskensis Nikitin (non Bogoslovsky)
Plate V, Figure 3; Plate IX, Figure 1; Plate X, Figure 1; Plate XI, Figure 1

1888. *Olcostephanus spasskensis* Nikitin, p. 95, pl. I, figs. 9–11.
Non 1895. *Olcostephanus spasskensis* Bogoslovskii, p. 50, pl. II, fig. 1.
1949. *Paracraspedites spasskensis* Bodylevskii, p. 197, pl. LII, fig. 3.

Holotype. *Olcostephanus spasskensis* Nikitin, pl. I, figs. 9–11. Museum of the Leningrad Mining Institute. Near Staraya Ryazan on the Oka River. Berriasian stage.

Material. More than 15 specimens, mostly in an excellent state of preservation.

Description. Shell markedly flattened on the inner and outer whorls, less so on the middle whorls. Maximum thickness in the umbilical part. Sides descending in the direction of the venter. Whorls moderately involute, covering about 1/3 of the preceding ones. Whorl section oval, slightly narrower at the top, becoming a little wider with growth of the shell. Umbilicus cup-shaped, moderately wide, occupying 25–33% of the diameter. Sculpture of inner and middle whorls up to a diameter of 50–60 mm consisting of bipartite ribs, 26–30 per whorl, with the point of branching situated in the middle of the sides or a little higher. As an anomaly triple ribs sometimes appear earlier than at the indicated sizes (50–60 mm). As the shell grows, a third rib appears which may attach itself to the main rib or remain free. In large specimens the umbilical ribs form elongate tubercles (Plates X, XI); in the middle of the sides the ribs smooth out; the outer ribs are preserved even on the largest specimens known, in which to each main tuberous rib there are 3–4 accessory ribs that practically lose their connections with the main ribs (Plate XI, Figure 1)

Measurements, mm:

	Specimen 19 Plate V, Figure 3	Specimen 20 Plate IX, Figure 1a		
D	51	42	36	185
W. u.	13(0.25)	14(0.33)	11(0.30)	67(0.37)
L. h.	20(0.40)	–	15(0.41)	67(0.37)
I. h.	–	14(0.33)	–	–
T	–	17(39)	–	–
C. b.	2.1	2.0	2.1	4.0

The suture line of *Surites (Surites) spasskensis* is identical to that of the other representatives of this genus and of many forms of *Subcraspedites* (in particular, *S. suprasubditus*). It is clearly visible in specimen 20, pictured in Plate IX, Figure 1c.

Variability. The species variability is manifested in the somewhat earlier or later appearance of the third rib and in the variable width of the umbilicus (in the limits of about 10%).

Comparison. The most similar form is a specimen illustrated by Bogoslovskii (1895, pl. II, fig. 1) under the name *spasskensis*. However, there are distinguishing signs, obliging us to give Bogoslovskii's specimen the new name *Surites (Surites) spasskensoides* Schulgina n. sp. The differences are as follows: *S. (S.) spasskensoides* has finer and more acute ribs that are more densely arranged; the curve of the ribs on the periphery of the sides and on the venter is not as marked as in *spasskensis*; the venter in the holotype of *spasskensis* is more compressed than in *spasskensoides*.

Forms related to *spasskensis* are the specimens described by Sazonova (1951) under the name *Surites pechorensis* Sason. (type species) and *S. poreckoensis* Sason. There are no differences between the last two species, and they should be united. Furthermore, Bodylevskii considered that they are identical to *S. spasskensis*. In fact, *S. (S.) pechorensis* Sason. [=*S. (S.) poreckoensis* Sason.] is very similar to *S. (S.) spasskensis*, although in the former (as in the form named *poreckoensis*) the shell is a little thicker, the ribs are slightly coarser, and they are more sparsely distributed, whereas at a shell diameter of 50–60 mm *S. (S.) spasskensis* Nik. has 28–32 main ribs, *S. (S.) pechorensis* Sason. has 20–22. Apart from this, third branches constantly appear at a shell diameter of about 55 mm in *pechorensis*, while a third branch appears only sporadically at these dimensions in *spasskensis*.

Occurrence. Khatanga basin, Boyarka River. Exposure 15, layers 1–3; exposure 16, layers 1–2 (collections of 1964). Paks Peninsula (Cape Urdyuk-Khaya), exposure 67 (collections of 1958).

Age and distribution. Berriasian stage of the Russian Plain, *Surites spasskensis* zone. Lower strata of the *Hectoroceras kochi* zone of the Berriasian stage in northern Siberia.

Surites (Surites) subanalogus Schulgina n. sp.
Plate IX, Figure 2; Plate XII, Figures 1–3; Figure 10, *9*

? 1895. *Olcostephanus analogus* Bogoslovskii, p. 66, pl. III, fig. 6.

Holotype. Specimen 26/10118, F. N Chernyshev Central Geological Museum, Leningrad. Plate XII, Figure 3. Boyarka River. Berriasian stage. *Surites analogus* zone.

Material. More than 20 excellently preserved specimens.

Description. Shell of medium thickness, 34–40% of the diameter. Sides moderately convex. Venter smoothly rounded or slightly flattened. Cross section oval or subquadrate. Whorls slowly increasing in height (height increasing over half a whorl by a factor of 1.32). They are moderately convolute, covering 2/3 of the preceding whorls. Umbilicus changing from moderately wide to wide as the shell grows; it occupies 30–40% of the diameter and is shallow, cup-shaped. The thickness of the shell is either greater than its width (lateral height) or equal to the width.

The sculpture hardly changes with development. On the young whorls it consists of bipartite, relatively fine but prominent ribs with the point of branching situated above the middle of the sides or in the middle of the lateral surface. There are 27–29 umbilical ribs at a diameter of 20 mm. On the middle and large whorls the same bipartite ribs are present, but they are coarser and higher. The number of umbilical ribs increases; there are 32–38 at a diameter of 50–90 mm. The ribs are sparsely arranged, prominent, bipartite, with the point of branching situated above the middle of the sides. They begin on the upper part of the umbilical wall and slope slightly forward as they cross the lateral surface; the curvature increases in the middle of the venter. In large specimens a third rib appears which as a rule remains free. There are sometimes 1–2 constrictions per whorl. The body chamber occupies almost a complete whorl. The sculpture on it does not change relative to the phragmocone. On the whole the species is characterized by almost exclusively bipartite branching of the ribs at all stages of growth and their sparse distribution.

As seen in Figure 10, *9*, the suture line of *S. (S.) subanalogus* hardly differs from that of *S. (S.) spasskensis* and *Subcraspedites (Subcraspedites)* ex gr. *plicomphalus*. It consists of 7 or 8 elements, 4 or 5 of which are auxiliary lobes. The first lateral lobe is the same length as the ventral lobe, the second just over half as long as the first. The first and second saddles are wider than the lobes. As the suture crosses the lateral surface it slopes slightly toward the umbilical margin.

Variability. Individual deviations in the species are minor, expressed just in a more rounded or more quadrate whorl section and in the slightly varying coarseness of the ribs.

Comparison and remarks. The new species is very similar to *Surites (Surites) analogus* (Bogosl.). Differences are the thicker shell and the lower point of branching of the ribs in the latter species. It is very difficult to compare the admirable material, consisting of a large number of specimens, with the fragments of the lectotype of *S. (S.) subanalogus,* in which not all the characters can be traced.

Apparently belonging to the new species is the form illustrated by Bogoslovskii (1895) in pl. III, fig. 6, which the author considered to be a variety of *analogus.* This variety, like *S. (S.) subanalogus,* is more laterally flattened.

Our collection contains a number of specimens that combine characters indicated 1) for the above-mentioned variety, 2) for the lectotype of *S. (S.) analogus,* and 3) for the newly described species.

When an investigator has an abundance of material at his disposal, it is much harder for him to identify species and subspecies than if his material is scant, because the boundaries between related forms are obliterated and melt into each other, and it becomes tempting to unite forms previously assigned to different species into larger groups. Still, the criterion for distinguishing *S. (S.) analogus* and *S. (S.) subanalogus* is the thickness of the shell (but again with the presence of transitional forms). Thus, the specimens shown in Plate XIII, Figures 1 and 2 are placed by us in *S. (S.)* ex gr. *analogus* (Bogosl.). They are thicker than *S. (S.) subanalgous* n. sp. and not as thick as *S. (S.) analogus.*

The collection includes fragments of ammonites (not shown in the plates) that are

TABLE 10. Shell dimensions, mm

	Specimen 57		Specimen 21 Plate IX, Figure 2	Specimen 26 (holotype) Plate XII, Figure 3	Specimen 38	Specimen 24 Plate XII, Figure 1	Specimen 46	Specimen 48	Specimen 49
D	20	61	53	56	66	70	90	78	62
W. u.	6(0.30)	25(0.40)	18.5(0.35)	21(0.38)	23(0.35)	26(0.37)	36(0.40)	29(0.37)	21(0.34)
L. h.	8(0.40)	21(0.34)	19.5(0.36)	20(0.36)	–	24(0.34)	29(0.32)	29(0.37)	23(0.37)
I. h.	–	–	14(0.26)	14(0.24)	–	–	–	–	–
T	7.5(0.37)	–	21(0.40)	22(0.40)	–	24(0.34)	–	25(0.32)	23.5(0.37)
C. b.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.0

determined as *S. (S.) analogus* (Bogosl.) due to the thick shell and sparse ribbing.

This form and similar specimens are widely distributed in the Ryazan horizon of the Russian Plain and occur plentifully in northern Siberia. In Siberia they occupy a narrow stratigraphic horizon situated between beds with *Hectoroceras kochi, Subcraspedites* spp. (below) and *Bojarkia mesezhnikowi* and *Tollia* spp. (above). We therefore isolate a special zone *Surites analogus*, at the bottom of which there are occasional representatives of *Subcraspedites* s. str.

Similar to *S. (S.) analogus* and *S. (S.) subanalogus* are the species *S. (S.) kozakowianus* (Bogosl.) and *S. (S.) clementianus* (Bogosl.); in fact, they are easily confused in the early and middle stages of growth. They are also readily mistaken in the early stages for *S. (S.) spasskensis* (Nik.) Adult stages of *S. (S.) analogus* and *subanalogus* differ from *S. (S.) kozakowianus* in having fewer third ribs and from *S. (S.) clementianus* in the finer, weaker, and more numerous ribs (in *clementianus* the number of main ribs at a diameter of 65–70 mm does not exceed 20–22, while in *analogus* and *subanalogus* at the same diameter there are 30–38 main ribs).

Occurrence. Khatanga basin, Boyarka River, exposure 16, layers 6–8 (collection of 1964); Kheta River, exposure 21, layer 4 (collections of 1961); Maimecha River, exposure 43, layer 3 (collection of 1964); Paks Peninsula (Cape Urdyuk-Khaya), exposure 67 (collections of 1958).

Age and distribution. Berriasian stage. Ryazan horizon of the Russian Plain. *Surites analogus* zone of northern Siberia.

Genus *Paracraspedites* Swinnerton, 1934

Type species: *Paracraspedites stenomphaloides* Swinnerton, 1934, p. 38, pl. IV, figs. 1a,b. Berriasian of England, Lincolnshire, Spilsby sandstone.

Diagnosis. According to Swinnerton, "this genus includes several species which differ from *Subcraspedites* in having coarse, moderately widely spaced lateral ribs on the inner as well as the outer whorls. The spacing does not show any marked or rapid increase during development. All peripheral ribs arise as branches of the main ribs, and are well defined both by greater prominence and by deeper furrows than in *Subcraspedites*. Intermediaries are absent" (judging from the photograph, they are present in the holotype). "Ribs cross the venter without a distinct forward bend."

To this diagnosis it should be added that the shell is laterally compressed, and the umbilicus is wide and cup-shaped. The cross section of the holotype was not given, but judging from the Siberian specimens, it is oval on the inner whorls and subrectangular on the adult whorls. Branching of the ribs takes place above the middle of the lateral side. The accessory ribs are set quite far apart, and between them are intermediate branches.

Species composition. Three species described from England, one English species *(P. stenomphaloides)* known from Siberia, and one new species, *Paracraspedites olenekensis* Erschowa n. sp. (in litt.).

Comparison and remarks. As already mentioned, the most closely related genus is *Surites*, the representatives of which were for a long time considered to belong to the genus *Paracraspedites. Paracraspedites* differs from *Surites* in that the ribs do not curve on the venter.

Age and distribution. In northern Siberia forms of *Paracraspedites* have been found in Berriasian sediments, in the *Chetaites sibiricus* and *Surites analogus* zones. In strata that he referred to the Lower Cretaceous (from the Spilsby sandstones) Swinnerton reported finding in the same place *Subcraspedites* cf. *precristatus* Swinn., *S.* cf. *subundulatus* Swinn., *S. preplicomphalus* Swinn., *Paracraspedites stenomphaloides* Swinn., *P. bifurcatus* Swinn., ? *P. trifurcatus* Swinn., and *Paracraspedites stenomphaloides* Swinn. (= *Polyptychites hoeli* Freb.), known from Spitsbergen (Frebold, 1929, pl. 2, fig. 3).

Paracraspedites stenomphaloides Swinnerton
Plate VII, Figure 1

1934. *Paracraspedites stenomphaloides* Swinnerton, p. 38, pl. IV, figs. 1a and?1b. British Museum (Natural History), London. Lincolnshire, Spilsby sandstone.

Material. Two specimens.

Description. Shell laterally compressed, of medium thickness, constituting 35% of the diameter. Venter smoothly rounded. Cross section oval on the early whorls, subrectangular on the later whorls. Umbilicus small, cup-shaped, wide, occupying on the average 36% of the diameter. Ribs originating on the umbilical wall, crossing the sides with a slight forward inclination. The ribs are strong, projecting. In the middle of the sides, or, more often, above the middle of the lateral surface, they bifurcate or trifurcate. The third rib may attach to the main rib or remain free. Unfortunately, the inner, juvenile whorls and large whorls with the body chamber are unknown to the author, so that a characterization of the species may be given only for the middle whorls, with a diameter of 69–77 mm. At this size the number of main ribs is 25–30 and the coefficient of branching on the average 2.3–2.6. Measurements, mm:

	Specimen 17 Plate VII, Figure 1	Specimen 18* Plate VIII, Figure 2	Specimen of *Paracraspedites stenomphaloides* (holotype) from the photograph in Plate IV, Figure 1a
D	77	108	69
W. u.	28(0.36)	43(0.39)	25(0.36)
L. h.	29(0.37)	39(0.36)	25.5(0.37)
I. h.	–	–	–
T	27(0.35)	–	–
C. b.	2.4–2.6	2.3	2.3

* Specimen 18/10118 is determined as *Paracraspedites* cf. *stenomphaloides* Swinn.

As noted above, the suture line is unknown. In describing the species, Swinnerton writes (p. 38): "The suture line is imperfectly known. That shown in fig. 1b is taken from another specimen of the same species." In the first place, it does not belong to the holotype, and secondly, the scraps of line shown in fig. 1b do not give any idea of what it should look like. We are to assume that the suture line is still unknown for *Paracraspedites*.

Variability. This is impossible to judge from two or three specimens.

Comparison and remarks. Swinnerton considered the closest species to be *stenomphalus*, from which, in his opinion, *stenomphaloides* differs in the more strongly projecting peripheral ribs and in the absence of curvature of the ribs on the venter. We may add that *stenomphalus*, assigned by the author to *Surites*, differs from *stenomphaloides* in the more sloping sides and the narrower umbilicus.

Specimen No. 18/10118, which is represented by an imprint of a shell, belongs to *Paracraspedites* cf. *stenomphaloides*. A cast from this imprint is shown in Plate VIII, Figure 2. The venter is not preserved, and therefore we cannot be quite sure that it does belong to this species.

Occurrence. Khatanga basin, Kheta River, exposure 21, layer 2 (collections of 1961); Maimecha River, exposure 48, layer 4 (collections of 1964).

Age and distribution. Berriasian stage of England and Spitsbergen. *Chetaites sibiricus* and *Surites analogus* zones of northern Siberia.

Genus *Praetollia* Spath, 1952

Type species: *Praetollia maynci* Spath, 1952, p. 12, pl. III, fig. 2. Berriasian of eastern Greenland.

Diagnosis (after Spath). Fairly involute platycones with slightly convex whorls, with faintly rounded umbilical wall and more or less narrowly curved venter. Lateral ribs gently sigmoidal, mainly dividing on the juvenile whorls; later the ribs become triple or intercalatory secondary ribs appear, so that in the more coarsely ribbed forms there are about 17 secondary ribs to 5 primaries. In one form the ribs remain double or simple. In passing over the venter the ribs form a small sinus that is directed forward. The suture line is simple, with seven saddles and lobes; it is elevated in the direction of the umbilicus.

All the specimens of *Praetollia* in Spath's plates are crushed and flattened, so that nothing can be said about the form of the cross section or the thickness of the shell; all the forms are shown only in lateral view. The state of preservation of the specimens collected on Paks Peninsula (Cape Urdyuk-Khaya) is similar to that of the Greenland forms, since they were all found in clays in a very flattened state. Only from one concretion was it possible to extract a specimen (Plate VI, Figure 1) with partly preserved venter, and therefore we should add to the diagnosis of the genus that the form of the cross section is oval but subquadrate at the end of the body chamber. The venter is smoothly rounded, flatter at the end of the adult whorl. The ribs do not bend forward as they cross the sides and venter.

Species composition. Two species are known from eastern Greenland. One of these occurs in northern Siberia.

Comparison. The genus *Praetollia* has its closest genetic ties with *Subcraspedites*; it is possibly no less closely related to the Volgian *Craspedites (Taimyroceras)*. Unfortunately, owing to the poor state of the *Praetollia* fossils, it is not possible to trace the course of change of all the characters with development.

Praetollia differs from *Subcraspedites* in the more involute shell and the absence of forward curving of the ribs on the venter. It differs further from *Subcraspedites* s. str. in the absence of many-branched fascicles and in the lesser elevation of the umbilical ribs in the middle stages of growth. Large individuals of *Praetollia* are unknown. The maximum shell size recorded is about 70 mm.

The genus differs from *Craspedites (Taimyroceras)* in not having smoothed ribs on the venter and in the greater complexity of the suture line.

To a lesser extent the representatives of *Praetollia* resemble *Tollia*. This resemblance is very remote, and there would be no point in dwelling on it if certain authors had not confused these two genera. *Praetollia* is distinguished from *Tollia* by the form of the shell and its cross section, by the bipartite ribs of the inner whorls, by the absence of forward-curving ribs on the venter, and by the lesser crimping of the suture line.

Remarks. From the illustration of *Praetollia maynci* var. *contigua* in Spath's pl. 2, fig. 1 (the largest imprint) and in pl. 3, fig. 1 (Spath, 1952) the impression is gained that these forms are closer to *Subcraspedites* than to *Praetollia* and should preferably be placed in the first genus. At any rate, a curve of the ribs on the outer margin of the shell is not characteristic for the holotype or the other specimens of *Praetollia* illustrated by Spath.

Age and distribution. Berriasian of eastern Greenland. *Chetaites sibiricus* and *Hectoroceras kochi* (lower part) zones of northern Siberia. There are reports (Dembowska, 1964; Marek, 1967) that *Praetollia* is present in the Berriasian of Poland; the state of the specimens, however, does not allow us to specify their generic affiliation.

Praetollia maynci Spath
Plate VI, Figure 1; Figure 12, *5*

1952. *Praetollia naynci* Spath, p. 12, pl. I, figs. 3, 4; pl. II, fig. 2; pl. III, figs. 2, 4, 5; pl. IV, figs. 5–7.

Holotype. *Praetollia maynci* Spath, 1952, pl. III, fig. 2. British Museum (Natural History). Maync's collection, England. From Lindeman Fjord on Wollaston Peninsula (eastern Greenland).

Material. Ten incomplete, deformed specimens. One very well-preserved specimen from a concretion.

Description. The specimen shown in Plate VI, Figure 1 is indistinguishable from the Greenland holotype. The identical nature of the ribbing (at first double ribs, with third intercalatory ribs appearing at the end of the whorl), the number of ribs and their almost rectilinear direction, plus the involuteness of the shell enable us to identify the Siberian specimen with the species *Praetollia maynci*.

The suture lines of the species presented by Spath are also identical to the suture of the Siberian specimen (Figure 10, *5*). Since the specimen is somewhat damaged and the umbilicus could not be freed entirely of the rock, the measurements given are approximate: D = 63 mm, W. u. = 15 mm (0.24), L. h. = 26 mm (0.41), C.b. = 2.3. The body chamber occupies about 5/6 of a whorl, and the ornament on it is the same as that on the phragmocone.

Due to the incompleteness of the specimens, the species variability could not be determined.

Comparison and remarks. Similar forms are the Greenland specimens that Spath named *Praetollia maynci* var. *communis, P. maynci* var. *contigua, P. maynci* var. *dispar,* and *P. aberrans*. The last species is represented by a poorly preserved specimen; it essentially does not differ from *P. maynci*.

P. maynci var. *communis* differs from the type in having thinner and more numerous ribs with almost exclusive bifurcation. *P. maynci* var. *contigua* would be better included within the type species *P. maynci*. These forms are pictured in Spath's pl. I, fig. 2 and pl. II, fig. 1 (the upper drawing is of a smaller specimen). As already mentioned, the other two specimens designated var. *contigua* (pl. II, and the specimen at the bottom in pl. III, fig. 1) (Spath, 1952) belong rather to *Subcraspedites*. *Praetollia maynci* var. *dispar* is represented by one badly preserved incomplete specimen, so that it is impossible to tell to which species or subspecies it belongs.

Occurrence. Paks Peninsula (Cape Urdyuk-Khaya), member IX, exposure 33, layers 18–22; exposure 32, layers 11–15; member X, exposure 33, layers 23–27; exposure 32, layers 16–18; member XII, exposure 33, layer 29; exposure 31, layers 4–5. Collections of 1967.

Age and distribution. Berriasian stage of eastern Greenland. *Chetaites sibiricus* zone and the lower part of the *Hectoroceras kochi* zone of northern Siberia.

Genus *Bojarkia* Schulgina, 1969

Type species: *Bojarkia mesezhnikowi* Schulgina, 1969, p. 42, pl. I, fig. 3. Berriasian stage. Khatanga basin, Boyarka River.

Diagnosis. Shells more or less laterally compressed, of medium thickness. Venter rounded with a varying degree of constriction in the middle. Umbilicus moderately wide. On the juvenile whorls the cross section is oval, while on the adult whorls it is subrectangular or in the form of a narrow-topped oval.

The sculpture on the inner whorls consists of numerous fine, prominent ribs that bifurcate and trifurcate. Double or triple ribs predominate on the middle whorls. The number of accessory ribs increases to 4–7 on large whorls about 100 mm in diameter. Very characteristic for this genus are high, acute, prominent ribs; on internal molds these are more weakly expressed. The ribs bend forward strongly in the middle of the venter. On whorls with a diameter of more than 100 mm the ribs are smoothed out in the middle of the sides and all that remain are umbilical thickenings and peripheral ribs; on the body chamber the ribbing disappears altogether, and the shell becomes almost smooth, with just barely perceptible peripheral ribs.

The suture line is constructed according to the type characteristic for the family Craspeditidae, resembling most closely the suture of *Surites spasskensis* Nik.

Species composition. Two species in northern Siberia and one species in eastern Greenland.

Comparison. Related genera are *Surites* and *Tollia*. The forms described are similar to *Surites* in the nature of the ribbing on the middle whorls and in the strong bend of the ribs in the middle of the venter. *Bojarkia* differs from *Surites* in the sculpture on the juvenile whorls and in the ribbing on the large outer whorls. The inner whorls have numerous fine, prominent double and triple ribs; in *Surites* the inner whorls show only double, coarser, widely spaced ribs. The outer whorls of *Bojarkia* have more prominent, higher ribs than *Surites,* in which the branches of the ribs are set farther apart. In addition, the number of accessory ribs in *Bojarkia* may reach 4–6, even 7 in some cases; this is not observed in *Surites.*

Linking the new forms with *Tollia* is the type of ornament on the inner whorls, particularly the presence of numerous fine double and triple ribs (they are also double and triple in *Tollia*) and the similar sculpture of the outer whorls. A distinguishing sign is the sculpture of the middle whorls with ribs that are mostly double and very prominent their whole length in *Bojarkia*, whereas in *Tollia* there are at least 3–4 accessory ribs, and these become obliterated in the middle of the lateral surface. The cross section of *Tollia* is more drawn out in height, and the shell is more involute.

Remarks. The species *Perisphinctes payeri* Toula (1870), which Spath (1947) referred to the genus *Tollia,* should be placed in *Bojarkia*. In the general form of the shell and the type of ribbing on the outer whorls *payeri* resembles *Bojarkia* much more than *Tollia.*

In view of the fact that the species *Bojarkia mesezhnikowi* Schulg. was described earlier (Shul'gina, 1969), only a drawing of this species is given here.

Age and distribution. Berriasian stage. *Bojarkia mesezhnikowi* zone of northern Siberia.

*Bojarkia bodylevskii** Schulgina n. sp.
Plate XVI, Figures 1, 2

Holotype. Specimen 35/10118. F. N. Chernyshev Central Geological Museum, Leningrad. Plate XVI, Figure 1. Boyarka River. Berriasian stage. *Bojarkia mesezhnikowi* zone.

Material. Two incompletely preserved specimens.

Description. Shells flattened, laterally compressed, of medium thickness (30% of the diameter). Venter constricted. Sides of shell quite strongly sloped in the direction of the venter. Cross section oval, drawn out in height. Umbilicus moderately wide, occupying 28% of the diameter, with fairly steep walls, but shallow. Sculpture of inner whorls

* Named after V. I. Bodylevskii.

represented by small, fine double and triple ribs that branch out in the middle of the sides. The only ornament on the middle whorls is of double ribs with a point of branching situated in the middle of the lateral surface. The ribs are coarse and uniformly prominent all along; they slope forward slightly as they cross the lateral surface. They bend forward strongly on crossing the venter, especially its middle part. On the large, adult whorls the ribs begin on the umbilical wall, slope forward as they cross the sides and bend even more strongly forward over the venter. The distance between the ribs becomes slightly larger and the ribs themselves become thicker. A third intermediary usually becomes united with the main rib. At the end of the adult whorls the ribs are smoothed out in the middle of the lateral surface and the connection between the elevated umbilical ribs and the peripheral ribs is broken.

The number of main ribs is more or less uniform (32–34) at shell diameters of from 70 to 110 mm, but the coefficient of branching increases from 2.0 to 2.8. One or two fairly wide yet shallow constrictions are observed per whorl.

The measurements of the two incomplete specimens are as follows: D = 109 mm, W. u. = 30 mm (0.28), L. h. = 45 mm (0.33), I. h. = ?, T = 33 mm (0.30); D = 79 mm, W. u. = ?, L. h. = 29 mm (0.36), I. h. = about 22 mm (0.27), T = about 25 mm (0.31).

The suture line is not preserved. Species variability impossible to determine from two specimens.

Comparison. The most closely related species is *B. mesezhnikowi* Schulg., from which the specimens described differ in the more constricted venter, the higher whorl section, the later appearance of tripartite ribs, and the coarser ribs, mainly on the large whorls.

The middle whorls of *B. bodylevskii* are surprisingly similar to those of representatives of *Surites*, and they may be mistaken for these if the material is superficially studied or poorly preserved. All the same, in the middle stages of development *B. bodylevskii* differs from *Surites* in the more constricted venter and the higher cross section. These signs, which distinguish this species from *Surites*, are present in *Tollia* but the difference between *B. bodylevskii* and *Tollia* is that there are bifurcate ribs in the middle stages of growth and prominent ribs (not obliterated in the middle of the sides) at stages when in *Tollia* the obliteration of ribs is marked (at diameters of 75–80 mm).

Remarks. In a study of Lower Cretaceous deposits on the Menya River (a tributary of the Sura) in the Middle Volga area in the summer of 1969 we came across ammonites that are very similar to *Bojarkia bodylevskii*.

Occurrence. Khatanga basin. Boyarka River, exposure 17, layers 8–9 (collections of 1964).

Age and distribution. Berriasian stage. *Bojarkia mesezhnikowi* zone of northern Siberia. Upper part of the Ryazan horizon or bottom of the Valanginian of the Russian Plain.

Bojarkia sp. juv. (cf. *payeri* Toula)

In Plate XV, Figure 3a, 3b we show a small specimen, 21 mm in diameter, that differs from specimens of *Bojarkia* of the same size in the collection in that it has finer and more numerous costules. There are about 32 umbilical costules and up to 3–4 secondary ribs per main rib (c. b. = 3.5–4.0). Neale (1962, pl. 40, fig. 5) presents just as small a specimen under the name *Tollia* cf. *payeri*, which is almost indistinguishable from the Siberian form (c. b. around 3.4–3.6). Judging from the density of distribution of the ribs, our form is similar to the species *payeri* Toula, described from eastern Greenland.

Occurrence. Paks Peninsula (Cape Urdyuk-Khaya), exposure 66 (collections of 1968).

Age and distribution. Berriasian stage, *Bojarkia mesezhnikowi* zone of northern Siberia.

Subfamily Tolliinae Spath, 1952

Genus *Tollia* Pavlow, 1913

Type species: *Tollia tolli* Pavlow, 1913, p. 39, pl. 12, fig. 2. Berriasian and lower Valanginian of northern Siberia (Anabar River).

Pavlow did not establish a type species when he instituted the genus *Tollia.* Following Krymgol'ts (1958), Voronets (1962), and Neale (1962), we take the species *Tollia tolli* to be the type.

Description. Shell laterally flattened, of medium thickness, involute, with a moderately narrow and fairly deep umbilicus that averages 20–25% of the shell diameter. The width of the umbilicus hardly changes as the shell grows. Venter rounded, sometimes slightly constricted in the central part. Form of cross section oval, drawn out in height, sometimes narrower toward the top, or else subrectangular. Sculpture of inner whorls consisting of fine double and triple costules that branch out in the middle of the sides or slightly lower down. On the middle whorls the ribs are double and triple with a fourth branch (more rarely a fifth), the third branch often uniting with the main rib either posteriorly or anteriorly, while the fourth and fifth remain free intermediaries. In the middle of the sides, in the place where they branch, the ribs smooth out almost to obliteration; they remain clearly expressed in the umbilical part, on the periphery of the sides, and on the venter, where they form an arch with the convexity forward. On the adult whorls the ribs practically disappear; all that may remain are barely perceptible umbilical tubercles and ribs along the margins of the sides and on the venter. Otherwise all ornament is obliterated. Bidichotomous ribs are sometimes observed. There are many constrictions, 2–5 per whorl. The suture line, as Pavlow writes, projects markedly forward with two saddles. The lobes are more or less of uniform width, with adjacent saddles, but they may be wider or narrower than the saddles (Figure 10, *8;* Figure 11, *1, 4,* Figure 12, *4, 11, 12*). The ventral lobe may be slightly longer than the first lateral lobe or the same length (rarely just a little shorter). Four auxiliary lobes, gradually decreasing in size, descend slightly toward the umbilical margin. A fifth small lobe is situated on the umbilical wall.

Species composition. Thirteen species, 8 of which are described from northern Siberia, two from England, one from eastern Greenland, and one from Novaya Zemlya.*

* [Either the author means 12 species or else she does not state the origin of the thirteenth.]

Comparison. Related genera are *Bojarkia* and *Neotollia.* There is some similarity, especially on the middle and large whorls, to *Subcraspedites.*

Tollia differs from *Bojarkia* in the larger number of accessory ribs corresponding to the main ribs in the middle stages of growth, in the more involute shell, in the narrower, high cross section of the whorls, and in the more complicated suture line.

It is distinguished from *Neotollia* as a rule by the more flattened sides, the greater evoluteness of the shell, the different whorl section (higher and narrower), and, most important, by the different ornament on the young whorls (in *Neotollia* there are only double ribs in the early stages, while in *Tollia* there are both double and triple ribs).

Tollia generally differs from *Subcraspedites* in having a more involute shell, a narrower whorl section, triple ribs in the juvenile stages (double in *Subcraspedites*), and a strong forward bend of the ribs on the venter. Large adult whorls of *Subcraspedites* s. str. show clearly expressed umbilical tubercles when the external ribs have almost disappeared; in *Tollia* umbilical tubercles are weak or absent, and the external ribs are retained longer.

Remarks. Among *Tollia, Bojarkia,* and *Neotollia* on the one hand and *Subcraspedites* and *Tollia* on the other there are a number of forms that hover on the borderline between contiguous groups. It is particularly easy to be confused in the case of specimens representing the middle stages of growth. Young and adult forms are easier to distinguish. However, the suture lines of all the groups mentioned are very similar. In eastern Greenland the species *groenlandicus* was described by Spath (1936) under the name *Subcraspedites groenlandicus* Spath, but due to the presence of double and triple ribs on the inner whorls and the form of the shell, we are obliged to place this species in the genus *Tollia.* On Novaya Zemlya, apart from the species *Tollia* cf. *tolli* Pavl. (Bodylevskii, 1967), there is the species *sosnovskii,* described by Sokolov as *Olcostephanus (Nikitinoceras) sosnovskii* Sok. Bodylevskii (1967) placed this species in the genus *Temnoptychites* with a question mark. However, the presence of ribs on the venter rules out the possibility of referring this species to *Temnoptychites.* Judging from the drawing and description (Sokolov, 1914, pp. 70–73, pl. 2, fig. 2), the species belongs either to *Tollia* or to *Homolsomites.*

Age and distribution. Berriasian and lower Valanginian of the Boreal Realm. Northern and Western Siberia, Novaya Zemlya, eastern Greenland, Arctic Canada, Spitsbergen, England, West Germany, Northeast of the USSR.

Tollia tolli Pavlow

Plate V, Figure 4; Plate XVII, Figure 1; Plate XVIII, Figure 2; Figure 10, *8;*
Figure 11, *1, 4;* Figure 12, *4, 11, 12*

1913. *Tollia tolli* Pavlow, p. 39, pl. 12, figs. 1,2.

Lectotype chosen by the author: *Tollia tolli* Pavlow, 1913, pl. 12, fig. 2. Karpinskii Museum, Leningrad. Anabar River in northern Siberia. It is not clear from what deposits the lectotype derives, Berriasian or lower Valanginian?

Material. More than 20 well-preserved specimens.

Description. Shell laterally flattened, involute, of medium thickness (30–34% of the diameter). Venter smoothly rounded. Cross section of inner whorls in the form of a high oval that is sometimes narrower on top. On the outer whorls the oval is broader, especially at the base. The whorls increase in height quite rapidly (by a factor of 1.57–1.60 over half a coil) and they are very involute, enclosing 3/4–4/5 of the preceding whorl. Umbilicus moderately narrow, deep, stepped, funnel-shaped.

The sculpture on the inner, small whorls consists of fine double and triple costules that branch out more or less in the middle of the sides. At shell sizes of 20–25 mm the number of umbilical ribs reaches 30–32 and the coefficient of branching is 2.5–2.7. At sizes of 40–50 mm there are 28–30 umbilical ribs and the coefficient of branching is 2.8–3.4, while at 80–100 mm these ribs number 26–28 and the c. b. = 4.0–4.2. The ribs begin on the umbilical wall; they form a small arch with the convexity backward as they cross the margin of the umbilicus. On crossing the lateral surface they slope forward, the slope increasing over the venter, where they form a forward-bent arch. Up to a diameter of 45–50 mm the ribs are of uniform strength all along. The third, intercalatory rib may attach itself to the main rib posteriorly or anteriorly, but it sometimes remains free. As the shell develops, the ribs become weaker in the middle of the sides (at sizes of 50–70 mm) and eventually disappear altogether (at sizes of around 100 mm). The umbilical and peripheral ribs remain. At larger shell diameters (120–150 mm) the ornament disappears completely both on the phragmocone and on the body chamber. Barely perceptible ribs on the venter and faintly visible umbilical thickenings and constrictions may remain. On the inner whorls there are 1–2 constrictions per whorl. The body chamber occupies almost a complete whorl.

The suture line varies in complexity depending on the size of the shell. It consists of a fairly wide ventral lobe, a first lateral lobe, which is almost the same size as the ventral lobe (either shorter than it or just a little longer), a second lateral lobe that is half as large as the first, and five auxiliary lobes that descend slightly as they approach the umbilicus. The small fifth lobe is situated on the umbilical wall. The saddles on the young whorls are wider than or the same width as the lobes (especially the initial saddles on the large whorls are the same width as the lobes), or else they may be narrower than them. As noted by Pavlow, the two lateral and two auxiliary saddles project forward, though not always strongly, sometimes barely perceptibly. Measurements, mm:

	Specimen 40 Plate XVIII, Figure 2	Specimen 38 Plate XVII, Figure 1			Specimen shown by Pavlow in pl. XII, fig. 2
D	43	50	123	160	75
W. u.	10.5(0.24)	13(0.26)	24.5(0.20)	42(0.26)	15(0.20)
L. h.	19(0.44)	21(0.44)	56(0.45)	72(0.45)	34(0.45)
I. h.	–	13(0.26)	39(0.31)	40(0.25)	19(0.25)
T	13(0.30)	17(0.34)	42(0.34)	49(0.30)	25(0.30)
C. b.	2.8	2.8	4.0	–	3.4

Variability. The specimens referred to the species *T. tolli* Pavl. show a very unstable sign – the smoothing of the ribs in the middle of the sides, which may appear from diameters of from 50 to 70 mm. Other variable characters are the width of the umbilicus, from 20 to 25%, and the number of intercalatory (intermediary) ribs (3, 4, or rarely 5 per main rib). The third intermediary may become attached below the level of the point of branching of the main rib or at the same level, in front of or behind the main rib, or else it may remain free.

Comparison and remarks. The most similar species is *T. tolmatschowi* Pavl., from which *T. tolli* differs, according to Pavlow, in the slightly steeper and deeper umbilicus, the numerous, strongly sloped constrictions, and the straighter and more forward-sloped ribs. If a good number of specimens are at hand, one may observe forms that combine a number of characters of both species, and the difference between the two forms is reduced to nil. It would therefore be best to consider *tolmatschowi* as a subspecies (or variety) of *T. tolli.* Only the deep-rooted tradition on the one hand and the absence of drawings and descriptions of the juvenile whorls of the lectotype of *T. tolli* on the other prevent us from doing this.

I assign to *T.* aff. *tolli* a specimen shown in Plate XVIII, Figures 1a, 1b, 1c which differs from typical representatives of the species in the much earlier disappearance of the peripheral ribs, their lesser forward slope on the adult whorls, and the greater evoluteness of these whorls.

Occurrence. Khatanga basin, Boyarka River, exposure 17, layers 4–9 (collections of 1964). Paks Peninsula (Cape Urdyuk-Khaya), exposures 66–67 (samples 66w, 66u, collections of 1958); exposure 33, members XIV–XVI (collections of 1967). Anabar River, exposures 28–29 (samples 28w, 29b, 29c, collections of 1958).

Age and distribution. Berriasian stage, *Bojarkia mesezhnikowi* zone of northern Siberia; lower Valanginian on the Anabar.

Tollia emeljanzevi Voronez
Plate XIX, Figure 1

1962. *Tollia emeljanzevi* Voronets, p. 67, pl. XXI, fig. 1; pl. XXXII, figs. 1, 2; pl. XXXIII, fig. 1; pl. XXXIV, fig. 1.

Lectotype chosen by the author: *Tollia emeljanzevi* Voronets, 1962, pl. XXXII, figs. 1,2. NIIGA*, Leningrad. Paks Peninsula, sample 25c, Berriasian stage.

Material. Two well-preserved, slightly deformed specimens.

Description. Voronets gave a detailed description of the species. We would point out, however, that according to our observations, *T. emeljanzevi* is characterized by the fact that the ribs in the middle of the lateral surface disappear markedly earlier and the peripheral ribs later than in the other northern species. In addition, the external ribs are thinner and more densely distributed than in *T. tolli,* and the number of intercalatory ribs per main rib reaches 4–6 in the middle stages of growth, whereas in *T. tolli* at the same size there are 3–4 intercalatory ribs. According to Voronets, this species differs from *T. tolli* in the "lower and thicker whorls, the narrower umbilicus, the fewer internal ribs, the

* [Geological Research Institute of the Arctic.]

wider first lateral saddle, and the bipartite first lateral lobe." The first of these distinguishing characters is indeed present, but as for the others, they simply do not exist. Pavlow claims that in *T. tolli* the width of the umbilicus between the sutures constitutes 20–21% of the diameter. Voronets also measured the width of the umbilicus between the sutures and obtained the same values as in *T. tolli*, 20–21% of the diameter (at the same shell size). Thus, the umbilicus of *T. emeljanzevi* is not narrower than that of *T. tolli;* on the contrary, it is even slightly wider, if we go on the basis of our specimens, in which the width of the umbilicus constitutes 23–26% of the shell diameter. Further, the "internal" ribs (i.e. the umbilical ribs) number 24 in the lectotype of *T. emeljanzevi* (the count was made on the original specimen) and 23 in *T. tolli*, so that it is wrong to say they are more numerous in *T. tolli*. A bipartite first lateral lobe and a fairly broad first lateral saddle are characteristic for some specimens of *tolli* as well, and therefore this sign is not significant either. In other words, the main distinguishing characters, as pointed out above, are the earlier and more intensive planing of the ribs in the middle of the sides in *emeljanzevi*, the later disappearance of the peripheral ribs, the thicker and lower whorls, and the larger number of accessory ribs.

Remark. A very similar species is the English form *T. pseudotolli* Neale. Unfortunately, all Neale's specimens (Neale, 1962) are in a poor state of preservation, and therefore I decided not to include them in the synonymy of *T. emeljanzevi*.

Occurrence. Paks Peninsula (Cape Urdyuk-Khaya), exposure 66 (sample 66y, collections of 1958) and exposure 33, layer 49, member XVI (collections of 1967).

Age and distribution. Berriasian stage, *Bojarkia mesezhnikowi* zone of northern Siberia.

Tollia pakhsaensis Voronez
Plate XIX, Figure 2

1962. *Tollia pakhsaensis* Voronets, p. 66, pl. 46, figs. 1, 3.

Lectotype chosen by the author: *Tollia pakhsaensis* Voronets, 1962, pl. 46, fig. 1, NIIGA, Leningrad, Paks Peninsula, Sample 26a. Berriasian stage.

Material. One incomplete specimen. Parts of the penultimate and last whorl are preserved.

Description. Voronets described the species from one large specimen (possibly with the body chamber) and from a fragment of an inner, middle whorl. Judging from the drawing and description, *T. pakhsaensis* differs from the other known representatives of the genus in the coarse, thick ribs of the inner whorls with wide-set branches, 2–3 per umbilical rib (regrettably, the fragment of the young specimen presented by Voronets in pl. 46, fig. 3 does not give a full idea of the number of ribs and the ratio between secondary and primary ribs). In the sculpture on the outer whorl *T. pakhsaensis* differs from other forms of *Tollia* in the sparsely distributed umbilical and peripheral ribs. The umbilical ribs cannot be counted on the lectotype because they are practically obliterated. In our specimen about 110 mm in diameter there are 6 umbilical ribs on an area less than half of the last whorl, 20 peripheral ribs and the coefficient of branching is 3.3. At sizes of 80–110 mm the connection between the main and secondary ribs is scarcely detectable owing to the virtual obliteration of the ribs in the middle of the sides; however, on the external margin of the shell (on the periphery of the sides and on the venter) the ribs are strong, bending forward quite considerably as they cross the venter.

The suture line of the species is presented by Voronets on p. 67, fig. 24. Unfortunately, it is not shown in full (just the ventral element, the first and second lateral lobes, and an incomplete first auxiliary lobe), but it is seen to be essentially the same as that of *T. tolli* and other species.

Occurrence. Paks Peninsula (Cape Urdyuk-Khaya), exposure 66 (sample 66 y, collections of 1958).

Age and distribution. Berriasian stage, *Bojarkia mesezhnikowi* zone of northern Siberia.

Genus *Neotollia* Schulgina, 1969

Type species: *Neotollia klimovskiensis* Krymgol'ts, 1953, p. 76, pl. XI, fig. 1. Lower Valanginian of northern Siberia (Anabar River, Klimovskii ravine).

Diagnosis. Shells somewhat laterally flattened or moderately inflated. Thickness constituting 36–43% of the diameter. Whorls strongly involute, enclosing the preceding ones almost to the umbilical margin. Cross section oval on the inner whorls, oval with constricted upper part or in the form of a high trapezium on the adult whorls. Umbilicus narrow, 15–20% of the shell diameter, funnel-shaped, with steep walls.

Sculpture on inner whorls consisting of prominent double ribs with the point of branching situated in about the middle of the sides. At diameters of 50–60 mm (in rare cases earlier) triple ribs begin to appear, with a fourth branch occurring more rarely. The third branch is often attached to the main rib below the level at which the double ribs divide anteriorly, in which case a virgatic type of fascicle is formed. The third branch sometimes becomes attached behind the double fascicle, on the same level as the point of division of the main rib, but sometimes it remains free. The fourth branch generally remains free. At diameters of 60–80 mm and more, ribs with four, five, and six accessory branches may predominate. They bend forward as they cross the venter. At shell sizes of 80–100 mm the sides become smooth and ornament is preserved only on the external margin of the sides and on the venter, or else it disappears altogether except, sometimes, for umbilical inflations.

In pattern and direction the suture line is similar to that of the genus *Tollia.*

Species composition. Five species in the north of Siberia and two species in Western Siberia.*

Comparison. The most closely related genus is *Tollia.* Formerly the representatives of the new genus were referred to *Tollia* by all investigators, including the author. But after careful study of all the stages of shell development in the two groups, it emerged that

**Neotollia densa* Klimova n. sp., described in the present work by Klimova, belongs rather to the species *N. maimetschensis* Schulgina n. sp. Unfortunately, the specimen shown in Plate XXXVII, Figures 13–15 had not reached a size at which it would be possible to make an accurate species determination.

there are a number of marked differences justifying the establishment of a separate genus for the forms described: 1) the sides of the shell of *Tollia* are generally more flattened than in *Neotollia.* At the same size the thickness of the shell of *Tollia tolli* Pavl. constitutes 30–35% of the diameter, whereas in *Neotollia* it constitutes 40% (although there are individual forms of *Neotollia* with flattened sides); 2) the form of the cross section in *Tollia* is oval, strongly drawn out in height, while in *Neotollia* it is wider and lower, trapezoidal on the adult whorls; 3) *Tollia* has a more evolute shell. At the same shell sizes the width of the umbilicus is 25–30% of the diameter in *Tollia,* 15–25% in *Neotollia;* 4) in the early and middle stages of growth up to a diameter of 50–60 mm the sculpture consists primarily of triple ribs in *Tollia* and of double ribs in *Neotollia.*

At diameters of 60–70 mm the two genera become very similar where the sculpture is concerned, but still the differences we have mentioned are enough to distinguish them.

Remarks. Possibly belonging to *Neotollia* is a specimen pictured by Kemper (1964) in pl. I, figs. 3a, 3b under the name *Tollia tolmatschowi* Pavl. At similar sizes (69 mm) in *Tollia* the umbilical ribs are elevated and have the form of elongate tubercles, while in the middle of the sides the ribs smooth out. These characters are not evident in the German specimen. However, the drawings and description of the inner, juvenile whorls are not sufficient for us to be quite sure that this specimen does refer to *Neotollia.*

The species *"Polyptychites" anabarensis* Pavl., which I previously assigned to *Tollia* (Shul'gina, 1965), occupies an intermediate position in the series *Tollia – Neotollia.* According to certain characters this species may be included in either genus with equal justification. For instance, in the involuteness of the shell, the form of the cross section, and the general habitus it should be placed in *Neotollia.* But in the sculpture, that is, the presence of trifurcate fascicles at a shell diameter of 50–60 mm, this species comes closer to *Tollia,* even though in some species of *Neotollia* a third rib appears at the same size. If it were to be proved that the inner whorls of *anabarensis* have bifurcate ribs, the species could without any doubt be considered to belong to the genus *Neotollia.*

Tollia sibirica Klimova (Klimova, 1960), with a stage of bifurcated ribbing lasting to a diameter of 60–70 mm, should be placed in the genus *Neotollia.*

Apart from the typical forms similar to *Neotollia klimovskiensis* (Krimh.), the genus *Neotollia* includes forms with strongly inflated sides and a suture line in which the lobes and saddles are markedly shorter than in the holotype. On the other hand, specimens are found which have much more flattened sides than in *N. klimovskiensis* and which have a very similar form of shell to that of *Tollia tolli* Pavl. However, there is no need to isolate them into separate genera or subgenera. In the first place, they all have the same type of development of the sculpture, and second, they include forms occupying an intermediate position.

Since the species *Neotollia klimovskiensis* was described earlier (Krymgol'ts, 1953; Shul'gina, 1969), only a drawing is given here.

Age and distribution. Lower substage of the Valanginian stage (*Neotollia klimovskiensis* and *Polyptychites stubendorffi* zones) of northern Siberia (Anabar, Boyarka, Maimecha, and Bol'shaya Romanikha rivers). Klimova's collection contains representatives of *Neotollia* from lower Valanginian deposits of Western Siberia (*Temnoptychites insolutus* zone).

Neotollia maimetschensis Schulgina n. sp.
Plate XX, Figures 1, 2; Plate XXI, Figure 2; Figure 10, *6a, 6b*

Holotype. Specimen 45/10118. F. N. Chernyshev Central Geological Museum, Leningrad. Plate XX, Figures 2a, 2b. Maimecha River, Valanginian stage, lower substage. *Polyptychites stubendorffi* zone (beds with *Astieriptychites astieriptychus*).

Material. Five excellently preserved specimens.

Description. Shells strongly involute, slightly inflated in the periumbilical part, sides descending in the direction of the venter. Thickness 43–46% of the diameter. Venter smoothly rounded, sometimes slightly flattened. Whorls very involute, enclosing the preceding for 7/8, but increasing in height relatively slowly (height of whorl increasing by a factor of 1.20–1.22 over half a coil). On the inner whorls the cross section is a high oval slightly narrowed on top. On the middle and large whorls the cross section may be oval, subrectangular, or in the form of a high trapezium. Umbilicus narrow, deep, stepped. Its width constitutes 15–18% of the diameter on the outer, middle, and large whorls and 20–23% on the juvenile, inner whorls.

The inner whorls are ornamented with double ribs which branch in the middle of the sides. At a diameter of 13–15 mm, at the beginning of the whorl the ribs bifurcate below the middle of the sides, while in the periumbilical part, at the end of the same whorl the point of branching is shifted to the middle of the lateral surface. At these dimensions there are 22 umbilical ribs, and as the shell grows, their number increases to 45–50 (at diameters of around 60 mm). The third rib appears at a shell size of 45–50 mm; it usually becomes attached to the main rib below its point of branching or on the same level as this, but sometimes it remains free. The ribs are fine, prominent, and of uniform strength all along; they originate on the umbilical margin, so that the walls of the umbilicus are left smooth. The ribs bend forward as they cross the venter. They do not form any periumbilical thickenings. A fourth and a fifth rib appear at shell diameters of 65–70 mm. At the end of the whorls, at the sizes indicated, the ribs begin to smooth out. On the lateral surface they are preserved only on the venter and near the umbilicus. From two to three constrictions may be observed at these stages. As the shell increases in size, the sculpture disappears, and only the constrictions remain. The size of the body chamber could not be determined, since the largest shells present in the collection (150–160 mm) are represented only by phragmocones. Measurements, mm:

	Specimen 45 (holotype) Plate XX, Figure 2		Specimen 47 Plate XXI, Figure 2
D.	13	60	58
W. u.	3(0.23)	11(0.15)	11(0.19)
L. h.	6(0.46)	28(0.47)	27(0.46)
I. h.	4.5(0.34)	15(0.25)	
T	6(0.46)	26(0.43)	
C. b.	2.0	2.4–3.2	2.7

The suture line (Figure 10, *6a, 6b*) consists of 8 elements. The first lateral lobe is shorter than or the same length as the ventral lobe, but narrower than it, and the second is almost twice as narrow and short as the first. Three narrow auxiliary lobes, gradually decreasing in size, are situated on the lateral surface. The fourth auxiliary lobe is situated on the umbilical margin, while the fifth and sometimes a minute sixth lobe are arranged on the wall of the umbilicus. The ventral saddle is as a rule divided into two equal parts, but sometimes division is into three parts. The ventral saddle is just a little narrower than the ventral lobe, or else the same width as this. The first lateral saddle is also either narrower than or as wide as the first lateral lobe; the other saddles are wider than the lobes. At first the suture line is quite strongly elevated in the direction of the umbilicus, but at the level of the second or third auxiliary lobe it descends.

Variability. The species variability consists in the different number of accessory ribs, the thickness of the ribs, the stage at which they are obliterated, and in the slightly varying width of the umbilicus.

Comparison. *N. maimetschensis* is similar to *N. klimovskiensis,* but it differs in the following signs: the earlier appearance of triple ribs, the finer and denser umbilical and peripheral ribs, and the earlier disappearance of the sculpture. The suture lines of the two species are very similar.

Occurrence. Khatanga basin, Boyarka River, exposure 8 (in taluses), exposure 13 in taluses (collections of 1964); Maimecha River, exposure 49, layer 3 (collections of 1964); Bol'shaya Romanikha River, exposures 129 and 130, 29 and 30 (collections of 1961 and 1964).

Age and distribution. Lower substage of the Valanginian stage. *Neotollia klimovskiensis* zone and the bottom of the *Polyptychites stubendorffi* zone in northern Siberia.

Neotollia klimovskiana Bodylevsky and Schulgina n. sp.
Plate XXI, Figure 1; Plate XXII, Figure 1; Plate XXIII, Figure 1; Figure 11, *3*

In Bodylevskii's collection I found an ammonite labeled *Tollia klimovskiana.* The photograph that Bodylevskii made of this specimen is presented here in Plate XXI. The place where it was found is not mentioned, but the label reads: "Collection of Kiselev, 1936, No. 185." Presumably, the ammonite comes from the Klimovskii ravine on the Anabar River (judging from its name). No records on this new species came to light among Bodylevskii's papers.

The name is not very appropriate, since the type species of the genus bears the very similar name *klimovskiensis,* but it cannot be changed as it was given by Bodylevskii.

Apart from this ammonite, my collection contains a large specimen, also from the Klimovskii ravine, with distinctly visible inner whorl, which we refer to this species.

Holotype. Specimen 48/10118. F. N. Chernyshev Central Geological Museum, Leningrad. Plate XXII, Figure 1; Plate XXIII, Figure 1. Anabar River. Valanginian stage, lower substage.

Material. Two well-preserved specimens.

Description. Shell laterally flattened, involute, of medium thickness. Sides gently descending toward the venter. Form of cross section an elongate oval that is narrower in the upper part so that it looks somewhat like a triangle. Whorls markedly involute, enclosing the preceding ones almost completely. Umbilicus narrow, constituting 18% of the shell diameter, deep. Its walls are stepped. Unfortunately, the description had to be based on two large specimens (122 and 175 mm in diameter) in which the inner whorls, measuring about 55 mm, are only partly visible, so that not all the changes taking place with growth of the shell can be followed up.

As seen in Plate XXII, Figure 1, the sculpture on the inner whorl consists of just double, quite densely arranged ribs. At a shell size of about 54 mm there are 48–50 umbilical ribs. The ribs begin on the upper half of the umbilical wall, where they slope slightly backward and then slope forward as they cross the sides and venter, bifurcating in the middle of the sides. The ribs are fine and of uniform strength all along. At a diameter of 120 mm the nature of the ribbing at the beginning of the whorl remains as described, except that the number of accessory outer ribs increases to three; the third rib often becomes attached to the main rib, forming a virgatic-type fascicle. On the second half of the same whorl (or even a little earlier) the umbilical ribs become elevated, the distance between them increases, and the number of accessory ribs is now 5–6; the ribs in the middle of the sides begin to smooth out until all that remain are umbilical thickenings and outer ribs on the margin of the sides and on the venter. At the size indicated the umbilical ribs number 26–27. Bidichotomy was observed in one case. On the large whorl (Plate XXIII, Figure 1) at a diameter of about 170 mm ribs are still preserved on the first third of the lateral surface, while later they remain only just at the margin of the sides (they are not visible on the photograph) and subsequently at the end of the whorl; they apparently disappear on the body chamber. Barely perceptible umbilical thickenings are all that remain.

The dimensions of the specimen pictured in Plate XXI, Figure 1 are as follows: D = 122 mm; W. u. = 23 mm (0.18); L. h. = 59 mm (0.48); I. h. = 33.5 mm (0.29); T = 40 mm (0.33); C.b. (average) = 4.8.

The suture line differs from that of *Neotollia klimovskiensis* Krimh. and *N. maimetschensis* Schulg. simply in being less frilled. Its general form and direction are the same as in these species.

The species variability could not be determined because there are too few specimens.

Comparison and remarks. The species is intermediate between *Neotollia* and *Tollia.* In the general form of the shell (flattened sides, constricted venter, form of cross section) *N. klimovskiana* is extremely similar to the forms of *Tollia.* However, the fact that there are only double ribs on the inner whorls and the accessory branches are formed later obliges us to place the species in the genus *Neotollia.* At any rate, according to the double ribs, *N. klimovskiana* can in no way be referred to *Tollia.* As mentioned on several occasions in describing other groups of ammonites, one has to take into account that there will be forms diverging from the type of the genus that cannot always be fitted into the framework of our concepts of a particular genus.

To some extent *N. klimovskiana* resembles *Virgatoptychites,* but it differs in the more flattened shell, the finer and denser ribs on the middle whorls, and in the less distinct virgatic sculpture.

The new species differs from the above-described representatives of *Neotollia* in having a more flattened shell (less thick), a different whorl section (more elongate), and in the much later disappearance of the sculpture.

Occurrence. Anabar River, Klimovskii ravine. Exposure 29 (sample 29b, collections of 1958), one specimen from Kiselev's collection (possibly also from the Klimovskii ravine).

Age and distribution. Lower substage of the Valanginian stage. *Neotollia klimovskiensis* zone or lower part of the *Polyptychites stubendorffi* zone in northern Siberia.

Genus *Virgatoptychites* Voronez, 1958

Type species: *Virgatoptychites changalassensis* Voronets, 1958, p. 68, pl. I, figs. 2, 3, 4. Berriasian and lower Valanginian of northern Siberia (basin of the Khangalas-Yuel').

Diagnosis. Shell with more or less inflated sides and a moderately narrow or narrow umbilicus. Cross section in the form of an oval widening toward the bottom. Judging from the photograph shown by Voronets in his pl. I, fig. 4, the sculpture of the inner whorls consists of fine double ribs. On the middle whorls the ornament is represented either by predominantly double ribs or by triple ribs. The outer whorls bear triple and many-branched fascicles having a virgatic type of structure.

Species composition. Three species in northern Siberia and in Canada.

Comparison. The most closely related genus is *Tollia,* from which *Virgatoptychites* differs in the bipartite ribs on the inner whorls, the virgatic sculpture of the middle whorls, and the more inflated shell on the large whorls with distinct umbilical thickenings. From *Polyptychites* (which Voronets considered to be the closest relative of this genus) *Virgatoptychites* differs in the little-incised suture line, which has the pattern characteristic for *Craspedites,* with a larger number of auxiliary lobes; this induced me to place the representatives of this genus in the family Craspeditidae, not Polyptychitidae as Voronets thought. Moreover, the sculpture typical for the forms of *Polyptychites* is not observed in *Virgatoptychites.*

Age and distribution. Berriasian and lower Valanginian of northern Siberia and Canada.

Virgatoptychites trifurcatus Schulgina n. sp.
Plate XXIV, Figures 1, 2; Figure 12, *1*

Holotype. Specimen 50/10118. F. N. Chernyshev Central Geological Museum, Leningrad. Plate XXIV, Figure 1a, 1b. Boyarka River. Valanginian stage, lower substage, *Neotollia klimovskiensis* zone.

Material. Two specimens, well preserved, but without the body chamber.

Description. Shell involute, inflated, thickest in the umbilical part, sides steep, venter smoothly rounded. Cross section in the form of an oval widened at the base and slightly narrowed toward the top. Umbilicus narrow, stepped, deep, constituting 20% of the shell diameter. The sculpture on the youngest whorls is unknown. On the inner whorls 45 mm in diameter the sculpture is of trifurcate fascicles, these beginning on the upper half of the umbilical wall and branching just below the middle of the sides. At diameters of 60–70 mm the virgatic type of sculpture is observed. The ribs are of uniform strength all along; at first they slope a little backward and then are directed forward. They bend forward considerably as they cross the venter. At diameters exceeding 70 mm the umbilical ribs become higher, and at the end of the whorl (shell size 75–80 mm) they are transformed into elongate tubercles that are markedly elevated above the lateral surface. In the middle of the lateral surface, at the points of branching, the ribs descend, smoothing out slightly. The peripheral ribs are clearly visible. At the above-mentioned sizes the number of accessory ribs increases to 5–6 with the point of branching shifting to the middle of the sides. Dimensions of holotype: D = 85 mm; W. u. = 19 mm (0.20); L. h. = 37 mm (0.43); I. h. = 18 mm (0.21); T = 40 mm (0.47). Seventeen umbilical ribs per complete whorl; coefficient of branching for the first half of the whorl 4.6, for the second half 6.1, average for the whole whorl 5.7. There are 19 umbilical ribs at a diameter of 75 mm; hence with development their number decreases on account of the larger space between them. Constrictions are absent.

The body chamber is unknown. The suture line consists of 7 or 8 elements (Figure 12, *1*). The ventral lobe is fairly wide; the ventral saddle is almost as wide as the lobe and is divided into two parts by a small auxiliary lobe. The first lateral lobe is a little shorter than and just more than half as wide as the ventral lobe. Very characteristic are the next two very narrow lobes, the latter of which, that is, the first auxiliary lobe, is shorter than the second lateral lobe. The auxiliary saddles are very wide. A fourth and sometimes a fifth small lobe are situated on the wall of the umbilicus. As it passes over the sides, the suture line ascends toward the umbilical margin, descending slightly only on the umbilical margin. In its pattern and overall shape the suture line of this species is very similar to that of *V. changalassensis* Voron. and to the suture lines of some forms of *Surites, Subcraspedites,* and *Neotollia.*

Comparison and remarks. The new species resembles *V. changalassensis* Voron. except for the bifurcate ribs on the middle whorls, the more flattened sides and consequently the thinner whorls, and the denser arrangement of the umbilical ribs.

Occurrence. Khatanga basin, Boyarka River. Exposure 39, layer 2 (collections of 1961). Boyarka River, exposure 25, layer 4 (collections of 1961).

Age and distribution. Berriasian (*Bojarkia mesezhnikowi* zone) and lower Valanginian (*Neotollia klimovskiensis* zone) in northern Siberia.

Subfamily Garniericeratinae Spath, 1952

Genus *Hectoroceras* Spath, 1947

Type species: *Hectoroceras kochi* Spath, 1947, p. 20, pl. I, fig. 2a, 2c. Berriasian of eastern Greenland.

Diagnosis. Spath (1947) gave the following description of the genus *Hectoroceras:* "Narrowly umbilicated platycones, with elliptical to compressed, occasionally almost oxynote, whorl-section, and narrow, smooth venter. Ribbing flexuous, with long primaries which branch (generally by bifurcation) above the middle of the flat whorl-side. Secondary ribs terminate when reaching smooth siphonal area, except towards the end of the body-chamber where they may be continuous across the periphery with a fairly pronounced forward sweep. Ribbing (he apparently means the primaries – N. Sh.) also declines near end where all the costae appear to be equally long or disappear almost completely (apparently referring to the obliteration of the ribs in the middle of the sides – N. Sh.). Umbilical wall high, but sloping and with rounded edge. Aperture sigmoidal, with slight rostrum; body-chamber nearly three-quarters of a whorl, becoming smooth and rounded ventrally in large forms. Suture-line fairly simple, but with numerous elements." The diagnosis is quite comprehensive and needs no supplementation.

Species composition. One species with two varieties is known from eastern Greenland (plus another species from the same region that has not been given a name). The type species *Hectoroceras kochi* is widely distributed in northern Siberia; the species *H. tolijense,* which was formerly included by all investigators in the genus *Garniericeras,* occurs in the Northern Urals. Klimova assigned this species to the genus *Hectoroceras.*

Comparison. The most similar genus is the Volgian *Garniericeras,* from which *Hectoroceras* differs in the sculpture. The youngest whorls of *Hectoroceras* show a sculpture that is highly typical for all growth stages (apart from senile forms). On the young stages of *Garniericeras* there is either no sculpture or just umbilical costules and wrinkles.

Remark. *Hectoroceras* is the most clearly differentiated of the Berriasian genera due to the distinctively flattened shell with sagittate whorl section.

Age and distribution. Berriasian of the Boreal Realm. Eastern Greenland, northern and Western Siberia, (?) Arctic Canada, and England.

Hectoroceras kochi Spath
Plate IV, Figure 2; Plate XXV, Figure 1; Figure 11, *2*

1947. *Hectoroceras kochi* Spath, p. 21, pl. I, figs. 1–5; pl II, figs. 1–4; pl. III, fig. 1.

Holotype. *Hectoroceras kochi* Spath, 1947, pl. I, fig. 2. Eastern Greenland (Jameson Land). Berriasian stage.

Material. More than thirty specimens, for the most part excellently preserved.

Description. Shell markedly flattened, whorls very involute, large whorls covering the preceding ones almost completely on the small whorls and about 7/8 on the large whorls. Venter strongly constricted, somewhat wider and rounder on the very large whorls. Cross section of inner and middle whorls sagittate, on the outer whorls in the form of a very high oval. Thickness of shell 18–24% of the diameter. Umbilicus narrow, more or less cup-shaped. Its width increases with growth of the shell. On the small whorls the width is 10–12% of the diameter, on the large whorls 14–15%.

On the inner whorls the sculpture consists of prominent ribs that begin on the umbilical wall. As they cross the lateral surface the ribs at first slope forward, and then, in about the middle of the sides they branch out, the branches as a rule sloping backward, approaching the venter almost along the radius. The peripheral ribs sometimes slope forward again on the exterior of the sides.

The venter remains smooth.* Apart from double ribs there is quite often a single rib with an intermediary, while sometimes there is a third branch that may be situated in front of or behind the double fascicle, as a rule remaining free. At a diameter of 40 mm there are 27 umbilical ribs, and the coefficient of branching is 2.6. As the shell develops, the nature of the sculpture remains the same, except that the ribs become coarser and the distance between them larger. At a shell diameter of 133 mm there are 27–28 umbilical ribs; c. b. = 2.8. Beginning from shell sizes of around 150 mm the ribs smooth out. At first they descend in the middle of the sides and then, at still larger diameters (about 200 mm) they disappear altogether.

Dimensions of Siberian specimens: D = 41 mm; W. u. = 4.5 mm (0.10); L. h. = 20 mm (0.50); I. h. = 15 mm (0.36); T = 10 mm (0.24). D = 133 mm; W. u. = 20 mm (0.15); L. h. = 65 mm (0.40); I. h. = 50 mm (0.38); T = 28 mm (0.21).

The suture line (Figure 11, *2*) differs from that of most Craspeditidae in being more frilled and in having wider lobes. The first lateral lobe is longer than the ventral lobe, but the width of the two lobes is about the same. The second lateral lobe is either a little smaller than the first lateral lobe or only just over half its size. The auxiliary lobes, shortened and widened as they approach the umbilical margin, descend. In general, the suture line of *H. kochi* is very similar to that of the Volgian genus *Garniericeras* and the Valanginian genus *Pseudogarnieria.*

Variability. The species variability consists in the degree of sloping of the ribs and in the varying number of intercalatory ribs.

Comparison. As already mentioned, the representatives of *Hectoroceras* are so distinctive that they should not be confused with any other Berriasian ammonites. But, they are very similar to the Volgian *Garniericeras* and may be mistaken for forms of this genus.

Forms of *Garniericeras* are found that have a similar shell to that of *Craspedites* and that resemble the Berriasian *Hectoroceras.* The genus *Garniericeras* is in need of revision to determine its size. The species *tolijense* Nik. to some extent is in the same situation, as a number of characters ally it to *Hectoroceras* (the whorl section and the sculpture of the middle whorls) and a number of others relate it to *Garniericeras* (absence of sculpture and the form of the section of the inner whorls). Unfortunately, there are no records of the large whorls of *tolijense* with the body chamber, and we do not know to which genus and species the small specimen presented by Nikitin (1881) in pl. 2, fig. 8 belongs. In our opinion, it is indistinguishable from small specimens of *Garniericeras.* On the other hand, a larger individual of *tolijense,* pictured by Nikitin in pl. 2, fig. 7, resembles *Hectoroceras* more than *Garniericeras* as far as the type of ornament and cross section are concerned.

As for the two varieties identified by Spath (*H. kochi* Spath var. *magna* and *H. kochi* Spath var. *tenuicostata*), they may have to be considered as independent species, but there is not enough material to do this. One specimen of each of these two varieties is recorded from eastern Greenland; none has been found in the Siberian sections.

Remark. In the present study the genus *Hectoroceras* is placed in the subfamily Garniericeratinae Spath, 1952 (not in the subfamily Craspeditinae Spath, 1952, as the author of the genus decided) on the basis of the fact that there are very many characters

* A similar type of ribbing is observed in representatives of Volgian *Craspedites (Taimyroceras)* spp.

allying the genera *Garniericeras* and *Hectoroceras*. According to the nature of shell development and the suture line, *Hectoroceras* is a direct descendant of the Volgian *Garniericeras*.

Occurrence. Khatanga basin, Boyarka River, Exposure 15 (35), layers 1–3; exposure 16, layers 1–4 (collections of 1961 and 1964); Kheta River, exposure 21, layer 3 (collections of 1961). Right bank of the Anabar River (collection of Z. V. Osipova). Olenek River (collection of E. S. Ershova).

Age and distribution. Berriasian stage of eastern Greenland, England, (?) Arctic Canada, Northern Urals, *Hectoroceras kochi* zone of northern Siberia.

FAMILY BERRIASELLIDAE SPATH, 1922

Subfamily Berriasellinae Spath, 1922

Genus *Argentiniceras* Spath, 1924

Type species: *Odontoceras malarguense* Steuer, 1897. Berriasian of Argentina.

Argentiniceras (?) n. sp.

The collection of Siberian Berriasian ammonites on the Kheta River in the *Chetaites sibiricus* zone, exposure 21, layer 2 (collections of 1961) contains one specimen of a very distinctive species, clearly of southern origin, from the family Berriasellidae. It is unfortunate that the generic affiliation of the species has not been clarified definitively. In Plate XV, Figure 1a, b, c, d, e we give drawings of this specimen, which was able to be uncoiled to the inner whorls. The most characteristic sign of the form is the rather sparse tubercles on the inner whorls that are situated at the border between the side and the venter. The tubercles disappear on the outer whorl. A similar feature is observed in the Berriasian genus *Argentiniceras*. The suture line of this specimen is presented in Figure 12, *8*. It shows the pattern typical for the Berriasellidae. However, the Siberian form differs from the type species *Argentiniceras malarguense* (Steuer) in having a different arrangement of the tubercles: on the periphery of the sides, not at the margin of the umbilicus, and in the primarily regular double ribs on the outer whorl, whereas in the type the branching of the ribs is irregular. The Siberian form has thus been designated *Argentiniceras* (?) n. sp. This form may belong to a new genus, but it is not worthwhile establishing a new genus on the basis of one specimen.

AMMONITES OF THE RUSSIAN PLAIN*

The Berriasian ammonites of the Russian Plain have been fully described by Bogoslovskii

* The collection is deposited at the F. N. Chernyshev Central Geological Museum, Leningrad, item No. 10223.

(1897, 1902), and therefore here we will just describe newly instituted genera and subgenera of boreal forms and a few new species.* I propose isolating from the family Craspeditidae its Berriasian representatives and placing them in the separate family Suritidae I. Sasonova. The ammonites of this family differ from the Craspeditidae in that the ribs show a linguiform bend on the venter, there are no tubercles on the umbilical margin, and the suture line has wide saddles and small underdeveloped lobes at the apexes and more elongate lateral lobes. I also suggest that the subfamily Garniericeratinae Spath be raised to the status of the family Garniericeratidae. On p. 76 of the "Fundamentals of Paleontology" it is shown how different are the suture lines of *Craspedites subditus* and *Garniericeras catenulatum,* not only in overall configuration, but also in the angle of the bend toward the umbilical margin. In *C. subditus* this angle does not exceed 15°, while in *G. catenulatum* it is greater than 20°. The different suture lines show that the subfamily Garniericeratinae cannot be included in the family Craspeditidae.

FAMILY SURITIDAE I. SASONOVA, 1971

Description. Shells of medium thickness. Whorls moderately convolute. Cross section from a low oval to a high, drawn-out oval. Primary ribs short, convex, bifurcating, more rarely trifurcating in the middle of the lateral surface, the third rib being weakly attached to the main one. The ribs are not interrupted on the venter; they bend forward, forming a linguiform curve. The suture line is markedly incised; two lateral lobes are distinguished, narrower than the saddles; the suture bends backward at an angle of up to 15° toward the umbilical margin.

Generic composition. *Surites* Sasonov, 1951, with the subgenus *Caseyiceras* I. Sasonova, 1971; *Bogoslovskia* I. Sasonova, 1965; *Borealites* Klimova, 1969; *Chandomirovia* Sasonov, 1951; *Stchirowskiceras* I. Sasonova, 1971; *Pronjaites* I. Sasonova, 1971; *Externiceras* I. Sasonova, 1971.

Age and distribution. Boreal Realm. Berriasian and lower Valanginian.

Genus *Surites* Sasonov, 1951

Surites N. Sazonov, 1951, p. 59, I. Sazonova, 1965, p. 104.

Type species: *Surites pechorensis* Sazonov, 1951, pl. I, figs. 3, 4. Berriasian stage.

Description. Shells from flattened to medium-thick. Rate of coiling moderate, umbilicus for the most part moderately wide, but on adult specimens it is quite narrow. Cross section oval at all stages of growth. Maximum whorl thickness occurring somewhat below the middle lateral surface. The degree of involuteness varies from moderate on young

*After this book had gone to press, Sazonova (1971) published her new genera and species in the proceedings of VNIGNI. We have retained their description and illustration here so that the reader may gain an idea of the complex of Berriasian and lower Valanginian ammonites that is characteristic for the Russian Plain.

whorls to marked on adult whorls. The primary ribs branch in the middle of the lateral surface, a little closer to the umbilical margin. Bipartite ribs predominate, but there are also tripartite primary (umbilical) ribs with a sickle-shaped bend toward the venter. The third rib is weakly connected with the main rib, although there is no connection on the adult whorls, and the ribs become intermediaries. On the venter the ribs project sharply forward, forming a linguiform curve. On the very large specimens (diameter more than 100 mm) this curve becomes gentler. The suture line is markedly incised. The saddles are wider than the lobes, and at the apexes they have small auxiliary lobes (1–2). The first lateral lobe ends as two sharp teeth, while the second and third lobes end in a single tooth. From the latter the suture bends backward at an angle between 5 and 15°. It has three more lobes.

Comparison and remarks. Ammonites differing appreciably from the type species in the form of the shell, the sculpture, and the pattern of the suture have been included in the genus *Surites.* We propose isolating in the genus a new subgenus, *Caseyiceras* n. subgen.

Klimova (1969) instituted the genus *Borealites,* in which she placed *Surites suprasubditus.* We cannot agree with this. In the type species of *Borealites* the suture line has five lateral lobes, it begins to bend toward the umbilical margin starting from the second lobe, and the angle of bending is 14–18°. The species *suprasubditus* also has five lateral lobes, but the bend toward the umbilical margin begins from the third lobe, and the angle at which it bends is not more than 5°. Klimova included in the new genus species that lived in the West Siberian Basin and that show morphological peculiarities in shell structure, for example, a gentler linguiform bend of the ribs on the venter and, most important, a different pattern of the suture.

Subgenus *Surites* s. str. Sasonov, 1954

Composition: *Surites pechorensis* Sasonov, *S. poreckoensis* Sasonov, *S. simplex* (Bogosl.), *S. subtzikwinianus* (Bogosl.), *S. tzikwinianus* (Bogosl.), *S. spasskensis* (Nik.), *S. kozakowianus* (Bogosl.), *S. suprasubditus* (Bogosl.), *S. clementianus* (Bogosl.), *S. pervulgatus* I. Sasonova, *S. nikitini* Geras., ? *S. unschensis* (Nik.).

Surites (Surites) pervulgatus I. Sasonova, 1971
Plate XXX, Figure 3a, 3b

Holotype No. 30/10223, Plate XXX, Figure 3. Oka River, *Surites spasskensis* zone.

Description. Shell flattened. Umbilicus moderately wide, cup-shaped. Cross section oval, slightly compressed in the upper part near the venter. Ribs fine, well expressed at all stages of growth. They are more densely distributed on the young whorls, becoming sparser as the shell develops. On the juvenile whorls up to a diameter of 40 mm the umbilical rib in the middle of the lateral surface trifurcates, the three ribs bending slightly forward. At diameters of 40–65 mm the initial ribs bifurcate (a third rib is not always clearly connected to the main rib). The curve of the ribs on the venter has a linguiform shape. Measurements, mm:

D	64.0	L. h.	23.4(0.37)
Thickness between ribs	17.0(0.27)	I. h. : L. h.	0.57
Thickness along ribs	18.6(0.29)	I. h. : T	0.78
I. h.	13.3(0.21)	N. u. r.*	22

The suture line is unknown.

Comparison and remarks. *S. pervulgatus* differs from the type species in the finer and denser ribs and in the flat shell. This species apparently represents a side branch in the phylogenesis of the genus *Surites.*

Age and distribution. Berriasian stage, *Surites spasskensis* zone. Right bank of the Oka River near the village of Chevkino, layer 5 of the lectostratotype of the Ryazan horizon.

Subgenus *Caseyiceras* I. Sasonova, 1971**

Type species: *Surites (Caseyiceras) caseyi* I. Sasonova. Upper Berriasian, *Surites spasskensis* zone.

Description. Shell inflated. Umbilicus moderately wide, stepped. Whorls not very involute. Form of cross section semicircular, but slightly flattened from the venter. Ribs dense, convex, the primaries bifurcating, in places with a slight weakening of the attached posterior branch. On the venter the ribs are not interrupted and bend forward very slightly. A tripartite branching of the initial rib appears on the adult whorls.

Composition. *Surites (Caseyiceras) caseyi* I. Sasonova, *S. (C.) dorsorotundus* (Bogosl.), *S. (C.) analogus* (Bogosl.).

Comparison and remarks. This subgenus differs from the subgenus *Surites* in the weakening of the linguiform bend of the ribs on the venter, in the more open umbilicus, with gently sloping wall, and in the pattern of the suture line.

Bogoslovskii noted that *S. (C.) analogus* differs from the species *kozakowianus,* one of the typical representatives of the genus *Surites,* in the sparse ribbing, the rounded cross section, and in the frilling of the suture line. The shell shown in his pl. 3, fig. 6a does not have the linguiform bend of the ribs on the venter, which brings it close to *S. (C.) caseyi.*

S. (C.) dorsorotundus (Bogosl.) is distinguished from the species *S. (C.) caseyi* by the more open umbilicus with gently sloping wall. The whorl thickness in this species constitutes 42% of the shell diameter. The shell bears frequent, fine, not very convex ribs. They branch in the middle of the lateral surface or a little higher into two or three ribs that bend slightly forward. There is a faint smoothing at the place of branching. Bogoslovskii mentions that at a shell diameter of 120 mm "the main ribs break down into three or four branches," and notes further on: "on the venter the ribs arch forward but just slightly, this being characteristic for the species and differentiating it from all the above-described forms of *Olcostephanus* (that is, from the ammonites of the subgenus *Surites* – N. Sh.).

The suture line of *S. (C.) dorsorotundus* is typical for the genus as a whole. It crosses

* N. u. r. stands for the number of umbilical ribs.

** The subgenus and type species are named after the English paleontologist R. Casey.

the shell almost along the radius. The ventral lobe is pointed. The lateral lobes are semicircular, little incised. The first lateral lobe is considerably shorter than the ventral. Saddles asymmetrical. The suture line of this species has a distinctive pattern that is found only in this genus. Still more different are the suture lines in *Subcraspedites*, on the lateral surface of which only one lobe is well developed; from this lobe the suture bends sharply backward at an angle of 27°,whereas in *S. (C.) dorsorotundus* it does not bend at all.

Age and distribution. Berriasian stage, *Surites spasskensis* zone of the Russian Plain.

Surites (Caseyiceras) caseyi I. Sasonova, 1971
Plate XXVI, Figures 2a, 2b, 3a, 3b

Holotype No. 2/10223, Plate XXVI, Figure 3. Menya River. *Surites spasskensis* zone.

Material. Five well-preserved shells.

Description. Shell inflated, maximum whorl thickness in the lower part of the lateral surface, practically at the umbilical margin. Umbilicus moderately wide, deep due to the proximity of the maximum shell thickness to the umbilical wall. The structure of the umbilicus is stepped. Degree of involuteness generally weak, but on some shells moderate. Form of cross section semicircular, though slightly compressed in the upper part. Ribs coarse, pointed, 2 mm high. The primaries bifurcate in the lower part of the lateral surface; the two branches are slightly bent. A rib that is weakly connected to the primary branches out posteriorly. The ribs bend gently on the venter, not showing the linguiform curvature that is characteristic for typical forms of *Surites*. The distinctive type of ribbing, that is uniform at all stages of development, and the presence of numerous forms of this type justify our isolating a new species and including this in a new subgenus.

The suture line is unknown. Measurements, mm:

	Figure 2	Figure 3
D	63.4	56.5
T	28.4(0.45) between ribs	24.5(0.43)
	30.3(0.48) along ribs	26.0(0.46)
I. h	17.57(0.27)	15.8(0.28)
L. h	20.0(0.32)	18.0(0.32)
W. u.	23.0(0.36)	19.8(0.35)
I. h. : L. h.	0.88	0.88
I. h. : T	0.60	0.60
N. u. r.	25	23
N. e. r.*	50	46
C. b.		2

* N. e. r. stands for the number of external ribs.

Age and distribution. Berriasian stage, upper strata of the *Surites spasskensis* zone. Right bank of the Oka near the village of Chevkino, layer 5, sample 5/10223 (Plate XXVI, Figure 2). Menya River near the village of Pekhorka, Abal exposure, layer 5, sample 2/10223 (Plate XXVI, Figure 3a).

Genus *Bogoslovskia* I. Sasonova, 1965

Type species: *Bogoslovskia pseudostenomphala* I. Sasonova. Berriasian of the Russian Plain.

The name *Bogoslovskia* was first proposed for the genus by the author in 1961, and the diagnosis of the genus and the description of the type species were published in 1965. Pavlow described two ammonites under the name *Olcostephanus stenomphalus.* The first of these is shown only from the lateral side in his pl. 3, fig. 1. This small, well-preserved shell has a diameter of 48 mm and a thickness of 20 mm, with an umbilical width of 10 mm. It derives from the Spilsby sandstones. The original is deposited in the Museum of Cambridge. The second ammonite (pl. 3, fig. 10) was found in Russia and subsequently lost. We consider that Pavlow's figs 1 and 10 show different ammonites that should be assigned to different species. In 1965 this form was chosen by the author as the type of the genus *Bogoslovskia.* Spath (1947) mentions that he takes the form illustrated by Pavlow in fig. 1 as the lectotype of the species *stenomphalus.* For the Russian specimen accepted to be the type of the genus *Bogoslovskia* we propose a new species name, *pseudostenomphala.*

Bogoslovskia pseudostenomphala I. Sasonova, 1971
Plate XXX, Figure 2a, 2b

Olcostephanus stenomphalus Pavlow, 1890, p. 59, pl. 2 (3), fig. 10.
Bogoslovskia stenomphala I. Sazonova, 1965, p. 103.

Holotype No. 21/10223, Plate XXX, Figure 2, Menya River, *Pseudogarnieria undulato-plicatilis* zone.

Description. Shell medium-thick, inflated on adult specimens. The rate of coiling increases rapidly. Umbilical margin strongly projecting. Umbilical wall, steep, umbilicus deep, moderately wide. Degree of involuteness from moderate to considerable. Cross section oval. Body chamber occupying 2/3 of a whorl.

The shell is covered with convex ribs at all stages of development. The primaries are bent forward and bifurcate in the lower part of the lateral surface. At the adult stage an intercalatory rib often appears between the main ribs and the upper lateral surface; it is not connected to the main rib or else connected very weakly. Owing to this the coefficient of ribbing, that is, the ratio of ventral to umbilical (initial) ribs is greater than 2 and reaches 2.5 in the region of the body chamber (Plate XXX, Figure 2a). The ribs are not interrupted on the venter but bend forward, forming a suritic-type linguiform bend that characterizes the entire family Suritidae. Measurements, mm:

D	48	I. h. : L. h.	0.65
T	20.8(0.43)	I. h. : T	0.64
I. h.	13.3(0.28)	N. u. r.	28
L. h.	20.6(0.43)	N. e. r.	60
W. u.	9.4(0.20)		

The suture line is almost identical to that drawn by Pavlow in pl. 3, fig. 10c. The ventral lobe is narrow, slightly longer than the first lateral lobe, and it ends in a sharp tooth. The first lateral lobe is long and narrow and ends in three short teeth. The second lateral lobe is about half as long as the first. The ventral saddle and the first and second lateral saddles are narrow, semicircular, well dissected.

Comparison and remarks. The ammonite described by Pavlow in pl. 3, fig. 10 was apparently found by him near the village of Pekhorka on the Menya River. The holotype was also discovered there.

Age and distribution. Upper strata of the *Surites spasskensis* zone and the *Pseudogarnieria undulato-plicatilis* zone. Menya River near Pekhorka; Oka River near Staraya Ryazan.

Genus *Stchirowskiceras** I. Sasonova, 1971

Type species: *Stchirowskiceras principale* Sasonov. Lower Valanginian of the Russian Plain.

Description. Shell of medium thickness up to a diameter of 70–90 mm, after which it becomes inflated or very inflated. Umbilicus ranging from quite narrow to narrow. Cross section semicircular-oval. Up to the diameter indicated the sculpture consists of sparse, coarse umbilical ribs that in the lower part of the lateral surface split into two or three ribs which are slightly forward-bent. The ribs are not interrupted on the venter. With further growth they are smoothed out all over the shell, but the umbilical ribs are preserved a good deal longer in the form of oblique, convex, short ribs.

The suture line has wide saddles and six narrow lobes. From the third lateral lobe the suture bends backward at an angle of up to 10°.

Species composition. *S. principale, S. tumefactum.*

Comparison and remarks. The ammonites of the genus *Stchirowskiceras* are distinguished from the forms of the genus *Surites* by the weaker linguiform bend of the ribs on the venter, the lower point of branching of the primaries, the overall smoothing of the ribs on adult shells with the persistence of short, oblique, convex, longitudinally drawn-out primaries, and also by the time of their existence.

Age and distribution. Upper strata of the Berriasian to the lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone. Basins of the Sura, Menya, Neplozha (village of Mosolovo), and Unzha.

* Named after paleontologist V. A. Shchirovskii, who was the first to describe the fauna from the Menya River.

Stchirowskiceras principale I. Sasonova, 1971
Plate XXXI, Figure 2a, 2b; Figure 13, *3a*

Holotype No. 32/10223, Plate XXXI, Figure 2, Menya River.

Description. Shell of medium thickness, but on adult whorls at a diameter of more than 80 mm there is a tendency toward a rapid increase of thickness, and the shell becomes inflated. Umbilicus moderately narrow. The degree of involuteness varies from moderate to strong at different stages of growth. Form of cross section varying from a low oval that is slightly flattened laterally to a well-defined oval drawn out in height. Maximum thickness of shell in the lower part. Up to a diameter of 70–80 mm the shell is ornamented with clearly expressed ribs. In the middle of the sides the main ribs bifurcate, the branches bending slightly forward (to be more precise, one rib branches off from the main rib posteriorly). At the same diameter the ribs on the lower lateral surface begin to be gradually obliterated, while at a diameter of about 90 mm they disappear altogether, only the primaries being preserved in the form of very short, oblique, convex, longitudinally drawn-out tubercles. On the upper lateral surface and on the venter the ribs persist up to a diameter of 90–95 mm. At 95–120 mm the shell bears no ribs but a few oblique convex primaries remain on the umbilical margin. The body chamber is smooth, bearing fine threadlike growth striae. Measurements, mm (Plate XXXI, Figure 2):

D	108.2	89.7	69.5
T	43.3(0.40)	39.0(0.43)	27(07.39)
I. h.	24.4(0.23)	19.7(0.22)	15.5(0.22)
L. h.	50.0(0.46)	31.5(0.35)	31.6(0.45)
W. u.	–	19.6(0.22)	17.0(0.24)
I. h. : L. h.	0.49	0.63	0.50
I. h. : T	0.56	0.50	0.57

We observed the suture line (Figure 13, *3a*) starting from a diameter of 50 mm. It has the pattern characteristic for the whole family Suritidae. Ventral lobe wide, with two long, sharp teeth and a narrow ventral saddle. The first lateral lobe is the same length as the ventral lobe and ends in three long, sharp teeth. The second lateral lobe is shorter and the third is sloped toward the external side of the shell. The suture then bends toward the umbilical margin at an angle of 10–12°. Another two short lobes occur farther along it. The first and second lateral saddles are considerably wider than the lobes; in the upper part they are symmetrically divided into fields by small straight secondary lobes, this being a typical feature of the genus.

Comparison and remarks. The species *S. principale* has much in common with some species of *Surites,* but it differs in the type of ribbing, especially in adult specimens, and, more important, in the gradual smoothing of the ribs and in their obliteration in large individuals. The primary ribs are preserved as short, oblique, longitudinally drawn-out tubercles, which is absolutely not a feature of *Surites.* All this permits us to assume that *S. principale* had an ancestor in *Surites,* whose structure it repeats at the initial stage of ontogenesis.

Age and distribution. Lower Valanginian. Lower part of the *Pseudogarnieria undulatoplicatilis* zone. Right bank of the Menya near the village of Pekhorka.

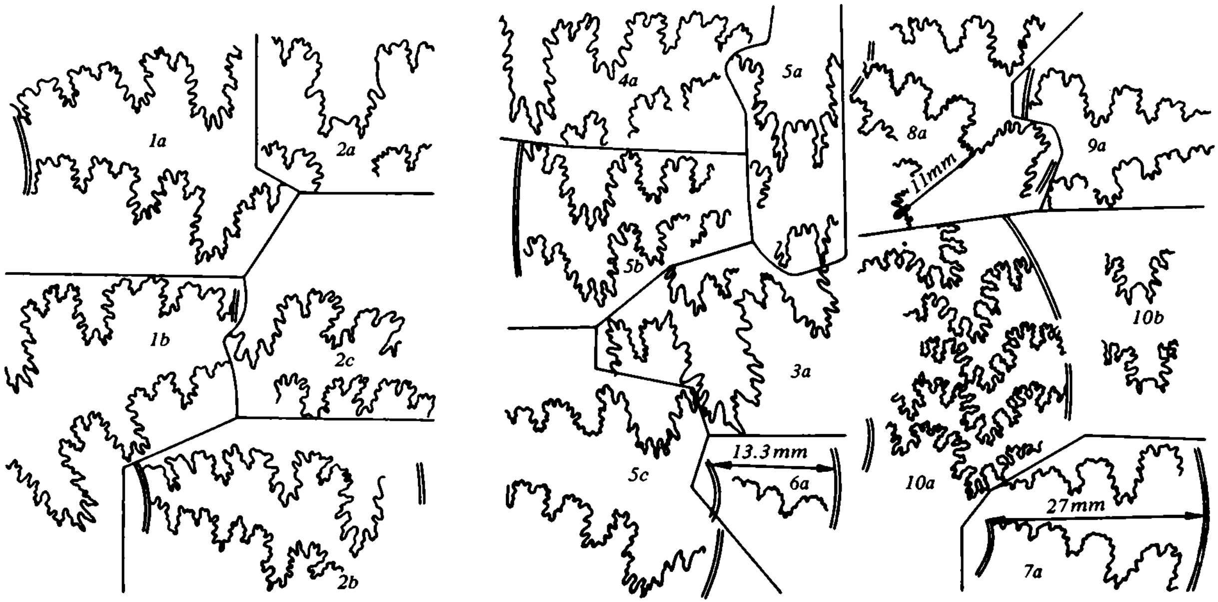


FIGURE 13. Suture lines:
1) *Menjaites magnus* I. Sason., shown in Plate XXVIII, Figure 1a, at a diameter of 122 mm (1a: lateral right and 1b: lateral left side of shell); 2) *Stchirowskiceras tumefactum* I. Sason., shown in Plate XXXI, Figure 1a, at a diameter of 80 mm (2a: ventral lobe, 2b: lateral right and 2c: lateral left side of shell); 3a) lateral left side of shell of *Stchirowskiceras principale*, shown in Plate XXXI, Figure 2a; 4a) lateral left side of shell of *Stchirowskiceras* aff. *principale* I. Sason.; 5) *Menjaites imperceptus* I. Sason. at a shell diameter of 65 mm (5a: ventral lobe, 5b: lateral left and 5c: lateral right side); 6a) *Menjaites magnus* I. Sason., shown in Plate XXVIII, Figure 3a, at a diameter of 25 mm; 7a) lateral right side of *Menjaites fidus* I. Sason, shown in Plate XXX, Figure 1a; 8a) lateral right side of *Menjaites magnus* I. Sason., shown in Plate XXVIII, Figure 2a; 9a) lateral left side of *Menjaites* aff. *fidus* I. Sason.; 10) *Proleopoldia menensis* (Stchir.), shown in Plate XXXII, Figure 1a (10a: ventral lobe, 10b: lateral right side).

Stchirowskiceras tumefactum I. Sasonova, 1971
Plate XXXI, Figure 1a, 1b; Figure 13, *2a, 2b, 2c*

Holotype No. 35/10223, Plate XXXI, Figure 1. *Pseudogarnieria undulato-plicatilis* zone, Menya River.

Description. Shell of medium thickness. Umbilicus moderately narrow. Involuteness marked. Cross section (Plate XXXI, Figure 1b) semicircular-oval. Maximum whorl thickness in the region of the umbilical margin, along which are distributed convex, obliquely forward-sloping primary ribs which split into two anteriorly bent branches in the middle of the lateral surface. At a diameter of 60 mm the ribs in the middle part of the shell begin to smooth out gradually, but on the venter they are preserved up to a diameter of 80–90 mm. At diameters exceeding 60 mm in the upper part of the lateral surface there are, in addition to the two main ribs, accessory ribs that are not connected with the primaries. Hence, the number of ventral ribs increases with development. At a diameter up to 82 mm the body chamber is unknown. Measurements, mm:

D	80.3	I. h. : L. h.	0.55
T	37.8(0.47)	I. h. : T	0.47
I. h.	18.0(0.23)	N. u. r.	18
L. h.	33.0(0.41)	N. e. r.	50
W. u.	20.0(0.25)	C. b.	28

The suture line is characteristic for the genus. The ventral lobe is wide and long, asymmetrically shifted to the right side of the lateral surface. It ends in a short, sharp tooth. The first lateral saddle is asymmetrically divided by a small auxiliary lobe that is situated closer to the first lateral lobe. The second lateral saddle also has a small auxiliary lobe, situated at the base of the first lateral lobe. This lobe is narrow and ends in two sharp teeth. A comparison of the sutures of *S. tumefactum* and *S. principale* draws attention to the asymmetrical structure of the different elements.

Comparison and remarks. *S. tumefactum* is very similar to *S. principale* except for the deeper umbilicus with almost sheer, stepped margin, the coarser ribs, and the pattern of the suture line. The primary whorls go through a stage of development undergone by ammonites of the genus *Surites,* but later they diverge from the species of this genus in the rapid increase in the thickness of the shell and in its involuteness, this leading to a narrowing of the umbilicus.

Age and distribution. *Surites spasskensis* and *Pseudogarnieria undulato-plicatilis* zones. Menya River near Pekhorka.

Genus *Subpolyptychites* I. Sasonova, 1971

Type species: *Subpolyptychites distinctus* I. Sasonova. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone. Russian Plain.

Description. Shell inflated, umbilicus narrow, funnel-shaped. Cross section oval, slightly compressed in the upper part. Primary ribs convex, acute, dividing in the lower part of the lateral surface, sloped forward. On adult whorls single fascicles of ribs with the polyptychitic type of branching are observed.

Species composition. *S. distinctus* and *S. orbicularis.*

Comparison and remarks. Differs from typical forms of *Polyptychites* in the type of ribbing.

Age and distribution. Lower Valanginian. Upper strata of the *Pseudogarnieria undulato-plicatilis* zone and the lower strata of the *Temnoptychites hoplitoides* zone.

Subpolyptychites distinctus I. Sasonova, 1971
Plate XXIX, Figure 4a–d

Holotype. Chernyshev Museum, No. 17/10223, near the village of Pekhorka on the Menya River. Upper strata of the *Pseudogarnieria undulato-plicatilis* zone of the lower Valanginian.

Description. Shell inflated. Umbilicus narrow, funnel-shaped. Maximum thickness of shell reached in the lower part of the lateral surface. Ribs forming a zigzag on the venter that is characteristic for the species: in bifurcating, the primary rib on one side crosses to the other side of the shell, each of these two branches now corresponding to different primaries. The ribs are strongly convex. On juvenile whorls the primaries branch into two ribs in the middle of the lateral surface; with subsequent growth the point of branching is displaced lower, closer to the umbilical margin. Fascicles of ribs with polyptychitic branching appear. On the venter the ribs bend forward gently. The shell described has a diameter of 49 mm and a thickness of 25.0 mm. The suture line is unknown.

Comparison and remarks. *Subpolyptychites distinctus* is phylogenetically intermediate between the families of Berriasian *Surites* and late Valanginian *Polyptychites.* The new (polyptychitic) morphological features of the shell appear only on the adult whorls, the young whorls showing the structural characteristics of their forerunners, *Surites.*

Age and distribution. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone of the Russian Plain.

Subpolyptychites orbicularis I. Sasonova, 1971
Plate XXX, Figure 4a–d

Holotype No. 40/10223, Plate XXX, Figure 4. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone, Menya River near Pekhorka.

Description. Shell strongly inflated. Umbilicus narrow, funnel-shaped. Degree of involuteness considerable. Cross section oval, slightly flattened ventrally. Shell densely covered with ribs, the umbilical ribs gently sloped forward, bifurcating in the lower part of the lateral surface. The ribs bend forward slightly on the venter. This type of ribbing pattern persists up to a diameter of 40–45 mm. With further growth the umbilical ribs become gradually thicker and are transformed into oblique, convex ribs that branch almost right at the umbilical margin into three or four ribs, the anterior of these uniting weakly with the umbilical rib. A polyptychitic fascicle is formed. Maximum thickness of shell occurring in the lower part of the lateral surface. Suture line unknown. Measurements, mm:

D	40.0	I. h. : L. h.	0. 56
T	21.7(0.54)	I. h. : T	0.41
I. h.	9.0(0.23)	N. u. r.	28
L. h.	16.0(0.40)	N. e. r.	56
W. u.	10.5(0.26)	C. b.	2

Comparison and remarks. *S. orbicularis* is distinguished from *S. distinctus* by the very narrow umbilicus and by the thickness, which constitutes 50–60% of the diameter. It differs from the forms of *Temnoptychites* in that the ribs are not interrupted on the venter.

Age and distribution. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone. Russian Plain, Menya River.

Genus *Pronjaites** I. Sasonova, 1971

Type species: *Olcostephanus bidevexus* Bogoslovskii, 1897.

Description. Shell very laterally compressed, a high oval that is bluntly pointed in the ventral part. Umbilicus narrow. Shell very involute, the whorls enclosing the preceding for 6/7. Maximum thickness a little below the middle of the lateral surface. Umbilical ribs fine, gently bent in the middle of the lateral surface, bifurcating. There is one intermediary. The ribs are densely distributed on the venter, where they bend insignificantly. Body chamber unknown.

Species composition. The type species.

Comparison and remarks. Bogoslovskii notes that the species *bidevexus* has much in common with *Surites spasskensis.* We did not find this; on the contrary, *Pronjaites* differs substantially from *Surites* in not having a linguiform bend of the ribs and in the high oval cross section. A certain similarity in the structure of the ribs may be found in a number of species of the genus *Menjaites* in the young stages, but in *Pronjaites* the ribs are more clearly expressed and show bifurcation.

Age and distribution. Berriasian stage, *Riasanites rjasanensis* zone and the base of the *Surites spasskensis* zone. Russian Plain from the Pechora basin to the Caspian lowland.

Genus *Peregrinoceras* I. Sasonova, 1971

Type species: *Olcostephanus pressulus* Bogoslovskii, 1897.

Description. Shell flattened. Umbilicus moderately narrow, cross section oval, slightly flattened on the sides and venter. Lower part of lateral surface sparsely covered with convex, slightly bent ribs that begin at the umbilical margin. The ribs gradually smooth

* Named after the Pronya River, a right-hand tributary of the Oka.

out in the middle of the sides or slightly below this. On some shells the connection between the umbilical and ventral ribs is preserved, e.g. in *P. bellum* (Plate XXIX, Figure 2). To each umbilical rib in the upper part of the lateral surface corresponds a fascicle of 6–8 fine ribs which project more strongly on the venter and are bent slightly forward. We consider that in the holotype of the type species *P. pressulum* (Bogosl.) the ribs are eroded in the place where the umbilical and ventral ribs unite, and therefore we give a drawing of a paratype of *P. pressulum* in Plate XXIX, Figure 1a; the specimen is excellently preserved and clearly shows the sculpture.

Comparison and remarks. The question as to which genus should be referred the peculiar species *pressulus, subpressulus,* and other forms similar to them that are found in large numbers in the upper strata of the Berriasian has been the subject of repeated discussion. Sazonov (1951), in establishing the genus *Surites,* ruled out the possibility of including these species in it. Casey (1962) and later Shul'gina (1965, 1967) placed them in *Surites.* Swinnerton (1935) assigned them to the genus *Subcraspedites,* but not the main form *subpressulus,* presented by Bogoslovskii in pl. IV, fig. 2a, but a less characteristic one (fig. 3 of the same plate), though he affixed the sign aff. to the species. In his broad interpretation of the genus *Subcraspedites,* Spath (1947) referred to it both *pressulus* and *subpressulus.* This view was supported by Bodylevskii and Shul'gina. Sazonova (1965) pointed out that the ammonites of the genus *Subcraspedites* differ from the Berriasian forms described by Bogoslovskii and they lived much earlier, in late Volgian time according to Casey, Sazonov, and Gerasimov, among others. We therefore do not think it possible to place the Berriasian species in the genus *Subcraspedites.*

On the basis of the above we propose that the species similar to *pressulus* be placed in the genus *Peregrinoceras.* This genus differs from the genus *Surites* in the much weaker linguiform bend of the ribs on the venter, in the way in which the umbilical ribs unite with the ventral ribs, and in the density of the latter. The differences between *Peregrinoceras* and *Subcraspedites* are the absence in the latter of fascicles of fine ribs on the upper lateral side of the shell, the cross section, and, above all, the structure of the suture line. In *Subcraspedites* there are two lateral lobes with a bend backward at an angle of 23–27°. In *Peregrinoceras* this angle does not exceed 10°, and the lateral lobes number three or four.

Age and distribution. Upper part of the Berriasian. Basin of the Oka River between Staraya Ryazan and Nikitino, Menya River near Pekhorka, eastern part of the Caspian lowland.

Peregrinoceras bellum I Sasonova, 1971
Plate XXIX, Figure 2a, 2b

Holotype No. 11/10223, Plate XXIX, Figure 2. Oka River, *Surites spasskensis* zone.

Material. Fifteen well-preserved shells of various size.

Description. Shell of medium thickness. Umbilicus wide, deep, stepped. Cross section round, somewhat compressed in the upper part. Oblique forward-sloping convex ribs are distributed along the umbilical margin and in the lower part of the lateral surface. A little below the middle of the lateral surface the umbilical ribs branch out into three. In addition, there are two intercalatory ribs that are not united with an umbilical rib. Hence, to each umbilical rib there is a fascicle of five fine ribs, three of which are connected. There are shallow constrictions on juvenile whorls at a diameter of 40–50 mm. On the venter the ribs are bent very weakly forward, but there is no linguiform curve as in ammonites of the genus *Surites.* The very dense convex ribs give this species its unique appearance. The body chamber is known on shells 50 mm in diameter; it occupies 3/4 of a whorl. Measurements, mm:

D	68.0	I. h. : L. h.	0.86
T	22.5(0.36)	I. h. : T	0.84
I. h.	19.0(0.30)	N. u. r.	20
L. h.	21.8(0.35)	N. e. r.	105
W. u.	22.5(0.36)	C. b.	5.3

The suture line is markedly dissected. The ventral lobe is almost twice as long as the first lateral lobe, which is situated in the middle of the lateral surface and ends in three teeth. The first lateral saddle is wide, shallow, semicircular; the second is narrow. Then follow two lobes that slope forward slightly. In its general pattern the suture differs appreciably from that of the genus *Surites.*

Comparison and remarks. The very distinctive species *bellum* differs from the species *pressulum* and *subpressulum* in the very well-defined union of the umbilical rib and the fascicle on the upper lateral surface, in the wider umbilicus, and in the low cross section on adult shells.

Age and distribution. Upper Berriasian, upper part of the *Surites spasskensis* zone. Oka River basin (villages of Shatrishchi and Chevkino), Sura basin (Pekhorka on the Menya River).

Genus *Externiceras* I. Sasonova, 1971

Type species: *Perisphinctes solowaticus* Bogoslovskii, 1897. Bogoslovskii (1897) described *P. solowaticus* and *Olcostephanus? mostjae* from the Ryazan horizon (Solovatskie Vyselki, east of Pronsk). On p. 43 he mentions that he found these two ammonites together with *Hoplites rjasanensis.* According to our observations, there are two strata in this exposure. The lower stratum corresponds to the *Riasanites rjasanensis* zone and the upper to the *Surites spasskensis* zone. The species *solowaticus* and *mostjae* occur only in the upper zone. In sections near the village of Tsyvkino and Klement'evskii Pogost on the Oka River these ammonites are found en masse in a bed with *Buchia,* that is, in the lower strata of the *Surites spasskensis* zone.

Species composition: *solowaticus* and *mostjae.*

Description. Shell flat, umbilicus wide. Cross section almost round, somewhat flattened in the lower part of the lateral surface. Along the umbilical margin the primary ribs are straight, very dense, and convex. They bifurcate in the middle of the sides. On young whorls a third intercalatory rib appears which does not unite with the main rib. Body chamber occupying 4/5 of a whorl.

The suture line is essentially different from that of *Perisphinctes* in the number of lobes on the lateral surface and in their lesser deflection toward the umbilical margin. Saddles wide, semicircular, little dissected. First lateral lobe shorter than the ventral, ending in three short, blunt teeth. The second lateral lobe is about half as long as the first. Farther on toward the umbilical margin the suture is deflected backward at an angle of up to 10°, with three small lobes divided by wide semicircular saddles.

Comparison and remarks. The genus *Externiceras* is distinguished from the genus *Surites* by the structure of the shell and suture line. No form of *Surites* has in its ontogeny such a flat, weakly involute shell as that in *Externiceras.* The venter of *Externiceras* does not have the linguiform bend of the ribs characteristic for *Surites.* There are a number of similarities between *Externiceras* and the subgenus *Caseyiceras,* but in the latter the shells are thicker. In accordance with the pattern of the suture line, the forms of the genus *Externiceras* cannot be referred to the Olcostephanidae or Perisphinctidae; they belong to the subfamily Suritinae.

Age and distribution. Berriasian stage, Russian Plain.

Genus *Menjaites** I. Sasonova

Type species: *Menjaites imperceptus* I. Sasonova.

Description. Shell flattened on the juvenile whorls, medium-thick on older whorls. Umbilicus narrow, its wall gently sloped. Cross section a high oval, slightly compressed in the upper part near the venter. Shell reaching a diameter of 160–250 mm. Body chamber occupying 2/3 of a whorl. In shells with a diameter between 40 and 180 mm the ratio I. h.:L. h. is 0.49–0.54, while on young whorls it increases to 0.70. Up to a diameter of 40 mm the shell is covered with fine filamentous ribs diverging in fascicles from the umbilical margin; on internal molds they are almost imperceptible (Plate XXVII, Figure 3). More adult whorls have no ribbing at all, but on shells 70–80 mm in diameter fine growth striae can be detected (Plate XXVIII, Figure 4a). This genus comprises two groups of ammonites. The first, in which we include the type species, has four to five deep constrictions on one whorl in the ontogenesis (Plate XXVII, Figure 1e, 1f); these are absent on the next more adult whorls. Belonging to the second group are forms that do not have such constrictions in the ontogenesis. This group is very large both in species composition and in number of forms. Further study may oblige us to divide the genus into two subgenera.

The suture lines are sparse and arranged along the radius. The ventral lobe is elongate and ends in a long, pointed tooth. The first lateral lobe is shorter than the ventral and is followed by six lateral lobes. Saddles semicircular, wide, shallowly incised. All the saddles have in the center underdeveloped small lobes that are generally asymmetrically arranged and gently sloped (Plate XXVI, Figure 1; Plate XXVII, Figure 2). In some species the

* Named after the Menya River, a left-hand tributary of the Sura.

suture lines are crowded around the body chamber, but their overall pattern remains the same.

Comparison and remarks. We do not know of a single ammonite in the late Berriasian or early Valanginian that resembles the forms of the genus *Menjaites.* There is a certain similarity to *Temnoptychites elegans* Bodyl. (1967), but the shell of this species is covered with coarser ribs and, more important, the ribs are interrupted on the venter. The species *"Temnoptychites" glaber* (Nik.) and *"T." lgowensis* (Nik.), described by Nikitin, differ from *Menjaites* in the fine ribbing, the pointed upper part of the oval cross section, and, above all, in the structure of the suture line. These ammonites were placed in another new genus by the author.

Age and distribution. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone. Neplozha River near the village of Mosolovo and Menya River near Pekhorka.

Menjaites imperceptus I. Sasonova, 1971
Plate XXVI, Figure 1, Plate XXVII, Figure 1a–g; Figure 2;
Plate XXVIII, Figures 4a–c, 5a–c; Plate XXIV, Figure 2; Figure 13, *5a–c*

Holotype No. 3/10223, Plate XXVII, Figure 1a–g. Menya River, *Pseudogarnieria undulato-plicatilis* zone.

Material. About 200 well-preserved specimens.

Description. Shell flat to a diameter of 70 mm. With further growth it becomes of medium thickness with a rapid rate of coiling. Umbilicus moderately narrow. Degree of involuteness moderate, on adult whorls marked. Cross section a high oval that is somewhat compressed in the upper part (Plate XXVIII, Figure 5c, 5d; Plate XXVII, Figure 1c). On juvenile whorls (up to a diameter of 40 mm) the shell is covered with fine growth striae that diverge in a small fascicle from the umbilical margin. Each whorl bears five deep constrictions (Plate XXVII, Figure 1e, 1f; Plate XXVIII, Figures 4a, 4b and 5a, 5b). With subsequent development the constrictions disappear, the growth lines are obliterated, and the shell becomes smooth. Internal molds are smooth. Measurements, mm:

	Plate XXVI, Figure 1		Plate XXVII, Figure 1		
D	127.6	77.6	73.1	43.4	25.1
T	40.3(0.31)	26.0(0.34)	25.7(0.35)	14.0(0.32)	7.3(07.29)
I. h.	–	16.1(0.21)	16.3(0.22)	11.1(0.26)	7.2(0.29)
L. h.	53.2(0.42)	35.0(0.46)	33.7(0.46)	20.6(0.47)	12.6(0.50)
W. u.	34.4(0.26)	15.4(0.20)	17.0(0.25)	–	2.2(0.25)
I. h. : L. h.		0.46	0.48	0.54	0.57
I. h. : T		0.62	0.63	0.80	0.99

	Plate XXVIII, Figure 4	Plate XXVIII, Figure 5	
D	32.0	32.7	24.5
T	8.0(0.25)	10.2(0.31)	7.8(0.30)
I. h.	8.0(0.25)	7.6(0.23)	6.4(0.26)

L. h.	13.7(0.43)	14.6(0.45)	10.3(0.42)
W. u.	8.5(0.27)	8.1(0.2)	5.9(0.24)
I. h. : L. h.	0.58	0.52	0.62
I. h. : T	1.00	0.75	0.90

The suture lines are sparse, very well dissected, drawn out in an even line, without a bend at the umbilical margin. The ventral lobe is a little longer than the first lateral lobe, and it ends in a sharp tooth. Saddles semicircular. Even though they are very small, the first lateral lobe and the four small lobes following it are clearly traced from diameters of 10 mm to 180 mm.

Comparison. *M. imperceptus* differs from the other representatives of the genus in the presence of constrictions on the juvenile whorls and in the finer, threadlike striation. In *M. magnus* there are no constrictions and the filamentous ribs are more convex (Plate XXVII, Figure 3).

Age and distribution. Lower Valanginian. *Pseudogarnieria undulato-plicatilis* zone. Right bank of the Menya River near Pekhorka.

Menjaites magnus I. Sasonova, 1971
Plate XXVII, Figure 3; Plate XXVIII, Figures 1a, 1b, 2a, 2b, 3a, 3b;
Figure 13, *1a, 1b, 6a, 8a*

Holotype No. 4/10223, Plate XXVIII, Figure 1. Menya River, *Pseudogarnieria undulato-plicatilis* zone.

Material. Twenty-two well-preserved shells.

Description. The distinctive feature of the species is the absence on shells measuring 10–40 mm in diameter of the constrictions that characterize *M. imperceptus.* Up to a diameter of 40 mm the shell is ornamented with fine filamentous ribs (not seen on internal molds) that diverge from the umbilical margin in fascicles (Plate XXVII, Figure 3a; Plate XXVIII, Figures 2a, 2b, 3a). Young whorls flattened, adult whorls more than 70 mm in diameter of medium thickness. Umbilicus fairly wide; involuteness of shell moderate. Cross section oval on young whorls; with growth there is a rapid increase of thickness at the umbilical margin, which gives the cross section a more rounded outline. This is seen by comparing the cross sections in Figures 2b, 3b, and 1b in Plate XXVIII. Measurements, mm:

	Plate XXVIII, Figure 1		Plate XXVIII, Figure 2		Plate XXVIII, Figure 3	
D	120.0	91.0		34.0	34.0	23.0
T	47.7(0.40)	32.0(0.35)	20.0	10.0(0.30)	10.5(0.30)	7.6(0.33)
I. h.	29.5(0.25)	20.5(0.23)	16.5	11.0(0.33)	8.6(0.25)	6.0(0.26)
L. h.	56.0(0.47)	39.0(0.43)	28.0	15.7(0.46)	14.0(0.40)	9.0(0.40)
W. u.	37.0(0.31)	19.4(0.21)	?	5.4(0.16)	8.6(0.25)	6.0(0.26)
I. h. : L. h.	0.53	0.53	0.56	0.70	0.61	0.67
I. h. : T	0.62	0.64	0.78	1.10	0.82	0.80

The suture line has well-dissected lobes and saddles. The first and second lateral lobes end in two sharp teeth. Saddles semicircular with small lobes at the apex. The following saddles are a good deal wider than the first two. After the third lobe the suture bends slightly backward at an angle of not more than 5° (Figure 13, *1a*). The asymmetry of the suture line can be observed on the sides of the shell. It is expressed mainly in the changes of the deflection of the lobes and in some details of their structure. As a rule, with growth of the shell the suture lines become denser, closer together, and around the body chamber the lateral lobes of one suture become intergrown with (or cut into) the adjacent saddle or lobe. This does not occur with the ventral lobes.

Age and distribution. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone, Menya River, near Pekhorka.

Menjaites fidus I. Sasonova, 1971
Plate XXX, Figure 1a, 1b; Figure 13, *7a*

Holotype No. 38/10223, Plate XXX, Figure 1.

Description. Shell flattened. Umbilicus moderately narrow, funnel-shaped, with gently sloping margin. Whorls from very involute to almost completely involute. Cross section a very high oval that is slightly pointed on some whorls. Up to a diameter of 40–50 mm the ribs are filamentous, beginning in small fascicles on the umbilical margin. As the shell grows, fine growth striae appear. Internal molds are smooth. Sazonova (1971) illustrated *M. fidus* at various stages of growth. Some forms differ considerably from the holotype, and we affix to them the sign affinis (Figure 13, *9a*). Measurements, mm:

Plate XXX, Figure 1, holotype

D	77.0	50.8	38.0
T	22.3(0.29)	14.4(0.28)	11.0(0.30)
I. h.	27.0(0.35)	12.5(0.25)	9.5(0.25)
L. h.	36.0(0.47)	23.7(0.47)	18.0(0.48)
W. u.	15.1(0.20)	10.0(0.20)	0.0(0.21)
I. h. : L. h.	0.75	0.53	0.53
I. h. : T	1.22	0.90	0.86

The suture line differs little from that of the type species. The ventral lobe is asymmetrically displaced toward the left lateral side and ends in an elongate tooth on the side of the shell. The first lateral lobe is half as long as the ventral and ends in two asymmetrically arranged teeth. The first and second lateral saddles are semicircular, well dissected. The second lateral lobe is half as long as the first, and the third and fourth are small, very weakly developed.

Age and distribution. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone. Menya River, near Pekhorka.

Description. Shells ranging from flattened to moderately thick. Umbilicus small, cup-shaped. Its wall is mostly steep. Cross sections ranging from a high trapezium with rounded walls to sagittate. Most genera are characterized by tubercles along the umbilical margin, while along the ventral margin there are sharp spines on young whorls that are transformed into small inflations on adult shells. Suture line complicated. The ventral lobe is short; the first lateral lobe is elongate with three branches that split up into three more small branches, these ending in three small teeth. The second lateral lobe resembles the first. The three saddles, divided by lobes, are round, wide, with two or three elongate teeth at the apex, the middle tooth projecting more strongly than the others.

Composition. *Garniericeras* Spath, 1923; *Pseudogarnieria* Spath, 1923; *Platylenticeras* Hyatt, 1900; *Tolypeceras* Hyatt, 1903; *Proleopoldia* Spath, 1923.

Comparison and remarks. The basis on which the family Garniericeratidae was established was the marked difference in the structure of the suture line, in the cross section, and in the shell morphology. In this family there are only two lateral lobes and the saddles are strongly branched and wide. The family Craspeditidae has three lateral lobes and the Suritidae up to five; the saddles are narrower in these families. The cross section is trapezoidal to sagittate in the Garniericeratidae, while in the Craspeditidae it ranges from a round to a transversely drawn-out oval and in the Suritidae it is mostly oval and high-oval.

Age and distribution. Upper Volgian substage to Valanginian. Boreal Realm: Europe and Siberia.

Genus *Pseudogarnieria* Spath, 1923

Pseudogarnieria securis I. Sasonova, 1971
Plate XXXIII, Figure 1a, 1b; Plate XXXIV, Figure 3

Holotype: Plate XXXIII, Figure 1a, 1b; Plate XXXIV, Figure 3. Chernyshev Museum, specimen 27/10223. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone. Menya River near Pekhorka.

Description. Shell flattened, with slowly increasing whorls. Umbilicus moderately wide, small, cup-shaped. Its walls are steep, their height constituting 9 mm at a shell diameter of 107 mm. Whorls strongly involute on young stages, moderately involute at adult stages. Cross section sagittate in the lower part, rounded, expanded closer to the umbilical margin. Along this margin are small, convex, spinous tubercles from which depart short, weakly expressed folds; these disappear rapidly, before reaching the middle of the lateral surface. The rest of the shell is smooth.

The suture lines are very close together but clearly differentiated from each other. The ventral lobe is very narrow; its outer branches are situated on the lateral sides and end in short teeth with two small denticles at the end; a saddle passes along the ventral side. The first lateral lobe is a little longer than the ventral and is asymmetrically divided into three branches, the middle one of which is longer than the others. Each branch is in turn divided into three parts with two or three short denticles at the end. The second lateral lobe is constructed similarly, but it is shorter. There is no third lateral lobe. The first lateral saddle is wide, rounded. At all stages of growth its apex bears a small tooth with finely incised margins. There are two such elongate teeth on the second saddle. Half of the third lateral saddle is weakly deflected onto the umbilical wall. Measurements, mm:

D	107.0	73.0
T	26.7(0.25)	22.5(0.31)
I. h.	–	27.6(0.38)
L. h.	41.5(0.39)	35.0(0.48)
W. u.	32.0(0.30)	20.8(0.29)
I. h. : L. h.	–	0.80
I. h. : T	–	1.23
N. u. r (tubercles)	13	none

Comparison and remarks. This species differs from other forms of the genus *Pseudogarnieria* in the absence of striated fascicles and of wrinkled convexities on internal molds such as are characteristic for the species *undulato-plicatilis* and *tubiculiferum,* and also in the absence of a wedge-shaped projection on the ventral part of the shell. It differs from the genus *Tolypeceras* in the form of the tubercles: rounded in *Tolypeceras* and pointed, spinelike in *P. securis.* The suture line in *Platylenticeras* is strongly deflected backward after the first lateral lobe, whereas in *P. securis* it follows a practically even course. The ventral lobe is much wider in *P. tuberculiferum* and *P. alatyrensis* than in *P. securis.*

Age and distribution. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone. Menya River, near Pekhorka.

Genus *Proleopoldia* Spath, 1923

*Proleopoldia stchirowskii** I. Sasonova, 1971
Plate XXXII, Figure 2a, 2b

Holotype: Plate XXXII, Figure 2a, 2b. Chernyshev Museum, No. 21/10223. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone. Menya River, Pekhorka.

Material. Eight shells.

Description. Shell flattened. Umbilicus moderately wide, small, cup-shaped. Degree of involuteness from moderate to weak. Up to a diameter of 50 mm the cross section is a laterally compressed trapezium drawn out in height. With development the sides and venter become faintly rounded. Up to a diameter of 60 mm the umbilical margin bears weakly expressed small, acute tubercles which give off small folds that slope forward. The folds smooth out in the middle part of the lateral surface. The ventral margin is demarcated on both sides by sharp spines up to 1.5 mm high. At diameters of more than 60 mm

* Named after V. A. Shchirovskii, the first to describe the ammonites of this genus.

the ventral spines are soon obliterated and become weakly projecting swellings, while the umbilical tubercles are displaced along the umbilical margin. The whole lateral surface of the shell is smooth at this diameter. In some forms the venter becomes more rounded.

The suture line is strongly dissected. The successive lobes very often cut into the preceding lobes and saddles. The ventral lobe is narrow and ends in two elongate, bent teeth situated on the ventral margins of the shell. The first lateral lobe is markedly dissected and passes almost in the middle of the lateral surface, displaced slightly ventrally. It is divided into three main branches that are strongly bent in different directions. Each of them is redivided into three, ending in two or three small, sharp denticles. Such repetitive trifurcation is very characteristic for this lobe. The second lateral lobe mostly repeats the pattern of the first, but its branches and denticles are narrower and longer. The saddles and lobes are of the same width. The saddles are strongly dissected, and at their apex projects a long, narrow, incised tooth. Measurements, mm:

Plate XXXII, Figure 2

D	?	43.0	?	38.0
T	25.2	12.0(0.30)	30.0	14.0(0.40)
I. h.	27.0	18.0(0.42)	31.5	12.5(0.33)
L. h.	37.0	21.0(0.50)	35.0	17.5(0.46)
W. u.	24.0	12.6(0.30)	–	11.0(0.29)
I. h. : L. h.		0.86	0.80	0.71
I. h. : T	1.07	1.50	–	0.86
N. u. r. (tubercles)				?

Comparison and remarks. This species differs from *P. kurmyschensis* (Stchir.) (Plate XXXIII, Figure 2a, 2b; Plate XXXIV, Figure 1) and *P. menensis* (Stchir.) (Plate XXXII, Figure 1a–c; Figure 13, *10a, 10b*) in the spinelike tubercles on the ventral margins and in the structure of the suture line with narrower saddles and twice-repeated branching of the first lateral lobe.

Age and distribution. Lower Valanginian, *Pseudogarnieria undulato-plicatilis* zone. Menya River, near Pekhorka.

AMMONITES OF WESTERN SIBERIA

FAMILY CRASPEDITIDAE SPATH, 1924

Genus *Borealites* Klimova, 1969

Borealites Klimova, 1969, p. 126.

Type species: *Borealites fedorovi* Klimova, 1969. Berriasian (*Hectoroceras kochi* zone) of Western Siberia.

Description. Shell disklike. Umbilicus from moderately narrow to moderately wide, shallow, stepped. Its low walls are sheer or slanting. Lateral surfaces flat or slightly convex. Venter from arcuate to rounded, slightly compressed. Sculpture of inner whorls consisting of double ribs. Point of branching situated more or less in the middle of the lateral surface. With an increase of the shell diameter the ribs trifurcate, and at this point the umbilical ribs in the lower part of the lateral surface increase in strength and become wider at the base; after the point of branching they become narrower and descend, in no way differing from the external ribs. This type of branching does not persist for very long. With further growth of the shell intercalatory ribs appear between the fascicles, beginning near the point of branching of the umbilical ribs but not attached to them. The umbilical ribs take on the form of low, pointed inflations. Toward the point of branching they descend and fade out, forming a smooth band in the middle of the lateral surface. At this stage of development there are 4 or 5 external ribs to one umbilical rib. The ribs either bend gently forward or do not bend as they cross the venter.

The suture line is fairly simple, having 4 or 5 auxiliary lobes. It is situated radially or is elevated in the direction of the umbilicus.

Comparison. In the sculpture of the inner and outer whorls *Borealites* shows a resemblance to *Subcraspedites* Spath, 1924. The two genera differ in the type of ribbing (coarse, widely spaced ribs in *Borealites* and fine, crowded ribs in *Subcraspedites*). Also different is the sculpture of the middle whorls (maximum c. b. is achieved in *Subcraspedites* at a shell diameter for which the appearance of the third branch in the fascicle is characteristic for *Borealites*).

Borealites resembles the genus *Surites* Sasonov, 1951 in the sculpture of the inner whorls and in the suture line, which is practically identical in the genera *Borealites*, *Subcraspedites*, and *Surites*. The sculpture of the middle whorls differs in these genera; moreover, the linguiform bend of the ribs on the venter that is typical for *Surites* is absent in *Borealites*.

Age and distribution. Berriasian of Western and northern Siberia, Russian Plain, Arctic Canada.

About 10 species.

Borealites radialis Klimova, n. sp.
Plate XXXV, Figures 1, 2

Holotype. Collections of the Department for Paleontology and Stratigraphy of SNIIGGIMS,* Novosibirsk. Sample No. 18 (Plate XXXV, Figure 1). Western Siberia, Yatriya River, Berriasian, *Hectoroceras kochi* zone.

Diagnosis. Shell disklike, umbilicus moderately narrow, no bend on the venter, five auxiliary lobes.

Material. Two specimens, one well preserved, the other a crushed clay mold.

Description. Measurements, mm:

* [Siberian Research Institute of Geology, Geophysics and Mineral Resources.]

No. of sample	D	W. u.	Whorl width	Whorl height	C. b.
18	74(28%)	21(39%)	29(25%)	19(23%)	3.8

The shell is disklike. Sides flat, slightly sloped to the arcuate venter. Cross section a wide oval. Umbilicus moderately narrow, shallow, stepped. Umbilical wall low, gently slanting. The sculpture begins in the upper part of the umbilical wall. On the youngest part of the shell that could be examined the fascicles are triple and intercalatory ribs appear. At this stage of growth the umbilical ribs do not differ from the external ribs in width or height, and they extend over the whole lateral surface without undergoing any change. Point of branching in the middle of the side. As the shell diameter increases, the umbilical ribs become markedly elevated, expanded at the base, and pointed. They become much thicker and higher than the external ribs. To each umbilical rib there are four external ribs, the lower ends of which converge to form an intricate fascicle. At the point of branching the umbilical ribs descend, smooth out, and do not become directly attached to the external ribs. The direction of the ribbing is radial. On the venter the ribs do not bend. Traces of injury during life are visible.

The suture line has wide, low, weakly incised lobes and saddles. The apexes of the saddles lie on a line that almost coincides with the radius. The ventral lobe is the same length as the first lateral lobe, which is twice as wide and as long as the second lateral lobe, the latter being larger than the first auxiliary lobe. There are five auxiliary lobes, each of them with its apex toward the venter. The auxiliary saddles are wider than long, and the widest of them is the first.

Comparison. *Borealites radialis* resembles most closely *B. fedorovi* Klim. (Klimova, 1969, p. 71, pl. I, figs. 1–5). It differs in having a slightly thicker shell, a more rounded cross section, radial sculpture, no bend on the venter, and a different suture line with five auxiliary lobes.

Occurrence. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

Age and distribution. Berriasian, *Hectoroceras kochi* zone of Western Siberia.

Borealites explicatus Klimova n. sp.
Plate XXXVI, Figures 1, 2

Holotype. Collection of the Department for Paleontology and Stratigraphy of SNIIGGIMS, Novosibirsk. Sample No. 17 (Plate XXXVI, Figure 1). Western Siberia, Yatriya River, *Hectoroceras kochi* zone.

Diagnosis. Shell disklike, with narrowed venter and beveled sides. Ribs arching gently on the sides, with the convexity facing forward. Suture line with five auxiliary lobes.

Material. Two incomplete specimens.

Description. Measurements, mm:

No. of sample	D	W. u.	Whorl height
4	71	23(32%)	17(22%)
17	106	35(34%)	19(18%)

Shell disklike. The flattened sides are strongly chamfered toward the narrow venter. Umbilicus moderately narrow. Its walls are low, very sloping, gradually merging with the lateral surface. Cross section oval, its maximum width occurring at the level of the umbilical margin. The ribs begin in the upper half of the umbilical wall; they become stronger on the umbilical margin and then they bifurcate in the lower third of the sides. After this the fascicles very rapidly become triple with a single point of branching. At a shell diameter of 52 mm there are three external ribs to each umbilical rib, then four, and then five. When the number of external ribs per umbilical rib reaches four, smoothing occurs near the point of branching, and the umbilical ribs become higher and thicker than the external ribs, eventually assuming the form of pointed, crestlike inflations. At all shell diameters the ribs bend gently on the sides, while on the venter they bend weakly forward. As the diameter increases, the point of branching is raised, but its highest position on the outer whorl is just slightly below the middle of the lateral surface.

The suture line has five auxiliary lobes. Lobes narrower than saddles. The apex of each lobe, beginning from the second lateral, is directed toward the venter. The saddles are bipartite. Their apexes lie on a line forming an acute angle with the radius.

Comparison. This species is very similar to *B. fedorovi* Klim. (Klimova, 1969, p. 70, pl. I, figs. 1–5). It differs in the more gently sloping wall of the umbilicus, the narrower venter, the more pronounced bending of the ribs on the sides, the slightly lower point of branching, and in having five, not four auxiliary lobes.

Occurrence. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

Age and distribution. Berriasian, *Hectoroceras kochi* zone of Western Siberia.

Borealites mirus Klimova n. sp.
Plate XXXV, Figure 3

Holotype. Collection of the Department for Paleontology and Stratigraphy of SNIIGGIMS, Novosibirsk. Sample No. 11 (Plate XXXV, Figure 3). Western Siberia, Yatriya River, Berriasian, *Hectoroceras kochi* zone.

Diagnosis. Shell disklike with strongly beveled sides. Umbilicus narrower than in the other representatives of the genus. Cross section wide-oval. As the diameter increases, the elements of the suture line become narrower and higher. There are four auxiliary lobes.

Material. Two specimens, one of which, more finely ribbed, is placed in the species with the sign cf.

Description. Measurements (sample No. 11), mm:

D	W. u.	Whorl width	Whorl height	C. b.
61	18(26%)	25(41%)	14(23%)	2.2
68	–	–	16(23%)	2.6
113	–	–	–	4.8

Shell disklike, passing into a platycone. Sides slightly convex, sloped toward the narrow, rounded venter. Cross section wide-oval, the width almost twice the height. Maximum width at the level of the lower 1/5 of the height of the lateral surface. Umbilicus moderately narrow. Walls of umbilicus low, steep, smooth. The ribs begin on the umbilical margin and slope very slightly backward, bifurcating below the middle of the sides, the two branches extending in the same direction to the venter, where they bend slightly forward. The direction of the umbilical ribs is radial. On the sides they form a very gentle arc with the convexity posteriorly. The umbilical and external ribs are the same size. At a shell diameter of 66 mm the double fascicles become triple, the third branch sometimes assuming the character of an intermediary. At this stage of growth the umbilical ribs become stronger, higher and thicker than the external ribs. The subsequent development of the sculpture may be observed on a fragment of an outer whorl the diameter of which, according to the reconstruction, is 113 mm. The umbilical ribs assume the form of low, pointed inflations; in the lower third of the whorl they smooth out and eventually are obliterated. There are 4–5 external ribs per umbilical inflation.

As the shell grows larger, the suture line changes its outline, but the number of lobes remains the same: four auxiliary lobes at all stages of development. At shell diameters of less than 60 mm the suture is characterized by wide, short ventral and first lateral lobes (Plate XXXV, Figure 3c). The ventral saddle is narrow and high. The first lateral saddle is also high and narrow, but it is wider at the base than at the apex. The second lateral saddle is low and wide. After a diameter of 60 mm the saddles and lobes become high and narrow (Plate XXXV, Figure 3d). The ventral lobe remains the widest. The first lateral saddle is equal in height to the second lateral saddle but almost twice as narrow as it.

Comparison. The species differs from the other forms of *Borealites* in the strong slope of the sides toward the venter, the narrower umbilicus, the lower and wider cross section, and in the peculiar suture line.

Occurrence. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

Age and distribution. Berriasian, *Hectoroceras kochi* zone of Western Siberia.

Genus *Tollia* Pavlow, 1913
Tollia cf. *payeri* (Toula)
Plate XXXVII, Figures 1–12

Perisphinctes payeri Toula, 1874, p. 498, pl. I, fig. 1.
Tollia payeri Spath, 1952, pl. IV, fig. 8.

Diagnosis. Shell disklike with narrow or moderately narrow, shallow umbilicus. Cross section oval. Venter narrowly rounded. Sculpture of inner whorls consisting of dense, fine ribs that form triple fascicles and sparse double fascicles with a low point of branching – at the level of 1/3 of the height of the lateral surface. The inner whorls characteristically have constrictions, these being most distinct on the venter. The outer whorls bear double fascicles with two or three intercalatory ribs between them. The suture line has four auxiliary lobes.

Material. Six incomplete, deformed specimens of inner whorls and 21 fragments, five of which belong to larger whorls. All the ammonites were found in one concretion.

Description. Shell disklike. Sides weakly convex, sloped toward the umbilicus and venter. Cross section oval. Umbilicus moderately narrow, its diameter constituting from 18 to 21% of the shell diameter. Walls of umbilicus low, almost sheer, smooth. Umbilical margin rounded. The fine, sharp, closely spaced ribs begin on the umbilical margin. On the inner whorls the umbilical ribs divide at the level of 1/3 the height of the lateral surface, forming narrow triple, more rarely double, fascicles. At a shell diameter of 34 mm the coefficient of branching is 2.5–3. The umbilical ribs are directed anteriorly at an angle of 30° to the radius. After the point of branching, the posterior branch is deflected slightly backward from the direction of the middle branch. In the upper third of the sides all the external ribs are directed anteriorly and they bend forward on the venter. The anterior branch of the fascicle has the nature of an intercalatory rib, beginning at the level of the point of branching at an equal distance from the two adjacent fascicles. The umbilical ribs are higher and a little thicker than the external ribs. As the shell develops, the anterior branch becomes a definitive intermediary. Constrictions are observed on some specimens (Plate XXXVII, Figure 4). The suture line has four auxiliary lobes. The apexes of the saddles lie at a tangent to the umbilicus. The last auxiliary saddle descends toward the umbilicus.

Variability. Individual variability is manifested in more wide-set ribs and in a lower coefficient of branching.

Comparison. The group of ammonites described is referred to *Tollia payeri* (Toula) (Toula, 1874, p. 498, pl. I, fig. 1) on the basis of the form of the shell, the width of the umbilicus, the sculpture, and the suture line. However, due to the deformation of the specimens and the poor illustration of the ammonite in Toula's work, the determination cannot be made without reservations. The form that Spath (1952, pl. 4, fig. 8) assigned to this species has a higher point of branching than the holotype. Spath's poorly preserved specimen, and the absence of a description or drawing of the suture line make it difficult to undertake a comparison with this ammonite. The Speeton ammonites which Pavlow (Pavlow and Lamplugh, 1892, p. 148, pl. 18, fig. 1) and Neale (1962, p. 285, pl. 40, fig. 5) placed in the same species are represented by very young specimens, in which the species characters are not well defined.

In considering the similarities and differences between *Tollia payeri* (Toula) and forms of the genus *Bojarkia* (*B. mesezhnikowi* Schulg.) (Shul'gina, 1969, p. 46, pl. I, fig. 1) we must examine the features in common and the differences in the genera *Bojarkia* and *Tollia.* The similarity consists in the sculpture of the inner (dense double and triple fascicles of ribs) and outer whorls, while the difference is in the sculpture of the middle whorls, the form of the cross section (higher in *Tollia*), the more involute shell in *Tollia,* and the absence of constrictions in *Bojarkia.* Since Toula illustrated the inner and outer whorls of *Tollia payeri* and the middle whorls are unknown, we might have considered this species to belong to the genus *Bojarkia.* However, the type of cross section proves that the species described by Toula is a form of *Tollia.*

The species *Tollia payeri* is represented primarily by inner whorls, which have a sculpture reminiscent of that in *Bojarkia mesezhnikowi* Schulg. But the narrower umbilicus (its width constitutes 23–33% of the shell diameter in *B. mesezhnikowi*), the higher coefficient of branching (2.3–2.5 in *B. mesezhnikowi* at a shell diameter of 34 mm), the presence of constrictions, the stronger bend of the ribs in the upper part of the lateral surface and on the venter, and also the direction of the ribs, not radial but forward, at an acute angle to the radius, all these features distinguish *payeri* from *B. mesezhnikowi* and prove that it belongs to the genus *Tollia.*

Occurrence. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

Age and distribution. Berriasian of Greenland and Western Siberia, *Tollia payeri* zone.

Genus *Neotollia* Schulgina, 1969

Neotollia venusta Klimova, n. sp.
Plate XXXVIII, Figure 1; Plate XXXIX, Figure 1

Holotype. Collection of the Department for Paleontology and Stratigraphy of SNIIGGIMS, Novosibirsk, sample No. 20 (Plate XXXVIII, Figure 1; Plate XXXIX, Figure 1). Western Siberia, Yatriya River, lower Valanginian, *Temnoptychites insolutus* zone.

Diagnosis. Shell disklike, with moderately narrow and deep umbilicus. Cross section changing from oval on the inner whorls to trapezoidal-oval on the middle and outer whorls. There is a prolonged stage of bifurcation; triple fascicles appear at a shell diameter of about 80 mm. Constrictions appear slightly later. On the outer whorls the sculpture disappears first on the sides and then on the venter, only a few crestlike inflations remaining on the umbilical margin. The suture line has four auxiliary lobes.

Material. Five specimens, three of them large shells, 180–200 mm in diameter, one representing half of a medium-sized shell, and one fragment of a clay mold of an outer whorl. We managed to uncoil one complete shell.

Description. Shell disklike, with flattened sides that slope gently toward the venter. Narrow and rounded on the inner whorls, the venter becomes wider and almost flat as the shell diameter increases. Umbilicus moderately narrow (23–27%), sunken. Walls of umbilicus almost sheer on the inner whorls, becoming more gently sloped on the outer whorls. Umbilical margin rounded. Cross section oval on the inner whorls, later trapezoidal-oval. Its maximum width occurs at the level of the umbilical margin. Sculpture of inner whorls represented by double fascicles. The umbilical ribs begin on the umbilical margin, bending backward slightly, after which they are directed forward at an acute angle to the radius. They divide a little above the middle of the lateral surface. At the border between the side and venter the external ribs bend strongly forward, forming a sharp curve on the venter. The height and thickness of the umbilical and external ribs are uniform at this stage of development. When the shell reaches a diameter of 80 mm, the double fascicles are replaced by triple fascicles, at which stage several of the first triple fascicles are observed to alternate with double fascicles. The posterior branch of a triple fascicle departs from the umbilical rib above the anterior branch. The fascicles are narrow. The umbilical ribs become thicker than the external ribs. The direction of the ribs on the sides and the bend of the ribs on the venter remain as before. With further growth an intercalatory rib appears between the fascicles, fading away at the level of the lower point of branching. The branches of the fascicles now also take on the appearance of intermediaries. The first constriction appears at the same time as the intercalatory ribs. The constrictions maintain the direction of the ribs. There are two on each whorl. As the shell diameter increases further (to 104 mm), the sculpture on the sides begins to smooth out, remaining on the umbilical part and on the venter. At 190 mm the venter becomes smooth, just a few inflations remaining on the umbilical part. The constrictions are preserved, but they become shallower.

The suture line is incised and has four auxiliary lobes. The ventral and first lateral lobes are almost of the same size. The second lateral lobe is not much more than half the size of the first. The ventral saddle is about one-and-a-half times as wide as the first lateral saddle. All the saddles, including the auxiliaries, are nonuniformly bipartite. The apexes of the saddles line at a tangent to the umbilicus.

Variability. Individual variability is expressed in the form and size of the first lateral saddle, the width of the first lateral lobe, and in the size of the secondary lobes.

Comparison. The prolonged stage of bifurcation and the trapezoidal-oval whorl section make the inner whorls of this form similar to *Neotollia klimovskiensis* (Krimh.) (Krymgol'ts, 1953, p. 76, pl. XI, fig. 1). The differences between these two species are the narrower umbilicus, the almost radial distribution of the ribs on the sides, and the gentler bend of the ribs on the venter in *N. klimovskiensis.*

In the form of the shell, the width of the umbilicus, the direction of the ribs on the sides and their bend on the venter the inner whorls of the species in question are similar to *N.* (?) *anabarensis* (Pavl.) (Pavlow, 1913, p. 27, pl. IV, fig. 3). But in Pavlow's species triple ribs appear at a diameter of 50 mm and the stage of alternation of double and triple fascicles lasts for quite a long time; moreover, the cross section is almost twice as high as in *N. venusta.*

Occurrence. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

Age and distribution. Lower Valanginian of Western Siberia, *Temnoptychites insolutus* zone.

Neotollia densa Klimova n. sp.
Plate XXXVII, Figures 13–15

Tollia aff. *anabarensis* Klimova, 1960, p. 169; pl. XIX, figs. 4–6.

Holotype. Collection of the Department for Paleontology and Stratigraphy of

SNIIGGIMS, Novosibirsk, sample No. 19 (Plate XXXVII, Figure 13). Yatriya River, lower Valanginian, *Temnoptychites insolutus* zone.

Diagnosis. Shell disklike. Umbilicus narrow. Walls of umbilicus sheer and smooth. Ribs fine, very dense, directed at an acute angle to the radius. They branch just above the middle of the lateral surface, forming narrow double fascicles. The suture line has four auxiliary lobes. The apexes of the saddles lie along a line parallel to the tangent to the umbilicus.

Material. Two incomplete, crushed internal molds of shells with a small diameter.

Description. Shell disklike. Sides flattened. Umbilicus narrow, stepped (15%). Walls of umbilicus low, sheer, smooth. Umbilical margin rounded. The fine, dense ribs begin on the umbilical margin, bending backward barely perceptibly. They bifurcate below the middle of the lateral surface. Relative to the radius the ribs are directed anteriorly, at an acute angle to it. On the venter the ribs bend forward. With growth of the shell the density of the ribs increases: at a diameter of 30 mm there are 13 umbilical ribs on half a whorl (Plate XXXVII, Figure 14), while at a diameter of about 49 mm there are 24 (Plates XXXVII, Figure 13). The direction and size of the ribs do not change as the shell diameter increases. The suture line has four auxiliary lobes; all the lobes are tripartite. The saddles are narrow, nonuniformly bipartite. The apexes of the saddles lie along a line parallel to the tangent to the umbilicus.

Comparison. This species differs from *Neotollia* (?) *anabarensis* (Pavl.) (Pavlow, 1913, p. 27, pl. IV, fig. 3) in the greater density of its ribs. The fine, abundant ribs, bifurcating just above the middle of the sides, render it similar to *Praetollia maynci* Spath var. *communis* Spath (Spath, 1952, pl I, fig. 1a; pl. IV, fig. 6). In Spath's form, however, the direction of the ribs follows the radius, whereas in *N. densa* they form an acute angle with the radius.

Occurrence. Right bank of the Yatriya, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

Age and distribution. Lower Valanginian of Western Siberia, *Temnoptychites insolutus* zone.

Genus *Hectoroceras* Spath, 1947

Hectoroceras tolijense (Nikitin)
Plate XL, Figures 1–4

Ammonites catenulatus Eichwald, 1868, p. 1110, pl. 35, fig. 3.
Oxynoticeras tolijense Nikitin, 1884, p. 65, pl. 2, fig. 7.

Lectotype. Nikitin, 1884, p. 65, pl. 2, fig. 7. Western Siberia (Tol'ya River), Berriasian.

Diagnosis. Shell disklike, flattened, with elliptical cross section; venter narrowed, rounded. Umbilicus narrow, funnel-shaped. Sculpture consisting of long umbilical ribs that bifurcate (more rarely trifurcate) above the middle of the sides. The ribs become interrupted as they approach the venter. The suture line has five auxiliary elements.

Material. More than 30 specimens of various diameter, most of them not very well preserved.

Description. Measurements (sample No. 1), mm:

D	W. u.	Whorl width	Whorl height
85	13(15%)	19(22%)	24(28%)
94	14(15%)	–	–

Shell flattened, disklike, sides flat, gently sloping to the very narrow rounded venter. Cross section narrow, elliptical. The degree of compression of the venter and the width of the cross section vary in dependence on the size of the shell. As the diameter increases, the venter becomes wider and more rounded, and the cross section also expands somewhat. Umbilicus narrow, in the form of a wide funnel. Its walls are low, gently sloped, smooth. In the uppermost part of the umbilical wall begin fine, hairlike costules which become just a little thicker as they cross the rounded umbilical margin, bending very slightly backward. They then rise and bend forward strongly in the middle of the sides and in the upper third of the whorl they curve slightly backward. Hence, the overall bend of the ribs is sigmoidal. In the upper half of the whorl, above the middle of the lateral surface, the umbilical ribs bifurcate or, more rarely, trifurcate. In very rare cases with bifurcation the posterior rib divides again in the upper quarter of the lateral surface. Such is the sculpture on the inner and middle whorls. When the shell reaches a diameter of 90 mm, the outer ribs assume the nature of intermediaries, the lower ends of which do not unite with the umbilical ribs. The ribs are low, thickened at the base, pointed. They remain the same with a further increase in shell size. In cases where the shell layer is not preserved the outline of the ribs becomes slightly diffuse.

The suture line has five auxiliary lobes. The apexes of the saddles lie on a line tangential to the umbilicus that bends backward just above the umbilical margin. The steepness of this curve diminishes as the shell develops. The lobes and saddles are low and wide. The lobes are tripartite; the first and second lateral saddles are nonuniformly bipartite; the auxiliary saddles are divided by a secondary lobe into two almost equal parts. The suture lines are situated very close together, often touching each other.

Variability. The density of the ribs and, to a lesser extent, the coefficient of branching vary among individuals. The degree of dissection of the suture line also varies, but this is not just a case of individual variability but an ontogenetic feature.

Comparison. The species differs from *H. kochi* (Spath, 1947, p. 20, fig. 5; pl. 1, figs. 1–5; pl. 2, figs. 1–4; pl. 3, fig. 1) in having a somewhat thicker shell and a more complicated suture line, with more dissected lobes and saddles and longer secondary lobes separating the auxiliary saddles. This might be attributed to the size differences between the specimens studied and those from which the sutures were drawn in Spath's work: our specimens are markedly larger than his, and both suture lines illustrated by Spath (1947, p. 21, fig. 5a, 5c) are magnified, although the magnification is not indicated in the first case.

H. tolijense is identical to *Oxynoticeras tolijense* Nik. (Nikitin, 1884, p. 65, pl. 2, fig. 7). Its place in the genus *Hectoroceras* became evident after studying the lectotype of Nikitin's species (Museum of the Leningrad Mining Institute). In his description of the genus *Hectoroceras*, Spath mentioned a similarity to *Oxynoticeras tolijense* Nik. (1947, p. 21). However, the less distinct sculpture and Nikitin's point about the Russian form's having a different suture line made Spath refrain from placing it in *Hectoroceras*. Nikitin's lectotype (1884, pl. 2, fig. 7) is represented by an eroded internal mold which was processed only partially, so that the sculpture is not revealed in full. The suture line very closely resembles that of *Hectoroceras kochi* Spath. The first lateral lobe is just a bit longer than the ventral lobe, although Nikitin says the opposite. The differences from Spath's species are the slightly thicker shell and the somewhat more rounded cross section.

Apart from the specimen mentioned above, Nikitin placed in *O. tolijense* a small ammonite (1884, pl. 2, fig. 8) which has a different sculpture and a pointed venter. It probably belongs to another genus.

The ammonite determined by Eichwald as *Ammonites catenulatus* Fischer (Eichwald, 1968, p. 1110, pl. 35, fig. 3) was considered by Nikitin to be a synonym of his species. The resemblance between the forms described and this one is indisputable, despite the fact that the drawing is poor.

Occurrence. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya, left bank of the Tol'ya River, 1.5 km below the mouth of the Botsalym-Alym' River.

Age and distribution. Berriasian, *Hectoroceras kochi* zone of Western Siberia.

BELEMNITES

At the end of the Jurassic and beginning of the Cretaceous there was an extraordinary outburst of the family Cylindroteuthidae in the seas of the Boreal Realm, whereas the Tethyan Realm in the Mediterranean marine region was the habitat of the Duvaliidae and Belemnopsidae (excluding the genus *Belemnopsis*), and the Indo-Pacific Region was also inhabited by Belemnopsidae and rare Duvaliidae. Substantial changes occurred in the composition of the belemnites in the Boreal Realm during the Late Jurassic and Early Cretaceous which, as will be shown below, did not take place synchronously in the various zoogeographic regions and provinces. We will begin our survey with the Boreal-Atlantic Region, the birthplace of the systematic groups of belemnites that were later, in the Neocomian, to spread throughout the Boreal Realm.

According to Swinnerton (1936–1955), a complex of belemnites with *Acroteuthis* s. str. (Table 11) appears at the base of the Spilsby sandstones together with the ammonites *Paracraspedites* and *Subcraspedites*. The latter are considered by most investigators to be of early Berriasian age; only Casey (1962) dates them to the end of the middle Volgian. It should, however, be acknowledged that, proceeding from the general course of development of the boreal faunas at the end of the Jurassic and beginning of the Cretaceous periods, an earlier appearance in the West European Province of genera and subgenera that later spread to other parts of the Boreal Realm does seem possible.

Occurring together with *Acroteuthis* s. str. at the base of the Spilsby sandstones are small rostra which Swinnerton assigned to *Acroteuthis subquadrata* Roem. (Swinnerton, 1936–1955, pl. 1, figs. 6–13). Very likely these are representatives of the subgenus

TABLE 11. Species composition of English belemnites

System	Cretaceous		
Series	Lower		
Stage	Berriasian		Valanginian
	lower part (Volgian strata)	upper part	
Acroteuthis (Acroteuthis) explanatoides (Pavl.)	+	+	+
A. (A.) arctica (Blüthg.)		+	+
A. (A.) acmonoides Swinn.			+
A. (A.) paracmonoides Swinn.			+
A. (A.) partneyi Swinn.	+		
A. (A.) acrei Swinn.			+
A. (A.) lateralis (Phill.)	+	+	
A. (A.) sublateralis Swinn.	+	+	
A. (A.) lindseyensis Swinn.	+		
A. (A.) festucalis Swinn.	+	+	+
A. (A.) prismatica Swinn.			+
A. (A.) dactylis Swinn.			+
A. (Microbelus) sp. "A"	+		
A. (M.) sp. "B"		+	
Coefficient of variation		125	267

Microbelus (sp. "A"), that is so common in upper Volgian and lower Berriasian sediments in the Boreal-Atlantic Region.

In sediments of the higher Berriasian horizons of northeastern England (beds D8–D6 of the Speeton clays) the species composition of the belemnites changes considerably, although, as before, there are still representatives of the subgenus *Acroteuthis* s. str. and, possibly, *Microbelus* sp. "B" (small rostra, identified by Pavlow as belonging to *Belemnites russiensis* – Pavlow, 1892, pl. 3/6, figs. 6–9).

In order to make a quantitative assessment of the changes occurring in the species composition of the belemnites, Saks and Shul'gina (1968) calculated the coefficient of variation (CV), that is, the ratio between the sum of extinct and newly appearing species and the number of transitional forms, in % (Tables 11–16). Between the complexes of the lower Berriasian (?) in the Spilsby sandstones and the higher horizons of the Berriasian in the Speeton clays the CV is 125. The composition of the belemnites receives more additions in the Speeton section between beds D6 and D5 at the boundary between the Berriasian and Valanginian. The CV here reaches 267, and all eight Valanginian species belong to *Acroteuthis* s. str. In England this subspecies is replaced by representatives of the Oxyteuthidae only during the Hauterivian.

In the northern part of West Germany the Berriasian is absent in the marine facies, while at the bottom of the Valanginian only *Acroteuthis* s. str. occurs according to Kemper (1968): *A. (A.) arctica* Blüthg. and *A. (A.) explanatoides* (Pavl.). In Denmark, on the other hand, judging from the nature of the forms of *Buchia*, belemnites are found only in upper Volgian or Berriasian deposits. As the drawings of Sorgenfrei and Buch (1964) show, these are juvenile *Lagonibelus* sp. (? cf. *sibiricus* Sachs and Naln.) and *Acroteuthis (Microbelus)* sp. (? cf. *uralensis* Sachs and Naln.). Belemnite finds are not reported from the Polish Berriasian; from the lower Valanginian Marek (1969) mentions *"Oxyteuthis primus"* Blasz., which is probably a representative of the Cylindroteuthidae, possibly *Acroteuthis (Acroteuthis) explanatoides* (Pavl.). From the Lofoten Islands Sokolov (1912) described along with Valanginian forms of *Buchia* a rostrum of *Belemnites* aff. *subquadratus* Roem. Judging from the drawing, this is of *Lagonibelus (Holcobeloides) sitnikovi* Sachs and Naln.

On the Russian Plain in the East European Province, according to Gustomesov (1964), Gerasimov (1969), and Saks (collections of 1966 and 1969), the upper horizons of middle Volgian sediments (*Epivirgatites nikitini* zone) still yield *Lagonibelus (Holcobeloides) volgensis* (d'Orb.) together with representatives of the subgenus *Microbelus* (Table 12). Higher up in the section, in upper Volgian deposits, we find, along with a predominance of *Microbelus, Boreioteuthis* starting from the *Craspedites subditus* zone and *Acroteuthis* s. str. in the *Craspedites nodiger* zone. The CV values are 33 at the boundaries between the *Epivirgatites nikitini* and *Kachpurites fulgens* and the *K. fulgens* and *Craspedites subditus* zones and 67 at the boundary between the *C. subditus* and *C. nodiger* zones.

In the *Riasanites rjasanensis* zone the belemnite complex resembles the Volgian complex, the CV being 133 on the transition to this zone; as before, forms of *Microbelus* predominate among the Belemnoidea.

In the next zone, *Surites spasskensis*, the composition of the belemnites undergoes a marked change: the CV reaches 1200 and *Acroteuthis* s. str. predominates, together with a good number of *Boreioteuthis*, the presence of which distinguishes the East European Province from the West European. Finally, in the lower Valanginian *Pseudogarnieria undulato-plicatilis* zone there are especially large numbers of *Acroteuthis* s. str. and *Boreioteuthis*. Also here are immigrants from Siberia – isolated *Cylindroteuthis (Arctoteuthis)*. Little is known of the belemnite complex in the overlying strata of the lower Valanginian; there are records just of *Acroteuthis* s. str.

On the Izhma River in the Pechora basin the upper layers of the middle Volgian substage (*Epivirgatites nikitini* zone) contain a belemnite complex typical for the Russian Plain (Table 13); only one upper Volgian Middle Russian species is known from, presumably, upper Volgian sediments. Species were collected from the base of the visible section of the Berriasian that are characteristic for the upper strata of the Jurassic and bottom strata of the Cretaceous of Siberia. Higher up the section in the *Surites analogus* zone there is now a predominance of *Acroteuthis* spp., which occur only in Europe in the Berriasian, along with Siberian forms, including *Pachyteuthis (Simobelus) curvula* Sachs and Naln., that in Siberia and the Urals characterizes only the *Surites analogus* zone and the bottom strata of the *Bojarkia mesezhnikowi* zone. Sediments of the latter zone and higher deposits at the base of the lower Valanginian yielded a complex with *Acroteuthis* spp. which is richer than in the older strata, together with *Acroteuthis (Microbelus)* ex gr. *russiensis* (d'Orb.).

From Spitsbergen (Kong Karls Land) Blüthgen (1936) reports a rich belemnite

TABLE 12. Species composition of belemnites in the central part of the Russian Plain

System	Jurassic			Cretaceous				
Series	Upper			Lower				
Stage	Volgian						Valanginian	
Substage	middle	upper					lower	
Zone	*Epivirgatites nikitini*	*Kachpurites fulgens*	*Craspedites subditus*	*Craspedites nodiger*	*Riasanites rjasanensis*	*Surites spasskensis*	*Pseudogarnieria undulato-plicatilis*	*Temnoptychites hoplitoides*
Cylindroteuthis (Arctoteuthis) repentina Sachs and Naln.							+	
Cylindroteuthis (Arctoteuthis) sp. n. inden.							+	
Lagonibelus (Holcobeloides) volgensis (d'Orb.)	+							
Acroteuthis (Acroteuthis) corpulenta (Nik.)				+				
A. (A.) lateralis (Phill.)					+	+	+	+
A. (A.) arctica Blüthg.						+	+	+
A. (A.) explanatoides (Pavl.)						+	+	+
A. (A.) anabarensis (Pavl.)						+	+	+
A. (A.) bojarkae Sachs and Naln.						+	+	
A. (A.) chetae Sachs and Naln.						+	+	
A. (A.) vnigri Sachs and Naln.							+	
A. (Microbelus) russiensis (d'Orb.)	+	+	+	+	+			
A. (M.) mosquensis (Pavl.)	+	+	+	+	+			
A. (M.) praecorpulenta (Geras.)	+	+	+					
A. (M.) uralensis Sachs and Naln.					+			
A. (Boreioteuthis) prolateralis Gust.			+	+	+			
A. (B.) explorata Sachs and Naln.						+	+	
A. (B.) hauthali Blüthg.						+	+	
A. (B.) freboldi Blüthg.							+	
Pachyteuthis sp.					+			
Coefficient of variation		33	33	67	133			

complex from Berriasian–Valanginian deposits (33 species and subspecies belonging mostly to *Acroteuthis* s. str. and more rarely to *Boreioteuthis, Lagonibelus* s. str., *Pachyteuthis* s. str., *Simobelus,* and *Pseudohibolites*). The collections were taken from taluses and are not allocated to a section; it is not known when the complex emerged, but all the species are quite soundly identified. We do not actually know the composition of the belemnites at the end of the Jurassic. Meriting attention, however, is the fact that the complex contains Tethyan Belemnopsidae *(Pseudohibolites),* which may have reached Spitsbergen in bypassing Northwest Europe, only with the warm Atlantic current.

TABLE 13. Species composition of belemnites in the Pechora basin

System	Jurassic		Cretaceous			
Series	Upper		Lower			
Stage	Volgian		Berriasian			Valanginian
Substage	middle	upper	–			lower
Zone	*Epivirgatites nikitini*	–	*? Hectoroceras kochi*	*Surites analogus*	*Bojarkia mesezhnikowi*	
Lagonibelus (Holcobeloides) rosanovi Gust.	+					
L. (H.) sitnikovi Sachs and Naln.	+		+	+		
L. (Lagonibelus) sibiricus Sachs and Naln.			+			
Pachyteuthis (Simobelus) curvula Sachs and Naln.				+		
Acroteuthis (Acroteuthis) explanatoides polaris Sachs and Naln.				+		
A. (A.) lateralis (Phill.)				+	+	+
A. (A.) arctica Blüthg.				+	+	+
A. (A.) anabarensis (Pavl.).						+
A. (A.) vnigri Sachs and Naln.				+	+	+
A. (A.) chetae Sachs and Naln.						+
A. (A.) bojarkae Sachs and Naln.						+
A. (Boreioteuthis) prolateralis Gust.			+			
A. (B.) hauthali Blüthg.				+		+
A. (B.) freboldi Blüthg.				+	+	
A. (B.) explorata Sachs and Naln.						
A. (A.) coartata Sachs and Naln.						+
A. (Microbelus) ex gr. *russiensis* (d'Orb.)				+	+	
A. (M.) praecorpulenta (Geras.)		+				
Coefficient of variation				100	67	175

Very few data are available on the composition of the Belemnoidea at the top of the Jurassic and bottom of the Cretaceous in Eastern Greenland. In middle Volgian sediments we know of a few finds of species that existed at the same time in the Pechora basin and in northern Siberia. There are reports from the Berriasian (*Hectoroceras kochi* zone) (Spath, 1947) and from a nonspecified part of the Berriasian (Donovan, 1953) of representatives of *Acroteuthis (Acroteuthis) arctica* Blüthg. and *A. (A.) bojarkae* Sachs and Naln. The first of these species has been recorded also from the Valanginian.

In middle Volgian time in the eastern foothills of the Cis-Polar Urals in Western Siberia lived a complex similar to the complexes of the Russian Plain, with a predominance of *Pachyteuthis* s. str. and *Simobelus.* In upper Volgian sediments in the *Kachpurites fulgens* zone, and also in the East European Province, there is a predominance of *Microbelus* (Table 14). But in the uppermost horizons of the Volgian stage there appears a completely different complex with *Cylindroteuthis* s. str., *Arctoteuthis*, and *Lagonibelus* ex gr. *elongatus*, consisting of species that for the most part are common for the north of Middle Siberia. This complex persists into the Berriasian. Presumably confined to the bottom of the Berriasian is a complex in which together with the Siberian species feature species of *Microbelus* that are characteristic for the East European Province. These disappear in the *Hectoroceras kochi* zone, and only the Siberian forms remain. The coefficient of variation at the transition from the Volgian stage to the Berriasian is 250, between the bottom of the Berriasian and the *Hectoroceras kochi* zone 18, and between the *H. kochi* and *Surites analogus* zones also 18. It is important to note that the zone *Surites analogus* contains *Pachyteuthis (Simobelus) curvula* Sachs and Naln., a species that in Middle Siberia is confined to the top of the *Surites analogus* and the bottom of the *Bojarkia mesezhnikowi* zone.

With the transition to the overlying zone *Bojarkia payeri* in the Urals foothills *Acroteuthis* s. str. appears, and the coefficient of variation increases to 129. Finally, at the bottom of the Valanginian, in the *Temnoptychites insolutus* zone, these forms assume supremacy in the complex. At the boundary between the *Bojarkia payeri* and *Temnoptychites insolutus* zones the CV is 75, the main factor being the extinction of representatives of the Berriasian complex.

The best studied to date are the belemnites from the north of Middle Siberia (North Siberian zoogeographic province), that are widespread in the seas of the Yenisei-Lena and Verkhoyansk depressions. In Volgian time there lived here a distinctive complex with forms of the subgenera *Cylindroteuthis* s. str., *Arctoteuthis*, *Lagonibelus* s. str., *Holcobeloides*, *Pachyteuthis* s. str., *Simobelus*, occasional *Boreioteuthis*, and *Microbelus*. Nineteen species are established in this complex at the end of middle Volgian time. In the late Volgian there occurred a certain, albeit insignificant impoverishment of the complex, now numbering 15 species, the subgenus *Microbelus* now having dropped out (Table 15).

At the transition from the middle Volgian to the later Volgian the CV becomes 33, during late Volgian time between the *Craspedites okensis* and *C. taimyrensis* zones it is 45, and between the *C. taimyrensis* and *Chetaites chetae* zones it is 57. At what we consider the Jurassic-Cretaceous boundary between the *Ch. chetae* and *Ch. sibiricus* zones the CV drops to 50, but this can only be attributed to lack of material on these two zones. In general, however, the gradual impoverishment of the north Siberian belemnite complex continued in the late Volgian: from 16 species in the *Craspedites okensis* zone to 11 in the *Craspedites taimyrensis* zone and 7 in the *Chetaites chetae* zone. Meanwhile, the subgenus *Holcobeloides* disappears after "*Craspedites okensis*" time.

In the Berriasian the CV is calculated at 50 between the *Ch. sibiricus* and *Hectoroceras kochi* zones, 71 between the *H. kochi* and *S. analogus* zones, and 40 between the *S. analogus* and *Bojarkia mesezhnikowi* zones. As far as the base of the *S. analogus* zone the changes consist mainly in the impoverishment of the complex that made the transition from the Volgian. Only 7 species are found in the *Chetaites sibiricus* zone, 7 in the *Hectoroceras kochi* zone, and now 12 in the *Surites analogus* zone, with the first-time appearance of representatives of the subgenus *Acroteuthis* s. str. In the *Bojarkia me-*

TABLE 14. Species composition of belemnites on the eastern slope of the Cis-Polar Urals

System	Jurassic			Cretaceous					
Series	Upper			Lower					
Stage	Volgian			Berriasian				Valanginian	
Substage	Upper							Lower	
Zone	*Kachpurites fulgens*	*Craspedites subditus*	*upper part of stage*	*Chetaites sibiricus*	*Hectoroceras kochi*	*Surites analogus*	*Bojarkia payeri*	*Temnoptychites insolutus*	*Polyptychites michalskii*
Cylindroteuthis (Cylindroteuthis) lepida Sachs and Naln.				+	+	+	+	+	+
C. (C.) luljensis Sachs n. sp.				+	+	+	+		
C. (Arctoteuthis) porrectiformis And.				+	+	+			
C. (A.) aff. *subconoidea* Sachs and Naln.				+	+	+			
C. (A.) repentina Sachs and Naln.			+	+	+	+	+		
Lagonibelus (Lagonibelus) elongatus (Blüthg.)			+	+	+	+	+	+	
L. (L.) sibiricus Sachs and Naln.				+	+	+			
L. (L.) gustomesovi Sachs and Naln.			+	+	+	+			
Pachyteuthis (Pachyteuthis) acuta (Blüthg.)				+	+	+	+	+	+
P. (P.) subrectangulata (Blüthg.)				+	+	+	+	+	+
P. (Simobelus) subbreviaxis Sachs and Naln.	+								
P. (S.) insignis Sachs and Naln.	+	+	+						
P. (S.) curvula Sachs and Naln.						+			
Acroteuthis (Acroteuthis) arctica Blüthg.								+	+
A. (A.) anabarensis (Pavl.)							+	+	+
A. (A.) explanatoides polaris Sachs and Naln.								+	+
A. (A.) vnigri Sachs and Naln.							+	+	+
A. (A.) bojarkae Sachs and Naln.							+	+	+
A. (A.) chetae Sachs and Naln.								+	
A. (Microbelus) mosquensis Pavl.				+					
A. (M.) russiensis d'Orb.	+								
A. (M.) posterior Sachs n. sp. (in litt.)									+
A. (M.) uralensis Sachs and Naln.				+					
A. (Boreioteuthis) explorata Sachs and Naln.				+	+	+	+	+	+
A. (B.) hauthali Blüthg.								+	+
Acroteuthis n. sp.						+			
Coefficient of variation				250	18	18	129	75	30

TABLE 15. Species composition of belemnites in the north of Middle Siberia

System	Jurassic				Cretaceous						
Series	Upper				Lower						
Stage	Volgian				Berriasian				Valanginian		
Substage	mid-dle	upper			–				lower		up-per
	Epivirgatites variabilis	*Craspedites okensis*	*Craspedites taimyrensis*	*Chetaites chetae*	*Chetaites sibiricus*	*Hectoroceras kochi*	*Surites analogus*	*Bojarkia mesezh-nikowi*	*Neotollia klimov-skiensis*	*Polyptychites stuben-dorffi*	
1	2	3	4	5	6	7	8	9	10	11	12
Cylindroteuthis (Cylindroteuthis) lepida (Sachs and Naln.	+	+	+	+	+						
C. (C.) glennensis And.	+	+	+	+							
C. (C.) jacutica Sachs and Naln.	+	+	+								
C. (C.) luljensis Sachs n. sp.					+						
C. (Arctoteuthis) comes Voron.	+	+									
C. (A.) porrectiformis And.	+	+	+	+	+	+	+	+			
C. (A.) bacculus Crick.						+	+	+			
C. (A.) repentina Sachs and Naln.					+	+	+	+	+	+	
C. (A.) subconoidea Sachs and Naln.									+	+	
C. (A.) harabylensis Sachs and Naln.									+	+	+
Lagonibelus (Lagonibelus) gustomesovi Sachs and Naln.		+	+	+	+	+	+				
L. (L.) superelongatus (Blüthg.)	+	+	+	+	+	+	+				
L. (L.) elongatus (Blüthg.)	+	+	+	+	+	+	+	+			
L. (L.) sibiricus Sachs and Naln.	+	+	+	+	+	+	+			+	
L. (Holcobeloides) sitnikovi Sachs and Naln.	+	+									
Pachyteuthis (Pachyteuthis) apiculata Sachs and Naln.	+	+	+								
P. (P.) subregularis Sachs and Naln.	+	+	+								
P. (P.) acuta (Blüthg.)							+	+	+	+	

TABLE 15 (continued)

1	2	3	4	5	6	7	8	9	10	11	12
P. (P.) subrectangulata (Blüthg.)							+	+	+	+	+
P. (Simobelus) insignis Sachs and Naln.	+	+									
P. (S.) mamillaris (Eichw.)	+	+									
P. (S.) obtusiformis Sachs and Naln.	+	+									
P. (S.) subbreviaxis Sachs and Naln.	+	+	+								
P. (S.) fortuita Sachs and Naln.	+										
P. (S.) curvula Sachs and Naln.							+	+			
Acroteuthis (Acroteuthis) lateralis (Phill.)								+	+		
A. (A.) sublateralis Swinn.									+		
A. (A.) explanatoides polaris Sachs and Naln.							+	+	+	+	+
A. (A.) arctica Blüthg.								+	+	+	+
A. (A.) anabarensis (Pavl.)							+	+	+	+	+
A. (A.) chetae Sachs and Naln.									+		
A. (A.) bojarkae Sachs and Naln.									+	+	+
A. (A.) cylindrica Sachs and Naln.									+	+	
A. (A.) vnigri Sachs and Naln.									+	+	+
A. (A.) acrei Swinn.										+	+
A. (Microbelus) mosquensis Pavl.	+										
A. (M.) russiensis d'Orb.	+										
A. (M.) uralensis Sachs and Naln.									+		
A. (Boreioteuthis) niiga Sachs and Naln.	+										
A. (B.) hauhali Blüthg.										+	+
A. (B.) freboldi Blüthg.										+	+
A. (B.) coartata Sachs and Naln.										+	+
Coefficient of variation	33	45	57	50	50	71	40	171	82	45	

sezhnikowi zone 11 species are encountered, 5 of them belonging to *Acroteuthis* s. str.

At the Berriasian-Valanginian boundary between the *Bojarkia mesezhnikowi* and *Neotollia klimovskiensis* zones the CV reaches 71, which is the maximum value for all the zone boundaries in the Upper Jurassic and Lower Cretaceous. At the same time, in place of the hitherto predominating subgenera *Lagonibelus* s. str. and *Arctoteuthis*, there is a clear supremacy of *Acroteuthis* s. str. (10 out of 15 species). Within the Valanginian the CV drops to 82 at the boundary between the *Neotollia klimovskiensis* and *Polyptychites* *stubendorffi* zones and to 45 between the *P. stubendorffi* and *Dichotomites* spp. zones.

The Upper Jurassic and Lower Cretaceous belemnites of Alaska and Canada have been studied very little. From the Berriasian–Valanginian of northern Alaska Imlay (1961) described a rostrum which Saks and Nal'nyaeva (1964) referred to *Lagonibelus (Lagonibelus) sibiricus* Sachs and Naln. In the Valanginian of the Canadian Archipelago (Ellef Ringnes Island) a curious subconical rostrum was found that Jeletzky (1964) determined as belonging to *Acroteuthis?* n. sp. A, but which probably belongs to *Cylindroteuthis (Arctoteuthis)* n. sp. (ex gr. *subporrecta* Bodyl.). In the same locality in the upper Valanginian a rostrum was discovered that according to Jeletzky refers to *Acroteuthis (Acroteuthis) subquadrata* (Roem.). Judging from the wide, long ventral sulcus, this is more likely a representative of the subgenus *Boreioteuthis.*

On Vancouver Island from the top of the middle Volgian Jeletzky (1965) presents a drawing of a rostrum which apparently belongs to *Cylindroteuthis (Cylindroteuthis) jacutica* Sachs and Naln., a species widely distributed in the Volgian stage.

From the Berriasian of British Columbia Crickmay (1930) described *Cylindroteuthis (Arctoteuthis) baculus* Crickmay and *Pachyteuthis (Simobelus) cretacea* Crickmay. According to Jeletzky and Tipper (1958), the first of these species, which is known also from the Berriasian of Siberia, is confined to the upper part of the Canadian Berriasian. The second species resembles the Volgian Siberian species. The discovery of these species in western Canada shows that a complex of belemnites similar to the Volgian and Berriasian complexes of northern Siberia was distributed here in Volgian and Berriasian time.

In the Valanginian of British Columbia rostra are encountered which Jeletzky (1965) concluded were of *Acroteuthis* n. sp. A, but in fact, they probably belong to *Cylindroteuthis (Arctoteuthis)* cf. *harabylensis* Sachs and Naln.

The upper Volgian (upper Tithonian) and Neocomian belemnites of California and Oregon were described by Anderson (1938, 1945). The originals are deposited at the Museum of the California Academy of Sciences and were examined by Stevens (1965) and in 1971 by Saks. Predominant at the end of the Jurassic in the west of the USA were forms of *Cylindroteuthis* s. str. and *Arctoteuthis* that are similar to the Siberian representatives, along with forms with spindle-shaped rostra without sulci, primarily *Hibolites.* On the other hand, as Stevens (1965) noted, the species that Anderson placed in *Belemnopsis* belong, apart from the species *berrysae,* to the Cylindroteuthidae, more specifically, to *Cylindroteuthis,* with moderately elongate rostra, or possibly to *Lagonibelus* ex gr. *elongatus* (without knowning the inner structure of the rostra it is impossible to specify the genus). As for the rostrum of *Acroteuthis watsonensis* And., which has no alveolar part, it may belong to the subgenus *Boreioteuthis,* but it could also prove to be similar or identical to the rostra of *Cylindroteuthis (Arctoteuthis) tehamaensis* Stant. Stevens is also doubtful about Anderson's correctness in isolating the genus *Hibolites,* although the rostra assigned to this genus are different from those of the Cylindroteuthidae in their being spindle-shaped. We leave them in the genus *Hibolites.* The species *"Belemnopsis" berrysae* And. apparently also belongs to this genus.

According to Stevens and Saks, many of Anderson's species should be united, a question which cannot be resolved just by examing the museum material, but only by thorough processing of the specimens. Therefore, in Table 16 we keep all Anderson's species but correct their classification into genera and show possible variants of species groupings.

It should be pointed out that *Cylindroteuthis (Lagonibelus?)* and *Hibolites* are also present in lower Tithonian (Portlandian) sediments in California.

It is worthy of note that not a single species described by Anderson in the upper Tithonian of California passes over into the Cretaceous system. Such a marked difference between the Jurassic and Cretaceous belemnite complexes on the Pacific coast of the USA can be attributed to the large gap separating them in time. That the Berriasian is present in the west of the USA is now a proven fact (Imlay and Jones, 1970), but the species of *Acroteuthis* and *Pachyteuthis* that Anderson described (Anderson, 1938) from the lower strata of the Cretaceous (the Paskenta group) do not tie in with finds of Berriasian ammonites and may be not of Berriasian but of early Valanginian age. In the Valanginian of the western part of the USA, as in Canada, the complex with *Acroteuthis (Boreioteuthis)* and rarer *Arctoteuthis* becomes the dominant one.

Stevens (1965) referred the Neocomian *Acroteuthis* forms described by Anderson to *Aulacoteuthis* on the basis of the presence of a well-developed ventral sulcus on the rostrum of many of them. We cannot agree with this, since a ventral sulcus is present in *Acroteuthis* as well, especially in the subgenus *Boreioteuthis*.. The genus *Aulacoteuthis,* which belongs to the family Oxyteuthidae, differs from *Acroteuthis* in the lateral sulci, such sulci being absent in the Californian representatives of *Acroteuthis.*

In general, in the Boreal-Atlantic Region the middle Volgian complex of belemnites with *Pachyteuthis* s. str., *Simobelus,* and *Lagonibelus* s. str. became replaced in the middle and late Volgian and early Berriasian by a complex with *Microbelus,* this genus spreading eastward as far as the western part of the West Siberian Sea inclusive. Beginning from the later part of late Volgian time, this complex saw the emergence of *Acroteuthis* s. str., which became supreme in the Berriasian everywhere to the west of the Urals meridian. Meanwhile, in the East European Province, *Boreioteuthis* assumed an important role in the complexes beginning with the Volgian.

In the Arctic Region, including the Boreal-Pacific Province, a complex existed in Volgian time that comprised *Cylindroteuthis* s. str., *Arctoteuthis, Lagonibelus* ex gr. *elongatus, Pachyteuthis* s. str., and *Simobelus;* it gradually became impoverished, but still persisted to the end of the Berriasian. This complex spread in the Boreal-Pacific Province as far as California and the present-day Maritime Territory, and at the end of the late Volgian it penetrated still farther west to the Urals. Only at the end of the Berriasian in the Arctic Region did *Acroteuthis* s. str. and *Boreioteuthis* disperse. Starting from the Valanginian, the belemnite complex with *Acroteuthis* s. str. occupied the entire Boreal Realm. Only *Boreioteuthis* is unknown in Western Europe.

What we have said allows us to conclude that the birthplace of the new groups of boreal belemnites in late Volgian time (*Microbelus* ex gr. *russiensis, Acroteuthis* s. str., the Neocomian *Boreioteuthis*) was the Boreal-Atlantic Region, possibly the Middle Russian Sea. Only Neocomian forms of *Arctoteuthis* appeared and developed in the Arctic Region.

TABLE 16. Species composition of belemnites in the western part of North America

System		Jurassic		Cretaceous		
Series		Upper		Lower		
Stage		Tithonian				
Substage		lower	upper	Berriasian	Berriasian–Valanginian	Valanginian
Cylindroteuthis (Cylindroteuthis) cf. *jacutica* Sachs and Naln.		+	+			
C. (C.) occidentalis And.	*C. (C.)* sp. *A*		+			
C. (C.) glennensis And.			+			
C. (C.) knoxvillensis And.	*C. (C.)* sp. *B*					
C. (C.) newvillensis And.			+			
C. (C.) klamathonae And.			+			
C. (Arctoteuthis) tehamaensis Stant.			+			
C. (A.) porrectiformis And.			+			
C. (A.) clavicula And.			+			
C. (A.) baculus Crickmay			+			
C. (A.) kernensis (And.)				+		+
C. (A.) cf. *harabylensis* Sachs and Naln.						+
C. (Lagonibelus?) californicus (And.)	*Cylindroteuthis (Lagonibelus?)* sp. *C*	+				
C. (L.?) cachensis (And.)		+				
C. (L.?) napaensis (And.)			+			
C. (L.?) mercurialis (And.)			+			
C. (L.?) tomsensis (And.)			+			
C. (L.?) spiculoides (And.)			+			
C. (L.?) tercensis (And.)			+			
Pacyhteuthis (Pachyteuthis) macarthyensis Stanton					+	+
P. (Simobelus) cretacea Crickmay				+		
Acroteuthis (Boreioteuthis) impressa Gabb					+	
A. (B.) kewana And.						+
A.? (B.?) watsonensis And.			+			
A. (B.) onoensis And.						+
A. (B.) winslowensis And.						+
A. (Microbelus) shastensis And.					+	+
Hibolites berryasae And.	*Hibolites* sp. *D*		+			
H. wiburensis And.		+				
H. arrogoensis And.			+			

Genus *Cylindroteuthis* Bayle and Zeiller, 1878

Subgenus *Cylindroteuthis* Bayle and Zeiller, 1878

*Cylindroteuthis (Cylindroteuthis) luljensis** Sachs n. sp.
Plate XLIII, Figures 1–4

Holotype No. 86-1. Museum of IGG SO AN SSSR,** Novosibirsk. Yatriya River, on the east slope of the Cis-Polar Urals. Berriasian, *Surites analogus* zone.

Diagnosis. Rostrum of medium size, moderately elongate (Pa 614–675), subconical; a shallow, clearly expressed sulcus is present in the preapical part. Cross section subrectangular. Aleveolus not deep, weakly folded. Axial line closer to the ventral side.

Material. Three rostra from the *Hectoroceras kochi* zone, 2 rostra from the *Surites analogus* zone, 3 rostra from the *Bojarkia payeri* zone on the Yatriya River (collections of Saks), and one rostrum from the *Chetaites sibiricus* zone on the Kheta River (collections of Zakharov).

External characters. Rostrum of medium size, moderately elongate (Pa 614–675), subconial. Preapical part elongate, constituting about 1/4 of the total length of the rostrum. Apex pointed, central. Apical angle 23–27° in the lateral plane. Dorsal side weakly convex, ventral and lateral sides slightly flattened. There is a distinct shallow sulcus on the ventral side in the preapical part. The cross section at the apex of the alveolus is rounded-subrectangular, laterally compressed. The dorsal-ventral diameter exceeds the lateral diameter (VL 93–98). Toward the posterior end the lateral compression is slightly reduced (ll 98–102), and the cross section becomes more rounded.

Internal characters and ontogenesis. Alveolus shallow, occupying about 1/5 of the length of the rostrum, weakly folded. Ventral radius 30–40% of the diameter at the apex of the alveolus. Axial line bent near the apex of the alveolus. Alveolar angle 20° in the dorsoventral plane. Initial rostra slightly subconical, very elongate; on a polished section of a rostrum of specimen No. 86-3 it is seen that the first visible rostrum at a diameter of 4.7 is 465 mm long, that is, Pa is 989. The length of the postalveolar part diminishes in adult forms.

Variability. Eight rostra of this species, collected in one exposure, show negligible fluctuations in the ratio of the length of the postalveolar part (Pa varying between 614 and 675).

Comparison. In general appearance the rostra examined resemble those of the genus *Lagonibelus* and are preliminarily determined as belonging to this genus. The relatively small value of Pa, the form of the rostrum, and the type of lateral compression relate this species to the group *L. (L) elongatus.* However, an examination of longitudinal polished sections showed that in the initial stages the rostra are markedly elongate, and therefore should be referred to the genus *Cylindroteuthis.* The species *luljensis* n. sp. is quite a

* Named after the Bol'shaya Lyul'ya River, near the mouth of which rostra of this species were collected.

** [Institute of Geology and Geophysics, Siberian Branch of the Academy of Sciences of the USSR.]

TABLE 17. Measurements of rostra of *Cylindroteuthis (Cylindroteuthis) luljensis* Sachs n. sp.

Parameter	86–1	86–2	86–3	86–4	86–5
Total length (hypothetical)	154.0 895	150.0 892	132.0 985	113,0 911	205,1 919
Total length established	136.0 733	133.0 792	117.0 860	88,0 710	169.0 756
Length of postalveolar part	110.2 641	110.0 655	89.4 675	82.1 662.1	137.0 614
Dorsoventral diameter at apex of alveolus	17.2 100	16.8 100	13.6 100	12.4 100	22.3 100
Lateral diameter at apex of alveolus	16.5 96	16.0 95	13.0 97	12.2 98	20.7 93
Ventral radius at apex of alveolus	6.5 37	5.7 34	5.5 40	3.4 27	6.5 29
Length of preapical part	41.5 241	43.0 256	33.02 43	31.0 250	54.0 242
Dorsoventral diameter in preapical part	13.4(100)78	13.0(100)77	10.0(100)74	9.9(100)79	17.2(100)77
Lateral diameter in preapical part	13.2(98)76	13.0(100)77	10.0(100)74	10.0(99)81	17.5(102)78
Alveolar angle, degrees			20		
Apical angle, degrees	23			24	25

unique representative of the genus *Cylindroteuthis*, having a well-expressed subconical shape and not occurring earlier in Berriasian sediments. *C. (C.) luljensis* n. sp. may be compared with *C. (C.) lepida*, which is also found in Berriasian sediments, but it differs in being less distinctly subconical, in its larger size, in the much greater degree of elongation (Pa 800–1000 in *lepida*), and in the more weakly expressed ventral sulcus.

Age and distribution. Berriasian of northern Siberia (from the *Chetaites sibiricus* zone to the *Bojarkia payeri* zone).

BIVALVES

In estimating the stratigraphic importance of bivalves, two features must be taken into account: 1) the sharp differences between complexes of species of the same age coming from different facial zones and 2) differences between complexes from the same facies and of the same age that derive from different paleobiogeographic regions and provinces. Hence: 1) comparisons were made of same-aged complexes of bivalves coming from strata that were formed under similar facial conditions; 2) changes in the complexes were observed separately in sections formed under the same type of facial conditions; 3) a stratigraphic assessment of species complexes was performed mainly within the limits of individual paleobiogeographic provinces.

A special paper has been devoted to the changes occurring in the species complexes of bivalve mollusks at the Jurassic-Cretaceous boundary in the Boreal and Arctic zoogeographic regions (Zakharov, 1968). During the last three years new collections of bivalves have been made from the Berriasian and boundary layers in sections on Paks Peninsula and on the Kheta River (north of Middle Siberia). Since these collections have not been treated monographically, the present survey also takes into account the results of preliminary determinations. The new data yielded have made it possible to pinpoint more exactly the limits of distribution of different species in horizons transitional between the Jurassic and Cretaceous and in the Berriasian. A more detailed paleobiogeographic zoning of the Arctic Region based on bivalves has also been proposed for the end of the Jurassic and beginning of the Cretaceous (Zakharov, 1970). The Late Jurassic and Early Cretaceous Arctic zoogeographic region is divided into three subregions on the basis of the marked difference observed in the systematic composition of the fauna, attributable to climatic factors and the isolation of the basins: the Canadian-Chukchi zoogeographic subregion–Late Jurassic-Early Cretaceous Circumpolar zone (northeast of the USSR, Alaska, and northern Canada), the Central Arctic zoogeographic subregion (western sector of the Arctic), and the Boreal-Pacific zoogeographic subregion (the province given the same name by Saks). The Central Arctic subregion is divided into several provinces in the Late Jurassic and Early Cretaceous. In late Volgian time we isolate the Northern Urals and North Siberian provinces, in the early Berriasian these regions are combined into a single province in the category of subprovinces, and in the late Berriasian and Valanginian they are classified as different districts. Since the Berriasian bivalve complexes from the different paleozoogeographic subdivisions differ within the Boreal Realm, we will consider them on the basis of data from specific areas, beginning with the western ones.

The marine Berriasian sediments farthest west known to us are in northeastern England (the Speeton clays and Spilsby sandstones). Yet it is hard to make an assessment of the bivalve complexes from this area because they have not been identified. In the north of Western Europe the Berriasian is unknown in marine facies.

In Poland (Kujawy) about twenty genera of bivalves and gastropods have been determined in beds with *Riasanites*. Practically the same complex is encountered in higher strata with *Surites* (these layers are characterized by the presence of *Exogyra sinuata*) (Marek, 1967, 1969). Found together with Berriasian ammonites is a complex of bivalves with the same composition as that indicated in the publications mentioned; it cannot be regarded as typifying the Berriasian alone, as these genera and species have a wider stratigraphic interval.

The bivalve complexes on the Russian Plain (East European province of the Boreal-Atlantic Region) at the Jurassic-Cretaceous boundary differ substantially from the complexes in the Arctic Region (Gerasimov, 1955; Zakharov, 1966). Fairly complete sections of the Volgian and Berriasian stages are present on the Russian Plain. Most of the species found in beds with *Craspedites* (28 according to a communication by Gerasimov) were discovered in middle Berriasian sediments (Ryazan horizon). Quite different is the composition of Bivalvia inside the Berriasian between the *Riasanites rjasanensis* and *Surites spasskensis* zones. The renewal index of the species complex (the sum of extinct and newly emerging species) is maximal at this boundary, 26, as against 11 at the boundary between the beds with *Craspedites* and the Ryazan horizon (Zakharov, 1968, pl. V). However, at the boundary between the *R. rjasanensis* and *S. spasskensis* zones the complex changes only on account of the disappearance of species, while above the Ryazan horizon the complex becomes greatly impoverished. Only one species drops out at the Berriasian-Valanginian boundary, so that the Valanginian depleted complex is not distinct as compared with the upper Berriasian complex. The upper Neocomian (upper Hauterivian-Barremian) complexes of bivalves are very different from the lower Neocomian ones (Valanginian-lower Hauterivian). These distinctive features in the distribution of the bivalves through the section are due largely to changes in the life conditions of the benthos at the end of the Jurassic and beginning of the Cretaceous. Similar facial conditions existed in late Volgian and early Berriasian time in the central part of the Russian Plain which was conducive to the survival of the majority of the Volgian species at the beginning of the Berriasian. The nature of the facies (and consequently of the life conditions of the benthos) changed at the end of the early Berriasian, causing a marked reduction of the benthos, including bivalves. Hence, the appreciable change in the composition of the bivalve complexes within the Berriasian can be attributed largely to the worsened situation for the benthos at the end of the early Berriasian.

In the Pechora basin continuous sections of relatively deepwater facies have been established according to core samples in the northern part of the Pechora Territory. Berriasian sediments have not, however, been identified owing to the absence of finds of Berriasian ammonites. The only bivalves discovered in the horizons transitional between the Jurassic and Cretaceous are species of *Buchia,* which have not been described monographically. The Berriasian bivalve complex observed by Bodylevskii (1963) from the *Surites spasskensis* zone is represented mainly by *Buchia: B. terebratuloides* (Lah.), *B. volgensis* (Lah.), and *B.* cf. *lahuseni* (Pavl.).

In the Northern Urals the Berriasian is distributed everywhere in marine shallow-water facies. Preliminary determinations of bivalves show that their species complexes are most clearly distinguished between the *Craspedites subditus* and *Hectoroceras kochi* zones. The renewal index of the species complex is maximal at the boundary between these zones, being equal to 25 (Table 18). But on the Yatriya River between beds with *Craspedites* and with *Hectoroceras* there is about 3 m of section that is not characterized by ammonites. This horizon is nominally referred to the Upper Jurassic. The most typical species of bivalves from this horizon is *Liostrea sibirica* Zakh. n. sp. occurring in large numbers and found during the 1969 field work on the Kheta River in a bed with *Chetaites sibiricus* Schulg. The other bivalves observed in the same place do not have a strict stratigraphic interval. If this horizon is eventually placed in the Jurassic on the basis of the ammonites, no clear-cut change in the bivalve complexes will be observed at the Jurassic-Cretaceous boundary. Although there is a change in the species complex higher up in the section, it is negligible and probably fortuitous, since the newly appearing species in other sections have a very wide range. There is large-scale renewal of the complex in the *Temnoptychites syzranicus* zone. Occurring here are species typical for the Valanginian of northern Siberia: *Liostrea anabarensis* Bodyl., *Astarte (Astarte) veneriformis* Zakh., and *"Musculus" sibiricus* (Bodyl.). Some of the true Lower Cretaceous species emerge as early as in the *Hectoroceras kochi* zone (Table 20), but the Berriasian has its own species, such as *Liostrea lyapinensis* Zakh. n. sp. (particularly numerous in the lower Berriasian), *L. uralensis* Zakh. n. sp., *Buchia volgensis* (Lah.), *B. okensis* (Pavl.), *Aguilerella anabarensis* (Krimh.), and *Isognomon triviale* Zakh. (the last two species are known in the lower Valanginian in the north of Middle Siberia).

The Jurassic-Cretaceous boundary layers in eastern Greenland are not characterized by ammonites. The species complexes of bivalves change abruptly at the boundary between

TABLE 18. Systematic composition and quantitative description of Berriasian bivalves in the Cis-Polar Urals

System	Jurassic		Cretaceous			
Series	Upper		Lower			
Stage	Volgian		Berriasian			Valanginian
Substage	upper		lower	upper		lower
Zone	Vlg_3^1	Vlg_3^2	$Berr_1^2$	$Berr_2^1$	$Berr_2^2$	Vlh^1
Liostrea ex gr. *expansa* (Sow.)	○					
Gresslya keyserlingi n. sp.	○	○				
Musculus uralensis (d'Orb.)	○	○?				
Dicranodonta sibirica (d'Orb.)	○	○				
Camptonectes (Camptonectes) lens (Sow.)	○	○				
Eriphyla (Lyapinella) asiatica Zakh.	◑	●				
Protocardia concinna d'Orb.	○	○				
Myophorella (Myophorella) borealis Savel.	○	○				
Solecurtus sp.	○	○				
Mactromya verioti (Buv.)	◑	○				
Pseudolimea aff. *arctica* Zakh.	◑	○				
Lucina (?) sp.	●	●				
Pholadomya lyapinensis n. sp.	?	○				
Plagiostoma (?) ex gr. *grandis* Roemer	?	○				
Arcomya (?) *qualeniana* (d'Orb.)	?	○				
Liostrea plastica (Trautsch.)	?	○				
Panopae borealis Eichw.	○	●	○			
"Musculus" strajeskianus (d'Orb.)	◑	○	?	?	○?	
Entolium nummulare (Fisch.)	○	◑	◑	○	?	○
Pinna cf. *suprajurensis* d'Orb.	○	○	○?	?	○?	○?
Arctica cf. *cancriniana* (d'Orb.)	○	◑	○?	?	○?	○
Aguilerella varians Zakh.		◑				
Liostrea sibirica n. sp.		●				
Inoceramus indet. sp.		○	○?			
Cucullaea indet. sp.		○	?	○?		
Parallelodon indet. sp.		○	?	?	?	○?
Camptonectes (Boreionectes) breviauris Zakh.			○?			
Liostrea uralensis n. sp.			◑			
Isognomon triviale Zakh.			◑			
Camptonectes (Camptonectes) lamellosus (Sow.)			◑			
Aguilerella anabarensis (Krimh.)			○			
Oxytoma (Oxytoma) aff. *expansa* (Sow.)			○			
Cucullaea sp.			◑	○		
Plagiostoma incrassata (Eichw.)			○	○		
Liostrea lyapinensis n. sp.			●	○		
Astarte (Astarte) veneris d'Orb.			◑	○?	○?	
Buchia volgensis (Lah.)			○	◑	◑	
Camptonectes (Boreionectes) imperialis (Keys.)			○	?	○?	◑
Entolium demissum (Phill.)			○	?	?	○
Limatula consobrina (d'Orb.)			○	?	?	○

TABLE 18 (continued)

System	Jurassic		Cretaceous			
Series	Upper		Lower			
Stage	Volgian		Berriasian			Valanginian
Substage	upper		lower	upper		lower
Zone	Vlg_3^1	Vlg_3^2	$Berr_1^2$	$Berr_2^1$	$Berr_2^2$	Vlh^1
Buchia okensis (Pavl.)				○		
B. uncitoides (Pavl.)				○		
Pleuromya uralensis (d'Orb.)				◑	◑	◑
Pseudamussium aff. *bojarkaensis* Zakh.				○	?	○?
Oxytoma (Oxytoma) expansa (Phill.)				○	?	○
Pholadomya indet. sp.					○?	
Goniomya sp.					○?	
Limatula aff. *consobrina* (d'Orb.)					○	○
Buchia crassa (Pavl.)						○
Liostrea anabarensis Bodyl.						○
Astarte (Astarte) veneriformis Zakh.						◑
"Musculus" sibiricus (Bodyl.)						○
Placunopsis indet. sp.						○
Teredo (?) indet. sp.						○
Number of new species		2	13	5	1	4
Number of dropouts		1	12	7	4	3
Renewal index of species complex		3	25	12	5	7

Note. ○ denotes a very rare or rare form; ◑ a frequently occurring form; ● –numerous, in places abundant; ? – the stratigraphic position is doubtful.

the beds with *Craspedites* sp. (Harzfield sandstone, Portlandian) and the beds without ammonites – Lower Marl and Shale series (Berriasian, lower strata with *Hectoroceras* sp., Spath, 1936, 1947). Of the 34 species described from the Portlandian only two pass into the Berriasian. Seven species appear at the Jurassic-Cretaceous boundary. The renewal index of the species complex at the boundary of the indicated series is 20 (Zakharov, 1968, Table 3). Only *Buchia volgensis* (Lah.) can be considered to be a characteristically Berriasian species from among the bivalves mentioned for the Lower Cretaceous strata.

In the north of Middle Siberia the Berriasian and boundary horizons can be observed in sections of three types of sediments: 1) sediments of littoral-marine shallows (middle reaches of the Kheta and the Valanginian on the Boyarka River); 2) sediments of moderate depths of marine shallows (Boyarka basin); 3) sediments of the relatively deepwater open sea (Paks Peninsula). The systematic composition of the bivalves differs considerably in horizons of the same age in these three areas. At the same time, the complexes from the same facies but from strata of different age are more similar to each other than those from strata of the same age but from different facies (Table 19). The only exceptions are a few species of *Buchia* that are present in all three types of facies. On the Kheta

TABLE 19. Systematic composition and quantitative description of bivalves from Berriasian sediments of different facies in the Khatanga Depression (north of Middle Siberia)

Facies	Littoral-marine shallow-water conditions. Bottoms fine-sandy, sandy-muddy, and muddy (middle reaches of the Kheta River)				Conditions of moderate depths of marine shallows. Bottoms muddy and muddy-clayey (Boyarka basin)			Shallow-water conditions. Bottoms fine-sandy and sandy-muddy (Boyarka basin)	Relatively deepwater conditions of the open sea. Bottoms clayey and muddy-clayey (Paks Peninsula)			
Stage	Volgian	Berriasian		Valanginian	Volgian	Berriasian		Valanginian	Volgian	Berriasian		Valanginian
Substage or zone	upper	*Chetaites sibiricus, Hectoroceras kochi*	*Surites analogus, Bojarkia mesezhnikowi*	lower	upper	*Chetaites sibiricus, Hectoroceras kochi*	*Surites analogus, Bojarkia mesezhnikowi*	lower	upper	*Chetaites sibiricus, Hectoroceras kochi*	*Surites analogus, Bojarkia mesezhnikowi*	lower
1	2	3	4	5	6	7	8	9	10	11	12	13
Buchia tenuicollis (Pavl.)	○											
Astarte (Astarte) praeveneris Zakh.	○											
Pleuromya donazina Ag.	◑											
Pholadomya hemicardia Roem.	○											
Isognomon ind. sp.	○		○									
Buchia terebratuloides (Lah.)	○	◑			○							
B. lahuseni (Pavl.)	○											
Arctica ind. sp.	○					○		◑				
Goniomya sp.	○		○					○				
Oxytoma (Oxytoma) expansa (Sow.)	○		○				○	○				
Buchia fischeriana (d'Orb.)	◑	○?				◑			●	◑?		
B. okensis (Pavl.)	○?	○?					○	○		◑		
Entolium demissum (Phill.)	○						○?	◑		○?		

Buchia volgensis (Lah.)	○	○	◑			●	●		○?	●	◑	
Nucula sp.	○					○	◑	○	○	◑	○	○
Limatula consobrina (d'Orb.)	○							○	○	○	○	○
Buchia inflata (Toula)	○?										◑	○?
Camptonectes (Boreionectes) breviauris Zakh.		○										
Liostrea sibirica n. sp.		◑										
Astarte (Astarte) veneris d'Orb.		●										
Inoceramus ind. sp.		○	◑		◑	○	○					
Pinna ind. sp.		○	○				○					
Musculus sibiricus Bodyl.		○	◑									
Neocrassina (Anabarella) vai (Krimh.)		○	○					●				
Plagiostoma incrassata (Eichw.)		○						○				
Entolium nummulare (Fisch.)		◑						◑				
Cucullaea arctica Bodyl.		◑	◑									
Parallelodon sp.		◑	○				○	○		○		
Panopaea (?) sp.								○				
Trigonia ind. sp.			◑									
Mactromya sp.			○									
Anomia ind. sp.			○									
Liostrea aff. *anabarensis* Bodyl.			○									
Buchia keyserlingi (Lah.)			◑									
Camptonectes (Boreionectes) imperialis (Keys.)			◑					◑				
Pseudolimea arctica Zakh.			◑					●				
Modiolus romanikhaensis Zakh.			○					○				
Arctotis anabarensis (Petr.)			○					◑				
Tancredia sp.			○					◑				
Arctica sp.			●					◑				
Protocardia sp.			◑					●				
Oxytoma (Oxytoma) ind. sp.			○			○	○	◑		○	○	
Prorokia transitoria Zakh.					●	●						
Lucina (?) sp.					○	○	○					

TABLE 19 (continued)

Modiolus ind. sp.						○		◑				
Astarte (Astarte) ind. sp.						○	○					
Buchia uncitoides (Pavl.)							◑				○?	
Quenstedtia ind. sp.							○	○				
Camptonectes (Camptonectes) lens Sow.							○	○		○?		
Isognomon triviale Zakh.								○				
Buchia sibirica (Sok.)								○			○	
Anomia aff. *suprajurensis* d'Orb.								○				
Pleuromya sp.								○				
Solecurtus sp.								○				
Pholadomya ind. sp.								○				
Liostrea cucurbita Zakh.								○				
Pinna romanikhaensis Zakh.								◑				
Inoceramus taimyricus Zakh.								○				
Spondylus (?) sp.								○				
Pseudolimea aff. *parallela* d'Orb								○				
Pseudamussium (?) *bojarkaensis* Zakh.								○				
Inoceramus ovatus Stanton								○				
Gryphaea borealis Zakh.								○				
Astarte (Astarte) supraveneris Zakh.								◑				
Liostrea anabarensis Bodyl.								●				
Oxytoma (Oxytoma) articostata Zakh.								○		○?	○?	
Buchia crassa Pavl.												○?
Buchia subinflata (Pavl.)										●	●	○
Aequipecten (?) *arachnoideus* Sok. and Bodyl.											○?	
Platiostoma ind. sp.											○?	
Buchia bulloides (Lah.)											○	○?

Note. For explanation of symbols see Table 18.

River, as shown by investigations conducted in 1969, the species complexes of bivalves from the Berriasian are clearly differentiated both from the upper Volgian complexes and, partly, from the lower Valanginian ones (the lower Valanginian complexes were taken from deposits of analogous facies on the Boyarka River). In beds with *Chetaites sibiricus* already predominate typically Lower Cretaceous species that are unknown in upper Volgian deposits: *Musculus" sibiricus* (Bodyl.), *Cucullaea arctica* Bodyl., *Neocrassina (Anabarella) vai* (Krimh.), *Astarte (Astarte) veneris* (d'Orb.), and *Aguilerella anabarensis* (Krimh.). Found in this zone was *Liostrea sibirica* Zakh. n. sp., which in the Cis-Polar Urals occurs in a horizon without ammonites at the Jurassic-Cretaceous boundary (Yatriya River). This species is unknown lower down and higher up in the section on the Kheta River and in general in northern Siberia. Found for the first time together with the species listed in Lower Cretaceous sediments is *Camptonectes (Boreionectes) breviauris* Zakh. Until now this species was known only from the Volgian stage. Beds with *Hectoroceras* on the Kheta River have not been exposed and therefore the bivalves from this zone have been little studied. Judging from fragments of a section that was observed in boreholes, we should expect to find in this zone a bivalve complex similar to the upper Berriasian complex. In the upper Berriasian a number of species emerge that characterize the lower Valanginian: *Camptonectes (Boreionectes) imperialis* (Keys.), *Modiolus romanikhaensis* Zakh., *Buchia keyserlingi* (Lah.), *Arctotis anabarensis* (Petr.), and others. Discovered only in the upper Berriasian on the Kheta River is *Liostrea* aff. *anabarensis* Bodyl., which differs from the true *L. anabarensis* in its smaller size and in the wider shell with almost symmetrical anterior and posterior margins.

The last representatives of *Buchia volgensis* (Lah.) apparently occur in the upper Berriasian. The lower Valanginian bivalve complexes (see the Boyarka River) differ from the upper Berriasian complexes above all in the greater species diversity. One of the most widely distributed species in the Valanginian is *Liostrea anabarensis* Bodyl. In accordance with the stratigraphic scheme proposed in this book, the beds containing this oyster, which were previously classed in the upper zone of the Berriasian, are referred to the lower Valanginian. Hence, as in the Kheta basin, in the Cis-Polar Urals *L. anabarensis* Bodyl. begins to emerge in the lower Valanginian. On the Popigai River this species is found near the base of the Lower Cretaceous section with *Surites* and other ammonites that have not been described monographically. These beds are for the time being considered upper Berriasian. Thus, in the north of Middle Siberia the shallow-water littoral-marine sediments referable to the Berriasian stage according to the ammonite fauna are characterized by a distinctive complex of bivalve species which differs from the late Volgian and early Valanginian complexes.

A completely different picture from that observed on the Kheta River is seen in the Boyarka and Paks Peninsula sections. Here the upper Volgian and lower Berriasian bivalve complexes do not have a single species "of their own." The species that characterize these sections most specifically, such as *Prorokia transitoria* Zakh. (on the Boyarka) or *Aequipecten* (?) *arachnoideus* Sok. and Bodyl. (Paks Peninsula), occur in abundance both at the top of the Jurassic and at the bottom of the Cretaceous. Some species of *Buchia* appear at various levels, but in other sections of the Khatanga Depression they are known throughout the upper Volgian-lower Berriasian interval. Bivalves cannot, therefore, be used to determine the Jurassic-Cretaceous boundary in continuous sections of relatively deepwater sediments in the Khatanga Depression. Nor is it possible to isolate a complex of bivalves that is specific to the Berriasian. *Buchia volgensis* (Lah.) and *B. okensis* (Pavl.), which are characteristic for the Berriasian stage, are occasionally encountered in the topmost strata of the upper Volgian substage, in the *Craspedites taimyrensis* zone, but mass occurrences of these species are known only from Berriasian sediments. Similarly, it is not possible to establish the boundary with the lower Valanginian in the types of sections described according to bivalves, since such typically Valanginian species as *B. inflata* (Toula), *B. crassa* (Pavl.), and *B. bulloides* (Lah.) occur in the upper part of the Berriasian as well. We can state more or less safely that the species of bivalves characteristic for the Berriasian (including the transitional forms from the upper Volgian) are absent in Valanginian sediments (Table 19).

In Northeast Asia the Berriasian complex of bivalves is made up mostly of *Buchia: B. okensis* (Pavl.) and *B. volgensis* (Lah.). The boundary between the Berriasian and Valanginian is drawn according to the disappearance of these two species and also according to the appearance of other forms of this genus: *B. sibirica* (Sok.), *B. inflata* (Toula), *B. bulloides* (Pavl.), and *B. piriformis* (Lah.).*

In northern Alaska the Berriasian and boundary layers are characterized by *Buchia*. The topmost strata of the Jurassic are fixed according to finds of *Buchia piochii* (Gabb.). The base of the Berriasian is established according to the *B. subokensis* zone and the upper part according to the emergence of *B. okensis* (Pavl.). The boundary with the Valanginian is determined from the appearance of *B. sublaevis* (Keys.) in the section (Imlay, 1961).

In the Arctic and in the western part of Canada forms of *Buchia* are also the most commonly found fossils in the Berriasian. Due to the absence of ammonites, the stratigraphy of the Jurassic-Cretaceous boundary layers, like that of the lower Neocomian, is built on complexes of *Buchia*, according to which zones are demarcated. The uppermost upper Volgian strata are characterized by finds of *Buchia unschensis* (Pavl.). At the base of the layers referable to the Berriasian is the *B. okensis* zone; the upper horizons of the Berriasian are established from finds of *B. uncitoides* (Pavl.) and *B. volgensis* (Lah.) (Jeletzky, 1966).

In the Berriasian of British Columbia the same sequence of *Buchia* zones is found as in the Arctic part of Canada, except that the upper horizons of the upper Volgian stage are characterized by the species *B.* cf. *blanfordiana* (Stol.) (Jeletzky, 1965).

The boundary between the Jurassic and Cretaceous in California passes inside terrigenous-sedimentary strata that are not characterized by ammonites. The bivalve complexes from beds with known Jurassic or Cretaceous ammonites are clearly distinguished. For example, out of 31 species living at the end of the Late Jurassic, only two passed into the beginning of the early Neocomian (Anderson, 1938, 1945). The maximum renewal index of species complexes (36) occurs in the boundary layers: Tithonian (Newville group) – infra-Valanginian (Berriasian). Only the Berriasian is characterized by a large

* For more details on the distribution of Bivalvia in the Berriasian of Northeast Asia see Chapter III.

number of species. At the Berriasian-Valanginian boundary 11 species appear, and 12 species do not cross the Berriasian boundary (Zakharov, 1968, Table 4).

According to new data for Japan (Hayami, 1966), most of the Berriasian species of bivalves from northeastern Japan emerged in the Tithonian or even earlier. No large-scale dying out occurred at the end of the Upper Jurassic.

In summing up the above, we may draw the following conclusions.

1. For an assessment of the changes taking place in the composition of bivalve mollusks at the Jurassic-Cretaceous boundary, of prime importance are the complexes of species, not of genera or families, since almost all the families and most of the genera cross this boundary, and in this respect the Upper Jurassic and Lower Cretaceous complexes are similar.

2. The nature of the facies exerted a marked influence on the distribution of the bivalves both spatially and temporally. When conditions remained favorable (especially in the case of deepwater facies), the complexes underwent no change or changed only slightly with time (also at the boundaries of geological periods).

3. Among the bivalves of the late Jurassic and Early Cretaceous Arctic zoogeographic region we note a succession of various groups (*Buchia*, Ostreidae, *Modiolus*, *Inoceramus*, *Boreionectes*, *Arctotis*). Panchronous species also existed. This explains the similarity between the Upper Jurassic and Lower Cretaceous complexes.

4. The bivalve complexes in different areas of the Arctic and Boreal-Atlantic zoogeographic regions were renewed not simultaneously, but as a rule a little above the Jurassic-Cretaceous boundary determined according to ammonites.

5. The Berriasian phase in the development of the bivalves of the Boreal Realm is less distinctive than the Volgian phase. The Berriasian bivalve complex is similar to the Valanginian complex.

Genus *Liostrea* Douvillé, 1904

Liostrea uralensis Zakharov, n. sp.
Plate XLI, Figure 1; Plate XLII, Figure 9; Plate XLIII, Figure 5

Holotype No. 410/1, IGG Museum, Cis-Polar Urals, Mauryn'ya River, right-hand tributary of the Tol'ya, 8 km from the mouth as the crow flies, exposure 53 (talus), Lower Cretaceous, Berriasian, *Hectoroceras kochi* zone.

Material. Twelve specimens, mostly whole shells, well preserved.

Diagnosis. Shell large, almost equilateral, subquadrate, thick-walled, covered with several strong, rounded concentric folds.

Description. Shells large, very weakly convex, slightly beveled toward the posterior end, inequivalve: the left valves are slightly more convex than the right. Contour of valves variable; subquadrate, round, and slightly oval forms predominate, subtriangular and subrectangular forms occur more rarely. The umbones and preapical parts of the left (attached) valves are flattened. Umbones of right valves straight, weakly convex. Valve surface uneven. Typical specimens, having a small area of attachment, are covered with several wide, strong, rounded concentric folds and thick-lamellar growth marks. The relief of shells that adhered to the substrate by a large part of the valve is variable and often reflects the unevennesses of the substrate. The shell has a thick wall. The inner surface was not observed.

No.	Locality	L	H	H/L
410/1 holotype	Cis-Polar Urals, Mauryn'ya River, exposure 53	95.0	101.0	0.94
410/2	Lower Cretaceous, Berriasian, *Hectoroceras kochi* zone	88.5	96.2	1.09
410/3	As above	92.1	92.8	1.0
410/4	As above	99.6	99.1	1.0
410/5	Same place, exposure 52, layers 2–3	80.8	80.6(?)	1.0
410/6	As above	90.8	97.4	1.07

Individual variability. Two beds from similar facies were sampled. The form of the shell is largely determined by the size and form of the area of attachment. There are often clumps made up of several specimens, and in this case the outline of the individual valves is extremely vaguely defined.

Comparison. In its size and equivalve shell, the new species resembles *Liostrea cucurbita* Zakh. from the lower Valanginian of the north of Middle Siberia (Zakharov, 1966, p. 111, pl. XLI, figs. 1, 2; pl. XLII, fig. 1), but it differs from this in having a subquadrate shell and coarse, concentric ribs. In size and in the length/height ratio of the shell it resembles *Ostrea expansa* Sow. from the Portlandian of England (Sowerby, 1821, p.15, pl. 238, fig. 1). The differences consist in the subquadrate shell and in the coarse ribs on the valves of the new species.

Remark. In Upper Jurassic and Lower Cretaceous deposits in the north of the USSR, smooth Ostreidae are found that belong to two clearly defined groups of species. In the first group the shell is large, subtriangular or subrectangular, slightly beveled, massive, with a large area of attachment (*Liostrea* ex gr. *delta* (Smith) (Kimmeridgian), *L.* aff. *delta* Smith (Volgian stage), *L. cucurbita* Zakh. (Valanginian)). In the second group the shell is narrow, long, asymmetrical, sickle-shaped, relatively thin-walled, with a small scar of attachment (*L. preanabarensis* Zakh. (Volgian stage), *L. lyapinensis* Zakh. n. sp. (Berriasian), *L. anabarensis* Bodyl. (Valanginian–lower Hauterivian)). The new species described above clearly belongs to the first group. In recent years several species of Ostreidae belonging to both these groups have been found in Kimmeridgian, Volgian, and Berriasian sediments. Since they have not yet been studied, it would be premature to draw conclusions on the status of the two groups.

Facial distribution and taphonomy. *Liostrea uralensis* occurs in large numbers in fine-grained sands at the base of the Berriasian section on the Mauryn'ya River. Fine intercalations consisting almost entirely of shells of this species are a very characteristic feature. Whole shells are often encountered. Clumps of several specimens are typically found. The main accompanying forms in the oryctocenoses are belemnites and also other bivalves: *Pleuromya, Isognomon, Cyprina, Astarte.* The oysters are apparently entombed in situ, but the type of fossil cenosis could not be precisely determined owing to the difficulty of observations. The habit conditions were not established.

Occurrence. Right bank of the Mauryn'ya River, a right-hand tributary of the Tol'ya, 8 km from the mouth as the crow flies, exposures 52, 53.

Age and distribution. Lower Cretaceous, Berriasian, *Hectoroceras kochi* zone in the Cis-Polar Urals.

*Liostrea lyapinensis** Zakharov n. sp.
Plate XLII, Figures 1–8

Holotype No. 410/7, IGG Museum, Cis-Polar Urals, right bank of the Yatriya River, exposure 1, layer 2. Lower Cretaceous, Berriasian, *Hectoroceras kochi* zone.

Material. About 80 specimens – individual valves and whole shells, mostly well preserved.

Diagnosis. Shell small, elongate, narrow, very much beveled, with a sharp, prosogyral umbo and a bent-up posterior margin.

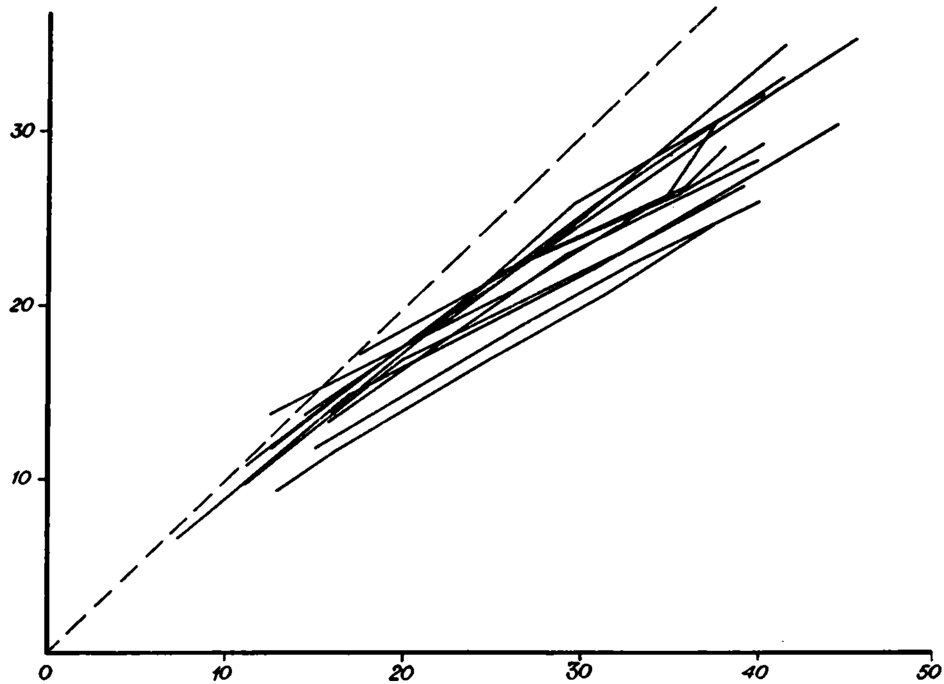


FIGURE 14. *Liostrea lyapinensis* Zakh. n. sp. Ontogenetic curves according to measurements of 12 specimens from layer 2, exposure 1 on the Yatriya River.

* Named (in coll.) after the Lyapin River by M. S. Mesezhnikov, who handed over his material to the author.

Description. Shell small, elongate, narrow, curved, very strongly beveled, inequivalve: the right valve is flat or slightly concave, the left valve weakly, more rarely moderately, convex. Contour of valves variable. Typical forms have a convex anterior margin, a gently curved ventral margin, a narrow drawn-out posterior margin, and a slightly notched dorsal margin. The lines contouring the dorsal and ventral margins are often roughly parallel. Behind the umbo is a process or a small wing-shaped expansion. Umbones small, acute, prosogyral. The valves are covered with 4–6 wide, gently sloping concentric folds that are divided by constrictions and lamellar growth lines. The ornament is less clearly expressed on the right valve. The umbo of the left valve usually has a small scar of attachment, less often a small area of attachment. Ligament areas small, subtriangular, narrow. Inner surface of valves smooth. Margin of left valve slightly recurved into the shell. Adductor scars situated near the dorsal margin, almost in the middle of the shell.

Age variability. In the initial stages of development the shell is rounded, while with growth it becomes relatively long, elongate-oval: at a length of 20–30 mm the average value of the H/L ratio, measured on 12 specimens, is about 0.82 (Figure 14). Adult specimens are still more elongate: the average H/L value, measured on 14 specimens, is 0.72. In addition, the shell becomes bent with age. Measurements in terms of age (left valves):

No.	Locality	L	H	H/L	No.	Locality	L	H	H/L
410/7	Cis-Polar Urals,	12.8	9.4	0.74	410/13		12.5	11.9	0.95
	Yatriya River,	16.0	11.6	0.73			18.3	16.6	0.91
	exposure 1,	24.7	17.0	0.69			25.1	22.0	0.80
	layer 2, Lower	31.2	20.8	0.67			35.7	27.0	0.76
	Cretaceous,	37.6	25.0	0.67			37.8	29.35	0.78
	Berriasian,				410/14		14.4	13.8	0.96
	Hectoroceras						26.00	21.00	0.81
	kochi zone						34.7	26.65	0.77
410/8		15.0	11.9	0.79			37.2	30.5	0.82
		26.3	18.9	0.72	410/15		7.25	6.65	0.92
		32.85	22.65	0.69			16.8	14.9	0.89
		39.9	26.2	0.66			30.4	22.2	0.76
410/9		14.4	13.80	0.96			38.9	27.1	0.70
		19.1	17.2	0.90	410/17		19.4	17.0	0.88
		27.3	23.0	0.84			30.3	25.5	0.84
		34.7	28.2	0.81			41.2	35.2	0.85
		40.85	32.7	0.80	410/18		11.0	9.8	0.89
410/11		45.2	35.65	0.79			19.8	16.95	0.86
		15.8	13.8	0.87			31.8	23.1	0.73
		24.1	21.3	0.89			44.2	30.7	0.69
		29.4	26.00	0.88	410/23		15.7	13.4	0.85
		36.5	30.3	0.83			28.85	23.0	0.80
410/10		39.9	32.3	0.81			39.7	28.5	0.72
		17.4	17.3	1.00	410/27		11.0	10.8	0.98
		25.2	21.8	0.87			25.4	22.1	0.87
		30.75	26.0	0.85			35.4	26.6	0.75
		37.1	30.55	0.82			40.0	29.5	0.74
		41.0	33.25	0.81					

Individual variability was studied on a sample from an oryctocenosis at the base of the layer (0–0.5 m interval). The form of the shell varies the most. The extreme links in the chain of variability differ considerably according to this sign. The varying degree of curvature and the varying length/height ratio are reflected in the contours of the left valves in the variability series (Figure 15; see also measurements). The convexity of the left valve is also variable: from gently convex to flattened. The size of the process behind the umbo varies from a small tubercle to a lamellar, wing-shaped expansion.

Comparison. In form and constitution of the shell the new species is extremely similar to *Liostrea anabarensis* Bodyl. (Bodylevskii, 1949, p. 157, pl. 39, fig. 5; Zakharov, 1966, p. 108, pl. XXXIX, fig. 3, pl. XLI, figs. 4, 5, pl. XLII, figs. 4, 5). *L. lyapinensis* differs in being less than half its size and in the ontogeny: at the stages corresponding to the size of adult *L. lyapinensis* the shells of *L. anabarensis* are relatively less elongate and less curved.

It is difficult to compare this form with *L. osmana* Wollemann, with similar size and shell (Wollemann 1900, p. 19, pl. 1, fig. 5; pl. 2, fig. 1), from the Neocomian of Western Europe, because no drawing is available of the left valve from the outer side. *L. lyapinensis* n. sp. differs, however, from this species in being slightly smaller and in its having a different ontogenesis (judging from the right valve in fig. 1c, pl. 2 in Wollemann's work).

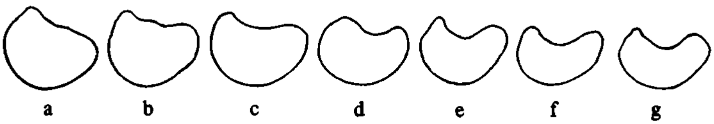


FIGURE 15. Variability sequence for the left valve in *Liostrea lyapinensis* Zakh. n. sp.:
a) specimen 410/29; b) specimen 410/31; c) specimen 410/10; d) specimen 410/13; e) specimen 410/30; f) specimen 410/7; g) specimen 410/32. Lower Cretaceous, Berriasian, *Hectoroceras kochi* zone, exposure 1, layer 2. Cis-Polar Urals, Yatriya River.

Facial distribution and taphonomy. This species occurs in large numbers in sandy leptochlorite-quartz micaceous silts with glauconite and sparse grains of fine gravel. The oryctocenoses are extremely rich in a variety of fossils. Oysters are represented in them as a rule by left (convex) valves. Accumulations of several shells are often formed. The shells are in a good state of preservation. The type of fossil cenosis on the Yatriya River at the base of layer 2 (exposure 1) is an allochthonous fossil thanatocenosis with elements of an autochthonous thanatocenosis.*

On the Mauryn'ya River (right-hand tributary of the Tol'ya River) the species occurs frequently at the base of the section (exposure 52, layer 2) together with *L. uralensis* n. sp. (see the description of this species).

Ethology. In the initial stages of development the oyster adhered by means of cement to shell fragments and small pebbles. The adult probably lived lying on the convex left valve.

* See the description of the Yatriya River section (exposure 1, layer 2) for a more detailed lithological and taphonomic survey.

Habitat conditions. The animal lived in the upper part of the upper sublittoral (infralittoral) in a mobile hydrodynamic environment. But it settled also at great depths, forming less dense aggregations here than in the shallows. It is hard to determine the biocenotic associations, but there is reason to believe that the majority of the benthic organisms found in the oryctocenoses together with this oyster settled and lived in the same areas of the bottom.

Occurrence. Right bank of the Yatriya, exposure 1, layer 2; right bank of the Mauryn'ya River, 8 km from the mouth as the crow flies, exposure 52, layer 2.

Age and distribution. Lower Cretaceous, Berriasian of the Cis-Polar Urals.

BRACHIOPODS

The Boreal-Atlantic and Arctic regions can be clearly traced using brachiopods as guidelines in the Late Jurassic and probably in the Early Cretaceous (Makridin. 1954; Dagis, 1968). An all-embracing picture of the changes occurring in the systematic composition of Brachiopoda at the Jurassic-Cretaceous boundary cannot be presented yet, because this group has been little studied in the regions mentioned. The fragmentary data available just allow us to note the overall trends of changes in their composition, which are very slight. In the Arctic Region the number of genera did not undergo any marked change at the Jurassic-Cretaceous boundary (Table 20), most of the genera being just as characteristic for the top of the Jurassic as they are for the lower horizons of the Cretaceous. An exception is the genus *Siberiothyris,* which at present is not found below the Berriasian. Unfortunately, given the status of study of Brachiopoda to date and the quality of the collections (no specialist has as yet undertaken such collections), it is extremely difficult to consider these changes as evolutionary; rather, they are connected with incomplete knowledge on our part or with facial factors. Almost every year, new collections alter the picture of distribution of certain species, and, as far as we can judge from recent experience, the number of purely "Jurassic" or "Cretaceous" genera is constantly dwindling. We may take the genus *Uralella* as an example. At first it was known specifically from the middle Volgian substage of the Northern Urals (Makridin, 1954). Then a few specimens were found in upper Volgian deposits in the north of Middle Siberia (Dagis, 1968). Finally, the genus was recently discovered in the upper horizons of the upper Volgian substage in the Northern Urals and in upper Valanginian sediments of Anabar Bay. The incompleteness of our knowledge comes out clearly in Table 20, which shows a very diverse stratigraphic distribution of the genera in the different areas.

Thus, on the generic level the brachiopod fauna of the Jurassic and Cretaceous of the Arctic Region discloses a very close continuity, sharply contrasting with the marked changes in the composition of Brachiopoda from the Triassic-Jurassic boundary.

It is still more difficult to compare the Jurassic and Cretaceous Arctic brachiopods on the species level, due to the extreme poverty of the upper Volgian substage and Berriasian in remains of this group, related, no doubt, to the facial features of the sections under study. In the north of Middle Siberia late Volgian forms are known only in one locality in Central Taimyr (Dyabka-tari River) from the *Craspedites taimyrensis* zone, while later

TABLE 20. Generic composition of brachiopods in the Arctic Region

Stage, substage / Genus	Middle Volgian	Upper Volgian	Berriasian	Valanginian
Lenothyris	——— ++++	——— ++++		
Uralorhynchia	——— • • • • •	——— ++++	——— ++++ • • • • •	
Taimyrothyris	——— ++++ • • • • •	– – –	——— +++++ • • • • • • • OOOOOOOO	——— +++++
Pinaxiothyris	——— +++++	——— ++++	– – – OOOOOOOO	——— +++++ .
Uralella	——— +++++ • • • • • • •	——— +++++ • • • • • •	– – –	——— ++++
Fusirhynchia	——— +++++ • • • • •	———	——— +++++ • • • • •	——— ++++
Siberiothyris			——— • • • • •	——— +++++
Ptilorhynchia	——— +++++ • • • • •	———	——— +++++ • • • • • • • OOOOOOOO	——— +++++

——————– – – general distribution of genera, established and presumed
++++ distribution in the north of Middle Siberia
• • • • • • • • • • distribution in the Northern Urals
OOOOOOOO distribution on Chukchi Peninsula

Berriasian forms are known only from the Popigai and Kheta rivers. The stratigraphic distribution of Brachiopoda in the upper horizons of the Jurassic and lower strata of the Cretaceous is shown in Table 21. According to the table, the most substantial changes in the composition of the northern Siberian brachiopods took place at the boundary between the middle and upper Volgian, when many Jurassic species became extinct, and at the Berriasian-Valanginian boundary, to which the emergence of most of the new species is confined. However, these boundaries coincide with sharp facial changes, and the true picture may prove to be very different, probably more blurred. The Volgian species certainly continued to exist in the Berriasian of northern Siberia, some of them *(Uralorhynchia striatissima, Fusirhynchia micropteryx)* being found in the uppermost horizons of this stage. Meanwhile, already at the base of the Berriasian (*Chetaites chetae* zone) new forms appear in this region which are similar or identical to the species that have their broadest distribution in the Valanginian (Table 21). Therefore, as far as can be judged from the imprecise data at hand, the Berriasian brachiopod fauna of the north of Siberia is characterized by a mixed composition, attesting to gradual changes in the complexes at the Jurassic-Cretaceous boundary.

TABLE 21. Species composition of brachiopods in northern Siberia

Species \ Stage	Middle Volgian	Upper Volgian	Berriasian	Valanginian
Ptilorhynchia lenaensis	+			
Ptilorhynchia obscuricostata	+			
Lenothyris perflexus	+			
Taimyrothyris bisulcatus	+			
Taimyrothyris gregarius	+			
Taimyrothyris kropotkini	+			
Uralella arctica	+			
Uralella gigantea	+			
Uralella stroganovi	+			
Russirhynchia bullata	+			
Pinaxiothyris campestris	+	+		?
Fusirhynchia micropteryx	+		+	
Uralorhynchia striatissima		+	+	
Lenothyris ovalis		+	+	
Uralella sp.			+	+
Taimyrothyris humilis		+		+
Ptilorhynchia seducta			+	+
Ptilorhynchia glabra			?	+
Fusirhynchia secreta				+
Taimyrothyris bojarkensis				+
Siberiothyris crassus				

A similar pattern of change in the brachiopod composition at the boundary between the Jurassic and Cretaceous is observed on the east slope of the Cis-Polar Urals (Table 22). In this area in the Berriasian (the *Hectoroceras kochi* zone, since from this stratigraphic level there is information that interests us) a number of Volgian species *(Fusirhynchia micropteryx, Uralorhynchia striatissima)* persist and there now appear some forms (*Siberiothyris* sp., *Taimyrothyris humilis*) that characterize the Valanginian or gravitate to the Valanginian species. Moreover, the species of *Uralella* that are massively distributed in the upper Volgian horizons do not cross over into the beds with *Hectoroceras* in the Cis-Polar Urals.

Just as incomplete are the data on the brachiopods from the upper horizons of the Jurassic and the bottom of the Cretaceous on the Russian Plain, i.e. in the Boreal-Atlantic paleozoogeographic region. Table 23, compiled from Makridin's material (Makridin, 1964), shows that there was a steady dying off of species beginning in late Volgian time and continuing in the Berriasian. No new species have been found in the Berriasian of this region, and all the known forms are in fact relicts of the Volgian complexes.

Hence, the main feature that emerges from an analysis of the systematic composition

TABLE 22. Species composition of brachiopods on the east slope of the Cis-Polar Urals

Species \ Stage	Middle Volgian	Upper Volgian	Berriasian	Valanginian
Uralella gigantea	+	+		
Uralella sibirica	+	?		
Uralella stroganovi	+	+		
Uralorhynchia striatissima	+	+	?	
Fusirhynchia micropteryx	+	+	+	
Uralorhynchia sp.			+	
Taimyrothyris bojarkensis			+	
Siberiothyris sp.			+	
Ptilorhynchia aff. *seducta*			+	

Note. A question mark denotes forms determined with the sign "conformis".

TABLE 23. Species composition of brachiopods on the Russian Plain

Species \ Stage and zone	Upper Volgian			Berriasian	
	Kachpurites fulgens	*Craspedites subditus*	*Craspedites nodiger*	*Riasanites rjasanensis*	*Surites spasskensis*
Septaliphoria subrotunda	+				
Rhynchonella roullieri eltonica	+				
Cyclothyris ulaganica	+				
Roullieria michalkovi	+				
Roullieria curvata	+				
Russiella bullata parva	+				
R. luna lata	+				
R. eichwaldi	+	+			
R. clemenci	+	+			
R. truncata	+	+			
R. pavlovi	+	+			
R. subpentagonalis	+	+			
R. choroschovensis	+	+			
R. bullata bullata	+	+	+	+	
R. luna luna	+	+	+	+	
R. volgensis		+	+	+	
R. royeriana royeriana	+	+	+	+	+
Phynchonella loxia	+	+	+	+	?

of Brachiopoda at the Jurassic-Cretaceous boundary in the Boreal Realm is the striking continuity of the complexes, preserving the biogeographic isolation of the fauna in the Arctic and Boreal-Atlantic regions. On the Russian Plain this continuity is complete, and a few Jurassic relicts are known in the Berriasian, whereas in the Berriasian of northern Siberia, along with species which crossed over from the Volgian stage, there appear forms that reach maximum development in the Valanginian or that are allied to the Valanginian species.

FORAMINIFERS

The Berriasian Foraminifera of the Boreal Realm have not all been studied with equal thoroughness. There are no foraminifers at all (or very few) in the brackish-water facies of the Purbeckian and Wealden of northwestern Europe. On the Russian Plain, in the Polar and Cis-Polar Urals, and on Franz Josef Land, where Volgian sediments have been investigated in marine facies, there are either no transitional layers to the Berriasian stage or no foraminifers in them, and hence we have no possibility of tracing the changes in the fauna at the Jurassic-Cretaceous boundary. Foraminifers are as yet unknown from marine sediments of the Volgian and Berriasian of Greenland and Canada, and only preliminary determinations have been made on Spitsbergen.

In northern Siberia the boundary layers of the Jurassic and Cretaceous that contain diverse foraminifer complexes are known both in natural outcrops and from numerous core samples in Western and northern Siberia. The Berriasian forms that were the first to be studied in detail in northern Siberia are genetically related to the foraminifers of the end of the Late Jurassic (Volgian). More than a quarter of all the Volgian species in the north of Siberia persist into the Berriasian. Some of them die out in various Berriasian horizons, while others pass into the Valanginian. At different levels of the Berriasian of northern Siberia about the same number of species emerge as crossed from the Volgian stage, the newly appearing species having their ancestors in the Volgian fauna. This attests to the autochthonous origin of the Berriasian foraminifers in the Siberian seas.

Fursenko (1963) noted that the fauna which grew up at the end of the late Kimmeridgian and became widely distributed in Volgian time represents a specific phase in development. The dominant representatives are forms of the family Nodosariidae (18 genera); the abundance of Polymorphinidae increases (6 genera), and the first Paradentalina and Spirofrondicularia appear. In the Volgian of Siberia, apart from foraminifers with secreted calcareous tests, agglutinated forms attained considerable development (families Ammodiscidae, Lituolidae, Trochamminidae, and others), most of these being small forms with a finely granular wall (*Ammodiscus, Spiroplectammina, Trochammina,* etc.) or large forms, *Haplophragmoides (Evolutinella).* The elements of the Cretaceous fauna increases in importance at the end of the Volgian. During "*Craspedites taimyrensis*" time appeared the genera *Orientalia* (?) (family Ataxophragmiidae) and *Arenoturrispirillina* (family Ammodiscidae) and numerous species groups among *Trochammina, Lenticulina,* and other genera, which developed in the Early Cretaceous.

The resemblance between the Volgian foraminifers of the Russian Plain and the

Neocomian forms of Western Europe was first observed by Fursenko (1949), who pointed out that the former are the ancestors of the latter. But until not long ago there was a gap between the Volgian and Neocomian European complexes, due to the absence or very scant representation of foraminifers in the regressively shallow-water facies at the end of the Volgian and Berriasian ages over the territory of Europe. The blanks were able to be filled in following a study of the late Volgian and Berriasian foraminifers of northern Siberia.

The Berriasian Arctic complex may be considered to be transitional between the boreal Volgian fauna of Eastern Europe and northern Siberia on the one hand and the Neocomian (beginning from the Valanginian or the top of the Berriasian) fauna of the north of Western Europe on the other.

Investigations of the systematic composition of the foraminifers and their distribution in Berriasian sediments of Central Siberia (Kheta and Boyarka rivers, Cape Urdyuk-Khaya on Paks Peninsula) and the north of the West Siberian Lowland made it possible to tie up the foraminifer complexes identified with ammonite zones. We must remember that the Berriasian was a time when agglutinated foraminifers predominated, many species existing for a long time – from the end of the Volgian to the end of the Berriasian and even of the Valanginian stage. Together with this, the complexes contained some species with a narrow stratigraphic distribution, and therefore we can isolate beds according to groups of species.

The vertical distribution of the species differs in different areas and in a number of cases embraces 1–3 zones or even 2–3 stages. Thus, out of the 40 species known in the Berriasian and lower Valanginian on the Boyarka River, 13 species (33%) are limited to one zone, 2 species (5%) to two zones, 18 species (20%) to three zones, 12 species (30%) to two stages, and 3 species (8%) to three stages. The high percentage of species which span over two stages explains their appearance at the end of the Volgian or Berriasian ages and their continued existence in the Berriasian or Valanginian. Almost 60% of the species are limited to 1–3 zones.

In the Urdyuk-Khaya section 42 foraminifer species are known in the Berriasian stage. Four of them (10%) are bound to one zone, two species (5%) are distributed in two zones, one species (2%) occurs in four zones, 22 (52%) embrace 2 stages, and 12 species (29%) spread over three stages. These figures show that the highest percentage of species in this section are limited to two stages. These are species that began their development at the end of the Volgian and flourished in the Berriasian.

The Boyarka and Urdyuk-Khaya sections belonged to different facial zones, apparently corresponding to the upper and lower sublittoral, and this caused marked differences in the composition of the complexes. Therefore, in correlating sections according to foraminifers within the limits of even one province of the Boreal Realm, and all the more within different regions and provinces, it is essential to take the facial features of the enclosing rocks into account.

In the case under consideration, communities of benthic calcareous foraminifers of the families Nodosariidae, Polymorphinidae, and Ceratobulimidae lived under conditions of the upper sublittoral (Boyarka River). The lower sublittoral (Paks Peninsula) was apparently inhabited mainly by agglutinated forms belonging to the families Ammodiscidae, Hyperamminidae, Saccaminidae, Lituolidae, Trochamminidae, and Ataxophragmiidae, although several of the calcareous forms of the genera *Marginulina* and *Lenticulina* (family Nodosariidae) are frequently encountered, even predominant at certain moments.

In the north of Middle Siberia elements of the Berriasian fauna appeared at the end of the Volgian: during "*Craspedites taimyrensis*" time there was already a marked differentiation of the foraminifer complexes in different facial zones.

The complexes in the Kheta River section contemporaneous with the above are represented almost exclusively by calcareous foraminifers. Here are beds with *Nodosaria invidiosa* and *Cuttulina* ex gr. *dogieli*, characterized, apart from by the index species, by *Lenticulina makarjevae* E. Ivan., *L. raritas* E. Ivan., *Ceratobulimina* (?) *prudens* Bass., and also *Marginulina zaspelovae* Rom., *Bojarkaella firma* Bass., and other forms that occur in the Berriasian stage.

Foraminifer complexes are unknown from Volgian-Berriasian boundary sediments on the Kheta and Boyarka rivers.

In the Urdyuk-Khaya section the complexes of the upper zones of the Volgian stage (*Craspedites taimyrensis* and *Chetaites chetae*) and the lower zone of the Berriasian (*Ch. sibiricus*) are practically indistinguishable, being united into beds with *Trochammina rosaceaformis* and *Haplophragmoides fimbriatus* (Table 24). These species, plus *Orientalis (?) baccula* Schl. and *Recurvoides paucus* Dubr. appear for the first time in the *Craspedites taimyrensis* zone; here there are abundant *Recurvoides obskiensis* Rom. and *Haplophragmoides (Evolutinella) emeljanzevi* Schleif. Calcareous forms include *Lenticulina sossipatrovae* Gerke and E. Ivan. n. sp., *Vaginulina (?) vermis* Gerke, and *Marginulina subformosa* Bass., that occur in underlying deposits on the Boyarka. Occasional finds of *Trochammina septentrionalis* Schar. and *Haplophragmoides volossatovi* Schar. are confined to the *Chetaites chetae* and *Ch. sibiricus* zones. At the top of the latter zone appear isolated *Trochammina parviloculata* Gerke and numerous *Gaudryina* ex gr. *gerkei* Vass.

The *Hectoroceras kochi* zone on the Boyarka is divided into two parts according to the foraminifer fauna (Table 25). In the lower part are beds with *Marginulinopsis borealis majmetchensis* and *Marginulina secta* that still contain Volgian species: *Ammodiscus veteranus* Kosyr., *Haplophragmoides (Evolutinella)* ex gr. *volossatovi* Schar. *Marginulina integra* Bass., and *M. glabroides* Gerke. Appearing for the first time in these sediments are *M. secta* Bass., *Marginulinopsis borealis majmetchensis* Bass., *Globulina chetaensis berriasica* Bass., and others. The beds with *Lenticulina pseudoarctica* and *Marginulina secta* embrace the upper part of the *H. kochi* zone and also the *Surites analogus* zone. In these strata the Volgian elements disappear almost completely, and the Berriasian forms of *Lenticulina* develop: *L. pseudoarctica* E. Ivan., *L. sossipatrovae* Gerke and E. Ivan. n. sp., *L. khatangensis* E. Ivan. n. sp., and others.

In the Urdyuk-Khaya section the *Hectoroceras kochi* zone is characterized by a uniform species composition of foraminifers, united in beds with *Gaudryina gerkei* and *Trochammina parviloculata* (Table 24). The boundaries of these beds only approximately coincide with the zone boundaries. Again some elements of the Volgian fauna are preserved here: *Ammodiscus veteranus* Kosyr., *Vaginulina (?) vermis* Gerke, *Trochammina septentrionalis* Schar., *Haplophragmoides (Evolutinella) emeljanzevi* Schleif., and *H. (E.)*

schleiferi Schar., plus the curious *Saccamina* (?) sp. In contrast to the case with the underlying beds, *Haplophragmoides fimbriatus* Schar. and *Trochammina rosaceaformis* become very rare, *Marginulina subformosa* disappears, and *Gaudryina gerkei* Vass., *Trochammina parviloculata* Gerke, *Recurvoides obskiensis* Rom., and Berriasian *Lenticulina* forms develop intensively.

In the *Surites analogus* and *Bojarkia mesezhnikowi* zones the Volgian elements are still further diminished and the abundance of *Lenticulina* forms increases, particularly that of *Lenticulina sossipatrovae* Gerke and E. Ivan. *L. gudinae* E. Ivan. is rarer. A few *Epistomina* sp. also appear in the *Surites analogus* zone. Agglutinated forms of the species *Recurvoides obskiensis* Rom. and *Gaudryina gerkei* Vass. become more plentiful. *Trochammina parviloculata* Gerke, *Orientalia* (?) *baccula* Schl., and *Glomospirella* sp. are constantly encountered. Various forms of *Ammobaculites*, including *A. gerkei* Schar., are characteristically present. This complex is isolated into beds with *Gaudryina gerkei–Trochammina parviloculata–Ammobaculites* spp.

At the top of the *Bojarkia mesezhnikowi* zone a species complex emerges that accompanies *Reinholdella tatarica* Rom., although this species actually occurs in sediments that belong already to the Valanginian. By analogy with the Kheta sections, beds with *R. tatarica* are identified in the Urdyuk-Khaya section (Table 24).

In the *Bojarkia mesezhnikowi* zone on the Boyarka River the calcareous foraminifers become very diversified. The index species of the beds identified – *Astacolus bojarkaensis* Bass. and *Reinholdella tatarica* Rom. – plus *Marginulina occultata* Bass. and others appear for the first time in small numbers.

The transition to the Valanginian (*Neotollia klimovskiensis* zone) is characterized in all sections in northern Siberia by an impoverishment of the species composition of the foraminifers and by an increased abundance of *Reinholdella tatarica* Rom., *Glomospirella gaultina* Berth., and *Haplophragmoides infracretaceous* Mjatl. On the Boyarka River there now emerge *Marginulina corneola* Vass., new species of *Vaginulina*, and the sessile forms *Bullopora bojarkensis* E. Ivan., etc., while on Cape Urdyuk-Khaya *Reinholdella tatarica* Rom. and *Lenticulina arctica* Schl. make their appearance.

Similar transformations in the foraminifer composition are observed at the Jurassic-Cretaceous boundary in Western Siberia, and also in the north of the Russian Plain. The late Volgian was marked everywhere by suppression of calcareous forms and supremacy of agglutinated forms. In Western Siberia the transition to the late Volgian (*"Craspedites okensis"* time) goes along with mass development of *Ammodiscus veteranus* Kosyr., accompanied by *Haplophragmoides (Evolutinella) volossatovi* Schar., *H. (E.) schleiferi* Schar., *H. (E.) emeljanzevi* Schl., *Recurvoides praeobskiensis* Dain., *Trochammina rosacea* Zasp., and *T. mizinovi* Levina. The complex is distinguished by a numerical wealth of foraminifers and an impoverished generic and species composition. With the appearance of a few new species, this complex is traced to the end of the late Volgian (*"Craspedites taimyrensis"* time).

Changes in the foraminifer complexes at the boundary between the late Volgian and early Berriasian take place mainly at the species level. The new species *Haplophragmoides fimbriatus* Schar. and *Trochammina rosaceaformis* Rom. appear, and beds are named after them in the lower reaches of the Yenisei River. Sharovskaya (1968) draws the

TABLE 24. Distribution of foraminifer complexes in Berriasian sediments on Paks Peninusla (Cape Urdyuk-Khaya)

System	Stage	Zone	Foraminifers	Beds according to foraminifers
Cretaceous	Valanginian	*Neotollia klimovskiensis*	*Glomospirella gaultina* (Berth.), *Recurvoides obskiensis* Rom., *Haplophragmoides infracretaceous* Mjatl., *H.* ex gr. *latidorsatus* Born., *Gaudryina gerkei* Vass., *Orientalia*? *baccula* Schl., *Marginulina pyramidalis* Koch, *M. striatocostata* Reuss, *Astacolus suspectus* Bass., *Lenticulina gudinae* E. Ivan., *L.* cf. *arctica* Schl., *Globulina chetaensis* Bass., *Reinholdella tatarica* Rom.	*Reinholdella tatarica* and *Haplophragmoides* ex gr. *latidorsatus*
		Bojarkia mesezhnikowi	*Glomospirella gaultina* Berth., *Recurvoides obskiensis* Rom., *R. paucus* Dubr., *Haplophragmoides infracretaceous* Mjatl., *Orientalia*? *baccula* Schl., *Marginulina pyramidalis* Koch., *Pseudonodosaria insueta* Bass., *Lenticulina gudinae* E. Ivan.	
	Berriasian	*Surites analogus*	*Glomospirella intrita* Bass., *Recurvoides paucus* Dubr., *R. obskiensis* Rom., *Haplophragmoides* ex gr. *schleiferi* Schar., *Ammobaculites gerkei* Schar., *Ammobaculites* spp., *Trochammina parviloculata* Gerke, *Gaudryina gerkei* Vass., *Orientalia*? *baccula* Schl., *Marginulina pyramidalis* Koch, *Planularia pressula* Schl., *Lenticulina sossipatrovae* Gerke and E. Ivan., *L. munsteri* (Roem.), *L.* cf. *gudinae* E. Ivan., *L.* aff. *modica* Schar.	*Gaudryina gerkei, Trochammina parviloculata,* and *Ammobaculites* spp.
		Hectoroceras kochi	*Glomospirella intrita* Bass., *Recurvoides obskiensis* Rom., *Haplophragmoides schleiferi* Schar., *Trochammina parviloculata* Gerke, *Gaudryina gerkei* Vass., *Orientalia*? *baccula* Schl., *Vaginulina*? *vermis* Gerke, *Marginulina pyramidalis* Koch.	*Gaudryina gerkei, Trochammina parviloculata*
Jurassic		*Chetaites sibiricus*		
	Volgian	*Chetaites chetae*	*Glomospirella intrita* Bass., *Haplophragmoides emeljanzevi* Schl., *H. schleiferi* Schar., *H. fimbriatus* Schar., *Orientalia*? *baccula* Schl., *Marginulina subformosa* Bass., *Vaginulina*? *vermis* Gerke, *Lenticulina raritas* E. Ivan., *Trochammina rosaceaformis* Rom.	*Haplophragmoides fimbriatus* and *Trochammina rosaceaformis*
		Craspedites taimyrensis	*Ammodiscus veteranus* Kosyr., *Haplophragmoides emeljanzevi* Schl., *H. schleiferi* Schar., *H.* cf. *fimbriatus* Schar., *Trochammina* ex gr. *rosaceaformis* Rom., *Orientalia* ? *baccula* Schl., *Marginulina subformosa* Bass., *Vaginulina*? *vermis* Gerke, *Lenticulina sossipatrovae* Gerke and E. Ivan.	

TABLE 25. Distribution of foraminifer complexes in Berriasian sediments of the key section in the Kheta basin

System	Stage	Zone	Foraminifers	Beds according to foraminifers
Cretaceous	Valanginian	*Neotollia klimovskiensis*	*Glomospirella gaultina* (Berth.), *Nodosaria sceptrum* Reuss, *Pseudonodosaria insueta* Bass., *Vaginulina phragmifera* Bass., *Marginulina gracilissima* Reuss, *M. corneola* Vass., *M.* aff. *zaspelovae* Rom., *Reinholdella tatarica* Rom.	*Reinholdella tatarica* and *Vaginulina phragmifera*
Cretaceous	Berriasian	*Bojarkia mesezhnikowi*	*Glomospirella gaultina* (Berth.), *Pseudonodosaria insueta* Bass., *Nodosaria grossulariformis* Gerke, *Marginulina zaspelovae* Rom, *M. impropria* Bass., *M. occultata* Bass., *Astacolus suspectus* Bass., *A. trigonius* Bass., *A. bojarkaensis* Bass., *Planularia pressula* Schl., *Lenticulina gudinae* E. Ivan., *L. raritas* E. Ivan., *L. pseudoarctica* E. Ivan., *Globulina chetaensis berriasica* Bass., *G. praelacrima* Mjatl., *Reinholdella tatarica* Rom.	*Reinholdella tatarica* and *Astacolus bojarkaensis*
Cretaceous	Berriasian	*Surites analogus*	*Nodosaria sceptrum* Reuss., *Marginulina zaspelovae* Rom., *M. secta* Bass., *M. pyramidalis* Koch, *Lenticulina sossipatrovae* Gerke and E. Ivan., *L. gudinae* E. Ivan., *L. pseudoarctica* E. Ivan.	*Lenticulina pseudoarctica* and *Marginulina secta*
Cretaceous	Berriasian	*Hectoroceras kochi*	*Ammodiscus veteranus* Kosyr., *Haplophragmoides* ex gr. *volosatovi* Scharov., *Marginulina glabroides* Gerke, *M. integra* Bass., *M. secta* Bass., *Marginulinopsis borealis* E. Ivan. subsp. *majmetchensis* Bass., *Globulina chetaensis berriasica* Bass.	*Marginulinopsis borealis majmetchensis* and *Marginulina secta*
Cretaceous	Berriasian	*Chetaites sibiricus*		
Jurassic	Volgian	*Chetaites chetae*		
Jurassic	Volgian	*Craspedites taimyrensis*	*Nodosaria invidiosa* Bass., *N. grossulariformis* Bass., *Marginulina zaspelovae* Rom., *M. impropria* Bass., *M. integra* Bass., *Astacolus decalvatus* Bass., *Lenticulina makarjevae* E. Ivan., *L. xenia* E. Ivan., *Marginulinopsis chetae* Bass., *M. borealis* E. Ivan., *Globulina chetaensis* Bass., *Guttulina* ex gr., *dogieli* Dain, *Ceratobulimina*? *prudens* Bass.	*Nodosaria invidiosa* and *Guttulina* ex gr. *dogieli*

Jurassic-Cretaceous boundary at the base of these beds in this area. The beds in the Ust'-Yenisei area are probably partly analogous to the beds with the same names in the Urdyuk-Khaya section. At the base of the Cretaceous system in the north of Western Siberia beds with *Trochammina rosaceaformis* are isolated (Subbotina, et al. 1964). They yield *Haplophragmoides fimbriatus* Schar., *H. infracretaceous* (Mjatl.), *Trochammina rosaceaformis* Rom., and also Volgian species, so that they may be correlated with the beds with *Haplophragmoides fimbriatus* and *Trochammina rosaceaformis* in the Ust'-Yenisei área and, partly, with the beds bearing these names on Paks Peninsula (Table 26).

Changes in the composition of foraminifers at the boundary between the *Chetaites sibiricus* and *Hectoroceras kochi* zones and also the *H. kochi* and *Surites analogus* zones in the north of Middle Siberia are noted only at the species level. Essentially Berriasian complexes appear at the end of *"Hectoroceras kochi"* time and during *"Surites analogus"* time. The Volgian elements in the fauna gradually disappear, but a negligible percentage remains. In the lower reaches of the Yenisei the complexes apparently change only in terms of species. The complexes occurring here are not very typical, and *Ammobaculites gerkei* Schar. begins to gain steadily in importance. In the sections of the north of Western Siberia above beds with *Trochammina rosaceaformis* there is a complex with *Gaudryina gerkei* which contains *Trochammina polymera* Dubr., *Lenticulina pseudoarctica* E. Ivan., *Marginulina zaspelovae* Rom., and various forms of *Ammobaculites* (*A.* aff. *subcretaceous* Cush. and Alex., *A.* aff. *goodlandensis* Cush. and Alex.). This complex has a very similar composition to that of the complexes in the *Surites analogus* zone on the Boyarka River and on Cape Urdyuk-Khaya.

"Bojarkia mesezhnikowi" time in the north of Middle Siberia was the time of maximum diversity of the Berriasian species, of the appearance of the first representatives of the Valanginian fauna, and of the virtual disappearance of all Volgian elements. Species of the family Ceratobulimidae (genus *Reinholdella*) now reappear, plus a large percentage of new species (24% of the total number in the Boyarka complex).

In the lower reaches of the Yenisei and, apparently, in many sections of the north of Western Siberia, *"Bojarkia mesezhnikowi"* time is associated with the appearance of *Trochammina tatarica* Rom.; it is also a time of mass occurrence of *Trochammina polymera* Dubr. Accompanying species are *Recurvoides paucus* Dubr., *Verneulinoides perexiguus* Dubr., *Lenticulina variabilis* (Rom.), *L. observabilis* (Zasp.), *L. paulus* (Zasp.), and *Marginulina zaspelovae* Rom., in other words, for the most part species that are not found in the north of Middle Siberia.

The complexes of the north of Western and Middle Siberia in the period in question can be correlated only in terms of their joint occurrence with ammonites of the genera *Tollia* and *Bojarkia*.

The coming of the Valanginian age saw an impoverishment of the species composition of foraminifers all over Siberia. In the north of Middle Siberia in the *Neotollia klimovskiensis* and *Polyptychites stubendorffi* zones the species *Reinholdella tatarica* Rom. and *Haplophragmoides infracretaceous* Mjatl. are massively distributed, while species of the family Cornuspiridae (genus *Cornuspira*) and sessile tests of the families Nodosariidae (genus *Tentifrons*) and Polymorphinidae (genus *Bullopora*) appear (Ivanova, 1964, 1965, 1968).

In the lower reaches of the Yenisei and in the north of Western Siberia (beds with *Temnoptychites*) characteristic for this time are *Haplophragmoides infracretaceous* Mjatl., *Reinholdella tatarica* Rom., *Glomospirella multivoluta* Rom. (=*G.* ex gr. *gaultina* Berth., according to several authors), and *Recurvoides obskiensis* Rom., in other words, the

TABLE 26. Scheme correlating the foraminifer complexes in the Jurassic-Cretaceous boundary layers in northern Siberia and on Spitsbergen

Stage	Substage	Zones of the Northern Urals	Zones of the Khatanga Depression	Spitsbergen	Polar Urals	North of the Urals part of the West Siberian Plain	Turukhan-Ermakovo area	Ust'-Yenisei area	Khatanga area: Kheta basin	Khatanga area: Paks Peninsula (Cape Urdyuk-Khaya)	Olenek area
Berriasian		*Bojarkia payeri*	*Bojarkia mesezhnikowi*	*Recurvoides* ex gr. *obskiensis, Gaudryina gerkei, Lenticulina sossipatrovae*	*Glomospirella gaultina*	*Reinholdella tatarica, Trochammina polymera*	*Reinholdella tatarica, Haplophragmoides grandis*	*Ammobaculites gerkei, H. infracretaceous*	*Reinholdella tatarica, Astacolus bojarkaensis*	*Reinholdella tatarica*	*Gaudryina gerkei, Recurvoides obskiensis, Marginulina zaspelovae*
										Trochammina parviloculata, Gaudryina gerkei, Ammobaculites spp.	
		Surites spasskensis	*Surites analogus*			*Gaudryina gerkei, Lenticulina pseudoarctica, Ammobaculites* spp.	*Haplophragmoides infracretaceous, H. grandis, H. umbonatus*	*Haplophragmoides infracretaceous*	*Lenticulina pseudoarctica, Marginulina secta*		
		Hectoroceras kochi	*Hectoroceras kochi*			*Haplophragmoides fimbriatus*	*Haplophragmoides grandis, H. umbonatus, Trochammina ficta*	*Haplophragmoides fimbriatus, Trochammina rosaceaformis*	*Marginulinopsis borealis majmetchensis* and *Marginulina secta*	*Gaudryina gerkei, Trochammina parviloculata*	
		Chetaites sibiricus	*Chetaites sibiricus*								
Volgian	upper		*Chetaites chetae*	*Haplophragmoides schleiferi, Gaudryina* aff. *gerkei*	Radiolarian horizon (*Dictyomitra* sp.)	*Haplophragmoides emeljanzevi, Trochammina kondaensis*	*Ammodiscus veteranus, Haplophragmoides volossatovi*	*Ammodiscus veteranus, Haplophragmoides emeljanzevi, H. volossatovi*	*Nodosaria invidiosa, Guttulina* ex gr. *dogieli, Marginulina zaspelovae*	*Trochammina rosaceaformis Marginulina subformosa, Haplophragmoides fimbriatus*	*Ammodiscus veteranus, Haplophragmoides emeljanzevi, H. volossatovi, Trochammina septentrionalis*
			Craspedites taimyrensis			*Ammodiscus veteranus, Haplophragmoides volossatovi*			*Marginulina subformosa, Lenticulina ronkinae*	*Ammodiscus veteranus, Trochammina* ex gr. *rosacea*	
		Craspedites subditus	*Craspedites okensis*: *Craspedites originalis*								
			Craspedites okensis: *Craspedites okensis*	*Haplophragmoides* ex gr. *emeljanzevi, H. schleiferi*					*Haplophragmoides emeljanzevi, Trochammina* ex gr. *rosacea*		
		Kachpurites fulgens	*Craspedites okensis*: *Virgatosphinctes exoticus*								

composition is more or less the same as in the same-aged deposits of the Khatanga Depression. The first representatives of the genus *Hoeglundina* emerge in the northwest of Western Siberia.

Thus, similar transformations in the foraminifer complexes are observed everywhere in Siberia at the beginning of the Cretaceous, although they do not always coincide in time. At the very bottom of sediments referred to the Berriasian according to their ammonites the composition of the foraminifers retains a considerable number of Volgian elements. Beds with this composition are noted in the *Chetaites sibiricus* zone and in some sections of the *Hectoroceras kochi* zone. Essentially Berriasian complexes appear in the *Hectoroceras kochi* zone (Urdyuk-Khaya) or at the top of this zone and in the *Surites analogus* zone (Boyarka). In the *S. analogus* and *B. mesezhnikowi* zones the Berriasian species become diverse, and later new species appear that are to develop in the Valanginian.

During the Berriasian, therefore, we see three phases of transformation and correspondingly three different complexes of foraminifers. It is important to note that these complexes are observed in sections that are continuous and that have the same rock composition (clays and silts). Although the complexes bear the stamp of the local facial conditions in each specific section, the overall trend of change indicates that the causes of the transformation are rooted in the general evolution of the physicogeographical conditions in the Siberian marine basins and in the evolution of the foraminifer fauna itself.

It is noteworthy that a landmark of fairly substantial changes in the foraminifer composition is observed in the basins of Middle and Western Siberia with the onset of "*Bojarkia mesezhnikowi* and *B. payeri*" time. These changes are expressed in the appearance of representatives of different genera and families, and also in the development of forms of *Reinholdella, Trochammina,* and a large number of new species belonging to other genera.

According to Magne (1964), the composition of the *Calpionella* fauna from the stratotype of the Berriasian stage in France also shows three phases of transformation which are similar in content to the transformations of the foraminifers in the Berriasian of Siberia. Considerable changes in the foraminifer composition are established in the stratotype in the middle part of the Berriasian sediments, although the foraminifers have not been studied throughout the section.

In Poland, Berriasian foraminifers are known from the *Riasanites rjasanensis* zone and are represented by a very distinct complex that includes both calcareous and agglutinated forms: *Haplophragmoides concavus* (Chap.), *Ammobaculites subcretaceous* Cush. and Alex., *Trochammina keyniensis* Sztejn, *Lenticulina saxocretacea* (Reuss);* *Glomospirella gaultina* (Berth.), *Eoguttulina witoldi* Sztejn,* *Verneuilinoides neocomiensis* (Mjatl.), *Spirilina flora* Sztejn, *Epistomina caracolla anterior* Bart. and Brand, and others. This complex contains a small number of species (marked by an asterisk) that appeared in the upper part of the Purbeckian (Marek, 1969; Sztejn, 1967, 1969). This bears evidence of a relationship between the foraminifer fauna at the end of the Late Jurassic and in the Early Cretaceous. The transition to the Valanginian stage in Poland entrained negligible changes in the composition of foraminifers. The microfaunal complexes of the Berriasian and early Valanginian are very similar (Sztejn, 1969).

In the *Riasanites rjasanensis* zone on the Russian Platform in the Moscow area we find

Reinholdella sp. similar to *R. tatarica* Rom., *Nodosaria* ex gr. *paupercula* Reuss, and *Marginulina* ex gr. *glabroides* Gerke. In the Pechora basin in silts with *Surites spasskensis* (Nik.) the foraminifer complex is represented by agglutinated and calcareous forms, including *Geinitzinita* aff. *nodulosa* (Furss. and Pol.), *Haplophragmoides* aff. *volgensis* Mjatl., *H. infracretaceous* Mjatl.,* *Saracenaria* ex gr. *pravoslavlevi Furss.* and Pol., *Gaudryina gerkei* Vass., *Glomospirella* aff. *gaultina* (Berth.),** *Ammobaculites* aff. *goodlandensis* Cush. and Alex.,* and *Epistomina caracolla anterior* Bart. and Brand** (determined by Kositskaya, 1962). These are species that developed in the Volgian in the Middle Volga area or appeared in the Berriasian in the basins of Western and Middle Siberia (marked with one asterisk) and also in Poland (**).

Where the other areas of the Boreal Realm are concerned, there are no comprehensive data available on the microfauna of Berriasian sediments that would enable us to perceive the nature of the changes occurring in time.

An analysis of the systematic composition of the foraminifer communities in the Berriasian showed that it consists of 10 families, 32 genera, and 50 species in Middle Siberia, 7 families, 12 genera, and 25 species in the lower reaches of the Yenisei, 11 families, 29 genera, and 30 species in Western Siberia, and of 9 families, 17 genera, and 21 species in Poland. The proportion of agglutinated foraminifers is greater in northern Siberia. In the north of Middle Siberia they are represented by the families Lituolidae (3 genera), Trochamminidae (2 genera), Ataxophragmiidae (2 genera), Ammodiscidae (2 genera), and Saccamminidae (one genus); in Western Siberia they comprise the families Lituolidae (6 genera), Ammodiscidae (4 genera), Ataxophragmiidae (3 genera), Hyperamminidae, Reophacidae, Trochamminidae, and Astrorhizidae (one genus of each); in the Pechora basin there are the families Lituolidae (3 genera), Ataxophragmiidae (3 genera), Astrorhizidae, Saccamminidae, Hyperamminidae, Reophacidae, Textulariidae, and Trochamminidae (one genus of each); in Poland they are represented by the families Reophacidae, Ammodiscidae, Trochamminidae (one genus of each), Lituolidae and Ataxophragmiidae (2 genera of each).

The greatest diversity in the communities of calcareous foraminifers is seen in the family Nodosariidae. In the north of Middle Siberia the family is represented by 14 genera, in Western Siberia by 8 genera, in the lower reaches of the Yenisei by 5 genera, in the Pechora basin by 11 genera, and in Poland by 5 genera. Forms of the family Spirillinidae are not known at all in the basins of Siberia or the Pechora. Representatives of the family Reophacidae are not found in the complexes of Middle Siberia. Many genera of the family Nodosariidae existing in the northern Siberian and Pechora basins are absent in Poland. Regarding the species composition of foraminifers in the basins studied, we see here quite a high percentage of endemism. We have just to mention the species *Glomospirella gaultina* (Berth.), which is distributed in the Pechora basin, on Paks Peninsula, and in Poland, *Verneuilinoides neocomiensis* (Mjatl.), and *Hoeglundina caracolla anterior* Bart. and Brand., found in the Pechora basin and in Poland, and *Ammobaculites subcretaceous* Cush. and Alex., which features in the complexes of the north of Western Siberia and Poland. A very high percentage of common species is present in the basins of Middle and Western Siberia. These are *Haplophragmoides (Evolutinella) fimbriatus* Schar., *H. (E.) infracretaceous* Mjatl., *Recurvoides obskiensis* Rom., *Gaudryina gerkei* Vass., *Troch-*

ammina rosaceaformis Rom., *Lenticulina pseudoarctica* E. Ivan., *Marginulina zaspelovae* Rom., and *Reinholdella tatarica* Rom. The presence of common species shows that there were close ties linking these basins during the entire Berriasian.

Hence, a comparison of the foraminifer complexes of the regions discussed showed that for Middle Siberia and Poland, 7 out of 11 families are common, for Western Siberia and Poland 8 out of 12 families are common, for Middle and Western Siberia 7 out of 12 families are common, and for Middle and Western Siberia and the Pechora basin 9 out of 14 families are common. The proportion of common families among these regions is 54–66%, so that we can apparently say that they belong to a single large paleozoogeographic unit – the Boreal Realm. The foraminifer complexes both of Western and Middle Siberia and of Poland are appreciably different from those of southern France (the stratotype of the Berriasian). The proportion of common families constitutes 33–43%, and the representatives of 5 families present in the French complexes are unknown in Poland and Siberia. In generic composition the complexes of the compared regions are 15–27% common. The differences between the foraminifer complexes of France and those of Poland and Siberia are due to the fact that these basins belong to different paleobiogeographic realms: the former to the Tethyan, the latter to the Boreal Realm.

The basins compared differ markedly in generic composition: north of Middle Siberia–Poland 7 out of 37 genera common (18%); north of Western Siberia–Poland 9 out of 37 genera common (24%). The complexes of Middle and Western Siberia show much in common in their generic composition (out of 37 genera 17 are common, or 46%), just as do the complexes of Western and Middle Siberia and the Pechora basin (out of 39–42 genera 17–18 are common, or 42–43%). The picture is similar when we compare the complexes in terms of species composition. The Middle and Western Siberian complexes are completely different from the Polish complexes, in which elements of the Mediterranean fauna are present (there are practically no species in common with Siberia). These data show that the basins of Siberia and Poland apparently belonged to different zoogeographic regions in the Berriasian, the former to the Arctic and the latter to the Boreal-Atlantic.

The foraminifer complexes of the Pechora basin contain species that are similar, sometimes identical, both to the Berriasian species of Middle and Western Siberia and of Poland and to the Volgian species of the Russian Plain. It may therefore be that the Pechora basin was a border area between the Arctic and Boreal-Atlantic regions.

The Foraminifera of Western and Middle Siberia and of the Pechora basin have not yet been studied monographically. Nevertheless, the species composition and structural characteristics of the complexes possessing distinctive features in each of these basins suggest that beginning, apparently, with the end of the Berriasian, they belong to different provinces: West Siberian and Middle Siberian provinces. It is hard to say to which province the Pechora basin belongs according to the foraminifer fauna. It may, in fact, have been a separate province. According to the macrofauna (ammonites, belemnites), this basin was included in the Pechora-Greenland Province of the Boreal-Atlantic Region.

We may conclude from the above that the sediments placed at present in the Berriasian stage of the Boreal Realm contain a distinctive foraminifer fauna that differs both from the Volgian and from the Valanginian faunas. It is a fauna transitional between the Late

Jurassic (Volgian) and Early Cretaceous (Valanginian-Albian) faunas of Siberia and Northern Europe. In the lower horizons the Berriasian microfauna is still very similar to the Volgian. Elements of the Valanginian fauna appear in the late Berriasian. Many species that developed in the late Berriasian crossed its upper boundary, yet nevertheless, typically Valanginian species emerge in the early Valanginian.

During the Berriasian marked transformations took place in the composition of the foraminifers, enabling us to compare this phase in the faunal development with other phases that in volume are equivalent to stages of the Jurassic and Cretaceous systems.

Many foraminifers of the Siberian Berriasian have been described in works by Basov (1967, 1968, 1969) and Ivanova (1969). Below we give a description of some species of the family Nodosariidae from Berriasian and Valanginian deposits in the north of Middle Siberia.

FAMILY NODOSARIIDAE EHRENBERG, 1838

Genus *Lenticulina* Lamarck, 1804

*Lenticulina sossipatrovae** Gerke and E. Ivanova n. sp.
Plate XLIV, Figures 1–10

Holotype No. 250/3 in the collection of IGG SO AN SSSR; Khatanga Depression, Boyarka River. Berriasian, *Bojarkia mesezhnikowi* zone. Paratype No. 250/4; same age and occurrence. Paratype No. 1009/354 in the NIIGA collection; Nordvik area (Kozhevnikovo), borehole K-133, depth 151–157 m; "clay suite of the Valanginian," beds with *Haplophragmoides infracretaceous* and *Reinholdella tatarica,* Berriasian-Valanginian.

Material. More than 200 specimens in a good or satisfactory state of preservation.

Description. Test small or of medium size; round-oval, with a projecting angle of the last chamber, rounded in younger specimens, elongate-oval in older individuals; more or less flattened; for the most part involute or almost involute. Adults are generally slightly uncoiled toward the end – the inner ends of the late chambers retreat from the middle of the shell; sometimes one or two of the last chambers barely touch the whorl or depart from it, forming the uncoiled part of the test. The ratio of the large to the small diameter is from 1.0 to 1.4, usually between 1.1 and 1.3; that between the small diameter and the thickness 1.4–2.5, generally from 1.5 to 2.1. Sides of test moderately convex. The peripheral margin is strongly compressed and distinctly, but not broadly, keel-shaped, plane or slightly polygonal. The test consists of 1–1.5 whorls of a spiral. The total number of chambers is from 6 (in juveniles, with an incomplete spiral) to 15; the last whorl has 8–10 chambers; in uncoiled shells the number of chambers visible externally is 12, while in young specimens (with incomplete whorl) there are fewer than 8. Chambers triangularly semilunar (curved-triangular), relatively narrow; their height is greater than their length by a factor of 1.5–2.0 (usually about 2). The sides of the chambers are

* Named after micropaleontologist G. N. Sossipatrova. Description by A. A. Gerke and E. F. Ivanova.

flattened or weakly convex, but they do not project at the inner ends, except for the last 1–3 chambers in microspherical individuals. The last chamber often does not differ in size from the preceding one or is even narrower than this.

The initial chamber is spherical, with a diameter of 55–65 μ in microspherical forms and of 85–120 μ in megaspherical forms. In the latter case it is situated at the peripheral margin, while in the microspherical generation it lies in the center of the test and is sometimes translucent. The tests of the microspherical generation are mostly asymmetrical to a certain degree (inequilateral), as the following table illustrates.

Occurrence	Number of specimens		
	total	symmetrical	asymmetrical
Boyarka River	48	28	20
Maimecha River	31	7	24
Southern Tigyan	63	25	38
Nordvik	32	14	18
Anabar Bay	27	16	11

The asymmetry often leads to semi-involuteness of the one of the sides of the test (the "dorsal" side), while the other side ("ventral") is almost or fully involute.

The septal grooves are sickle-shaped, distinct, double-contoured, narrowish (11–27, rarely 27 μ), narrowing very slightly toward the periphery. In the early part of the test the grooves are superficial or very weakly convex, but in the later part, especially in uncoiled specimens, they become distinctly but not strongly convex and sometimes wider. In some cases the convexities of the last one or two grooves continue in the form of a fine costule that runs over the surface of the early chambers of the last whorl. The umbilical region is more or less open (its width is 0.03–0.10 mm) and filled with a thin layer of skeletal substance that does not form a boss. The initial chamber may be seen through this substance. The inner ends of the chambers sometimes unite to seal off the umbilical region. In asymmetrical tests the umbilical region is more open on the "dorsal" side (width 0.10–0.15 mm), where the initial chambers are seen. On the "ventral"side it is narrower (width 0.03–0.08 mm) or weakly expressed.

The septal surface is triangularly helmet-shaped, in uncoiled tests ovoid-helmet-shaped, not very wide (width 0.15–0.38 mm, usually 0.20–0.28 mm), markedly curved along the height, weakly concave or flattened along the width (i.e. along the thickness of the chamber), moderately or weakly incised at the base in adults (it is usually not incised at all in uncoiled specimens). Aparture radial, small. Surface smooth. Wall opaque or glassy-transparent, single-layered, 43–55 μ thick in places of the thickenings in front of the grooves and 11–33 μ thick at the beginning of each chamber. The dimensions are given in Table 27.

Variability is expressed in the size of the test, the dimensions of the initial chamber (from 55 to 120 μ), and in the number of chambers, this largely being a consequence of the specimens' being of the micro- and megaspherical generations. The thickness does not depend on the generation to which the tests refer.

TABLE 27. Dimensions (mm) of *Lenticulina sossipatrovae* n. sp.

Locality and number of specimens measured	Large diameter (D)	Small diameter (D_1)	Thickness (T)	Number of chambers		Ratios according to averaged data		
				in last whorl of spiral (C)	in uncoiled part (C_1)	$D:D_1$	D:T	$D_1:T$
Boyarka River (50)	0.30–0.88 (usually 0.45–0.58)	0.23–0.63 (usually 0.38–0.50)	0.15–0.43 (usually 0.20–0.28)	8–10	0–1	1.1–1.3	1.7–1.3 (usually 2.0–2.3)	1.5–2.4 (usually 1.6–2.0)
Maimecha River (59)	0.38–0.83 (usually 0.48–0.65)	0.30–0.70 (usually 0.38–0.50)	0.18–0.30 (usually 0.20–0.28)	8–10	0–1	1.1–1.4 (usually 1.1–1.3)	1.7–1.3 (usually 2.0–2.5)	1.6–2.4 (usually 1.6–2.0)
Nordvik (105)	0.28–1.0 (usually 0.35–0.60)	0.23–0.58 (usually 0.28–0.48)	0.15–0.38 (usually 0.16–0.30)	8–10	1–2	1.0–1.7 (usually 1.1–1.3)	1.5–3.2 (usually 2.0–2.5)	1.4–2.3 (usually 1.6–2.1)
Anabar Bay (27)	0.33–0.55 (usually 0.38–0.45)	0.23–0.43 (usually 0.33–0.40)	0.13–0.25 (usually 0.18–0.23)	8–10	–	1.1–1.4 (usually 1.1–1.3)	1.5–2.5 (usually 1.9–2.3)	1.5–2.5 (usually 1.6–1.8)
Photographed specimens								
Plate XLIV, Figure 1	0.78	0.63	0.33	9	1	1.2	2.3	1.9
2	0.50	0.43	0.25	9	–	1.2	2.0	1.7
3	0.63	0.40	0.20	10	1	1.4	3.1	2.0
4	0.45	0.35	0.25	6	–	1.2	1.9	1.5
5	0.70	0.58	0.33	8	–	1.2	2.1	1.7
6	0.60	0.45	0.28	8	1	1.3	3.3	1.6
7	0.60	0.48	0.20	9	1	1.1	2.0	2.4
8	0.75	0.58	0.38	9	1	1.2	1.9	1.6
9	0.58	0.43	0.23	9	1	1.2	2.5	1.8
10	0.48	0.38	0.20	9	–	1.2	1.9	1.9

Comparison. From the relatively similar *Lenticulina saxocretacea* (Bartenstein, 1954), originally described by Reuss (1863) from the Albian and Barremian of the northern part of West Germany under the preoccupied name *Cristellaria subalata,** the new species differs in its species characters: the form of the test, the flattening, the presence of uncoiled and asymmetrical specimens, the lower and wider chambers, the type of grooves, and the helmet-shaped septal surface that is much more weakly incised.

L. sossipatrovae differs from *L. nivalis* Schleifer and Gerke n. sp. in having a less convex test, a larger number of chambers that are narrower, the narrower and generally less convex or even superficial grooves, a narrower, helmet-shaped septal surface, and also in the presence of strongly uncoiled and asymmetrical specimens. Still, the two species are very similar, and there are apparently sometimes transitions between them.

Age and distribution. Ust'-Yenisei Depression. Malokheta anticline, Dzhanga area – rarely in the lower Valanginian (lower Kheta suite).

Khatanga Depression. Nordvik area – rarely in beds with *Ammodiscus veteranus* and *Haplophragmoides emeljanzevi* = upper substage of the Volgian stage to the bottom of the Berriasian (Uryung-Tumus, Southern Tigyan); usually in beds with *Haplophragmoides infracretaceous* and in the lower half of beds with *Reinholdella tatarica* = Berriasian to lower Valanginian (Uryung-Tumus, Il'ino-Kozhevnikovo area, Tigyan-Chaidakh area, Southern Tigyan, Syndasko). Anabar River – rare in the same deposits. Paks Pensinsula (Urdyuk-Khaya) – rare in the upper substage of the Volgian stage (*Craspedites taimyrensis* zone), Berriasian (all zones), lower Valanginian (*Polyptychites stubendorffi* zone). Boyarka and Maimecha rivers – usually in the Berriasian (*Surites analogus* and *Bojarkia mesezhnikowi* zones).

Lena-Anabar flexure. Olenek area – isolated specimens in beds with *Ammodiscus veteranus* and *Haplophragmoides emeljanzevi* = upper substage of the Volgian stage to the bottom of the Berriasian; rare in overlying sediments of the Berriasian to the lower Valanginian.

Lenticulina nivalis Schleifer and Gerke n. sp.**
Plate XLV, Figures 1, 3

Holotype No. 1009/356 in the collection of the Institute of Arctic Geology; Khatanga Depression, Nordvik area (Kozhevnikovo), borehole K-119, depth 170–175 m; "clay suite of the Valanginian," beds with *Haplophragmoides infracretaceous* and *Reinholdella tatarica* (Berriasian–Valanginian). Paratype No. 1009/538; same age and occurrence.

Material. More than 60 tests in a good or satisfactory state of preservation.

Description. Test generally of average size or small, but some specimens reach quite a considerable size. The test is involute, more or less thick, in profile broadly oval or almost round with a slightly projecting angle of the last chamber. Most specimens are tightly coiled to the end and fully involute. However, some of the larger forms have a slightly

* For more on this see the description of *Lenticulina nivalis* n. sp.

** Description by A.G. Shleifer and A. A. Gerke.

uncoiled spiral axis. Their last chambers do not reach the middle of the test with their inner ends. Ratio D: D_1 usually 1.2–1.35, rarely as much as 1.4; D_1 : T from 0.9 usually to 1.5–1.8, rarely to 2.1. In typical individuals the whorl thickness increases markedly, so that the test attains its maximum thickness in the region of the last chamber near the base of the septal surface, while in the umbilical region it is generally a little thinner. Peripheral margin acute, more or less keel-shaped, plane or slightly polygonal. The test consists of 1.0–1.3 whorls of a spiral, in which from 7 to 12 chambers are counted. The last whorl has 7–8 chambers, but in some specimens there are 9 or, very rarely, 10. All the chambers are nonconvex, triangularly semilunar, not very narrow. The adjacent chambers in the last whorl overlap like tiles in adult forms. The initial chamber has a diameter of 65–120 μ; there may be two generations, a microspherical (65–90 μ) and a megaspherical (90–120 μ). But the number of chambers in the whorl may be the same in either case.

The grooves are curved and form more or less strongly projecting, wide convexities in the form of comma-shaped crests. The inner ends of the crests diverge slightly from each other, ending in a glassy substance that is developed in the umbilical region, but a boss is not formed. The late grooves do not reach the middle of the test but approach it somewhat tangentially.

The septal surface of the last chamber is relatively wide, triangularly heart-shaped, markedly or strongly curved along the height, flattened or concave along the width (along the thickness of the chambers), more rarely weakly convex. Along the margins it is bordered by crests that in some cases are considerably elevated above the septal surface. Aperture radial, situated on a low conical elevation. Surface smooth. The wall is 33–66 μ thick and is thicker in the swellings near the grooves. Measurements, mm:

Specimen	Large diameter (D)	Small diameter (D_1)	Thickness (T)	Number of chambers in last whorl (C)	Ratios (averaged data) D:D_1	D:T	D_1:T
Nordvik area	0.33–0.75 (usually 0.35–0.48)	0.25–0.65 (usually 0.28–0.45)	0.15–0.38 (usually 0.20–0.33)	7–10	1.1–1.4 (usually 1.2–1.3)	1.3–2.5 (usually 1.6–2.2)	0.9–2.1 (usually 1.5–1.8)
Photographed specimens							
Plate XLV, Figure 1	0.60	0.48	0.28	8	1.2	2.2	1.7
Plate XLV, Figure 3	0.90	0.70	0.50	9	1.2	1.8	1.4

Variability manifested in the size of the test, its relative thickness, the size of the initial chamber (65–120 μ), the extent to which the septal surface is flattened, and the degree of convexity of the crests on the grooves.

Comparison. This species is extremely similar to *L. sossipatrovae* but it has a larger test that incresases in thickness more rapidly, wider and fewer chambers, more strongly developed crests on the grooves, a broader septal surface, and virtually no uncoiled tests. Hardly any asymmetrical specimens were observed (these are common in *L. sossipatrovae*). In the juvenile stage of development the representatives of these species especially resemble each other, although here too, *L. nivalis* usually shows better developed convexities on the grooves and a wider, more triangular septal surface. Transitions are sometimes noted between compared species in material from same-aged deposits, but on the whole the two species are quite clearly distinguished.

L. nivalis also shows a marked resemblance to *L. saxocretacea* Bartenstein, 1954 (olim *Cristellaria subalata* Reuss, 1863, non *C. subalata* Reuss, 1854), described by Reuss (1863, p. 76, pl. VIII, fig. 10; pl. IX, fig. 1) from the Albian and Barremian of the northern part of West Germany.* But *L. nivalis* differs in having narrower chambers, more strongly curved grooves, better developed crests on the grooves, and in the relatively wide and more weakly incised septal surface, due to which the surface becomes triangularly heart-shaped, less sagittate than in *L. saxocretacea*. In addition, *L. nivalis* reaches a much greater size (the large diameter in *L. saxocretacea* may reach 0.84 mm according to Reuss). After Reuss, a number of authors described the West European *L. saxocretacea* (most of them under the incorrect name *L. subalata*), but the data they give need to be revised, as it is certain that not all of them in fact refer to the same species.

Age and distribution. Ust'-Yenisei Depression. Malokheta anticline – rare in the lower Valanginian (lower Kheta suite).

Khatanga Depression. Nordvik area (Uryung-Tumus, Il'ino-Kozhevnikovo sector, Tigyan-Chaidakh area, Southern Tigyan, Syndasko, Kharabyl), Popigai River, lower reaches of the Kotuy – generally in beds with *Haplophragmoides infracretaceous* and in beds with *Reinholdella tatarica* = Berriasian (*Hectoroceras kochi?, Surites analogus,* and *Bojarkia mesezhnikowi* zones), lower Valanginian and, possibly, the lower strata of the upper Valanginian; occasional specimens, probably belonging to this species, found in Kharabyl and in the Kheta basin also in the underlying beds with *Ammodiscus veteranus* and *Haplophragmoides emeljanzevi* = upper substage of the Volgian stage to the lower strata of the Berriasian.

Lena-Anabar flexure. Olenek area – rare in sediments of the Berriasian to the lower Valanginian.

Lenticulina perspicua E. Ivanova n. sp.
Plate XLV, Figures 2, 4–6

Holotype No. 250/167 in the collection of IGG SO AN SSSR. Khatanga Depression,

* At different times Reuss described as *Cristellaria subalata* two different species (the first in 1854 from Upper Cretaceous deposits of Asia, the second in 1863 from Lower Cretaceous deposits of the northern part of West Germany). The name adopted for the second of these species (published in 1863) is consequently a younger homonym that is subject to change. On the basis of this, Bartenstein (1954) established the new name *saxocretacea* for the second species.

Boyarka River, exposure 25, Berriasian, *Bojarkia mesezhnikowi* zone; paratypes Nos. 250/168, 250/169, 250/170, and 250/171; age and occurrence the same.

Material. Ten well-preserved tests.

Description. The test is a plane, spiral, involute, oval. Peripheral margin wide, blunt. Sides weakly convex. The spiral consists of 7–11 triangular chambers that gradually increase in size and are bent into a sickle shape. The chambers are very slightly convex at the base in the region of the umbilical ends. They are twice as wide as high. The umbilical ends of the last 2–3 chambers are more convex and elevated above the umbilical region. This character is also present in young specimens. The initial chamber is quite large, with a diameter of 110 μ, almost double that of the second chamber. It is well defined in juvenile individuals and sometimes translucent in more mature forms. In the adult the initial chamber is closed by the chambers of the last whorl. The last chamber, which is hardly any different in size from the preceding one, has strongly bulging "cheeks." Its septal surface curves very gently at the base and is weakly or markedly convex, fringed by scarcely perceptible, fine crests. The widest part of the septal surface is the middle (0.18–0.50 mm). Its height is equal to or just slightly greater than the width. The septal grooves are thin, superficial, bent; they merge in the umbilical region. The last groove is slightly concave.

Aperture radial, in the form of a large tubercle, situated in the peripheral angle of the last chamber. In some cases the ray situated on the septal surface is more developed. The wall of the test is thin-radial, transparent or opaque. Its width is 11–33 μ in young specimens, 33–55 μ in adults. The chambers are joined together by thickenings before the grooves. The surface of the test is smooth, light-colored, sometimes yellowish. Measurements, mm:

Measurements	Boyarka River	Photographed specimens Plate XLV			
		Figure 2	Figure 4	Figure 5	Figure 6
D	0.43–1.05	0.90	0.85	0.90	0.43
D_1	0.35–0.85	0.73	0.68	0.75	0.35
T	0.20–0.50	0.40	0.40	0.40	0.20
C	7–11	8	9	11	7
$D : D_1$	1.1–1.3 (usually 1.2)	1.3	1,2	1.2	1.2
D : T	1.6–2.2 (usually 1.9–2.1)	2.0	2.1	2.2	2.1
$D_1 : T$	1.4–1.8 (usually 1.6–1.7)	1.6	1.7	1.8	1.7

Variability involves the size of the test and the degree of its flattening, to some extent the convexity of the septal surface, and also the number of chambers. The other characters of the subspecies are quite constant.

Comparison. This species bears some resemblance to *L. ronkinae* Bass., described by

TABLE 28. Measurements of tests (mm)

Specimen	Length (L)	Width (W)	Thickness (T)	L:W	L:T	Diameter of initial chamber	Number of chambers: of spiral	Number of chambers: of uncoiled part	Height of last chamber	Thickness of spiral	Diameter of spiral (D)	Diameter of spiral (D_1)
1	2	3	4	5	6	7	8	9	10	11	12	13
Upper Valanginian forms												
Microspherical B												
7-chambered	0.59	0.28	0.28	2.1	1.0	0.08	4	3	0.20	0.16	0.21	0.16
9- "	0.87	0.42	0.41	2.0	1.0	?	6	3	0.26	0.24	0.34	0.19
Megaspherical A_1												
5-chambered	0.49	0.28	0.30	1.7	0.9	0.10	3	2	–	0.18	0.21	0.14
6- "	0.75	0.31	0.31	2.4	1.0	0.10	3	3	–	0.17	0.21	0.12
Megaspherical A_2												
3-chambered	0.42–0.50	0.25–0.28	0.25–0.28	1.7–1.8	1.0	0.17–0.22	–	3	–	–	–	–
4- "	0.45	0.24	0.25	1.9	1.0	0.15	2	2	–	–	–	–
5- "	0.66	0.27	0.27	2.4	1.0	0.15	–	5	0.22	–	–	–
6- "	0.83	0.28	0.27	3.0	1.0	0.14	2	4	–	–	–	–
Lower Valanginian forms												

Range for	0.35–	0.23–	0.24–	1.5–	1.0	0.08–	4–6	1–4	0.16–	0.16	0.21	0.16
microspherical form B	1.02	0.47	0.46	2.2		0.12			0.26	0.25	0.38	0.24
Average	–	0.34	0.34	–	1.0	0.10	5	–	0.20	0.21	0.31	0.20
Range for	0.49–	0.28–	0.30–	1.7–	0.9–	0.10	3	2–3	–	0.17–	0.21	0.12–
megaspherical form A_1	0.75	0.31	0.31	2.4	1.0					0.18		0.14
Range for	0.42–	0.23–	0.24–	1.5–	1.0	0.14–	0–2	2–5	0.14–	–	–	–
megaspherical form A_2	0.83 –	0.28	0.28	3.0		0.22			0.23			
Average	–	0.26	0.26	2.1	1.0	0.16	–	–	0.18	–	–	–
Lower Hauterivian forms												
Megaspherical B												
7-chambered	0.45	0.31	0.24	1.5	1.3	0.06	6	1	–	0.22	0.35	0.23
8- "												
9- "	0.57	0.38	0.35	1.5	1.1	0.10	7	1	0.22	0.30	0.42	0.28
	0.72–	0.38–	0.38–	1.9–	1.0	–	6–7	2–3	–	0.24	0.39–	0.30–
	1.03	0.48	0.49	2.1							0.51	0.34
Megaspherical A_1												
4-chambered	0.60	0.27	0.28	2.2	1.0	0.18	–	4	–	–	–	–
5- " (bent)	0.69	0.33	0.32	2.1	1.0	0.13	2	3	0.25	–	–	–
5- " (straight)	0.72–	0.33–	0.34–	2.2–	0.9–	0.15–	–	5	0.24–	–	–	–
	0.80	0.34	0.35	2.3	1.0	0.16			0.25			
Range for	0.45–	0.31–	0.24–	1.5–	1.0–	0.06–	6–7	1–3	0.22	0.22–	0.35–	0.23–
microspherical form B	1.03	0.48	0.49	2.1	1.3	0.10				0.30	0.51	0.34
Average	–	0.39	0.36	–	1.1	0.08	6.5	–	0.22	0.25	0.42	0.29
Range for	0.37–	0.22–	0.19–	1.7–	1.0–	0.12	3	1–2	0.14–	0.22	0.28	0.17
megaspherical form A_1	0.57	0.31	0.32	1.8	1.2	0.15			0.24			
Range for	0.60–	0.27–	0.28–	2.1–	0.9–	0.13–	0–2	3–5	0.24–	–	–	–
megaspherical form A_2	0.80	0.34	0.35	2.3	1.0	0.18			0.25			
Average	–	0.32	0.32	2.2	1.0	0.16	–	–	0.25	–	–	–

Basov from upper Volgian deposits of the Khatanga Depression (Ivanova, 1967). The type of structure of the test and the convexity of the umbilical ends of the chambers relate these forms. However, *L. perspicua* differs in the involute spiral that shows no tendency to uncoil, the greater convexity of the test, the more convex umbilical ends only of the last 2–3 chambers, the size of the initial chamber, the form of the last chamber and its convex septal surface, and finally, in the superficial grooves (with the exclusion of the last groove). This species is distinguished from *L. rostriformis* E. Ivan. (Ivanova, 1967) by the size of the initial chamber (110 μ as against 65–86 μ), the convexity of the umbilical ends as early as in the juvenile stage of development, the slight larger number of chambers in the last whorl, the greater convexity of the test and of the septal surface, and also by the position of the maximum width of the septal surface in the middle.

Age and distribution. Boyarka River, Berriasian stage, *Surites analogus* zone (upper strata) and *Bojarkia mesezhnikowi* zone.

Genus *Marginulina* d'Orbigny, 1826

Marginulina corneola Vassilenko
Plate XLVI, Figures 1–5, 7, 8

Marginulina gracilissima (Reuss) var. *corneolus* Vasilenko, 1951, p. 70, pl. IV, figs. 7–10.

Lectotype, chosen by Basov, comes from Neocomian deposits of Cape Il'ya (Khatanga Gulf, Kozhevnikovo inlet, borehole K-1, depth 234 m). Vasilenko (1951), pl. IV, fig. 9a, 9b. Plate XLVI, Figure 1a, 1b in the present work. VNIGRI collection, No. 1507.

Material. About 40 tests, well or satisfactorily preserved, from exposures on the Boyarka, Popigai, and Anabar rivers and from boreholes in the Nordvik area.

Description. Tests of medium size, rarely large, elongate, with rounded convex late chambers that become considerably wider as growth proceeds. The initial part is spirally coiled or bent onto the ventral side. The chambers of the late part grow out along the rapidly uncoiling spiral, which sometimes straightens out completely, but more often is bent onto the ventral side. The ventral and dorsal margins are broadly rounded, lobelike. The cross section of the test is oval.

The test of the microspherical generation has a well-developed spiral part with a diameter of up to 0.51 mm, consisting of 4–7 low, triangular chambers that increase gradually in size. The initial chamber is round, with a diameter of 0.06–0.12 mm. In the uncoiled section there are up to 4 chambers which rapidly increase in thickness and width to give the test the form of a little horn. The chambers at the base are low and almost 2–3 times as wide as their visible height. The last chamber is inflated and relatively high, but its height is still smaller than its width.

In the megaspherical generation A_1 the tests are markedly smaller. The spiral is incomplete and is formed by 3 chambers. The initial chamber is relatively round, with a diameter of 0.10–0.15 mm. There are up to 3 low, weakly expanding chambers in the straightened-out part.

The test of the megaspherical generation A_2 do not form a spiral at all, but their first two chambers are usually strongly curved onto the ventral side. The diameter of the initial chamber is 0.13–0.22 mm. The total number of chambers may reach 6, but 3–5-chambered specimens predominate. It is to be noted that the tests of this generation that have a strongly bent initial part show a smaller diameter than the initial chamber (0.13–0.15 mm), whereas in completely straight, scaphopodlike specimens the diameter is equal to 0.15–0.22 mm.

Characteristic for all generations are relatively low chambers, as though flattened on top, their width far greater than their height.

The grooves in the spiral part of generations B and A_1 are radial, slightly bent, superficial or faintly sunken; in the straightened part in all generations they are straight, wide, beveled onto the ventral side, and deeply sunken.

Aperture rosette-shaped, situated at the end of a papilliform elevation with a basal diameter of 0.05–0.11 mm. It is made up of 3–5 petal-like or broad-rayed openings.

The wall is relatively thick, finely radial, porous, single-layered, in the spiral part secondarily multi-layered (?). The surface of the wall is warty, in places covered with numerous papilliform tubercles. If the tubercles are broken, it is seen that they are hollow inside; however, the cavity does not pass through the wall of the test.

Variability. All the main morphological characters vary considerably. Adults, for example, may show an almost double change in the thickness of the test. The length is highly variable, even with a uniform number of chambers, and the size of the spiral, the height of the last chamber, and other morphological signs vary. The wartiness may be coarse and abundant or else relatively minor and sparse (like spines). It may cover the whole test or only the middle chambers. The variability of these characters is not related to the cyclic polymorphism that is a property of the species and is considered as a specific character.

On the whole, the material consists predominantly of relatively massive tests with a conically expanding uncoiled part, and low, wide, gently beveled chambers. Some regular patterns of change in tests from different horizons may be noted. For instance, in the microspherical generation coming from the Valanginian the spiral is relatively small, consisting of 4–6 chambers. The whorl may be incomplete. Lower Hauterivian specimens of the same generation have 6–7 chambers in a complete whorl of the spiral, which is very large. In the megaspherical generations the changes are less regular through the section. It may be that the lower Hauterivian form should be isolated into a separate subspecies.

Comparison. This species differs markedly from *Marginulina gracilissima* from the Hauterivian-Barremian of the northern part of West Germany as originally understood by Reuss (1863). *M. gracilissima* is characterized by a narrow cylindrical uncoiled part with a larger number of chambers which are higher than in *M. corneola*. In Reuss' material the last chamber is particularly different, with its higher than wide, pear-shaped form strongly drawn out toward the neck of the aperture.

Subsequently *M. gracilissima* was described from the Neocomian of the same areas by Eichenberg (1933), Hecht (1938), Bartenstein and Brand (1951), and Zedler (1961), as well as from East Germany (Bach, 1965) and from Holland (Ten Dam, 1948). The variability of the characters has now been grasped more fully, but all authors agree that the tests of this species have narrower and higher chambers, and apart from this, the microspherical generation is only half as large (with the same number of chambers) as in *M. corneola*. In addition, judging from Bach's description, all the generations of *M. gracilissima* have correspondingly smaller diameters of the initial chamber. Finally, the nature of the ornament in this species is apparently spinelike rather than wartlike. Of the two forms of *M. corneola* observed the closer to *M. gracilissima* is the Valanginian form, whereas the lower Hauterivian form has such a characteristic microspherical generation that the significance of the differences between these two species leaves no room for doubt.

Differing just as essentially and in the same basic characters from *M. corneola* is *Marginulina gracilissima* from the Volgian stage of the Russian Platform (Myatlyuk, 1939; Fursenko and Polenova, 1950; Kuznetsova, 1965). *M. gracilissima* described by Romanova (Balakhmatova et al., 1955) from the Valanginian of Western Siberia closely resembles the Valanginian *M. corneola* in the degree of expansion of the test, the height of the chambers, and in the type of ornament, but it is smaller, and the microspherical forms have a less developed spiral. It may be a geographical subspecies of *M. corneola,* but the material available is insufficient for a detailed comparison or reliable conclusions. It is not excluded that the forms with relatively wide tests with low chambers from the lower Hauterivian of East Germany, that Bach (1969) described as *Lenticulina (Marginulinopsis) gracilissima* (Reuss), should also be referred to *Marginulina corneola,* although they are smaller. This point cannot be decided without a revision of the German material.

Other similar species that may be noted include *M. spinulosa* Mjatl. from the Hauterivian-Barremian of the Russian Platform (Myatlyuk, 1961) which, like *M. corneola,* has a large test and a massive spiral part. But this species shows a much narrower, slightly laterally flattened straight part and the last chambers are high.

Age and distribution. Khatanga Depression, Boyarka River, from the *Neotollia klimovskiensis* zone of the lower Valanginian (layer XXIII of the key section) to the upper Valanginian and the *Homolsomites bojarkensis* zone of the lower Hauterivian; Popigai River, lower and upper Valanginian and the base of the Hauterivian (?). Nordvik area, Valanginian and the bottom of the Hauterivian (?), Anabar River, lower Valanginian. This species may be distributed in the Valanginian of Western Siberia.

Chapter V

CORRELATIONS WITH THE MAIN SECTIONS OF THE BERRIASIAN OUTSIDE THE BOREAL REALM

The stratotype of the Berriasian near the village of Berrias in southeastern France was established by Pictet (1867) and Coquand (1869). It was later studied by Toucas (1889) and, especially minutely, by Busnardo et al. (1965). According to the observations of these last authors, the following are revealed here.

1. Upper Tithonian (?). Massive limestones and dolomites without fauna, more than 10 m thick.

2. Berriasian. *Berriasella grandis* zone, "horizon a" – *B. grandis.* Limestone, in the upper part with *Berriasella grandis* Maz. and *Holocophylloceras calypso* (d'Orb.), 5.5 m thick.

3. *Berriasella boissieri* zone, "horizon b" – *B. oppeli* and *B. subcallisto.* Limestone, clayey in the upper part, with pyrite aggregates, containing *Berriasella subcallisto* (Toucas), *B. grandis* Maz., *B. oppeli* (Kil.), *B.* sp., *Neocomites subalpinus* (Maz.), *Ptychophylloceras semisulcatum* (d'Orb.), *Lytoceras subfimbriatum* (d'Orb.), and *Prospondylus occitatus* (Pict.), in the upper part with *Berriasella boissieri* (Pict.), *Holcophylloceras calypso* (d'Orb.), and *Terebratula moutoniana* d'Orb., 2.5 m thick.

4. Brecciated limestone with undetermined ammonites and *Terebratula moutoniana* d'Orb., 2 m thick.

5. "Horizon c" – *Dalmasiceras dalmasi.* Laminated limestone with iron concretions, in the lower part with *Berriasella boissieri* (Pict.), *Neocomites occitanicus* (Pict.), *Haploceras carachtheis* (Zeuchn.), *Holcophylloceras calypso* (d'Orb.), *Ptychophylloceras semisulcatum* (d'Orb.), *Protetragonites* ind. sp., *Belemnites, Pygope diphyoides* (d'Orb.), and *Cydaris alpina* Cott., in the upper part with *Dalmasiceras dalmasi* (Pict.), *D. punctatum* Djan., *Holcophylloceras calypso* (d'Orb.), *Neolissoceras grasi* (d'Orb.), *Protetragonites* ind. sp., *Rhynchonella malbosi hoheneggersides* Jac. and Fall., and *R. malbosi contractoides* Jac. and Fall., 3.5 m thick.

6. "Horizon d" – *Neocosmoceras* spp. At the base there is a bed of marl and higher up limestone, containing in the lower part *Berriasella* aff. *chaperi* (Pict.), *B.* aff. *privasensis* (Pict.), *B. oxycostata* Jac., *B.* ind. sp., *Neocosmoceras rerollei* (Pag.), *N.* ind. sp., *Spiticeras multiforme* Djan., *Haploceras charachtheis* (Zeuchn.), *Holcophylloceras calypso* (d'Orb.), and *Pleurotomaria berriasensis* Pict. and in the upper part *Neocosmoceras bruni* Maz., *Euthymiceras euthymi* (Pict.), *Spiticeras* aff. *groteanum* (Opp.), *Negreliceras negreli* (Math.), *Neolissoceras grasi* (d'Orb.), *Holcophylloceras calypso* (d'Orb.), and *Lima berriasensis* Pict., 2 m thick.

7. Fine-laminated limestone, without fauna, 5 m thick.

8. "Horizon e" – *Berriasella picteti.* Limestone with iron concretions, higher up clayey limestone with intercalations of marl, in the lower part with *Berriasella boissieri* (Pict.), *B.* cf. *boissieri* (Pict.), *B. rarefurcata* (Pict.), *B. privasensis* (Pict.), *B. picteti* (Jac.), *B. latecostata* Kil., *B. malbosis* (Pict.), *Himalayites romani* Maz., *Spiticeras* aff. *multiforme* Djan., *S.* aff. *subguttatum* Djan., *S.* ind. sp., *Protetragonites* ind. sp., *Neolissoceras grasi* (d'Orb.), *Holcophylloceras calypso* (d'Orb.), *Belemnites, Prospondylus occitanicus* (Pict.), *Waldheimia tamarinda* (Sow.), *W. villersensis* (Lor.), *Pygope diphyoides* (d'Orb.), and *Rhynchonella contracta* d'Hombres Firmas, in the middle and upper part with *Berriasella picteti* Jac., *B. rarefurcata* (Pict.), *B. privasensis* (Pict.), *B. latecostata* Kil., *B. callisto* (?) (d'Orb.), *Protetragonites quadrisulcatus* (d'Orb.), *P.* ind. sp., *Spiticeras* ind. sp., *Neocomites occitanicus* (Pict.), *Neolissoceras grasi* (d'Orb.), *Holcophylloceras calypso* (d'Orb.), *Prospondylus euthymi* (Pict.), *Cidaris alpina* Cott., *Phyllocrinus malbosianus* (d'Orb.), *Pygope diphyoides* (d'Orb.), *Waldheimella villersensis* (Lor.), *W. tamarinda* (Sow.), *Terebratula euthymi* (Pict.), *Rhynchonella contracta* d'Hombres Firmas, *R. malbosi contractoides* Jac. and Fall., and *R. boissieri* Pict., 3.7 m thick.

9. Lower Valanginian. *Kilianella lucensis* zone. "Horizon f" – *Neocomites neocomiensis* and *Thurmanniceras thurmanni.* Platy limestones, with intercalations of marl in the lower part, higher up becoming clayey and passing into marls, in the lower 2.5 m with *Thurmanniceras thurmanni* (Pict. and Camp.), *Th.* aff. *pertransiens* Sayn, *Th.* cf. *salientina* Sayn, *Neocomites neocomiensis* (d'Orb.), *N. neocomiensis premolica* Sayn, *N.* aff. *longi* Sayn, *Kilianella lucensis* Sayn, *K.* aff. *pexiptycha* (Uhl.), *Protetragonites quadrisulcatus* (d'Orb.), *P.* ind. sp., *Spiticeras* ind. sp., *Neolissoceras grasi* (d'Orb.), *Pygope diphyoides* (d'Orb.), *P.* ind. sp., *Spiticeras* ind. sp., *Neolissoceras grasi* (d'Orb.), *Pygope diphyoides* (d'Orb.), *Rhynchonella contracta* d'Hombres Firmas, *Waldheimella villersensis* (Lor.), and *Collyrites berriasensis* Lor., higher up in the section with *Thurmanniceras* sp., *Neocomites* sp., and *Kilianella* sp., more than 8 m thick.

The Berriasian section is also characterized by *Calpionella.* Magne identifies four zones within the Berriasian and a fifth zone in the lower Valanginian. Horizons b, c, and d include a foraminifer complex with *Lenticulina eichenbergi* Bart. and Brand, "horizon e" has a foraminifer complex with *Marsonella* cf. *trochus* (d'Orb.), the boundary layers of the Berriasian and Valanginian contain a complex with *Neotrocholina valdensis* Reich., and finally, in the lower Valanginian, 5–8 m from the base, appears a complex with *Neotrocholina molesta* (Gorb.) and *Spirillina neocomiana* Moul.

The section near Berrias, which, as already mentioned, is taken as the stratotype for the Berriasian stage, has a number of serious shortcomings. The limestones underlying the Berriasian have no fauna, and therefore can be only provisionally referred to the upper Tithonian. We can thus only have a vague idea of the interconnections between the upper Tithonian and the Berriasian. Inside the Berriasian the lower zone, *Berriasella grandis,* is weakly characterized by fauna, so that we are stretching a point when we try to trace it in other regions.

The survey of Berriasian sediments performed in the Boreal Realm shows that the faunal complexes, primarily the ammonite communities, differ considerably among themselves in the Boreal Realm and in the stratotypic section of the Berriasian in southern

France. Nevertheless, since a number of Tethyan forms of ammonites penetrated into the Boreal Realm, mainly in its peripheral part, we are able to correlate sections of the Boreal and Tethyan Berriasian and accordingly apply our concepts to the Berriasian stage and Berriasian age in the Boreal Zoogeographic Realm.

If the Jurassic-Cretaceous boundary in Southern Europe is drawn between the Tithonian and Berriasian, as is done at present, it coincides with the upper limit of distribution of the Virgatosphinctinae and Simoceratinae and with the appearance of such typical Early Cretaceous genera as *Neocosmoceras, Euthymiceras, Subalpinites,* and *Negreliceras.* However, the Virgatosphinctinae and Simoceratinae did not reach into the Boreal Realm in Europe and, furthermore, almost everywhere here, excluding the Russian Plain, marine Lower Cretaceous sediments overlie freshwater-brackish-water strata of the Purbeckian and Wealden, which absolutely rules out the possibility of pinpointing the position of the boundary between the systems. A break is observed everywhere between the Jurassic and Cretaceous on the Russian Plain, and therefore in order to determine the position of the Jurassic-Cretaceous boundary in the Boreal Realm, we have to examine the north Siberian sections, above all the Paks Peninsula one, where there is a continuous section of the top strata of the Jurassic and bottom strata of the Cretaceous that is quite well characterized by ammonites.

Continuous sections that reveal the upper horizons of the Jurassic and lower horizons of the Cretaceous are known in other parts of the Boreal Realm as well: in Western Siberia, Northeast Asia, eastern Greenland, Spitsbergen, and in Canada (Canadian Archipelago, lower reaches of the Mackenzie River, British Columbia). But since their fauna is scant, with very few ammonites, they do not lend themselves to resolving detailed questions of stratigraphy.

In the north Siberian sections the Jurassic-Cretaceous boundary is demarcated, as in Southern Europe, by the disappearance of *Virgatosphinctes,* Late Jurassic *Berriasella (Lemencia),* and together with these the boreal *Craspedites* and *Garniericeras.* At the same time emerge *Argentiniceras* (?) and boreal *Subcraspedites, Paracraspedites, Surites, Praetollia,* and *Hectoroceras,* which are unknown in the underlying layers of the Jurassic.

In view of the rare finds of ammonites, Jeletzky (Canada) and Paraketsov and Avdeiko (Northeast Asia) are inclined to draw the Jurassic-Cretaceous boundary according to the emergence of the Berriasian *Buchia* complex (*B. okensis* (Pavl.) according to Jeletzky, *B. unschensis* (Pavl.), *B. elliptica* (Pavl.), *B. robusta* (Pavl.), *B. okensis* (Pavl.), *B. volgensis* (Lah.) according to Paraketsov). But, not being supported by finds of ammonites, this boundary seems very arbitrary. In British Columbia *B. okensis* (Pavl.) is associated with *Berriasella (Pseudoargentiniceras)* aff. *gallica* Maz. and *B. (Mazenoticeras)* aff. *broussi* Maz., which gives justification for the *B. okensis* zone (but not the vertical distribution of the given species) to be placed in the lower part of the Berriasian.

The boundary between the Berriasian and Valanginian stages in southern France is drawn in accordance with the disappearance from the sections of the typical Berriasian ammonites: Berriasellinae, Himalayitinae, *Neocosmoceras* and *Euthymiceras,* and in accordance with the appearance of a number of new groups and genera: Olcostephaninae, Desmocerataceae, *Kilianella, Thurmanniceras, Platylenticeras,* and *Tolypeceras.* Also confined to the lower Valanginian of France (*Kilianella roubaudiana* zone) are finds of boreal *Polyptychites* (Roman, 1938).

At the boundary between the *Berriasella boissieri* and *Kilianella lucensis* zones in the stratotypic section of the Berriasian, along with a change in the lithology, we find a substantial faunal change – scarcely any of the species and, apart from *Neocomites, Protetragonites,* and *Spiticeras,* not one of the genera of ammonites cross this boundary; the complexes of foraminifers and *Calpionella* also differ appreciably. All this obliges us to reckon with the possibility that there is a break here in sedimentation, a factor that must be borne in mind when correlating sections.

The stratotypic section of the Valanginian (Switzerland, Neuchâtel canton, Valangin hinge) is poor in fauna (Haefeli et al., 1965), so that it is even unclear whether the bottom strata of the Valanginian and the top strata of the Berriasian do not coincide (Donze, 1958).

In the Boreal Realm of Europe continuous sections of the top of the Berriasian and bottom of the Valanginian are present in England, where, however, there is not a single Tethyan ammonite. In Kujawy, Poland, the upper strata of the Berriasian include, along with boreal *Surites, Subcraspedites,* and *Tollia* (?), *Riasanites, Neocosmoceras, Euthymiceras,* and *Berriasella* cf. *boissieri* (Pict.), while the lower Valanginian yields *Platylenticeras, Polyptychites, Temnoptychites* (?), and *Neocomites neocomiensis premolica* Sayn. In the northern part of West Germany we find lower strata of the Valanginian with *Platylenticeras* and *Tolypeceras* and in the upper part of the *Platylenticeras* beds with boreal Polyptychitidae and *Tollia,* ammonites that are similar to *Neotollia.*

All this, and particularly the appearance of *Platylenticeras,* gives us the basis for drawing a more or less unified Berriasian-Valanginian boundary line everywhere in Europe.

By virtue of the endemism of the fauna, the Berriasian-Valanginian boundary is still insufficiently defined on the Russian Plain. As we have pointed out, we place the *Pseudogarnieria undulato-plicatilis* zone in the lower Valanginian, drawing the Berriasian-Valanginian boundary between the *Surites spasskensis* and *Pseudogarnieria undulato-plicatilis* zones. Since the fauna of the latter zone still contains Berriasian *Surites, Subcraspedites,* and *Bojarkia,* there is some justification for including the zone in the upper strata of the Berriasian. However, the ammonites of the genera *Temnoptychites* and *Menjaites* and the *Buchia* of the *inflata-crassa* group are to be considered characteristic for the lower strata of the Valanginian.

Early Valanginian *Platylenticeras* species are present in Novaya Zemlya, but to the east of the Urals they are not found. The criterion for drawing the Berriasian-Valanginian boundary here is the disappearance of the typically Berriasian *Surites, Subcraspedites,* and *Bojarkia* and the appearance of the genus *Neotollia.* Accompanying *Neotollia* in Siberia is a complex made up of *Buchia inflata* (Toula), *B. crassa* (Pavl.), and *B. keyserlingi* (Lah.), while higher up *Temnoptychites, Polyptychites, Euryptychites,* and *Astieriptychites* appear.

In Siberia the Berriasian-Valanginian boundary is also quite clearly demarcated by belemnites. The subgenera *Arctoteuthis, Lagonibelus, Pachyteuthis,* and *Simobelus,* which have supremacy in the Berriasian, are replaced by a complex with a predominance of the subgenera *Acroteuthis* and *Boreioteuthis*. This pattern is perceived both in the north of Middle Siberia and in the Cis-Polar Trans-Urals.

In Northeast Asia and in North America investigators have used *Buchia* to fix the Berriasian-Valanginian boundary, but this is not reliable enough. The emergence of the *keyserlingi-inflata-crassa* group and the disappearance of the *volgensis-terebratuloides-okensis* group in the sections characterized by ammonites are in fact established at the boundary between the Berriasian and Valanginian in northern Siberia. But, judging from a number of sections of the European part of the USSR, Siberia, the Far East, and North America, these two groups overlap in their vertical distribution. *Buchia uncitoides* (Pavl.), which was the index species for a zone established in the Berriasian of North America, is also preserved in the lower strata of the Valanginian in Siberia. It is sounder, therefore, in drawing the Berriasian-Valanginian boundary in America as well, to take as a basis the appearance of such ammonite genera as *Neotollia* and *Temnoptychites* and the disappearance of the typically Berriasian *Surites* and *Subcraspedites* (although judging from available data, these two genera are still present in the lower Valanginian zone *Pseudogarnieria undulato-plicatilis* on the Russian Plain).

Of course, broad correlations of sections of the Boreal and Tethyan realms always leave a certain element of doubt. We cannot be sure that the forms of *Virgatosphinctes* disappeared absolutely simultaneously in the Boreal Realm and in the north Siberian seas. Since the north Siberian forms of the genus are represented by species that differ from the Mediterranean species and that obviously adapted to life under the conditions present in the Boreal Realm, it may be that their extinction did not coincide in time with that of the main group of *Virgatosphinctes* in the Tethyan seas. It is with even less certainty that we can say that the formation of a whole series of new genera of boreal ammonites was synchronous with the appearance of new genera of Tethyan ammonites demarcating the Tithonian-Berriasian boundary in the Tethyan Realm (Figure 16).

Accordingly, there are still some doubts as to the correctness of correlating the time of appearance of *Neotollia* in northern Siberia, Western Europe, and North America. The Berriasian-Valanginian boundary, drawn in Southern Europe where a number of ammonite groups typical for the Berriasian disappear and, on the other hand, where a number of new groups appear, can quite justifiably be transposed to the Polish sections and thought of as coinciding with the base of the marine series in the north of West Germany. In northern Siberia, however, the emergence of such genera as *Neotollia* and a little later *Temnoptychites* and Polyptychitidae and the dying out of *Surites, Subcraspedites,* and *Bojarkia* might not necessarily have strictly coincided in time with the corresponding events that took place in the European seas, and consequently call for caution in correlating the Berriasian-Valanginian boundary in the stratotypic region and in Siberia. The same applies to finds of *Neotollia* and *Tollia* in North America even higher than in the beds with *Kilianella, Thurmanniceras,* and *Thorsteinssonoceras,* that are known to be lower Valanginian.

We must, however, remember the limited accuracy of biostratigraphic correlations in general and take into account that a relatively rapid settlement of such free-swimming organisms as ammonites within the limits of one zoogeographic realm is extremely probable. Hence, it is even so correct to draw correlations between beds with the same ammonites in Europe and Siberia and, consequently, to extend the boundaries of the stages and correlate the corresponding zones. We just have to remember that there is a certain arbitrariness in such correlations and in each specific case to carefully check all the data for and against a possible time shift of the boundaries of habitat of particular groups of organisms.

Still greater difficulties are encountered when it comes to correlating the Tethyan and Boreal Berriasian according to zones. The lower zone of the French Berriasian (*Berriasella grandis*) is insufficiently characterized by ammonites in the stratotypic section. What we have said remains true if to the *Berriasella grandis* zone proper, as understood by Busnardo et al., is added "horizon b" with *B. oppeli* and *B. subcallisto*, in which *B. grandis* still figures but from which these investigators begin the *B. boissieri* zone. Still, the list of ammonites from the lower strata of the Berriasian is seen to be very short (*Berriasella*

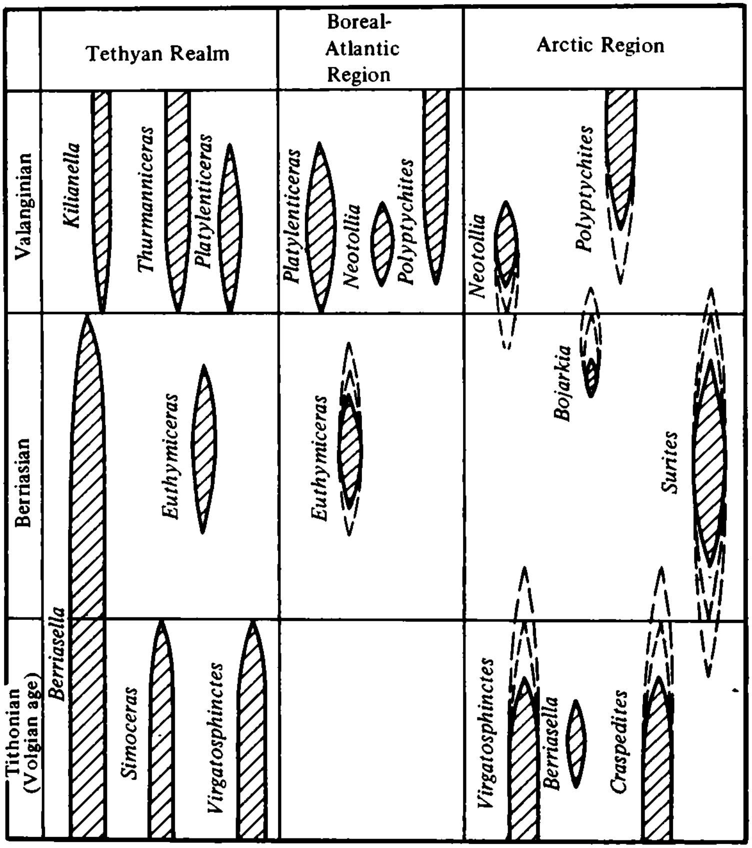


FIGURE 16. Possible deviations in the vertical distribution of various groups of ammonites in different zoogeographic realms and regions. Continuous lines with oblique hatching denote the outlines of the known vertical distribution, while interrupted lines show possible variants.

spp., *Neocomites subalpinus* Maz., plus *Lytoceras* and *Holcophylloceras*, that are of little use for stratigraphic purposes).

In the overlying horizons of the *Berriasella boissieri* zone the ammonite fauna becomes more diverse (*Dalmasiceras* in "horizon c", *Neocosmoceras* in "horizon d", and, finally, *Berriasella latecostata* Kil. in "horizon e").

These data allow us to correlate the *B. boissieri* zone (possibly "horizon d") with the *Riasanites rjasanensis* zone on the Russian Plain and in Poland, where *Euthymiceras* and *Neocomites* are also present, plus, in Poland, *Berriasella* cf. *boissieri* (Pict.), *B.* spp., *Protacanthodiscus, Himalayites,* and *Neocomites.* Accordingly, it must be acknowledged that in Poland and on the Russian Plain there are no analogues of the lower Berriasian (*B. grandis* zone) in the marine facies. This was the conclusion drawn by Marek (1967) and Wiedmann (1968).

Hence, the highest parts of the *Berriasella boissieri* zone ("horizon e"?) in France correspond to the second zone of the Berriasian of the Russian Plain *(Surites spasskensis)* and, possibly, the same-aged upper zone of the Berriasian in Poland, where *Riasanites, Euthymiceras, Neocosmoceras,* and *Berriasella* are still present. These zones cannot be younger than the *B. boissieri* zone (if we exclude the omission of certain beds from the section near Berrias at the Berriasian-Valanginian boundary), since *Platylenticeras,* which is confined to the base of the *Kilianella roubaudiana* zone in France and Switzerland, is encountered above them.

From the above we see that it is possible to correlate the zones of Siberia and Greenland with the stratotypic zones of the Berriasian. The *Surites analogus* zone, judging from the composition of its ammonites (*Surites* spp., *Subcraspedites* spp.), corresponds to the *Surites spasskensis* zone of the Russian Plain, i.e. to the upper part of the *Berriasella boissieri* zone. Perhaps the analogue of the Siberian zone *Bojarkia mesezhnikowi* on the Russian Plain is the top of the *Surites spasskensis* zone. In the glauconite-leptochlorite phosphorite-rich layers of minor thickness which make up the Berriasian on the Russian Plain and, in particular, on the Menya River, there may well be breaks that are not revealed in the exposures. In Poland, on the other hand, where the top of the Berriasian and bottom of the Valanginian are represented by clays, there are no traces of a break between the beds with *Surites* and *Subcraspedites* and the beds with *Platylenticeras.* In addition, *Tollia* (?) sp. is also indicated for the upper zone of the Berriasian of Poland.

The *Hectoroceras kochi* zone, which is fully apt to serve as the key horizon in correlating the Boreal Berriasian, since it is revealed in Siberia, the Urals, Greenland, Canada, and even in England, cannot now be reliably correlated with the zones of the European Berriasian. It may correspond to the *Riasanites rjasanensis* zone, or it could be older than it (as Wiedmann believes), but it might also be younger, corresponding to the bottom of the *Surites spasskensis* zone.

It must be remembered that the *Hectoroceras kochi* zone in Siberia and Greenland features *Praetollia maynci* Spath, a species that is reportedly present in the *Riasanites rjasanensis* zone in Poland. On the other hand, on the Russian Plain the *Riasanites rjasanensis* zone is characterized by a distinctive complex of belemnites with a predominance of the subgenus *Microbelus* (*Acroteuthis (M.) mosquensis* (Pavl.), *A. (M.)*

uralensis Sachs and Naln.). In the Urals this complex is absent in the *Hectoroceras kochi* zone and is apparently confined to the layers underlying this zone.

The lower zone of the Siberian Berriasian, the *Chetaites sibiricus* zone, lies above the *Chetaites chetae* zone of the upper Volgian substage, where *Virgatosphinctes* and *Craspedites* are still present. It should thus correspond to the lower zone of the South European Berriasian, that is, the *Berriasella grandis* zone. Indirect confirmation of this may be found, as will be shown below, by comparing the Siberian zones of the Berriasian with the zones of Argentina.

The sections of the other parts of the Tethyan Realm are of little help in defining more clearly the correlation of the Boreal and Tethyan Berriasian.

In southern Spain the upper Tithonian contains limestones with *Berriasella delphinensis* Kil., *Micracanthoceras micracanthum* (Opp.), *Proniceras pronum* (Opp.), and *Corongoceras rhodanicum* Maz., corresponding to the *Berriasella delphinensis* zone, while above it are beds with *Protacanthodiscus aizyensis* Kil., *Dalmasiceras kiliani* Maz., *Spiticeras pseudogroteanum* Djan., and *Hemispiticeras steinmanni* Maz., which Wiedmann correlated with the *Berriasella chaperi* zone. The Berriasian begins with limestones with *Berriasella pontica* Ret. and *Protacanthodiscus consanguineus* Ret., corresponding to the *Berriasella grandis* zone. Higher up are limestones with *Berriasella boissieri* Pict. and *B. moreti* Maz. These are overlain by limestones and marls with *Kilianella lucensis* Sayn that begin the section of the lower Valanginian (Barthel et al., 1966).

The bipartite division of the Berriasian is preserved in other regions of Southern Europe as well. In the Western Carpathians and in the Eastern Alps the top of the Tithonian is represented by limestones with *Virgatosphinctes transitorius* Opp., above which Wiedmann (1968) identified more beds with *Berriasella* sp., *Protacanthodiscus andreae* (Kil.), *Corongoceras rhodanicum* Maz., and *Dalmasiceras* sp. He correlates these strata with the *Berriasella chaperi* zone of the French Tithonian, while the Berriasian starts in the Eastern Alps from beds with *Berriasella* cf. *grandis* Pict., *B. carpathica* Opp., and *Spiticeras tenuicostatum* Kil. Overlying these are beds with *Berriasella boissieri* Pict., *Neocomites occitanicus* (Pict.), and *Negreliceras negreli* (Math.) (Franz, 1967).

In Tunisia the upper Tithonian is divided into beds with *Berriasella delphinensis* Kil. and beds with *Protacanthodiscus cularensis* Waag. and *Dalmasiceras progenitor* Opp. Phylloceratidae, Lytoceratidae, and *Calpionella* are also present. Identified in the Berriasian are beds with *Berriasella paramacilenta* Pict. and *Neocomites subalpinus* Maz. (analogue of the *B. grandis* zone) and beds with *Protacanthodiscus malbosi* Pict. and *Neocomites occitanicus* (Pict.), which correspond to the *Berriasella boissieri* zone. The limestones and marls of the Berriasian contain an abundance of Phylloceratidae, Lytoceratidae, and *Calpionella*. Above them are beds with *Thurmanniceras* aff. *pertransiens* Sayn, which constitute the base of the Valanginian and can be correlated with the *Kilianella lucensis* zone (Memmi, 1966).

In Feodosiya in the Crimea, limestones of the upper Tithonian and Berriasian contain a rich, purely Mediterranean fauna that does not include any boreal elements. Still, in the Crimean sections too, the Tethyan ammonites *Euthymiceras* and *Neocomites* accompanying *Riasanites* are confined to the upper part of the Berriasian rather than to its bottom (Drushchits and Mikhailova, 1966; Drushchits et al., 1969).

In the Northern Caucasus marls and limestones of the Berriasian (36–140 m) lie with erosion on the Tithonian and contain, along with *Berriasella boissieri* Pict., *Euthymiceras, Neocomites, Walbosiceras, Negreliceras,* and *Conobelus,* also *Riasanites rjasanensis* (Venez.) and *Buchia volgensis* (Lah.), that is, they correlate well with the *Riasanites rjasanensis* zone on the Russian Plain and with the *Berriasella boissieri* zone in France (Drushchits and Mikhailova, 1966). There are no data for defining a *Berriasella grandis* zone in the Caucasus. However, Wiedmann (1968) thinks that two Berriasian zones can be identified in the Caucasus: a lower zone, *Berriasella pontica* and *Negreliceras negreli,* which he correlates with the *Berriasella grandis* zone, and an upper zone, *Berriasella boissieri* and *Riasanites rjasanensis.*

Egoyan (1969) notes that in the Northwestern Caucasus, above a flysch series of clays, sandstones, and limestones of the Tithonian with *Virgatosphinctes* cf. *transitorius* Opp., *Aulacosphinctes* cf. *eudichotomus* Zitt., *Berriasella* ex gr. *richteri* Opp., and *B.* cf. *subcallisto* Touc. in the upper part, sandstones and conglomerates (50–200 m), occur and, above these, clays with sandstone intercalations (150–200 m) with *B. pontica* Ret., *B.* ex gr. *callisto* d'Orb., *Dalmasiceras dalmasi* Pict., and *Euphylloceras serum* Opp. Still higher there is a series of marls, clays, and limestones (300–400 m) with *Berriasella* cf. *boissieri* Pict., *B. subchaperi* Ret., *B. subrichteri* Ret., *Spiticeras spitiense* Uhl., *Riasanites* cf. *rjasanensis* Venez., *R.* cf. *subrjasanensis* Nik., *Euthymiceras, Neocosmoceras, Protacanthodiscus, Blanfordiceras, Neocomites, Neolissoceras, Conobelus, Buchia volgensis* (Lah.), *B.* ex gr. *mosquensis* (Buch), and others.

In Kopet-Dagh in marls and oölitic limestones of the Berriasian, *Buchia volgensis* (Lah.) and *B. terebratuloides* (Lah.) are present along with brachiopods that are typical for the Mediterranean Region (*Sellithyris sella* Sow., *Septaliphora khwalynica* Moiss., etc.). The Berriasian rocks overlie without any apparent disconformity a lagoon gypsiferous-carbonate series belonging to the top strata of the Jurassic and are overlain by Valanginian limestones with *Myophorella, Lima, Buchia terebratuloides* (Lah.), and *B.* cf. *crassicollis* (Keys.), and higher up in the section with *Neocomites* (Kalugin, 1957).

In the upper shales of Spiti in the Himalayas (Lochambel beds) we can distinguish the upper Tithonian with *Blanfordiceras wallachi* (Gray) and *Aulacosphinctes morikeanus* (Opp.), the Berriasian with *Spiticeras spitiense* Blanf. and *Berriasella boissieri* Pict., and the Valanginian with *Kilianella pexiptycha* (Uhl.) and *Sarasinella* spp. The underlying strata, the Chidamu beds (lower Tithonian), contain *Buchia blanfordiana* (Stol.) and *B. spitiensis* (Stol.) (Wiedmann, 1968; Stevens, 1965).

Farther south, to the east of the mouth of the Indus in Kacchi, sandstone-shale Umia formations belong to the Tithonian–Berriasian. The upper Tithonian is characterized by *Virgatosphinctes denseplicatus* (Waag.), *Aulacosphinctes occultefurcatus* (Waag.), *Micracanthoceras* aff. *micracanthum* (Opp.), *Umiaites rajnathi* Spath, and others. The Berriasian includes only *Trigonia* (*T. crassa* Kitch. and others) (Arkell, 1956; Wiedmann, 1968).

The following are known from Madagascar: the upper Tithonian with *Aulacosphinctes hollandi* Uhl., *Berriasella privasensis* Pict., *Blanfordiceras, Himalayites, Acanthodiscus* sp., *Micracanthoceras* cf. *brightoni* Spath, *Belemnopsis* and *Hibolites,* the Berriasian with *Berriasella boissieri* Pict., *Neocomites* aff. *occitanicus* Pict, and *Spiticeras* spp. and the

Valanginian with *Kilianella, Neocomites, Belemnopsis,* and *Hibolites* (Collignon, 1960–1962; Stevens, 1965).

In Japan the upper Tithonian is represented in northeastern Honshu by sandstones, argillites, and limestones with *Substeueroceras* sp.; corals and stromatophores are also present. In the south of Honshu upper Tithonian *Spiticeras (Kilianiceras?)* cf. *eucomphalum* (Steuer) and *Aulacosphinctes* sp. were collected in clay shales of the Torinosu group. On the western shore of the island the upper strata of the Jurassic are composed of sandy-clayey series (Toenisi and Kuzuryu groups) with brackish-water and marine bivalves: *Myophorella (Promyophorella) orientalis* Kob. and Tam., *Trigonia,* and others. The Berriasian is known in marine facies in the northeastern part of Honshu. It consists of argillites with *Berriasella* sp., *B.* ex gr. *berthei* Kil. (*"Kilianella"* Sato), and *Spiticeras* cf. *binodiger* Maz. (Sato, 1961; Wiedmann, 1968). Erosion is established at the roof of the Berriasian, but in places there are also lower Valanginian strata with *Thurmanniceras* and *Olcostephanus* (Minato et. al. 1968). In the south and west of Honshu the marine sediments of the top of the Jurassic are overlain by brackish-water sediments belonging to the bottom of the Cretaceous (Ryoseki and Itoshiro groups) containing remains of brackish-water and also some marine bivalves (oysters, *Trigonia,* etc.). These sediments doubtless also include the Berriasian.

On the Misol and Kepulaun Sula islands in Indonesia the upper Tithonian is characterized by *Blanfordiceras wallachi* (Gray), *Uhligites, Himalayites, Bochianites,* and *Kossmatia.* The underlying sandstones of the lower and middle Tithonian yield *Buchia* cf. *subspitiensis* (Krumb.), *B.* cf. *subpallasi* (Krumb.), *B. plicata* (Zitt.), *B. misolica* (Krumb.), *Belemnopsis uhligi* Stev., and others. Occurring at the bottom of the Neocomian are Berriasellidae, *Hibolites subfusiformis* Rasp., *Duvalia dilatata* Blain., and *D. lata* Blain. (Arkell, 1956; Stevens, 1965). In New Caledonia there are reports that the Berriasian is present with *Berriasella novoseelandica* Hochst., *Duvalia,* and *Trigonia* (Avias, 1954).

In northwestern Australia the Tithonian sediments include *Virgatosphinctes, Kossmatia, Belemnopsis, Malayomaorica* cf. *malayomaorica* (Krumb.), and *Calpionella* (Brunnschweiler, 1960). In Brunnschweiler's opinion, the beds with *Protancyloceras* (?), *Hibolites* cf. *subfusiformis* (Rasp.), and *Apiotrigonia* belong to the lower Neocomian. Stevens (1965) considers these beds as still Upper Jurassic.

According to Stevens (1965), in New Zealand the Puaroan series with *Aulacosphinctoides* spp., *Uhligites, Kossmatia, Belemnopsis, Hibolites, Buchia plicata* (Zitt.), and *B. hochstetteri* Flem. belongs to the lower Tithonian. Arkell (1956) is inclined to believe that this series includes also the Berriasian with Berriasellidae.

In Mexico the lower horizons of the limestones belonging to the Taraises formation with *Spiticeras zirkeli* (Steuer) and *Berriasella tenochi* refer to the bottom of the Berriasian; they are underlain by limestones of the upper Tithonian with *Substeuroceras* cf. *koeneni* (Steuer), *Berriasella* cf. *callisto* (d'Orb.), *Paradontoceras, Proniceras, Hildoglochiceras,* and others. The ammonites from the Tithonian feature some forms that can be placed in *Riasanites.* Above occur limestones with *Spiticeras uhligi* Burckh. and *Berriasella densistriata* Kil., corresponding to the upper part of the Berriasian; they are overlain by lower Valanginian limestones with *Kilianella* aff. *pexiptycha* Uhl., *Polyptychites,* and *Thurmanniceras* (Imlay, 1960; Imlay and Jones, 1970).

In Argentina and the Andes Valley a thick (about 1000 m) series of clay shales and limestones is developed with a fauna of the middle and upper Tithonian, the Berriasian, and the Valanginian (Leanza, 1947; Imlay and Jones, 1970). Belonging to the upper Tithonian are the *Corongoceras alternans* and *Substeueroceras koeneni* zones, and to the Berriasian the *Argentiniceras noduliferum* and *Neocosmoceras egregium* zones (with *Berriasella, Frenguelliceras, Substeueroceras,* and *Groebericeras*) and the *Spiticeras damesi* and *Cuyaniceras transgredienum* zones (with *Neocomites, Thurmanniceras,* and *Pseudoblanfordia*). The Valanginian begins with the *Neocomites wichmanni* and *Thurmanniceras pertransiens* zone.

The *Substeueroceras koeneni* zone is correlated with the top strata of the European Tithonian (with the *Virgatosphinctes transitorius* zone), the *Spiticeras damesi* and *Cuyaniceras transgredienum* zone corresponds to the *Berriasella boissieri* zone in Europe, and accordingly the lower zone of the Argentinian Berriasian, the *Argentiniceras noduliferum* and *Neocosmoceras egregium* zone, is at the level of the *Berriasella grandis* zone.

Since *Argentiniceras* (?) n. sp. is found in the *Chetaites sibiricus* zone, there is a basis for paralleling this zone as well with the *Berriasella grandis* zone. In view of the fact that *Praetollia maynci* Spath occurs in the *Chetaites sibiricus* zone on Paks Peninsula, the beds with *Praetollia* in Greenland and the underlying beds with *Subcraspedites* aff. *preplicomphalus* Swinn. should be considered synchronous with the sediments of the *Chetaites sibiricus* zone in Siberia. We should point out that in Argentina the ammonites that Leanza determined as *Riasanites* (two species) are encountered in the upper strata of the Tithonian in the *Substeueroceras koeneni* zone. This naturally makes us cautious about correlating the Russian *Riasanites rjasanensis* zone with the Argentinian zones, but it should not affect the correlation of the sections of the Boreal and Tethyan realms as a whole. As we have seen, this correlation is supported by numerous factual data. It is more likely, as Arkell (1956) admits, that the generic affiliation of these ammonites in Argentina needs to be reexamined.

The Argentinian section of the Berriasian gives us the possibility of correlating it with the Tethyan Berriasian and the Berriasian of North America. As we have already noted, the lower strata of the Canadian Berriasian with *Buchia okensis* (Pavl.), *Subcraspedites (Subcraspedites)* ex gr. *plicomphalus* (Sow.), *S. (Borealites)* cf. *suprasubditus* (Bogosl.), *Surites (Surites)* ex gr. *spasskensis* (Nik.), *Berriasella (Pseudoargentiniceras)* aff. *gallica* Maz., and *B. (Mazenoticeras)* aff. *broussei* Maz. do in fact stand closest of all to the lower Berriasian (to the *Berriasella grandis* zone). The higher beds of the Canadian Berriasian with *Buchia volgensis* (Lah.), *B. uncitoides* (Pavl.), *Spiticeras* cf. *scriptum* (Strachey), *S.* cf. *mojsvari* Uhl., *S.* ind. sp., *Groebericeras* (?) ind. sp., *Protacanthodiscus* aff. *micheicus* Bogosl., *Neocomites* sp., and *Tollia* cf. *tolli* (Pavl.) correspond, as observed by Jeletzky, to the *Spiticeras damesi* and *Cuyanites transgredienum* zone in Argentina and to the *Berriasella boissieri* zone in Europe. It appears most likely that the beds with *Buchia uncitoides* (Pavl.) and *Neocosmoceras* in California and Oregon correspond to the upper zone of the Argentinian Berriasian (judging from the presence of *Spiticeras*). The beds with *Tollia* cf. *tolli* (Pavl.), *Subcraspedites (Borealites)* sp., and *Buchia tolmatschowi* (Sok.) correlate with the *Bojarkia mesezhnikowi* zone in Siberia. In North America finds of *Tollia* and *Neotollia* even above the beds with *Thurmanniceras, Kilianella,* and *Thor-*

steinssonoceras are a weighty argument in favor of considering the Siberian zone *Neotollia klimovskiensis* to be of early Valanginian age.

All these data clearly show the incorrectness of the view expressed by Spath (1924), Swinnerton (1936–1955), and Müller and Schenk (1943) that the beds with *Spiticeras* (Spiticeratan) are older than the beds with *Subcraspedites* and *Tollia* (Subcraspeditan).

To sum up, there is every reason, with the knowledge now available, to consider the Berriasian stage (and the geological age corresponding to it) in a planetary scope, on a par with the other stages of the international stratigraphic scale. After the Lyon Colloquium in 1963, there was no longer any investigator willing to refer the Berriasian to the Valanginian. As shown by Busnardo et al. (1965), who studied the fauna of the Berriasian stratotype, the individuality of the Berriasian fauna in comparison with the Valanginian fauna is such that it is fully possible to raise the Berriasian to the rank of a stage. The genera *Berriasella, Dalmasiceras,* and *Spiticeras,* which predominate in the Berriasian, belong equally to the upper Tithonian and to the Berriasian. But at the boundary with the Valanginian the typically Berriasian genera and species disappear just as abruptly as the Valanginian genera *Thurmanniceras, Kilianella,* and *Olcostephanus* appear and become diversified. No less substantial transformations take place at the boundary between the Berriasian and lower Valanginian in the Boreal Realm. It was with good reason that in 1895 Bogoslovskii, in studying sediments on the Russian Platform that are transitional between the Jurassic and Cretaceous, assigned them to a special Ryazan horizon, thereby underlining their individual position.

Of the ten characteristically Berriasian boreal genera of ammonites, two, *Tollia* and *Virgatoptychites,* cross into the lower Valanginian, and one genus, possibly two (*Chetaites* and perhaps *Subcraspedites*) are common with the Volgian sediments. The distinctive character of the Berriasian ammonites is indisputable, but where the other faunal groups are concerned, we will show below that they are for the most part closer to the Volgian than to the Valanginian complexes. In the Tethyan Realm, the Berriasian ammonites are also closer to the Tithonian than to the Valanginian, which has led some investigators to the conclusion that the Berriasian should be transferred to the Jurassic system.

Where is the Berriasian to be placed: in the Jurassic or in the Cretaceous? The answer is not simple, for the material available allows for either decision. Naturally, since the Berriasian age stands on the borderline of the Jurassic and Cretaceous periods, the Berriasian fauna, originating in the Jurassic, is very closely bound to it. But it is also obvious that not all the groups of fauna could have disappeared at the same time. The more conservative groups persisted side by side with forms that emerged at different moments in the Berriasian age. For instance, among the ammonites from the French sections, according to Busnardo et al. (1963), out of 10 characteristic genera that developed in the Tithonian–Valanginian interval* two genera belong to the Berriasian proper (*Neocosmoceras* and *Subalpinites*) and one genus (*Berriasella*) was born in the early Tithonian, continued into the late Tithonian, and was massively distributed in the Berriasian, but did

* These authors omitted from their list *Euthymiceras* and *Negreliceras,* which are also specific to the Berriasian.

not cross the Berriasian-Valanginian border. Two genera (*Dalmasiceras* and *Himalayites*) are characteristic for the late Tithonian–Berriasian; one genus *(Spiticeras)* is also characteristic of the late Tithonian, but crosses into the lower Valanginian, 2 genera (*Kilianella* and *Thurmanniceras*) are specific to the early Valanginian, and one genus *(Olcostephanus)* is characteristic for the early and late Valanginian. Thus, of the ten most characteristic genera that developed in the boundary layers of the Upper Jurassic–Lower Cretaceous, 3 are common in the Tithonian and Berriasian, 2 are common in the Tithonian–Berriasian–Valanginian, 2 genera are strictly Berriasian, and 3 genera are strictly Valanginian.

In the Siberian sections, out of 21 genera (*Argentiniceras* (?), *Bochianites, Lytoceras,* and *Phylloceras* are disregarded as being uncharacteristic) that developed in late Volgian Berriasian, and Valanginian time, 5 genera are specific to late Volgian time *(Craspedites, Garniericeras, Virgatosphinctes, Aulacosphinctes, Berriasella),* 6 to the Berriasian *(Praetollia, Paracraspedites, Subcraspedites, Surites, Hectoroceras, Bojarkia),* 2 genera are common to the late Berriasian–early Valanginian (*Tollia* and *Virgatoptychites*), one genus *(Chetaites)* is common to the late Volgian–early Berriasian, and 7 genera are strictly Valanginian *(Neotollia, Temnoptychites, Astieriptychites, Polyptychites, Euryptychites, Neocraspedites, Dichotomites).*

The data presented show above all that the Berriasian is a stage in its own right. Further, it is seen from the Siberian ammonites that the change in the complexes of late Volgian, Berriasian, and Valanginian time took place much more distinctly and rapidly in the Boreal Realm than in the Mediterranean. The southern genera of ammonites had a longer life span than the northern ones.

The number of genera common to the Tithonian, Berriasian, and Valanginian in the French sections indicates that the Berriasian is closer to the Tithonian than to the Valanginian. The Siberian material does not bring us to this conclusion; on the contrary, the Berriasian ammonites here gravitate more to the Valanginian, since some of them became the ancestors of the many Valanginian genera. For example, the genus *Surites* gave rise to *Bojarkia, Tollia,* and *Neotollia,* and *Neotollia* in turn was the forerunner of the genus *Polyptychites* and, in particular, the subgenus *Propolyptychites.* In the Valanginian the new family Polyptychitidae appeared, but the genera of the family Craspeditidae did not play out their role here as yet. The genera of the subfamily Tolliinae present in the Valanginian in the Boreal Realm are *Tollia, Neotollia, Virgatoptychites, Temnoptychites, Menjaites,* and, possibly, *Homolsomites,* and from the subfamily Garniericeratinae *Platylenticeras, Tolypeceras, Pseudogarnieria,* and *Proleopoldia;* in other words, in the Valanginian 8 or 9 genera belong to the family Craspeditidae and 5 genera to the family Polyptychitidae *(Polyptychites, Astieriptychites, Euryptychites, Neocraspedites, Dichotomites).*

Consequently, the ammonites which are in the main to resolve the question of to which system the Berriasian belongs are still closer to the Valanginian than to the Volgian stage in the Siberian Berriasian. The other groups – bivalves, belemnites, and foraminifers – gravitate more toward the Jurassic, being, as we have seen, more conservative than the ammonites. The Volgian spore-pollen complexes differ markedly from the Berriasian complexes, and the latter differ from the Valanginian complexes.

In discussing this point, it is impossible to disregard the rule of priority. Since the fauna of the Berriasian was originally described by Pictet (1867) as Cretaceous, then the Berriasian stage should also be considered within the Cretaceous system. This is also convenient for drawing the Jurassic-Cretaceous boundary according to such a group as the Virgatosphinctinae, which is present in all the zoogeographic realms at the top of the Jurassic and is absent in the Berriasian. There is no such common group that could be traced just as extensively at the border between the Berriasian and Valanginian.

In the stratotypic section the Berriasian stage is divided into two zones: *Berriasella grandis* and *B. boissieri.* On the basis of this, we may divide the stage into two substages that correspond to these zones. In the Boreal Realm only the lower zone *Chetaites sibiricus, Praetollia maynci,* or *Paracraspedites stenomphaloides* apparently corresponds to the lower substage. The upper substage (or the *Berriasella boissieri* zone) must consist of the strata beginning from the *Hectoroceras kochi* and *Riasanites rjasanensis* zones, that is, the ones making up the middle and upper parts of the stage. In the following we will sometimes use the terms middle Berriasian time (*"Hectoroceras kochi"* and *"Riasanites rjasanensis"* time) and late Berriasian time (*"Surites spasskensis", "S. analaogus", "Bojarkia mesezhnikowi", "B. payeri"* time), without, however, predetermining the definition of a middle and an upper substage within the Berriasian stage.

Finally, we must look at the position of the Berriasian age and the Jurassic-Cretaceous boundary on the absolute geochronological scale. The data pertaining to this aspect are very scant and to a certain extent contradictory. Of course, only determinations performed in sedimentary rocks according to glauconite reliably tie up with the biostratigraphic scale, but their accuracy still does not match that of this scale.

The age of the middle Berriasian of England (beds with *Hectoroceras* in the Sandringham sands) has been established at 131 ± 3 million years, and that of the lower Berriasian (?) in the same locality (beds with *Paracraspedites*) at 132 ± 4 million years (Dodson et al., 1964). For the Ryazan horizon near Moscow, Casey (1964) gives a similar assessment (131 million years). The glauconite rocks in the Moscow Region, which are 125 million years old (Polevaya, 1961), apparently belong to the Berriasian.

However, in the Ryazan horizon on the Oka River, the dating received is 117 ± 3 million years, but in the upper Volgian sediments near Moscow in the *Craspedites subditus* zone 119 ± 3 million years (Dodson et al., 1964), in the *Kachpurites fulgens* zone 128–132 million years, and, without indication of a zone (Polevaya, 1961), 136 ± 6 million years. The middle Volgian deposits of England and eastern Greenland have been dated at 107–131 million years, and in the Münder marls (West Germany), which also probably correspond to the middle Volgian substage, 139–145 million years (Howarth, 1964). It should be added that for the lower Hauterivian in the Speeton clays of England (bed D2) the age is set at 114 ± 3 million years (Dodson et al., 1964).

All this makes the position of the Jurassic-Cretaceous boundary in the absolute chronology extremely vague. On the geochronological scale developed in the USSR in 1964 this boundary is recognized to date at 137 ± 5 million years ($\lambda_e = 0.557 \cdot 10^{-10}$ years^{-1}) or 131 ± 5 million years ($\lambda_e = 0.585 \cdot 10^{-10}$ years^{-1}, Afanas'ev et al., 1964). Casey (1964) proposes fixing the Jurassic–Cretaceous boundary at 136 million years, while Howarth (1964) gives 135 million years ($\lambda_e = 0.584 \cdot 10^{-10}$ years^{-1}). The age of the Jurassic-Cretaceous boundary is recognized to be 137 ± 5 million years in the scheme drawn up by the International Geological Commission in 1966.

There are still fewer data on the age position of the Berriasian-Valanginian boundary and correspondingly on the duration of the Berriasian age. Arbitrarily putting the duration of each geological age in the Cretaceous period at 6 million years, Casey (1964) determined this boundary at 130 million years. It is obvious that such an assumption cannot be relied upon. According to the geochronological scale of the USSR, the boundary between the Early and Late Cretaceous epochs is accepted to be 105 ± 5 million years. Accordingly, the average duration of the Early Cretaceous ages is closer to 5 than to 6 million years. Moreover, the Aptian and Albian ages might have lasted longer than the ages in the Neocomian. If we take into consideration the degree of change undergone by the marine fauna, the number of ammonite zones, and the respective thicknesses of sediments from the same facies, we may assume that the Berriasian, Valanginian, and Hauterivian had more or less similar durations and embraced from 4 to 5 million years each. Let us remember that the span of the Portlandian and Purbeckian (i.e. middle and late Volgian time) is, on the scale adopted at the Holmes Jubilee Symposium in 1964, accepted to be 10 million years.

Chapter VI

PALEOGEOGRAPHIC SURVEY

In the period of geological history with which we are dealing an Arctic Basin certainly existed as the center from which the boreal fauna was born and spread. We can be sure of this because the marine fauna proves to be the same in all the regions converging on the Arctic Basin: Europe, Siberia, the Far East, America, and Greenland. Common features are found in the fauna throughout the Volgian age and in the Berriasian and Valanginian.

As will be shown in more detail in the next chapter, at the end of the Jurassic and beginning of the Cretaceous the belt of distribution of the boreal fauna followed an essentially circumpolar course with respect to the present-day geographic pole. The Boreal Realm shows a boundary shift of only 10–15° to the north in Western Europe in comparison with the Pacific coast of America. Such a position of the boundaries may to some extent be explained by the presence of an extensive, latitudinally distributed warm Tethyan basin in Southern Europe, but probably, along with this, we must also assume that the pole was displaced in the direction of the Pacific Ocean, though not farther south than the latitude of Bering Strait. The west-north-west direction of the boundary of the tropical Indo-European and the temperate Siberian paleofloristic regions within the Angara continent in Volgian and Berriasian-Valanginian time, according to Vakhrameev (Atlas of Lithological-Palaeogeographic Maps of the USSR, Vol. 3, 1968), speaks in favor of there having been a certain, albeit inconsiderable shift of the geological pole toward Bering Strait. Such a boundary is not perceived in the Canadian Greenland continent. However, the position of the temperate flora of Kootenay and western Canada corresponding to the Siberian Region and that of the tropical flora of Patuxent on the east coast of the USA corresponding to the Indo-European Region suggests that the boundary of the paleofloristic regions in America ran either latitudinally or in an east-north-east direction, that is, on the whole it corresponds to the presumed position of the pole near Bering Strait.

According to north Siberian determinations (Pospelova et al., 1969), the magnetic pole was situated in middle and late Volgian time in the area of the Stanovoi Range (123°E, 54°N), which is out of the question for the geographic pole. A similar position (in Western Verkhoyansk) of the magnetic pole is indicated by the rocks of the index suite (Neocomian) in the Chulymo-Yenisei Depression (Pospelova and Saks, 1968). Analogous data were obtained by Pecherskii (1970) for the top of the Jurassic–bottom of the Cretaceous in the extreme northeast of the USSR, in the basin of the Bol'shoi Anyui (the pole lies at 113°E, 46°N) and for the bottom of the Cretaceous in the Koryakskii Range (pole at 70–130°E, 57–62°N). If the geographic pole had been present in the regions mentioned, the vegetation zones on the Angara continent (see Figures 17–21) and on the periphery of the West Siberian Sea (Gol'bert et al., 1968) would have been distributed meridionally, not more or less latitudinally, as is in fact the case.

For the Berriasian age we have the following data on the position of the magnetic pole. Determinations in the Wealden clays of England show that the pole was situated northwest of the Canadian Archipelago (79°N, 243°E; Wilson, 1959). The Karabil suite in the Gissar Range in Central Asia, which belongs to the upper Tithonian–Berriasian (?), gave coordinates 81°N, 145°E for the magnetic pole (Abdullaev, 1964). The coordinates of the pole lay to the north of Chukchi Peninsula according to determinations in Bucks granite batholith in California (age 129–142 million years according to Grommé, Merrill, and Verhoogen, 1967) and in granites of Mount Ascutney (Vermont, age 125–135 million years according to Opdyke and Wensink, 1966). North Siberian data (Pospelova and Saks, 1968) indicate that in the early Valanginian the magnetic pole lay in the area of the Koryakskii Range (174°E, 63.2°N).

The magnetic pole had a very different position in the west of the North Atlantic according to Spall (1968), in dolerite dikes on Spitsbergen that belong to the end of the Jurassic–beginning of the Cretaceous (age 125–149 million years). Its coordinates, obtained by a study of effusions, tuffs, and intrusions of the lower Neocomian in Japan (Oshima Island near the northeast coast of Honshu), lay in the northeastern part of the Pacific (Spall, 1968). According to measurements performed in the upper horizons of the Rajmahal trapps in India, the coordinates of the paleomagnetic pole fell in the Carribean (13°N, 70°W). As shown by determinations in East Africa (Malawi), in rocks of the Mlanje massif, which have an absolute age of 116–129 million years, the paleomagnetic pole proved to be positioned on the Podkamennaya Tunguska River in Siberia (99°E, 60°N) (McElhinny et al., 1968). Finally, in South America, on the border between Brazil and Uruguay, in the Serra Geral formation (124–149 million years) the position of the paleomagnetic pole has been established off the coast of eastern Greenland (Irving, 1964).

Obviously, all these recent determinations have nothing to do with the probable position of the geographic pole and are explained primarily by the successive shifting of the continental blocks of the southern hemisphere relative to Eurasia, as well as the displacement of the fringe areas of Eurasia itself (India, Japan, Spitsbergen). Indeed, these may not even have been horizontal movements, but turns of individual blocks, circumscribed, as on Spitsbergen, for example, by faults.

In summing up the above, the most probable position of the geographic pole at the end of the Jurassic and beginning of the Cretaceous was a little to the north of Bering Strait. This assumption ties up best of all with the boundaries of the paleozoogeographic realms, regions, and provinces in the seas and with the boundaries of the paleofloristic regions on the land; also, it sufficiently brings together the positions of the geographic and paleomagnetic (according to determinations inside Eurasia) poles. Proceeding from this, we will go on to examine the relations between the land and the sea, the possible directions of currents, the distribution of faunal complexes, and so on.

There is no doubt that at the end of the Jurassic period the West European (Portlandian) fauna exerted a strong influence on the fauna around the edges of the Arctic Basin, in particular in Eastern Europe, Greenland, and Siberia, a fact which obliges us to assume that there was a warm current that issued from the region of the Atlantic Ocean into the Arctic Basin. The resemblance between the Portlandian fauna of southern England and the middle Volgian fauna of eastern Greenland and the east slope of the Northern Urals is especially striking (Saks et al., 1968), so that we may be sure that there were currents which carried the organisms inhabiting the West European seas toward the coasts of Greenland and Siberia. A similar effect could to some extent have been produced by the shallow, narrow strait that connected the basins of southern England and France (the Portlandian Sea) with the region of the North Sea and, via this, with the Arctic Basin. There may well also have been migrations of the Late Jurassic marine fauna from the Anglo-French Basin into the Greenland Sea, bypassing the British Isles, and then into the Arctic Basin. The Volgian sediments of Spitsbergen, Greenland, and northern Siberia apparently contain immigrants from the West Indes region, in particular Cuba, which followed the warm current coming from the Antilles on the way to the Arctic.

As will be shown in greater detail below, the east Greenland fauna is extremely similar to the fauna of the English Portlandian, the Northern Urals, and northern Siberia. This could hardly have been the case if the Greenland Sea had been as wide and as deep as it is now. We may infer that during the Mesozoic Greenland was much closer to Taimyr and the Northern Urals, separated from them just by a shallow epicontinental sea. This supposition is supported by the structure of the anomalous magnetic field in the part of the Arctic Basin bordering on the Atlantic (Karasik, 1968), which is best explained by assuming that a new oceanic crust was formed here due to the retreat of the Lomonosov Ridge from Eurasia.

Another indication that Greenland moved much closer to Eurasia during the Mesozoic is the fact that if the Greenland Sea had been more or less as wide as it is at present, there would have been a system of currents analogous to that observed now due to the rotation of the earth. The warm current coming from the south would have been forced toward Scandinavia, while along the coast of Greenland, a cold East Greenland Current would have had to exist. Under such conditions the fauna of Greenland and of the English Portlandian could not have had as much in common as has in fact been established. If, on the other hand, there had been only relatively narrow straits in place of the Greenland Sea and the Atlantic part of the Arctic Basin, the warm current from the south could have encompassed the entire water surface and the cold runoff from the Arctic would have taken place on account of demersal currents.

We must also examine the salinity conditions of the marine basins at the end of the Jurassic and beginning of the Cretaceous in the Boreal Realm. Faunistic complexes known in sediments of the Boreal Berriasian in the USSR indicate that salinity was normal. But the fauna allows us to surmise merely the presence or absence of salinity deviations from the norm for the given epoch and it is impossible to estimate the difference of salinity in the present-day and ancient sea basins. Investigations of the composition of the absorbed complex in Jurassic and Cretaceous rocks led Gramberg and Spiro (1965) to the conclusion that in comparison with the present-day marine waters, those in the Mesozoic north Siberian seas were much poorer in potassium, slightly poorer in sodium, and richer in calcium and magnesium. According to Spiro (1969), the Jurassic and Cretaceous seas contained 61–70 Na, 1 K, and 29–38 eq.% Ca + Mg whereas in the World Ocean at present the figures are 83.6 Na, 3.1 K, and 13.3 eq.% Ca + Mg. The ratios of pyrite iron and organic carbon determined in Volgian, Berriasian, and Valanginian sediments of Western Siberia (Fe_{pyr}/C_{org} 0.2–6.0) indicate that the salinity of the basin was similar (according to Strakhov and Zalmanson, 1955) to the present salinity (Fe_{pyr}/C_{org} 0.2–2.0). Calculations performed in Siberia of the boron content of the clay fraction (27–220 parts per million) show, on the other hand, that the sedimentation environment underwent marked freshening (according to Eager, 1962, in sediments of seas with a normal salinity the boron content should be 522–642 parts per million).

It seems that all these data should be treated with a good deal of reservation. Determinations of the absorbed complex have not yet been applied to other Mesozoic basins and may give a distorted picture due to transformations in the process of diagenesis. The Fe_{pyr}/C_{org} ratio may also be subject to a secondary change, especially in permeable sandy rocks. An illustration of this is the upper Berriasian Achimov sandy series in the open sea in Western Siberia with very low values of the coefficient Fe_{pyr}/C_{org} (Kontorovich and Prozorovich, 1963). As for the boron contents, they are apparently representative only for hydromicaceous clayey rocks and give a very distorted idea of the conditions under which clayey sediments of a different composition were formed.

LATE VOLGIAN TIME

At the very end of the Jurassic period, in late Volgian time, the links between the Arctic Basin and Western Europe were essentially severed. In the south of England, in northern France, and on the southern shore of the North Sea the freshwater and some of the brackish-water basins of the Purbeckian and early Wealden developed, bordering, presumably, with a marine basin in the North Sea region (Figure 17). Casey's data (Casey, 1962) on finds of late Volgian *Craspedites* in northeastern England seem quite probable, although, as we have said, they await confirmation. Freshwater deposits of the Purbeckian have also been established in Poland.

On the Russian Plain the late Volgian basin, which was considerably smaller than the middle Volgian sea, apparently lost its ties with the seas of the Caucasus and Turkmenia and did not extend south of the Ural River basin. This was a shallow bay, in which primarily sandy sediments with phosphorites and glauconite were formed, with very frequent erosions. Deeper, in the opinion of Gerasimov (1969), were the radiolarian-sponge and algal limestone deposits of the Northern Volga area and the algae-containing glauconitic phosphorites of the Kostroma and Yaroslavl regions, that settled in the central parts of the bay. A relatively deep sea with clayey sediments existed in the northern part of the Pechora Depression, in the southern and western parts of Spitsbergen, and in the area of Franz Josef Land.

Along the east coast of Greenland in late Volgian time shallow-water, primarily sandy sediments were laid down; intercalations of conglomerates and, more rarely (on Wollaston Peninsula), sandy-clayey deposits are observed. The presence of conglomerates dismisses all doubt that nearby lay the coast of Greenland, which was elevated in the Volgian age.

The opposite shore of the Greenland Sea has been fixed near the edge of the Scandinavian massif on the Lofoten Islands, where sand deposits of the Ramsaa series formed at the end of the Jurassic and beginning of the Cretaceous.

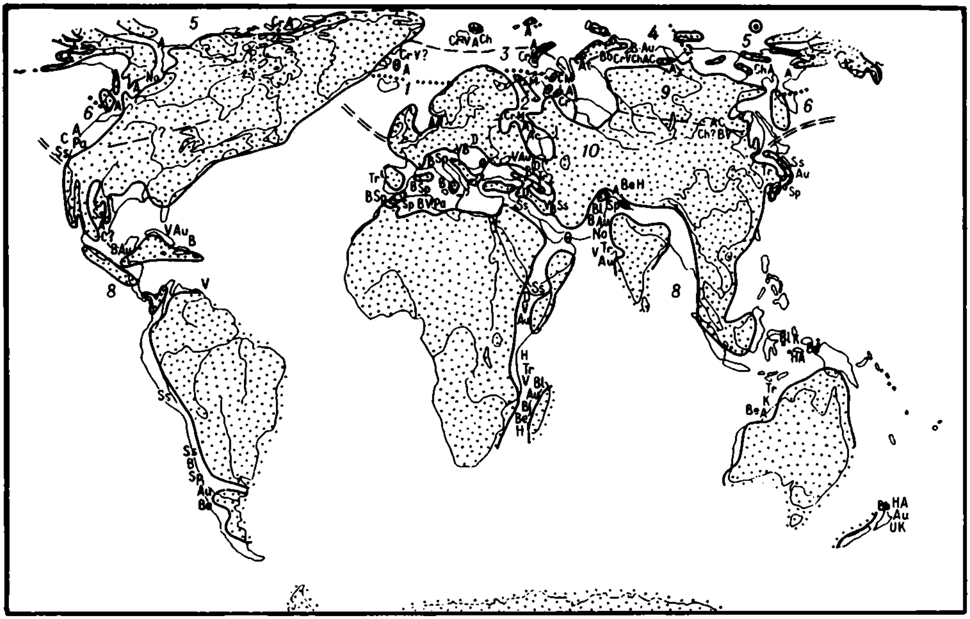


FIGURE 17. Late Volgian time (in the Tethyan Realm partly the nonsubdivided Tithonian). Notation: speckled areas denote land, a double dashed line indicates the boundaries of the Boreal and Tethyan realms, a single dashed line the boundaries of the paleozoogeographic regions in the seas (according to Cephalopoda) and of the paleofloristic regions (on land), and a dotted line shows the boundaries of the paleozoogeographic provinces in the Boreal Realm. 1–3) Boreal-Atlantic Region: 1) West European Province; 2) East European Province; 3) Urals-Greenland Province; 4–6) Arctic Region: 4) North Siberian Province; 5) Chukchi-Canadian Province; 6) Boreal-Pacific Province; 7) Mediterranean Region; 8) Indo-Pacific Region; 9) Siberian Region; 10) Indo-European Region. The circle with a dot in the middle indicates the probable position of the geographic pole. Letter symbols give the distribution of the most characteristic genera, subgenera, and groups of genera of fossil mollusks: *A – Buchia, Ac – Acroteuthis (Acroteuthis), At – Arctotis, Au – Aulacosphinctes, Aulacosphinctoides, B – Berriasella, Be – Belemnopsis, Bl – Blanfordiceras, Bo – Camptonectes (Boreionectes), C – Cylindroteuthis, Lagonibelus, Ch – Chetaites, Cr – Craspedites, D – Duvalia, H – Hibolites, K – Kossmatia, M – Acroteuthis (Microbelus), No – Notostephanus, Pa – Protocanthodiscus, Sp – Spiticeras, Ss – Substeueroceras, Tr – Trigonia, U – Uhligites, V – Virgatosphinctes.*

At the end of the Jurassic period Novaya Zemlya was submerged in its southern and western parts. The North Island and the northeastern part of the South Island might have been land on the periphery of which mostly sandy sediments were laid down, that were wiped out in the period of Quaternary glaciations and transgressions. All that is left of these sediments are individual boulders of sandstones and concretions with marine fauna.

An extensive area of marine sedimentation in the Jurassic and Cretaceous periods was Western Siberia. Silts, glauconites, and chloritolites accumulated in late Volgian time on its western margin, near the foothills of the Urals. It may be that where the Cis-Polar and Polar Urals now stand there were just a few islands, the straits between which carried the Middle Russian late Volgian fauna eastward away from the Urals. These ties were cut toward the end of the late Volgian, judging from the separation of the fauna. Farther to the east, in the lower reaches of the Ob, an island fringed by a strip of sand-pebble sediments was apparently preserved to the end of the Jurassic period. Inside the West Siberian Plain organically rich clayey muds settled, giving rise to the Bazhenov suite of bituminous argillites. Due to the scantiness of the remains of benthic fauna in this suite, together with the presence of Radiolaria and Coccolithophoridae, we may presume that the depths here were more than 200 m, perhaps even as much as 500 m. The thickness of the upper Volgian deposits is minor everywhere and could scarcely have compensated for the rate at which the bottom downwarped.

In the southern outlying area of the sea sandy-silty-clayey deposits were laid down with intercalations of marls, limestones, and variegated clays. Much thicker (to 100–150 m) clay series accumulated in the northeast, in the area of the lower reaches of the Yenisei. Clays were also deposited all over the inner parts of the Yenisei-Lena Strait, whereas on its periphery, off the shores of the Angara continent and the islands in the place where Taimyr and Severnaya Zemlya now are, silts and, partly, sands were formed. The depths of the strait in the middle probably exceeded 200 m, possibly reaching even 500 m (judging from the presence of radiolarians). To the south of the strait was a low piece of land. Until it was carried to the sea, the clastic material had time to weather considerably, so that maybe only epidote, brought from southern Siberia, entered the sediments in an appreciable amount (Ronkina, 1965).

In Northeast Asia the sea shrank considerably in late Volgian time in connection with the uplifting of Mesozoic structures. The Verkhoyansk Range and the regions of the upper reaches of the Yana, Indigirka, and Kolyma rivers became joined to the continent. All the same, a wide strait remained, connecting the Arctic and Pacific basins along the Cherskii mountain system. There were islands in place of the Kolyma-Omolon massif. A marine regime continued to prevail in the extreme northeast of Asia and along the Pacific coast of the Far East. The sediments show a very varied composition: silts, clays, and sands; in the lower reaches of the Kolyma, along with terrigenous rocks effusions and tuffs are present, and in the basin of the Anadyr, siliceous, relatively deepwater facies occur. In the Kolyma and Indigirka basins the marine conditions gave way in places to lagoon and continental conditions at the end of the Volgian age. The same is observed on the western shore of the Sea of Okhotsk. In the Maritime Territory, in the area of Sikhote Alin, there was a bay separated by a peninsula from the sea that was situated in the eastern part of the Japanese islands. This sea was already inhabited by a Tethyan (Pacific) fauna. The Tethyan forms penetrated into the Sikhote Alin inlet, which was mainly settled by a boreal fauna.

At the end of the Jurassic and beginning of the Cretaceous Japan was situated at least 10–15° nearer the pole than it is today, i.e. at the 45th–60th parallels. The absence of boreal elements within its limits can therefore be ascribed to the presence of a warm current coming from the south that veered eastward toward America, like the Kuroshio at present, only opposite Hokkaido Island.

In Alaska a marine regime presumably existed in the northern, western, and southern areas. Yet a late Volgian fauna proper has not been established within Alaska. Ammonites were apparently very rare, and among the forms of *Buchia* typical late Volgian species have not yet been discovered.

In northern Canada the sea, with a predominance of clay sediments, was at the end of the Jurassic period in the northwestern part of the Canadian Archipelago and in the area of the Mackenzie River. Judging from the distribution of the *Buchia* species prevailing here, the sea strait joined northern and western Canada. Along the Pacific coast of Canada and the USA marine conditions spread in late Volgian time all the way to California. In California, which seems to have been situated between the 45th and 50th parallels, boreal forms of *Buchia* and belemnites (Cylindroteuthidae) were widely distributed in late Tithonian time side by side with Tethyan (Pacific) ammonites and belemnites (Belemnopsidae), a possible indication that a cold current reached here via the above-mentioned Canada Strait. There are even records of Upper Jurassic *Buchia* and Cylindroteuthidae (but without definite reference to the Tithonian) for Central Mexico, where paleogeographists draw a bay separated from the California Sea by a peninsula that jutted far south in western Mexico (Imlay, 1956).

EARLY BERRIASIAN TIME

At the beginning of the Berriasian the sea in northwestern Europe began to spread out. Northeastern England was submerged, and the Spilsby sandstones started to accumulate here. In Holland, the north of West Germany, and in Poland, intercalations with marine fauna appeared in sediments of freshwater and brackish-water basins of the Wealden. On the Russian Plain, however, we do not know of any deposits that correspond to the beginning of the Berriasian or, possibly, the very end of the late Volgian (analogues of the Siberian *Chetaites chetae* zone). Since sediments of the middle part of the Berriasian (*Riasanites rjasanensis* zone) transgressively overlap various horizons of the Jurassic, there is a good reason to believe that sediments of the early Berriasian sea were present here but were washed out. Another possibility is that a continental regime was instituted on the Russian Plain in the early Berriasian, which went along with a break in sedimentation and erosion of the previously deposited strata. This assumption is reflected in our proposed paleogeographic map (Figure 18).

There are no specific data showing that lower Berriasian sediments existed also in the Caspian Basin and on Mangyshlak. In the Pechora Basin open-sea conditions, with clay sediments in the central parts and primarily silts on the periphery, were preserved throughout the Berriasian. Littoral sandy sediments built up near the west coast of Scandinavia as well.

In eastern Greenland the beginning of the Berriasian age was marked by activated elevation of the Greenland massif and accordingly an accumulation of thick sandy-conglomeratic and sandy series in the littoral part of the sea.

On western Spitsbergen the Berriasian is wholly represented by clay deposits, formed under conditions of the open sea. We may therefore think that the sea also flooded the development area of the Precambrian and Lower Paleozoic in the north of the archipelago. Land could have existed only in the area of Northeast Land. Lower Cretaceous deposits are unknown on Franz Josef Land, but since the igneous-sedimentary continental series of the Hauterivian-Barremian lies with erosion on the Jurassic,it may be that the Berriasian was present here in marine facies and was washed out prior to the deposition of the Hauterivian.

In the Novaya Zemlya area there was an island in the Berriasian that probably occupied a large part of the present-day North Island and the northeastern part of the South Island. In the littoral zone of the sea sandy sediments were laid down, now preserved only in the form of boulders of sandstones and concretions.

In the West Siberian Sea the conditions that existed in late Volgian time were fully preserved in the first half of the Berriasian: bituminous clays of the Bazhenov and Tutleima

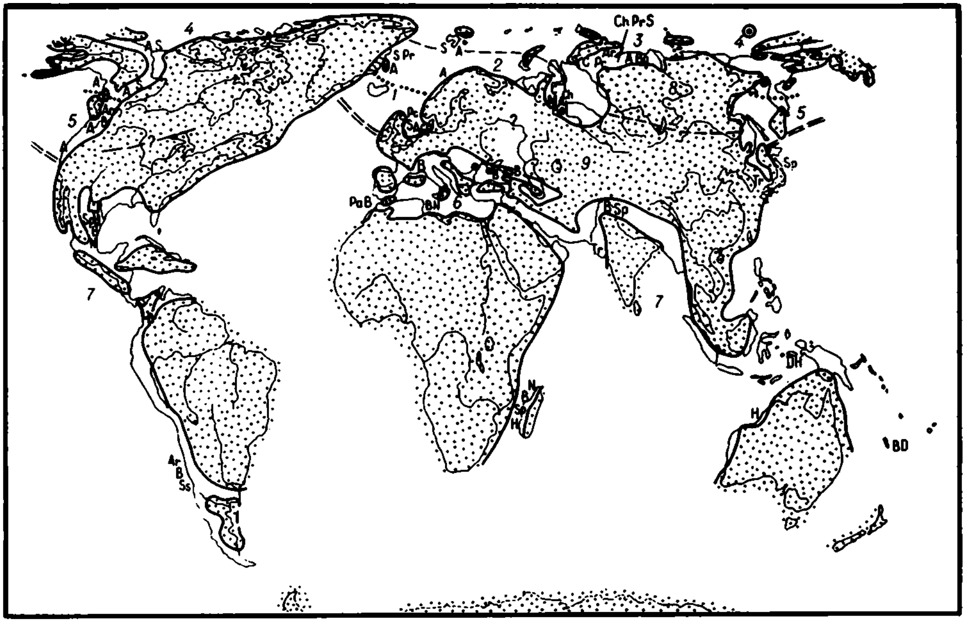


FIGURE 18. Early Berriasian time.
Notation: speckled areas denote land, a double dashed line indicates the boundaries of the Boreal and Tethyan realms, a single dashed line the boundaries of the paleozoogeographic regions in the seas and of the paleofloristic regions on land, and a dotted line shows the boundaries of the paleozoogeographic provinces in the seas of the Boreal Realm. 1, 2) Boreal-Atlantic Region: 1) West European Province; 2) Urals-Greenland Province; 3–5) Arctic Region; 3) North Siberian Province; 4) Chukchi-Canadian Province; 5) Boreal-Pacific Province; 6) Mediterranean Region; 7) Indo-Pacific Region; 8) Siberian Region; 9) Indo-European Region. The circle with a dot in the middle shows the probable position of the geographic pole. Letter symbols give the distribution of the most characteristic genera, subgenera, and groups of genera of fossil mollusks: *A – Buchia, Ac – Acroteuthis (Acroteuthis), Ar – Argentiniceras, Pseudargentiniceras, B – Berriasella, Bo – Camptonectes (Boreionectes), C – Cylindroteuthis, Lagonibelus, Ch – Chetaites, D – Duvalia, H – Hibolites, M – Acroteuthis (Microbelus), N – Neocomites, Pc – Paracraspedites, Pr – Praetollia, S – Surites, Subcraspedites, Sp – Spiticeras, Tr – Trigonia.*

suites, and in the outlying parts of the basin silts and sands with glauconite and leptochlorite, were deposited at relatively great depths (to 500 m). Instances of the lower Berriasian being missing from the section and of gravelly sediments of the *Hectoroceras kochi* zone occurring on upper Volgian strata, observed on the Yatriya and Tol'ya rivers, are of a local nature and are not on the whole reflected in the development of the West Siberian Basin.

The deposition of clays continued in the first half of the Berriasian in the Ust'-Yenisei Depression in the northeastern part of the West Siberian Sea. Their thicknesses markedly exceed those of the Bazhenov suite in the central parts of the sea, a circumstance that was brought about by the proximity of the region of washdown on the Siberian Platform and by the more rapid downwarping of the Ust'-Yenisei Depression.

The depths and expanses of the aquatory were somewhat reduced at the beginning of the Berriasian in the Yenisei-Lena Strait, with the result that the silts were replaced by sands in the outlying parts of the strait. The land to the south of the strait was low, but the beginning of the Berriasian saw a marked elevation of the Anabar massif, on which the series of amphibole gneisses began to undergo intensive erosion (Ronkina, 1965).

In the extreme northeast of Asia the marine basin became much smaller in the Berriasian than it had been in Volgian time, but it still occupied a large area to the east of the lower reaches of the Kolyma and in the Anadyr-Koryakskii and Kamchatka zones. The fauna was dominated by *Buchia;* ammonite remains are found very rarely (alongside boreal *Surites* and *Tollia* there are some *Euthymiceras,* which arrived from the south). The sea embraced a number of islands, volcanic phenonema occurred on the shores and on the bottom, thick (200–600 m) terrigenous-igneous series accumulated within the tectonically active troughs, and in areas of shallow depths, for instance, in the region of the Talovka Mountains, igneous siliceous sediments with radiolarians were formed.

In the Berriasian the sea remained along the north and west shores of the Sea of Okhotsk, in the Sakhalin and Sikhote Alin areas. Also deposited here were sands, silts, and clayey muds hundreds of meters thick. Downwarping took place especially intensively in the Sikhote Alin geosyncline, where the thickness of the Berriasian apparently reached one kilometer, the sediments bore a flysch character, and in the axial part of the geosyncline siliceous-clayey muds with radiolarians accumulated. Erosion is often, but not everywhere, observed at the base of the Berriasian. A lagoon-continental regime existed at the end of the Volgian age and possibly at the beginning of the Berriasian in the Udskaya Bay area.

In the Sikhote Alin region the Berriasian Sea was a bay which was closely linked to the marine basin in northern and northeastern Japan. Tethyan ammonites proper to the seas and, among the Bivalvia, *Trigonia,* migrated from the Japanese waters into Sikhote Alin Bay. The boreal elements in the fauna of this bay were represented by *Buchia.*

The Berriasian marine basins in the northern, western, and southern parts of Alaska had much in common with the seas of the Northeast and Far East of the USSR and were settled mainly by *Buchia.* There were apparently fairly deep troughs here, filled primarily with clayey sediments.

In northern Canada the marine regime was maintained at the beginning of the Berriasian in the northwestern part of the Canadian Archipelago and in the Mackenzie River area. Again clayey sediments predominate, with a fauna that contains, along with a predominance of *Buchia,* still quite an abundance of ammonites (*Surites* and *Subcraspedites*). These genera and the *Buchia* species penetrated to the south into the basin of the upper reaches of the Peace River, and the *Buchia* reached farther south, to the Pacific coast of Canada. This suggests that there was a strait connecting the Arctic Basin with the seas on the periphery of the Pacific Ocean. The geosyncline basin in the Cordilleras region in southern Alaska, British Columbia, and in the west of the USA was a zone in which mostly clayey sediments accumulated. *Buchia* reached as far as the western margins of the USA, possibly due to the presence of a cold current that streamed into the Pacific via Canada Strait.

MIDDLE BERRIASIAN TIME

Toward the middle of the Berriasian age (*"Hectoroceras kochi"* and *"Riasanites rjasanensis"* time) the marine bay in the North Sea area became much wider and deeper (Figure 19). The series of Speeton clays began to form in northeastern England, and beds with *Hectoroceras* are known in Norfolk. Ammonites *(Riasanites?)* appeared in the north of West Germany in intercalations of marine sediments among brackish-water deposits on the Wealden. Marine conditions set in also in Poland, and in the area of the Kujawy anticline a strait was formed, connecting the basins of the North Sea and of the Carpathian geosyncline. In *"Riasanites rjasanensis"* time the strait was shallow, and mainly sandy-silty sediments were formed in it (Marek, 1967). Among the fauna that settled in the strait, Mediterranean elements were accompanied by boreal forms *(Praetollia?)* and forms characteristic for the Middle Russian Sea *(Riasanites, Euthymiceras).* In view of this, and taking into account that a number of Russian boreal species of ammonites appeared in younger strata in Poland, we may assume that from the middle of the Berriasian a strait came into being that connected up the marine basins of Poland and Middle Russia. The existence of such a strait, whose sediments might eventually have been washed out completely, can be presumed also in the Pripyat' trough, as in Litva and in the basin of the Western Dvina. The last variant is shown in the paleogeographic map in Figure 19. Still, it must not be excluded that the boreal elements entered Poland around Scandinavia, and such southern representatives of the Russian fauna as *Riasanites,* finds of which are not reported in the Mediterranean Region west of the Caucasus, still reached Poland via the Crimea and Carpathians. This point of view is expressed by Polish investigators (Marek, 1967, and others). Sazonova had the opportunity to examine forms of *Riasanites* from Marek's collection and considers that the Polish representatives of the genus differ from the Middle Russian ones and resemble the forms from the Northern Caucasus. She is therefore inclined to believe that there is no direct link between the Berriasian basins of Poland and Middle Russia.

On the Russian Plain a shallow marine basin appeared in the middle of the Berriasian age that received glauconitic-leptochloritic phosphoritic, primarily sandy, more rarely clayey sediments; it was only in the Caspian Depression that more deepwater clays formed. In the south this basin joined up with the seas of Mangyshlak and the Caucasus,

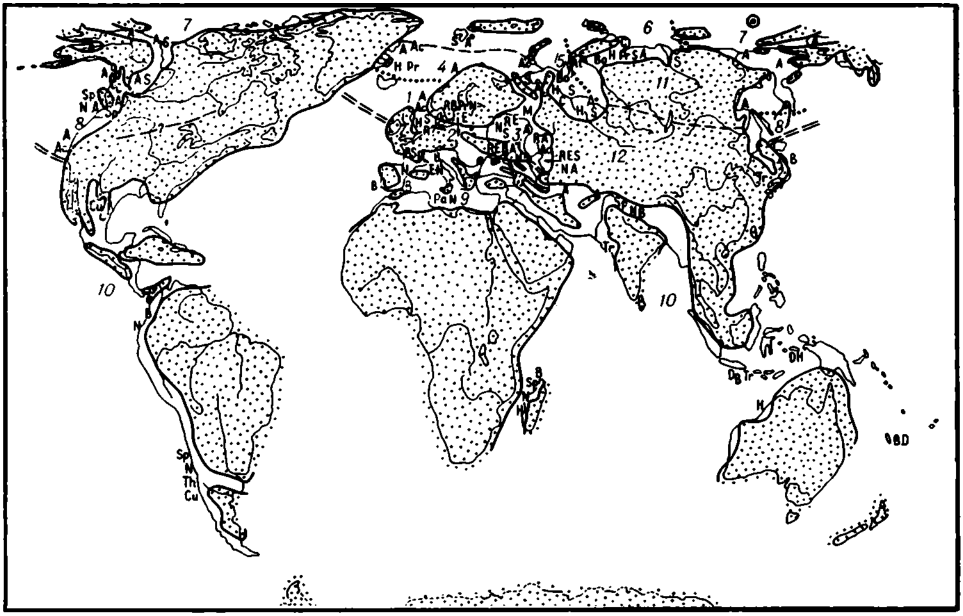


FIGURE 19. Middle Berriasian time.
Notation: speckled areas denote land, a double dashed line indicates the boundaries of the Boreal and Tethyan realms, a single dashed line the boundaries of the paleozoogeographic regions in the seas and paleofloristic regions on land, and a dotted line shows the boundaries of the paleozoogeographic provinces in the seas of the Boreal Realm. 1–4) Boreal-Atlantic Region: 1) West European Province; 2) Polish Province; 3) East European Province; 4) Pechora-Greenland Province; 5–8) Arctic Region: 5) West Siberian Province; 6) North Siberian Province; 7) Chukchi-Canadian Province; 8) Boreal-Pacific Province; 9) Mediterranean Region; 10) Indo-Pacific Region; 11) Siberian Region; 12) Indo-European Region. The circle with a dot in the middle indicates the probable position of the geographic pole. Letter symbols give the distribution of the most characteristic genera, subgenera, and groups of genera of fossil mollusks: *A – Buchia, Ac – Acroteuthis (Acroteuthis), At – Arctotis, B – Berriasella, Bo – Camptonectes (Boreionectes), C – Cylindroteuthis, Lagonibelus, Cu – Cuyaniceras, D – Duvalia, E – Euthymiceras, H – Hibolites, He – Hectoroceras, N – Neocomites, Pr – Praetollia, R – Riasanites, S – Surites, Subcraspedites, Sp – Spiticeras, Tr – Trigonia.*

while in the north it evidently opened onto the Barents Sea via the Pechora Depression. This is confirmed by the fact that the *Riasanites rjasanensis* zone in the Middle Russian Sea contains boreal forms of *Surites, Buchia,* and Cylindroteuthidae, including some that are common to the Cis-Polar Trans-Urals (*Acroteuthis (Microbelus) uralensis* Sachs and Naln.). The southern elements of the Middle Russian fauna, *Riasanites,* spread north just as far as the Vyatka and Kama river basins, while *Euthymiceras* and *Neocomites* reached to the latitude of Moscow.

From the Caspian Depression a shallow strait ran toward the northwest through the Ul'yanovsk-Saratov and Shilovo-Vladimir troughs. In the areas of Moscow, Yaroslavl, Kirov, and Syzran a shallow, semiclosed basin was formed with conditions especially favorable for the development of ammonites.

The sediments of this basin contain abundant phosphoritic nodules of two types: glossy, rounded and sandy-clayey with a rough surface. The wealth of phosphoritic nodules with smooth, glossy surface and, frequently, with a Volgian fauna inside them implies that there was a very intensive initial stage of transgression and that the rock masses were relatively large, eroded and redoposited by this transgression. The fact that the sediments of "*Riasanites rjasanensis*" time contain obliquely laminated glauconitic micaceous sands, in which the oblique layers consist of glauconite with sparse grains of coarse, well-rounded quartz, is an indication that there were strong currents here. Such currents are to be naturally expected in a basin that for the most part bears the character of a strait (it widened out only in the middle part of the Russian Plain). The southern current promoted the settlement of Tethyan ammonites in the Middle Russian Sea, and the northern current the settlement of *Buchia* species that penetrated as far as the Northern Caucasus, Mangyshlak, and Kopet-Dag.

Off the coast of eastern Greenland the sandy-pebbly sediments of the bottom strata of the Berriasian give way higher up to sandy-clayey sediments. so that we may infer that there was a certain expansion of the sea and a weakened erosion of the adjacent land in Greenland.

Conditions did not change to all intents and purposes in the area of the Barents and Pechora seas in the middle Berriasian. Local washouts occurred in the West Siberian Sea at the Urals foothills prior to the deposition of the beds with *Hectoroceras*, but clayey muds, which gave rise to bituminous argillites, continued to accumulate in the inner parts of the sea. No marked changes are perceived in the sedimentation situation in the Ust'-Yenisei and Anabar-Khatanga regions. There are still no data according to which we might judge the sedimentation conditions in the middle Berriasian in the Northeast and Far East of the USSR, Alaska, Canada, or the Pacific coast of North America.

LATE BERRIASIAN TIME

In late Berriasian time ("*Surites analogus*", "*S. spasskensis*", and "*Bojarkia mesezhnikowi*" time) the marine basin in the north of Western Europe continued to deepen and widen. The upper horizons of the Wealden in Holland and West Germany contain for the most part a brackish-water fauna, but intercalations with marine fauna become more frequent. Silty and clayey muds become dominant in the composition of the marine sediments in Poland, and meanwhile the boreal ammonites *Surites, Subcraspedites*, and *Tollia* (?) come to assume an important place in the fauna, side by side with remaining *Riasanites* and a number of Mediterranean genera. The fact that the same species of *Surites* are present here as in the Middle Russian Sea demonstrates clearly that there was a strait connecting this sea and that of Poland (Figure 20).

In Middle Russia the sea preserved similar outlines in the late Berriasian to those existing in "*Riasanites rjasanensis*" time. The main deposits formed here are inequigranular, glauconitic sands with a predominance of the fine variety, silty, clayey sands, in places phosphoritized sandstones, and also oölitic ferruginous marls. The Caspian Basin contained mainly clays with a smaller glauconite content and rare *Buchia*. In the sediments laid down in the Unzhina and Pechora straits the carbonate content increased and marls appeared. However, the links between the Middle Russian Sea and the Caucasus and Central Asia became definitely fewer, and there are no southern elements at all in the composition of the Middle Russian fauna (*Euthymiceras* is present only at the base of the *Surites spasskensis* zone). On the other hand, there is a marked increase in the abundance of boreal Craspeditidae (*Surites, Subcraspedites, Externiceras,* etc.), Cylindroteuthidae (*Acroteuthis* s. str. becomes widespread for the first time), and *Buchia,* showing that there was a much broader insurge of waters from the north, coming from the Pechora Basin.

On Novaya Zemlya and Spitsbergen the sedimentation conditions remained the same as before in the late Berriasian. In the Pechora Sea clayey muds developed considerably, and in the peripheral zone of the basin clay and sand sediments with phosphorites developed.

In eastern Greenland and the more northern regions the accumulation of sandy-clayey sediments continued in the late Berriasian, while farther south (Milne Land and Jameson Land) the marine sediments gave way to littoral sediments with plant remains after *"Hectoroceras kochi"* time.

The western part of the West Siberian Sea remained deep as before, with a continued buildup of organogenic clayey muds; at the eastern foothills of the Urals a transition is even observed, in comparison with the *Hectoroceras kochi* zone, to more fine-grained, clayey-silty sediments, indicating either that the basin became deeper or, more likely, that a calm zone was formed, possibly due to the appearance of islands. Probably due to uplifting, a number of islands and submarine banks arose inside the West Siberian Sea, which led to the formation of a thick series of Achimov sandstones in the central part of the sea; these were replaced by argillites in the southern part of the basin adjacent to the continent. A zone of littoral sandy-silty sediments spread in the east and south. In the Ust'-Yenisei area erosions are observed, apparently corresponding to Achimov sandstones, and after these, replacing formerly deposited black clay muds, appeared light-gray clayey-silty muds in the peripheral part of the sea.

Depths diminished still further in the Yenisei-Lena strait. The admixture of silt particles did not increase appreciably in the clayey muds in its central part, but near the southern shore, on the Boyarka River, clayey-silty muds of the middle sublittoral were replaced by silty muds of the upper sublittoral. In the more eastern-lying areas (Anabar River) even sands of the *Surites analogus* zone appear above the clayey-silty sediments of the first half of the Berriasian.

Signs that the basin became shallower (transition from clays to sandy-silty sediments) are noted in the upper strata of the Berriasian and in the lower reaches of the Olenek and Lena Rivers, in the Southern Maritime Territory (Suchan area), and in the north of America (Richardson Mountains). Analogous data are lacking for other regions where the Berriasian is developed.

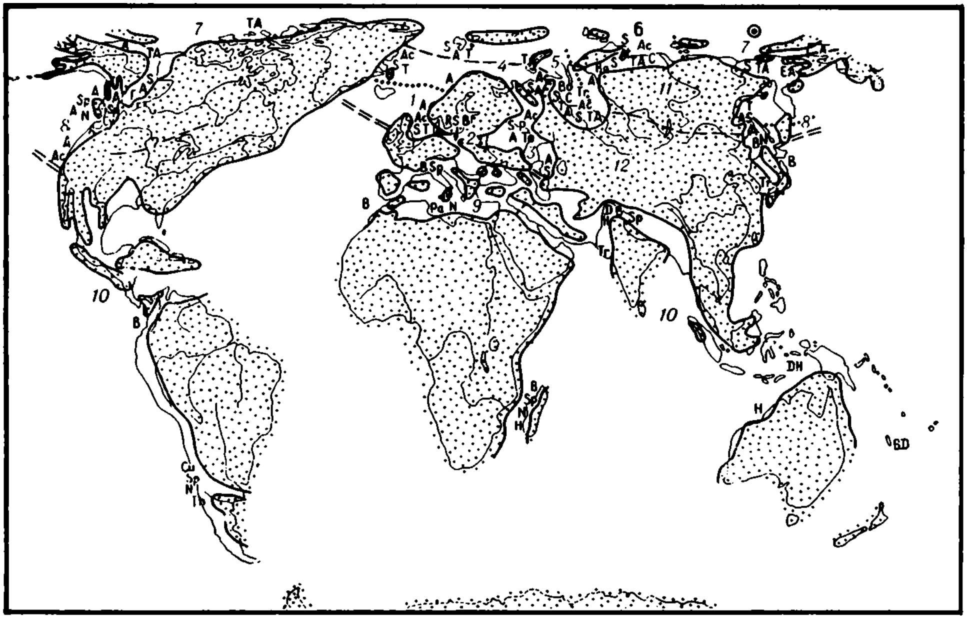


FIGURE 20. Late Berriasian time.
Notation: speckled areas denote land, a double dashed line indicates the boundaries of the Boreal and Tethyan realms, a single dashed line the boundaries of the paleozoogeographic regions in the seas and of the paleofloristic regions on land, and a dotted line shows the boundaries of the paleozoogeographic provinces in the seas of the Boreal Realm. 1–4) Boreal-Atlantic Region: 1) West European Province; 2) Polish Province; 3) East European Province; 4) Pechora-Greenland Province; 5–8) Arctic Region: 5) West Siberian Province; 6) North Siberian Province; 7) Chukchi-Canadian Province; 8) Boreal-Pacific Province; 9) Mediterranean Region; 10) Indo-Pacific Region; 11) Siberian Region; 12) Indo-European Region. The circle with a dot in the middle shows the probable position of the geographic pole. Letter symbols give the distribution of the most characteristic genera, subgenera and groups of genera and subfamilies of fossil mullusks: *A – Buchia, Ac – Acroteuthis (Acroteuthis), At – Arctotis, B – Berriasella, Bo – Camptonectes (Boreionectes), C – Cylindroteuthis, Lagonibelus, Cu – Cuyaniceras, D – Duvalia, H – Hibolites, N – Neocomites, R – Riasanites, S – Surites, Subcraspedites, Sp – Spiticeras, T –* Tolliinae, *Te – Tr – Trigonia.*

EARLY VALANGINIAN TIME

At the beginning of the Valanginian the marine basin spread from the North Sea area to the northern part of West Germany and Holland, presumably via the Anglo-Paris Basin, and connected up with the Tethys Sea and southern France (Figure 21). As a result, such genera as *Platylenticeras* and *Polyptychites* became distributed both on the periphery of the North Sea and in France and Switzerland. Clays were laid down at the beginning of the Valanginian in the northern part of West Germany, and later, at the end of *"Platylenticeras heteropleurum"* time the sea became shallower and the clays were replaced by sands.

In the early Valanginian in Poland clays and silts continued to be deposited; they included, along with *Platylenticeras* and *Polyptychites*, Mediterranean *Neocomites* and the genus *Temnoptychites* (?), that is characteristic for the lower strata of the Russian Valanginian. These facts indicate that the early Valanginian North Polish Sea and the Carpathian geosyncline were united, plus, maybe, the basin in Middle Russia. In this basin a number of ammonite genera appear at the beginning of the Valanginian that have not yet been found outside the Russian Plain and are even here discovered only in isolated sections. These are representatives of the Garniericeratinae: *Pseudogarnieria, Proleopoldia,* and *Menjaites*, together with forms that are transitional between the Suritidae and Polyptychitidae – *Temnoptychites* and the specifically north Siberian *Neotollia.* Since all these genera are absent in Western Europe, including (apart from *Temnoptychites*) Poland, we may assume that the strait linking up the basins of Middle Russia and Poland

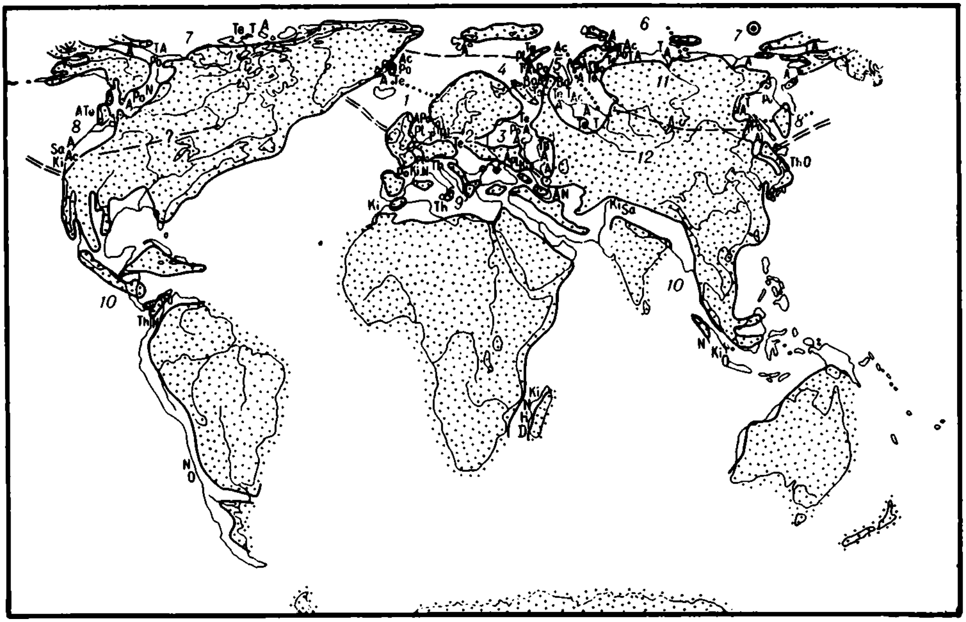


FIGURE 21. Early Valanginian time.
Notation: speckled areas denote land, a double dashed line the boundaries of the Boreal and Tethyan realms, a single dashed line the boundaries of the paleozoogeographic regions in the seas and of the paleofloristic regions on land, and a dotted line shows the boundaries of the paleozoogeographic provinces in the seas of the Boreal Realm. 1–4) Boreal-Atlantic Region: 1) West European Province; 2) Polish Province; 3) East European Province; 4) Pechora-Greenland Province; 5–8) Arctic Region: 5) West Siberian Province; 6) North Siberian Province; 7) Chukchi-Canadian Province; 8) Boreal-Pacific Province; 9) Mediterranean Region; 10) Indo-Pacific Region; 11) Siberian Region; 12) Indo-European Region. The circle with a dot in the middle shows the probable position of the geographic pole. Letter symbols give the distribution of the most characteristic genera, subgenera, groups of genera, subfamilies, and families of fossil mollusks: *A – Buchia, Ac – Acroteuthis (Acroteuthis), At – Arctotis, Bo – Camptonectes (Boreionectes), C – Cylindroteuthis, Lagonibelus, H – Hibolites, Ki – Kilianella, N – Neocomites, O – Olcostephanus, Pl – Platylenticeras, Po –* Polyptychitidae, *Sa – Sarasinella, T –* Tolliinae, *Te – Temnoptychites, Th – Thurmanniceras, Tr – Trigonia.*

dried up temporarily at the beginning of the Valanginian. Shallow sandy deposits with glauconite, leptochlorite, and phosphorites were formed in the Middle Russian Sea. The sea had an outline similar to that of the Berriasian basins and, as before, was united with the seas of the Caucasus and Central Asia in the south and with the Arctic Basin via the Pechora Depression. Deeper clayey-silty sediments dating from the beginning of the Valanginian are observed in the southwest of the Moscow tectonic depression, in the Ul'yanovsk-Saratov trough, and in the Caspian Depression.

A relatively shallow sea was preserved in the Pechora Basin in the Valanginian, with the formation of clayey muds. On the periphery of the Izhma River depression there was an accumulation of silts with phosphorites. Sands and limestones were deposited in the area of Wollaston Peninsula and Kuhn Island off the east coast of Greenland, farther south on Traill Island clayey muds, and still farther south sands with plant remains. Clays continued to built up on Spitsbergen.

Clayey muds were deposited in the West Siberian Sea at the Urals foothills and organogenic clayey muds in the western part of the basin along the lower reaches of the Ob and Irtysh. Farther to the east sandy-silty sediments came to occupy a greater and greater area due to the shrinking of the sea in area and depth.

In the Ust'-Yenisei area the conditions existing at the end of the Berriasian persisted at the beginning of the Valanginian, but along the southern shore of the Yenisei-Lena strait a broad zone of littoral sandy sediments with bars and lagoons appeared. These sands, which can be observed in the basins of the Kheta and Popigai rivers, may be connected with delta outflows of rivers flowing from the south. On the whole the Yenisei-Lena strait became shallower, even in its central zone (Paks Peninsula); the content of silt particles increased in the sediments, and the depths were probably of the order of 100–200 m. The degree of elevation of the land lying adjacent on the south side remained minor as before, the Anabar massif rising the highest.

In the Northeast and Far East of the USSR, in Alaska, and in Canada the marine regime remained essentially the same at the beginning of the Valanginian as in the Berriasian. In places, for example, on the west shore of the Sea of Okhotsk, marine conditions alternated with littoral-continental conditions. Along with Tethyan (Pacific) species of ammonites in California and Oregon, boreal *Tollia, Neotollia, Buchia,* and *Acroteuthis* are widely represented. This may be due to the presence of a cold current.

PALEOCLIMATES

For an assessment of the paleoclimates existing in the Boreal Realm at the end of the Jurassic and beginning of the Cretaceous we have data on the vegetation and weathering conditions on the land, the composition of the marine fauna and marine sediments, and, finally, on the paleotemperatures of the water, determined in belemnite rostra.

So far, about 200 determinations have been made of paleotemperatures according to the isotope composition of oxygen and the calcium/magnesium ratios in the rostra of late Volgian, Berriasian, and early Valanginian belemnites. Most of the determinations were performed for northern Siberia: according to oxygen isotopes at the Institute of Geochemistry (R.V. Teis and D.P. Naidin), the calcium/magnesium ratio, determined by chemical analysis, at the All-Union Geological Institute (T.S. Berlin and A.V. Khabakov), and according to the same ratio determined by means of spectral analysis at the Siberian Institute of Geology, Geophysics, and Mineral Resources (E.L. Kiprikova and I.D. Polyakova). The results of the determinations were reported in an article by Berlin et al. (1970), where it was shown that only the minimal values of the paleotemperature measurements obtained are worthwhile taking into consideration, since the rostral substance may recently have been enriched in O^{18} and magnesium carried in by groundwaters.

In the north of Middle Siberia the mean annual paleotemperatures of the water are calculated, according to the isotope composition of oxygen in accordance with the above, at 14.0° for middle Volgian time, 13.4° for late Volgian time, 11.8° for the late Berriasian, and 16.2° for the early Valanginian. Slightly lower figures are obtained when the calculation is based on the ratio of calcium and magnesium: 12.4°, 10.4°, 11.5°, and 9.8°, respectively. The considerable disparity of the results for the early Valanginian is probably due to the fact that the O^{18} content is affected by fluctuations of salinity in the littoral zone of the sea, which in the early Valanginian was situated in the Boyarka River area. There may have been an even stronger action of groundwaters, that circulated freely in the sandy series and brought O^{18} with them. The seasonal fluctuations of water paleotemperatures, judging from changes in the isotope composition of oxygen, amounted to 5–7° in the Kimmeridgian, and reached 10–12° in the early Valanginian (Teis et al., 1968).

As shown by Kozlova, in the warm summer seasons brightly colored dark chestnut-brown layers of the rostra, enriched in iron, manganese, titanium, and magnesium, were laid down, while in the cold winter periods light-yellow layers with a high calcium carbonate content were formed. The organic content is low in both types of layers, but the dark layers have more humic substance and the light layers more sapropelic substance. We can explain the above best if we assume that there was intensified loss from the land of iron, manganese, and humic compounds that were washed out of the soil in the summer. This type of phenomenon indicates the development of a podzolic type of soil formation and a monsoon climate, all of which is highly probable in the northern fringe of the Angara continent during the Mesozoic.

On the east slope of the Cis-Polar Urals the mean annual water paleotemperatures according to the calcium/magnesium ratio are determined at 11.8° for the middle Volgian, 10.3° for the late Volgian, 13.4° for the early Berriasian, 9.1° for the middle Berriasian, 10.5° for the late Berriasian, and 7.6° for the early Valanginian. Slightly higher values were obtained for the Pechora Basin: according to O^{18}/O^{16} ,14° for middle Volgian time and 14.7° for Berriasian–lower Valanginian; according to Ca/Mg, 14.3° for middle Volgian time, 14.9° for the Berriasian, and 11.6° for the early Valanginian. The seasonal fluctuations of the paleotemperatures are also markedly smaller on the Pechora (3–4°).

In the middle part of the Russian Plain the mean annual paleotemperatures according to O^{18}/O^{16} were 18.8° for the middle Volgian and 22.7° for the late Volgian and according to Ca/Mg 15.6° for the middle Volgian, 15.5° for the late Volgian and 17.2° (a single determination) for the Berriasian–early Valanginian. It may well be that here, too, the isotope composition of the oxygen in the rostra deviated slightly from the norm under littoral shallow-water conditions. The mean annual water paleotemperatures in eastern Greenland proved to be very high in middle Volgian time, according to single determinations: 21.5–25° (Bowen, 1966). Values of around 20° have been established for the mean annual paleotemperatures according to O^{18}/O^{16} in the Berriasian and Valanginian in southeastern France (that is, already in the Tethyan Realm). Still higher values (23.7°) with an amplitude of seasonal fluctuations of 3–7° were obtained in the Tithonian of Argentina (Bowen, 1966). Finally, in the early Tithonian of New Zealand Clayton and Stevens (1968) determined mean annual paleotemperatures of the water according to oxygen isotopes at around 16° in the presence of seasonal fluctuations (in the Kimmeridgian) of about 5–8°. Similar mean annual paleotemperatures (17°) have been established in the Late Jurassic of New Guinea (Bowen, 1966).

The paleotemperature values obtained must not be estimated too high. It may be that even the minimal values of the O^{18}/O^{16} and Ca/Mg ratios still depend to some extent on the O^{18} and magnesium introduced in the process of epigenesis. It may be assumed, however, that the mean annual paleotemperatures determined in belemnite rostra are lower than the actual temperatures of the surface waters in the sea in view of the fact that the animals lived in the depths. In general, though, it must be admitted that the paleotemperatures of the water thus established give a harmonious picture of the temporal and spatial changes that tie up well, as will be shown below, with the climate of the adjacent land.

Summing up the data, we may conclude that at the end of the Jurassic and beginning of the Cretaceous the sea off the northern coasts of Siberia, including the Urals, had mean annual water temperatures of 10–14°; temperatures were highest in middle Volgian time, with a gradual cooling that apparently lasted up to the middle of the Berriasian, then a warming up at the end of the Berriasian, and again a cooling which set in at the beginning of the Valanginian. These conditions approximately corresponded to those currently observed in the southern part of the temperate zone: off the coasts of France, in the west of the British Isles, in northern Japan, the Southern Maritime Territory, and between California and Vancouver Island. The seasonal fluctuations of the surface water temperatures are also similar to those observed at present (about 10–15° off northern Japan).

The water paleotemperatures in the Pechora Sea were higher, corresponding to the boundary of the present-day subtropical and temperate zones (12–15°). The Middle Russian Sea, with a water temperature above 15°, was subject to the conditions in the northern part of the subtropical zone. The paleotemperature determinations performed in Greenland are apparently overstated. In southern France the mean annual temperatures were as they are now off the coasts of Africa at the latitude of Senegal. Finally, in New Guinea and New Zealand the mean annual temperatures of seawater at the end of the Jurassic period were lower than the present ones, which is one indication that there has been a recent shift of those areas of the earth's crust to lower latitudes.

Judging from the diversity of the fauna inhabiting the north Siberian seas, including Ostreidae, *Isognomon, Pinna, Trigonia,* Radiolaria, and a wealth of Cephalopoda and Brachiopoda, and from the presence of Peridiniales and Coccolithophoridae, the mean annual temperatures of the Volgian Basin were not lower than those prevailing today in the Sea of Japan, that is, they in fact correspond to the southern part of the temperate zone. At the beginning of the Cretaceous, there was a slight drop in the water temperature of the north Siberian seas, as attested to by the overall impoverishment of the fauna.

A study of the land vegetation gives a similar picture. Vakhrameev et al. (1970) and Gol'bert et al. (1968) identify a Siberian paleofloristic region, the southern boundary of which ran to the south of the Cis-Polar Urals, south of the mouth of the Angara, near the southern tip of Lake Baikal, and through the Amur basin at the end of the Jurassic and beginning of the Cretaceous. The vegetation of this region developed in a warm, humid climate with sharp seasonal fluctuations. Conifer-gingko forests predominated, with an underbrush of Cicadaceae and Filicales. An analysis of spore-pollen data for Western Siberia (Gol'bert et al., 1968) tells us that the vegetation of the Siberian Region still lived in a climate close to subtropical; Cicadaceae were abundantly represented, conifers included Podocarpaceae and *Araucaria,* and Filicales included Schizaeaceae and Gleicheniaceae, that at present are specific to the tropical and subtropical zones.

The vegetation of the paleofloristic region situated south of the Indo-European one had a typically tropical or subtropical appearance at the end of the Jurassic and beginning of the Cretaceous. Xerophyta flourished at the end of the Jurassic in Europe and in the south of Western Siberia and included plants producing the pollen *Classopollis.* These may not be xerophytes at all, but perhaps even aquatic plants (Kondrat'ev, 1970). But in this case their high proportion (to 80%) in the spore-pollen spectra indicates that conditions were absent for the growth of other groups of flora; in other words, the climate was arid or semiarid.

It would be possible to believe that such a climate existed in Europe (which then formed an archipelago of islands) and on the periphery of the vast West Siberian Sea only if we were to assume that there was an eastern circulation of air masses, from the Angara continent. Consequently, a large part of Western and Southern Europe and the south of Western Siberia came into the zone of the northeastern tradewinds, the zone that at present does not reach north of the 25th–30th parallel.

At the beginning of the Cretaceous the boundaries of the arid zone in Europe and, judging from the diminished role of *Classopollis* pollen, in Western Siberia, were displaced to the south. This may have been brought about by a cooling of the climate, which, as we have seen, has been established in the north Siberian seas by means of paleotemperature determinations.

Assessments of the climate according to paleobotanical data find confirmation in the development of intensive chemical erosion on the land in the Siberian paleofloristic region and the accumulation of leptochloritic and glauconitic sediments, oölitic iron ores, and kaolinized clays in the contiguous seas (Gol'bert et al., 1968). In the zone of semiarid climate in the south of Western Siberia appears calcareous sediments and variegated and red clays, while still farther south in Central Asia saliferous series are formed. All this points to the fact that a climate transitional between subtropical and temperate existed in the Siberian paleofloristic region and in the seas of the Arctic zoogeographic region, and an unquestionably subtropical one in the northern part of the Indo-European paleofloristic region and in the seas of the Boreal-Atlantic zoogeographic region. The Tethyan

Realm falls into the tropical zone, but it is possible that the region of Australia, New Zealand, and New Guinea was situated in a zone of subtropical climate in the southern hemisphere.

Hence, the paleoclimatic conditions of the Mesozoic and accordingly the water paleotemperatures in the seas of the Boreal Realm differed substantially from the present-day conditions. There were no ice caps around the poles, an important factor in the cooling of the waters of the present-day World Ocean and a major cause of the sharp contrast of our climates. We must not assume that there was any marked weakening of solar radiation in the last 130 million years – the sun has been in the stage of a dwarf star for at least a billion years. Moreover, an increase of solar radiation would have most strongly affected the equatorial and tropical zones, and for these we have no data on an appreciable rise in water and air temperatures in the Mesozoic as compared with today. And so, the main cause of the leveling of the Mesozoic climates is an intensified heat exchange between the low and high latitudes due to sea and air currents. Dense cloudiness and a high atmospheric albedo, with a slightly different composition from that at present (richer in carbon dioxide) may be important factors.

In view of the above we can apparently adhere to the concept of tropical, subtropical, and temperate climates for the Mesozoic, although there is no doubt that the differences between them and the seasonal temperature variations must have been considerably weaker in the Mesozoic than they are today.

Chapter VII

PALEOZOOGEOGRAPHIC ZONING

The Jurassic period, particularly its second half, saw a sharp differentiation of the faunas that settled in the various seas. Two main faunistic complexes are defined, the one confined to the tropical belt, the other to relatively high latitudes of the northern hemisphere. The first complex is characterized by the development of reef-forming corals, Rudista, and by an especially rich diversity of the generic and specific diversity of the fauna. The second complex shows, along with the appearance of a number of endemic groups, a general impoverishment of composition: many of the genera, families, and even orders that are typical of the tropical zone disappear here.

We therefore single out two major zoogeographic units that may be called superregions (after Gur'yanova, 1957), zones (after Ekman, 1935; Zernov, 1949; Zenkevich, 1967) or, finally, belts. In English these units are designated by the term "realm." The concept of the belt, introduced into biogeography by Wagner (1884), was recently upheld by Yuferevyi (1969) and seems to us to be the most apt term for a higher zoogeographic entity embracing a particular geographic belt. The term "biogeographic zone" is liable to be confused with the biostratigraphic zone and, furthermore, it holds no advantages over the term "belt," since in Greek the word for zone (ζωνη) actually means belt.

At the end of the Jurassic period two geographic realms (belts)* are already clearly defined: the Tethyan, confined to the seas of Tethys and the adjacent basins, and the Boreal, which has a circumpolar distribution in the northern hemisphere. These realms are split up into zoogeographic regions and, in the case of finer differences in the faunal composition, into provinces. The idea of isolating two zoogeographic regions in the Boreal Realm at the end of the Jurassic and beginning of the Cretaceous was favored by Makridin (1964), Saks and Nal'nyaeva (1966), Zakharov, (1966, 1970), Saks, Mesezhnikov, and Shul'gina (1968), Dagis (1968), and Ivanova (1971). Taking the bivalve and foraminifer complexes as a basis, Zakharov and Ivanova believe it possible to subdivide these regions into subregions. We were obliged to refrain from doing this in view of the fact that there are not enough data to support such a subdivision where the other groups of fauna are concerned.

There is no question but that the very clear-cut differentiation of the Late Mesozoic marine fauna was due to differences in temperature conditions in the tropical and extra-

* [Notwithstanding the preceding paragraph, we shall adhere to the term "realm," as this is in keeping with the accepted English terminology.]

tropical seas. No other factor (remembering the distribution of the land and sea areas in the period of geological time with which we are concerned) could have led to such a sharp contrast of the fauna of the Tethys and that of the northern circumpolar belt. It must be borne in mind that links were always maintained between these faunas and that, as shown by Bodylevskii (1957), their spatial delimitation took place gradually, so that there is no room to speak of a dryland barrier or of differences in water salinity.

We cannot agree with Hallam (1969), who conjectures that the differences between the Boreal and Tethyan faunistic realms are reduced to a difference in the salinity of the waters of the Tethys and of the northern epicontinental seas. If the northern seas had really been completely or almost completely separated from the World Ocean, the differences in the composition of the fauna would have been immediate, not gradual, and there would have been no interpenetration of the faunisitic complexes of the two realms. Apart from this, the isolation of the northern seas would have resulted in a much greater increase in the temperature gradient on account of differences in the amounts of solar radiation present at different latitudes. Moreover, while slight differences are indeed established in the water and air temperatures in the tropics and at the pole in the Jurassic and Cretaceous periods, this, as we have said, is due primarily to the intensive water exchange that went on between the Arctic and tropical seas. Consequently, the salinity of these seas could not have been much different.

It is naturally not part of our task to examine zoogeographic zoning outside the Boreal Realm. Stevens (1967) identifies three regions in the Tethys Sea for the Late Jurassic epoch: Tethyan, in the strict sense (more correctly Mediterranean), Indo-Pacific, and Ethiopian. There are no substantial grounds for isolating an Ethiopian Region for the very end of the Jurassic and beginning of the Cretaceous; this is probably a province of the Indo-Pacific Region. The Mediterranean and Indo-Pacific regions, with the boundary passing through Iraq and Iran, are quite clearly defined. The first is characterized by a complex dominated by Duvaliidae among the belemnites and by *Berriasella* and *Virgatosphinctes* among the ammonites. Predominating in the second are the Belemnopsidae and ammonites *Blanfordiceras, Substeueroceras, Cyanoceras, Uhligites, Argentiniceras,* and a number of other genera.

It is appropriate to mention here that neither in the Jurassic nor in the Early Cretaceous faunistic complexes can faunas of the Antiboreal belt be identified that would be specific to the extratropical zone of the southern hemisphere. The most likely reason for this, as Stevens (1967) notes, is that during the Mesozoic the Antarctic block shifted in the direction of the Indian Ocean, in the region of the middle latitudes of the southern hemisphere. This being the case, the South Pole would have been located in the ocean in the Mesozoic, where shallow-water faunas, known for other Mesozoic seas, would have been quite unable to survive. To accept such a hypothesis means to acknowledge that there were subsequent displacements of the continental blocks of the southern hemisphere relative to each other. As we have pointed out, such shifts seem probable, especially if we take into account the different positions of the paleomagnetic poles as determined by observations on various continents.

Also to be reckoned with is the fact that the Mesozoic fauna in the southern hemisphere has not been studied in anywhere near the amount of detail that the fauna in the northern hemisphere has. An antiboreal fauna may thus eventually be discovered, especially on the periphery of Antarctica, that is now submerged following the glacial isostatic inundation of this continent. Assuming a constant position of the continental blocks and a stable diameter of the globe, then with the North Pole lying to the north of Bering Strait, the South Pole would come in the region of Queen Maude Land.

It should be pointed out here that elements of a boreal fauna in the form of *Buchia* in Upper Jurassic deposits have been established in the southern hemisphere on Misol Island near New Guinea (Krumbeck, 1934), on the west coast of Australia (Brunnschweiler, 1960), and in New Zealand (Stevens, 1965), that is, in the low present-day latitudes (2–40°S) and entirely in the near-equatorial Mesozoic latitudes (assuming a constant position of the continents). There are also records of *Buchia* from the Spiti shales (Chidamu beds, lower Tithonian) in the Himalayan foothills (30°N). Reconstructions performed on the basis of paleomagnetic data by Irving (1964) indicate that in the Jurassic period Australia and New Zealand moved to the 50–70° latitudes, New Guinea to 45°, and India to 40°S. All this certainly agrees much better with the paleozoogeographic data and also with the paleotemperatures of the sea.

Biogeographic zoning of the recent seas and oceans is known to be very problematic owing to the different modes of settlement of organisms inhabiting shallow littoral seas, open-sea areas, and deepwater zones. This is why in modern zoogeography it is usual to give biogeographic zoning data separately for the above three types of zones. No such difficulties have been experienced, at least so far, in producing paleozoogeographic zoning schemes. With rare exceptions the complexes of fossil fauna known to us characterize shallow-water conditions that correspond to present-day shelf seas. The paleozoogeographic zoning system delineated below can therefore be correlated only with the biogeographic subdivision of the littoral shallow-water zone of the World Ocean as it exists now.

It will be seen from the following that even inside the shallow seas of the Mesozoic the paleozoogeographic boundaries drawn on the basis of individual groups of fauna, in particular according to free-swimming cephalopods and benthos (bivalves, brachiopods, foraminifers) do not coincide. This obliges us in some cases to draw these boundaries differently for the Cephalopoda and for the benthos (especially for Bivalvia and Foraminifera).

VOLGIAN AGE

We will begin our survey of the Boreal zoogeographic realm with the second half of middle Volgian time, since not all the features of this realm can be brought to light for the late Volgian period due to the regression of the sea in Europe.

In the second half of the middle Volgian the Boreal zoogeographic realm was characterized by the development of ammonites Dorsoplanitidae, Virgatitinae, and the first Craspeditidae, belemnites of the family Cylindroteuthidae, and bivalves of the groups *Buchia, Arctotis,* certain Ostreidae, *Isognomon,* and Pectinidae *(Boreionectes).* Especially characteristic among the Foraminifera were the families Nodosariidae, Lituolidae, Ammodiscidae, Polymorphinidae, and Textulariidae. Meanwhile the belemnite subfamily Cylindroteuthinae and the brachiopod family Boreiothyridae were distributed only in the Arctic Region. The foraminifers Discorbidae and Miliolidae occur exclusively in the European seas, while the families Ceratobulimidae, Reophacidae, Trochamminidae, and Ataxophragmiidae are found in Siberia and in the Pechora Basin.

Differences between the Boreal-Atlantic and Arctic regions are quite clearly defined within the Boreal Realm. In the Boreal-Atlantic Region around the 30th–35th parallel at that time the Portlandian of southern England developed with its typical *Dorsoplanites, Zaraiskites, Crendonites,* and *Titanites*. Dominant among the belemnites were the subgenera *Pachyteuthis* s. str., *Simobelus,* and *Lagonibelus* s. str.

Similar cephalopod complexes are found in eastern Greenland and on the east slope of the Cis-Polar Urals, but in these areas representatives of the Arctic fauna already emerge, e.g. ammonites of the genus *Laugeites.*

The bivalve mollusks of the Cis-Polar Urals differ from those occurring in the north of Middle Siberia. Middle Volgian sediments of the Urals yield different species of Ostreidae, Astartidae (including the subfamily Eriphylinae that is unknown in the north of Siberia), *Tancredia,* and others. *Arctotis* and *Boreioxytoma,* plus a number of endemic species of other genera are found only in the north of Middle Siberia in middle Volgian beds. The north Siberian bivalve complexes are in turn similar to the east Greenland complexes, although the latter are less diversified. At the same time, in all three regions mentioned the generic complexes of bivalves are very similar and have some species in common. This prompts us to include eastern Greenland and the Cis-Polar Urals in the Arctic paleozoogeographic region, in which the east slope of the Urals is classed as a province.

The middle Volgian brachiopods in the eastern foothills of the Urals are also entirely represented, according to Dagis (1968), by Arctic forms: *Uralorhynchia, Fusirhynchia, Ptilorhynchia, Pinaxiothyris, Uralella,* and *Taimyrothyris.*

The middle Volgian foraminifer complexes of the Cis-Polar Urals display a close similarity to the complexes in the Pechora Basin where the composition of families, genera, and species is concerned. The following genera and species inhabited these basins: *Ammodiscus giganteus* Mjatl., *Ammobaculites haplophragmoides* Furss. and Pol., *Saracenaria prolata* K. Kusn., and *S. pravoslavlevi* Furss. and Pol. When we compare the complexes of these areas with those of the north of Middle Siberia, we find fewer common genera and species. On the basis of these data we can group the basins of the Pechora and Trans-Urals into a single province according to foraminifers. This makes it necessary to identify a special Urals-Greenland Province, occupying an intermediate position between the Boreal-Atlantic and Arctic regions, but clearly gravitating toward the former in terms of Cephalopoda. Apparently we should also include in this province the western part of the West Siberian Sea, which is subjected to the current coming from the west and is separated from the eastern part of this sea by a region of considerable depths. It must be remembered, however, that at the end of the Jurassic and beginning of the Cretaceous eastern Greenland, the Cis-Polar Urals, and the Pechora Basin were situated at roughly the same latitude (between the 50th and 60th parallels).

A peculiar faunal complex settled in the Middle Russian Sea, which there is every reason to assign to an independent East European zoogeographic province of the Boreal-

Atlantic Region. Living here alongside *Zaraiskites* and *Dorsoplanites* were the endemic genera *Virgatites* and *Epivirgatites;* among the belemnites endemic *Holcobeloides* ex gr. *volgensis* appeared together with *Lagonibelus* ex gr. *magnificus.*

The sea in the Pechora Basin should also have been referred to the Urals-Greenland Province, judging from the resemblance between the foraminifers in the Pechora and those in the Trans-Urals (Ivanova, 1971). But the ammonites, belemnites, and bivalves are so similar to the Middle Russian forms that we must assign the Pechora Sea to the East European Province. The differences between the foraminifer complexes may be due simply to facial factors – the sea was shallower in the middle belt of Russia and on the periphery of the Pechora Depression, where macrofauna has been collected in exposures and relatively deep in the central parts of the depression, where boreholes have been sunk and foraminifers studied in the cores.

The sea of northern Poland with its *Zaraiskites, Virgatites,* and foraminifers, which have a 70% identical species composition to that of the foraminifers in the Middle Russian Basin (Kuznetsova, 1965), can also quite safely be referred to the East European Province in the Volgian age, possibly as a separate Polish subprovince.

In the Arctic Region a province can be singled out approximately between the 60th and 70th parallels of the North Siberian Province, with a supremacy of the ammonites *Taimyrosphinctes,* plus distinctive *Dorsoplanites,* and also *Epivirgatites* and *Laugeites,* with belemnite complexes clearly dominated by *Cylindroteuthis, Arctotis,* and *Lagonibelus* ex gr. *elongatus,* and with certain species of *Pachyteuthis* s. str., *Simobelus,* and *Boreioteuthis.* Only in the north of Middle Siberia in middle Volgian sediments are such bivalves as *Arctotis* and *Boreioxytoma* widely distributed, and also original Ostreidae, *Boreionectes, Isognomon,* and others. Among the Brachiopoda, *Lenothyris* is found only here, along with the family Boreiothyridae. Very specific communities of foraminifers, containing a high proportion of endemic species (39–48%), lived in the basins of the north of Middle Siberia in middle Volgian time. The ranges of the species of the families Trochamminidae, Ataxophragmiidae, Reophacidae, and Astrorizidae are bound by the limits of the North Siberian Province. Actually, the foraminifer complexes of the north of Middle Siberia, Western Siberia, and the Pechora Basin show a similarity to the complexes in the middle part of the Russian Plain and England, which induced Ivanova (1969) to classify them just as subregions.

At the end of the middle Volgian the fauna of the North Siberian Province came to include some Tethyan elements – *Virgatosphinctes,* which immigrated here from the Indo-Pacific Region. The areas of Spitsbergen in the west and the lower reaches of the Lena in the east should be assigned to the North Siberian Province along with the seas of Taimyr, the eastern part of Western Siberia, and the Yenisei-Lena trough. In view of its bivalve fauna, eastern Greenland should also be referred to the same province (Zakharov, 1970).

Northeast Asia, Alaska, and northern Canada constituted the Chukchi-Canadian Province, situated north of the 70th parallel around the North Pole as it was positioned at the end of the Jurassic and showing (as far as can be ascertained from the data available) a very greatly depleted fauna. Ammonites and belemnites are rare here, represented by a few genera and species from the number characteristic for the North Siberian Province;

Buchia predominates in absolute terms, while other genera that are widespread in the north of Siberia are either absent or extremely scant.

Western Canada also belonged to the Chukchi-Canadian Province in the Volgian age. Farther south, in the western part of the USA, the ammonites and some of the belemnites characteristic for the Tethys appear, but still mixed with boreal belemnites and *Buchia.* We can thus consider this area as a separate Boreal-Pacific Province, which belongs to the Arctic zoogeographic region.

It could be that the Soviet Far East should be referred to this province, as its seas also contained Tethyan ammonites along with belemnites and *Buchia* typical for the Arctic Region.

In late Volgian time the Boreal Realm was defined according to the development of the Craspeditidae among the ammonites, the Cylindroteuthidae among the belemnites, *Buchia* among the bivalves, and agglutinated forms and Nodosariidae among the foraminifers. Only the Arctic Region was inhabited by Cylindroteuthinae, immigrant Virgatosphinctinae and Berriasellidae from the Tethyan Realm, bivalves of the genus *Arctotis,* and brachiopods of the family Boreiothyridae.

The fauna of the late Volgian seas in Western Europe is unknown due to the regression of the marine basins. Marine conditions were probably preserved only within the present-day North Sea. Indications by Casey (1962) that in England upper Volgian *Craspedites* have been found in beds characterized by *Acroteuthis* are still to be confirmed, as we have mentioned. Still, it may be assumed that a Boreal-Atlantic Region did exist in the late Volgian too. We may place in it the East European Province, that occupied a bay open to the north on the Russian Plain and was settled by ammonites belonging to the Craspeditidae *(Craspedites, Kachpurites, Garniericeras)* plus *Laugeites,* belemnites of the subgenera *Microbelus, Acroteuthis* s. str., and *Boreioteuthis,* bivalves of the genus *Buchia,* and, among foraminifers, sessile tests of the family Placopsilinidae (Moscow area) and a very meager complex made up of species that had survived from the middle Volgian (Middle Volga area).

A similar fauna inhabited the eastern foothills of the Urals, but here they intermingled with Arctic elements: brachiopods *Uralorhynchia* and *Fusirhynchia* and, at the end of the late Volgian, belemnites typical for the Arctic Region.

Unfortunately, little is known about the late Volgian fauna of eastern Greenland. There are records of *Craspedites,* a particular wealth of *Laugeites, Virgatosphinctes* (?), and some Dorsoplanitidae, all of which enables us to draw a parallel with the Portlandian of England. Thus, there is a basis for placing the late Volgian seas off the coasts of eastern Greenland and the Eastern Urals in the Urals-Greenland Province of the Boreal-Atlantic Region. Perhaps also to be included here is the sea in the Pechora Basin, although there are hardly any data available on its fauna.

In the Arctic Region the late Volgian fauna of the North Siberian zoogeographic province was unique. Together with Craspeditidae, among which only *Kachpurites* was absent (this genus is typical for the East European Province), occur the last representatives of the Dorsoplanitinae, *Chetaites,* as well as an abundance of Virgatosphinctinae and occasional Berriasellidae. As is known, the last two groups are characteristic for the Tithonian of the Tethyan Realm, so that a special explanation is required for their appearance inside the Arctic Basin. All that was stated in Chapter VI on the paleotemperature regime of the north Siberian seas indicates that the penetration of the Virgatosphinctinae and Berriasellidae into the Arctic was related not to a warming of the Arctic seas but rather to adaptation of the Virgatosphinctinae, in the process of evolution, to living in colder waters (Mesezhnikov, Saks, and Shul'gina, 1969). This conclusion is borne out by the fact that the difference between the Tethyan and Boreal faunas as a whole was not merely maintained but even sharpened.

The majority of the Siberian Virgatosphinctinae are forms similar to the Indian and Argentinian species. It is very unlikely that they reached the Arctic via the northern part of the Pacific, i.e. through the coldest part of the Cis-Polar Province. Since Virgatosphinctinae are also present on Spitsbergen and, theoretically, in eastern Greenland, it is more probable that they immigrated to the north with the warm current from Central America, which in the Late Jurassic belonged to the Indo-Pacific zoogeographic region.

The late Volgian belemnites, bivalves, and brachiopods of northern Siberia closely resemble the forms making up the complex that settled in the seas of northern Siberia in middle Volgian time. The late Volgian foraminifers in northern Siberia to the eastern foothills of the Urals inclusive form a very persistent complex with *Ammodiscus veteranus* Kosyr., *Haplophragmoides emeljanzevi* Schleif., and *Trochammina* ex gr. *rosacea* Zasp. in the lower part of the upper Volgian strata and with *Trochammina rosaceaformis* Rom. and *Orientalia* (?) *baccula* (Schl.) in their upper part (this last complex has been identified so far only in the north of Middle Siberia.

Also belonging to the North Siberian Province of the Arctic Region in the late Volgian was the area of Spitsbergen with the same genera and species of ammonites, *Buchia*, and foraminifers as in Siberia.

The Chukchi-Canadian Province kept the same outline and character in late Volgian time. *Buchia* dominated the fauna here. The single find in western Canada of a late Tithonian Tethyan ammonite *(Notostephanus)*, which is, moreover, badly preserved does not indicate that the boundaries of this province should be reexamined.

In the Boreal-Pacific Province in the USA the importance of the boreal elements increased still further, and in California the boreal belemnites became especially diverse (representatives of the subgenera *Cylindroteuthis* s. str. and *Arctoteuthis*). *Buchia* was also plentiful. It was possibly just at this time that the boreal *Cylindroteuthis* and *Buchia* reached Mexico, which was situated north of the 40th parallel at the end of the Jurassic. Cylindroteuthidae may also have existed in this period in the Soviet Far East.

BERRIASIAN AGE

The Boreal zoogeographic realm is just as clearly differentiated faunistically from the Tethyan Realm in the Berriasian age as it is in the Volgian. Ammonites of the family Craspeditidae, belemnites of the family Cylindroteuthidae, and, among the bivalves, *Buchia* and characteristic *Boreionectes* from the Pectinidae predominate here. Cylindroteuthinae, Boreiothyridae, and *Arctotis* from among the Bivalvia are known only from the Arctic Region.

The beginning of the Berriasian age in the Boreal-Atlantic Region was marked by the distribution of new boreal genera of ammonites *(Paracraspedites* and *Subcraspedites)* and belemnites of the subgenus *Acroteuthis* s. str. in northeast England. In Poland and European Russia a marine lower Berriasian is not known.

From the beginning of the Cretaceous period the East Greenland Sea was inhabited by *Surites* and *Subcraspedites,* plus, a little later, *Praetollia,* a complex very similar to that in northern Siberia. In the eastern foothills of the Urals and in Western Siberia the early Berriasian fauna is hardly anywhere identifiable with certainty. Records do exist, however, of *Praetollia* and *Chetaites* ex gr. *sibiricus* Schulg., and therefore we may assign these areas to the Arctic Region. The presumably early Berriasian belemnite complex that was present in the Cis-Polar Urals contained both Eastern European (*Microbelus*) and typically Arctic *(Cylindroteuthis* s. str., *Arctoteuthis, Lagonibelus* ex gr. *elongatus)* forms. We are thus justified in establishing a separate province in the Atlantic part of the Arctic Basin in the early Berriasian: the Urals-Greenland Province, by analogy with the Volgian age.

In the North Siberian Province in the north of Middle Siberia there was a fauna at the beginning of the Berriasian that differed from the late Volgian one. The Craspeditidae were represented by new genera: *Surites, Subcraspedites, Paracraspedites,* and *Praetollia.* The Virgatosphinctinae disappeared altogether, and of the Berriasellidae only one genus of American origin, *Argentiniceras* (?), has been discovered. Belemnites make up a complex that is similar (though greatly impoverished) to the Volgian complex, with the same subgenera and most of the same species. True Cretaceous species are by now present among the bivalves, but upper Volgian forms figure as well. Cretaceous forms of foraminifers also appeared in the early Berriasian, mingled with substantial amounts of Volgian elements. Many late Volgian species persisted in the basins of Western and Middle Siberia in the early Berriasian.

In early Berriasian time the seas of the Chukchi-Canadian Province were characterized mainly by *Buchia;* only in western and northern Canada did the ammonites *Surites* and *Subcraspedites* join these. In western Canada the boundaries of the Chukchi-Canadian Province shifted northward from their position in late Volgian time. Tethyan ammonites – *Berriasella, Pseudoargentiniceras* – penetrated into the southwest part of British Columbia from the south, and so we can place this sector of the sea in the Boreal-Pacific Province.

The seas of the West European Province of the Boreal-Atlantic Region were settled in the middle Berriasian by *Hectoroceras* and *Surites,* immigrants from the north. The genus *Praetollia* (?) even reached Poland, while the marine basin which appeared in the northern part of Poland was inhabited for the most part by a Mediterranean fauna. This is why it is extremely arbitrary to refer the Polish sea to the Boreal Realm. Nevertheless, in view of the fact that such typical representatives of the Middle Russian fauna as *Riasanites* are present in this sea and typically boreal forms of foraminifers predominate (Sztejn, 1969), there are certain grounds for including the Polish Basin in the Boreal Realm as a separate Polish Province.

The sea which transgressed into the territory of the Russian Plain in the middle Berriasian also had many Mediterranean representatives of ammonites *(Euthymiceras,* *Neocomites).* The most characteristic ammonites of the Ryazan horizon, *Riasanites,* also belong to the Tethyan Berriasellidae. These commingle with boreal *Surites* and *Subcraspedites, Buchia,* and, among the belemnites, the subgenera *Microbelus, Acroteuthis* s. str., and *Boreioteuthis,* surviving from late Volgian time, but in some cases with new species. All this carves out a definite East European Province, to which we must also assign the sea in the region of Mangyshlak.

There is good reason to place the Pechora Basin, in which *Riasanites* has by this time disappeared in the Pechora-Greenland Province of the Boreal-Atlantic Region together with the seas in the regions of Novaya Zemlya, Spitsbergen, and eastern Greenland. The most important ammonites here, judging from the Greenland sections, were forms of *Hectoroceras;* also present are *Praetollia, Surites, Subcraspedites,* and many *Buchia,* but the belemnites that dominate are still those characteristic for the Boreal-Atlantic Region, i.e. *Acroteuthis* s. str.

To the east of the Urals lay the Arctic Region with an ammonite complex similar in composition to that of the Boreal-Atlantic Region *(Hectoroceras, Surites, Subcraspedites, Praetollia)* but with a completely different belemnite complex from that in the west, a poorer one, yet with some hangers-on from the Volgian age *(Cylindroteuthis* s. str., *Arctoteuthis, Lagonibelus* ex gr. *elongatus);* the bivalves (*Arctotis, Liostrea anabarensis* Bodyl., and other species) and the brachiopods *(Ptilorhynchia, Uralorhynchia, Taimyrothyris, Siberiothyris)* are typically Arctic. This region includes the West Siberian Province, characterized by a specific complex of foraminifers with *Gaudryina gerkei* Vass. and important new species of agglutinated genera: *Cribrostomoides, Ammobaculites, Recurvoides,* and *Trochammina.* Present only here are forms of the genera *Haplophragmium* and *Reophax.* In the North Siberian Province there developed a complex of foraminifers with *Gaudryina gerkei* Vass., *Trochammina parviloculata* Bass., and *Lenticulina pseudoarctica* E. Ivan. Despite its containing species in common with those of Western Siberia, this complex features distinctive representatives of the families Nodosariidae, Ataxophragmiidae, Lituolidae, and others. Agglutinated forms predominate numerically in the complex, but the calcareous forms are very diverse and often account for a good proportion.

The Chukchi-Canadian Province kept the same boundaries in the middle Berriasian as it had at the beginning of this age and also preserved the same faunal complex (as far as the data available show). The major forms are *Buchia, Surites,* and *Subcraspedites,* and there are occasional finds of *Hectoroceras.*

The Boreal-Pacific Province contained a mixture of *Buchia, Arctoteuthis, Simobelus,* and Tethyan ammonites *(Berriasella, Spiticeras, Neocomites).*

At the end of the Berriasian in the West European Province of the Boreal-Atlantic Region *Surites* and *Subcraspedites* persisted from among the ammonites, *Tollia* appeared, and only *Acroteuthis* s. str. figured among the belemnites. In the Polish Province the proportion of the boreal genera *Surites, Subcraspedites,* and *Tollia* (?) increased among the ammonites, although boreal belemnites and *Buchia* did not penetrate here.

The ammonite complexes in the East European Province show a supremacy of boreal *Surites* and *Subcraspedites.* Belemnites were represented almost exclusively by *Acroteuthis* s. str. and *Boreioteuthis.* The only immigrants from the Arctic Region were

Arctoteuthis from among the belemnites and *Bojarkia* from among the ammonites.

The Pechora-Greenland Province was characterized in the late Berriasian by *Tollia* in addition to *Surites* and *Subcraspedites. Acroteuthis* s. str. remained dominant in the belemnite complexes.

What gives the Arctic Region a distinctive stamp in the late Berriasian is the survival of the belemnites *Cylindroteuthis* s. str., *Arctoteuthis,* and *Lagonibelus* with the simultaneous emergence of *Acroteuthis* s. str. Predominantly composed of *Surites* and *Subcraspedites,* the ammonite complexes become enriched with representatives of the Tolliinae *(Tollia, Bojarkia),* and the bivalves are joined by *Arctotis, Boreionectes,* and many endemic species.

The West Siberian Province is identified, as before, by the composition of the foraminifers. It is characterized by a complex with *Reinholdella tatarica* Mjatl. The first representatives of the genera *Hoeglundina, Bathysiphon,* and *Discorbis* appear (northwest of Western Siberia), while *Trochammina polymera* Dubr. and also species whose range is confined to this province became plentiful.

The North Siberian Province is also characterized by a complex with *Reinholdella tatarica* Mjatl., but this has a different composition from the West Siberian complex. Here we have the first emergence of the family Cornuspiridae (genus *Cornuspira*), sessile tests of the families Nodosariidae (genus *Tentifrons*) and Polymorphinidae (genus *Bullopora*). Also new on the scene were a large number of species whose distribution is limited to this province.

The Chukchi-Canadian and Boreal-Pacific provinces remained unchanged in the late Berriasian. All that may be noted is the fact that Tethyan ammonites such as *Euthymiceras* reached even as far as the basin of the Anadyr.

VALANGINIAN AGE

In the Valanginian the supremacy among the ammonites in the Boreal Realm passed to the Polyptychitidae, along with which the subfamily Tolliinae (Craspeditidae) persisted at the beginning of the Valanginian and, just in the Boreal-Atlantic Region, the Garniericeratinae. Belemnoidea were still represented by Cylindroteuthidae, of which only the subfamily Cylindroteuthinae was preserved in the Arctic Region. Among the Bivalvia, as before, *Buchia* and *Boreionectes* were specific to the Boreal Realm, while among the Brachiopoda, the Boreiothyridae were restricted to the Arctic Region.

The West European Province (northeast England, Holland, northern part of West Germany) in the Boreal-Atlantic Region was settled by Polyptychitidae, which in the early Valanginian cohabited with *Platylenticeras, Tolpeceras, Tollia,* and *Neotollia* and with belemnites of the subgenus Acroteuthis s. str. Via the strait between southern England and northern France Polyptychites, Platylenticeras, and Tolypeceras reached the seas of Western Tethys. In the Polish Province, along with *Polyptychites, Platylenticeras,* and the Mediterranean *Neocomites,* we may observe the presence of immigrant *Temnoptychites (?)* from the east. It should be stressed at this point that *Buchia* is absent both in the Berriasian and in the early Valanginian in Poland.

In the East European Province the dawn of the Valanginian saw the emergence of a number of new endemic genera of ammonites: *Pseudogarnieria, Proleopoldia, Menjaites, Temnoptychites, Stchirowskiceras,* and others, that did not spread (except for *Temnoptychites*) outside this province. In the later phases of the early Valanginian the East European Province was characterized by the development of Polyptychitidae, *Temnoptychites, Menjaites, Buchia,* and belemnites *Acroteuthis* s. str. Here, however, we do not find any *Tollia,* a genus which is typical of the Arctic Region but which, as we have seen, did fan out into the seas of the West European Province.

Within the Pechora-Greenland Province, which, as before, we should apparently include in the Boreal-Atlantic Region, the fauna of the early Valanginian is distinguished by an abundance of *Temnoptychites, Polyptychites, Acroteuthis* s. str., and *Buchia.*

In the Arctic Region, above all in the North Siberian Province, ammonites *Neotollia* and *Tollia* predominated at the beginning of the Valanginian, while in the West Siberian Province the richest element was *Temnoptychites;* this genus is found relatively rarely in the east and not at the very beginning of the Valanginian. Polyptychitidae also seem to appear here later than in the west. *Acroteuthis* s. str. assumes supremacy among the belemnites, and commingles with quite a wealth of *Boreioteuthis* and also with *Arctoteuthis,* which is absent in the Boreal-Atlantic Region. *Buchia* and *Arctotis* are plentiful, as in the Berriasian. Brachiopods are represented by *Ptilorhynchia, Fusirhynchia, Pinaxiothyris, Taimyrothyris,* and *Siberiothyris.*

The circumpolar Chukchi-Canadian Province showed great stability at the end of the Jurassic and beginning of the Cretaceous. The major forms at the beginning of the Valanginian were *Buchia,* along with occasional *Tollia, Neotollia, Temnoptychites,* and Polyptychitidae. In western Canada this fauna began to be intermixed with Tethyan ammonites *(Neocomites).* In the Boreal-Pacific Province Tethyan, or more exactly Indo-Pacific forms *(Kilianella, Sarasinella, Thurmanniceras)* already clearly predominated, although boreal genera reached as far as the area of Vancouver Island *(Temnoptychites)* and even to California *(Tollia, Neotollia).* Boreal *Buchia* and belemnites *(Acroteuthis* s. str., *Boreioteuthis)* also spread south to California inclusive.

In summing up, we may note that the division of the Boreal Realm in the Late Jurassic into Boreal-Atlantic and Arctic zoogeographic regions was maintained during the entire period of geological time under examination. The boundary between these regions seems to have shifted slightly westward from the middle of the Berriasian – from the deepwater region in the West Siberian Sea to the Urals. The subdivision of these regions into provinces also remained constant, with just slight shifts of various provincial boundaries (for example, to the north at the beginning of the Berriasian between the Chukchi-Canadian and Boreal-Pacific provinces). Due to the lack of specific data, the paleozoogeographic zoning of the early Berriasian proves to be less reliable.

CONCLUSION

The data we have presented in the foregoing chapters indicate quite clearly that an independent Berriasian stage may be identified within the Boreal paleozoogeographic realm, no less justifiably than other stages of the Upper Jurassic and Neocomian. Studies of the Jurassic-Cretaceous boundary layers in the Boreal Realm and of their characteristic fauna have confirmed that the Berriasian age was a specific phase in faunal development, particularly where ammonites are concerned, as their complexes are clearly set apart from both the Volgian and the Valanginian complexes. Just as in the Mediterranean Region, where the layers transitional between the Jurassic and Cretaceous are considered as a separate Berriasian stage, in the Boreal Berriasian the typically Jurassic species disappear and purely Berriasian species emerge, to be replaced by a new ammonite complex at the boundary with the Valanginian. This switchover is so clear-cut that there is every reason to regard the Berriasian as a stage in its own right.

The lower boundary of the Berriasian can be traced quite definitely in all paleozoogeographic belts according to the disappearance of such groups of ammonites as the Virgatosphinctinae. The upper boundary is also established more or less simultaneously in the Boreal and Tethyan realms, though it is not quite as distinct as the lower one. All paleozoogeographic belts are characterized by representatives of the genus *Polyptychites*, which are everywhere distributed slightly above the boundary layers of the Berriasian and Valanginian. We are therefore to assume that the Berriasian deposits were formed more or less at the same time all over the world, and hence the Berriasian is to be considered as a stage on the unified world scale. The other faunal groups (belemnites, bivalves, brachiopods, foraminifers) behave differently. The Berriasian and Valanginian complexes are always easy to differentiate, but at the boundary between the Volgian and Berriasian the changeover is much more weakly expressed and does not always coincide in time for the different groups.

In establishing the boundaries of any unit in the Mesozoic, but especially that between systems, we must look to the ammonites, as a group that depends least of all on facial conditions, being able to spread far and wide owing to their free-swimming mode of life or due to the action of currents, which carried off the empty shells. The other groups play an auxiliary role in broad correlations, particularly the benthic bivalves, brachiopods, and foraminifers, whose distribution is very closely tied to facies. If determinations are made on the basis of these groups, the boundaries of stratigraphic units are seen to slide, temporally speaking.

According to the ammonite complex developed in the Boreal Berriasian, a boundary of higher rank is traced more distinctly at the base of the Berriasian than between the Berriasian and Valanginian, and therefore it is advisable to place the Berriasian stage at the base of the Cretaceous system.

The Boreal Berriasian is divided into four zones: the lower *Chetaites sibiricus* zone, roughly correlatable with the *Berriasella grandis* zone in the stratotype of the Berriasian, and three zones corresponding to the *Berriasella boissieri* zone of the stratotype: *Hectoroceras kochi* (hypothetically *Riasanites rjasanensis* on the Russian Plain), *Surites analogus* (lower part of the *Surites spasskensis* zone on the Russian Plain), and *Bojarkia mesezhnikowi* (*Bojarkia payeri* in Greenland and the Urals). The bottom of the Valanginian is represented by the *Neotollia klimovskiensis* zone in Siberia, by the *Platylenticeras gevrilianum* zone in Western Europe, and by the *Pseudogarnieria undulato-plicatilis* zone on the Russian Plain.

The type of marine fauna existing at the end of the Jurassic and beginning of the Cretaceous shows how different from the Tethyan complexes were the faunistic complexes of the Boreal Realm, which developed at lower environmental temperatures around the geographic pole, that at that time was situated north of Bering Strait. On the basis of the fauna we distinguish inside the Boreal Realm Boreal-Atlantic and Arctic paleozoogeographic regions, each with a number of provinces. The first of these regions had temperature conditions characteristic for the present-day subtropical seas, while the second displayed a temperate marine regime.

The Boreal-Atlantic Region is split up into paleozoogeographic provinces: West European, East European, Polish (from the middle of the Berriasian), Greenland-Urals (in the Volgian age and at the beginning of the Berriasian), and Greenland-Pechora (from the middle Berriasian); the Arctic Region has the North Siberian, Chukchi-Canadian, Boreal-Pacific, and, from the middle of the Berriasian, the West Siberian provinces.

We have seen which aspects require further study. First and foremost, bearing in mind the need for a stratigraphic classification of sedimentary rocks in boreholes, we must stress the importance of identifying and describing the Foraminifera in the Berriasian of the European part of the USSR, on the east slope of the Urals, and outside the USSR — in North America, Greenland, and in northwestern Europe. Other essential tasks are a study of the Berriasian-Valanginian boundary layers on the Russian Plain, a search for continuous sections of Volgian and Berriasian sediments, an investigation of ammonites of southern origin, and their correlation with the Crimean-Caucasian complexes. In Siberia finds of Tethyan ammonites in the lower horizons of the Berriasian would be most significant, as these would make correlations of the Siberian and Tethyan Berriasian more accurate.

Our study of the Boreal Berriasian has underlined the need to organize a similar investigation of the overlying Valanginian stage within the framework of the Boreal paleozoogeographic realm. It would be very useful to conduct parallel research of marine boundary layers between the Jurassic and Cretaceous and of continental deposits and their fauna and flora, using the paleomagnetic method for correlations of the marine and continental strata along with the spore-pollen complexes. For this, a paleomagnetic scale must be worked out based on inversions of the magnetic field.

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PLATES

PLATE I

Figure 1. *Subcraspedites (Subcraspedites) anglicus* Schulgina n. sp. Specimen 1/10118, holotype. Reduced by 46 mm.* 1a) lateral; 1b) view from aperture; 1c) view from venter. The outer whorl of this specimen did not fit into the drawing. Boyarka River. *Hectoroceras kochi* zone.

Figure 2. *Subcraspedites (Subcraspedites) anglicus* Schulgina n. sp. Specimen 2/10118. 2a) lateral; 2b) view from aperture; 2c) view from venter. Paks Peninsula (Cape Urdyuk-Khaya). *Hectoroceras kochi* zone.

PLATE II

Figure 1. *Subcraspedites (Subcraspedites) plicomphalus* (Sowerby). Specimen 3/10118. 1a) lateral; 1b) view from aperture; 1c) view from venter. Boyarka River in a talus of beds with *Hectoroceras kochi.*

Figure 2. *Subcraspedites (Subcraspedites) anglicus* Schulgina n. sp. Specimen 4/10118. 2a) lateral; 2b) view from aperture. Boyarka River, in a talus of beds with *Hectoroceras kochi.*

PLATE III

Figure 1. *Subcraspedites (Subcraspedites) anglicus* Schulgina n. sp. Specimen 5/10118. 1a) lateral; 1b) view in section. Boyarka River, in a talus of beds with *Hectoroceras kochi.*

PLATE IV

Figure 1. *Subcraspedites (Subcraspedites) anglicus* Schulgina n. sp. Specimen 6/10118. Reduced by 10 mm. Lateral view. Boyarka River, in a talus of beds with *Hectoroceras kochi.*

Figure 2. *Hectoroceras kochi* Spath. Specimen 53/10118. 2a) lateral; 2b) view from venter. Boyarka River. Zone of the same name.

PLATE V

Figure 1. *Subcraspedites (Borealites) suprasubditus* (Bogoslovsky). Specimen 7/10118. Lateral view. Pravaya Boyarka River. Lower part of the *Hectoroceras kochi* zone.

Figure 2. *Subcraspedites (Borealites) suprasubditus* (Bogoslovsky). Specimen 8/10118. 2a) lateral; 2b) view from aperture. Pravaya Boyarka River. Lower part of the *Hectoroceras kochi* zone.

Figure 3. *Surites (Surites) spasskensis* (Nikitin). Specimen 19/10118. Lateral view. Levaya Boyarka River. Lower part of the *Hectoroceras kochi* zone.

Figure 4. *Tollia tolli* Pavlow. Specimen 37/10118. 4a) lateral; 4b) view from venter. Paks Peninsula (Cape Urdyuk-Khaya). *Bojarkia mesezhnikowi* zone.

Figure 5. *Neotollia* aff. *klimovskiensis* Krimholz. Specimen 54/10118. 5a) lateral; 5b) view from aperture. Anabar River. *Neotollia klimovskiensis* or *Polyptychites stubendorffi* zone.

PLATE VI

Figure 1. *Praetollia maynci* Spath. Specimen 55/10118. Lateral view.

Figure 2. *Subcraspedites (Ronkinites) rossicus* Schulgina n. sp. Specimen 9/10118. 2a) lateral; 2b, c, d) inner whorl of same specimen, from three sides. Boyarka River, in a talus of beds with *Hectoroceras kochi.*

* Unless otherwise mentioned, all the drawings are natural size.

Figure 3. *Subcraspedites (Borealites) suprasubditus* (Bogoslovsky). Specimen 10/10118. Lateral view. Levaya Boyarka River. Lower part of the *Hectoroceras kochi* zone.

Figures 4–6. *Subcraspedites (Borealites) suprasubditus* (Bogoslovsky). Lateral view. 4) specimen 11/10118; 5) specimen 12/10118; 6) specimen 13/10118. Levaya and Pravaya Boyarka rivers. Lower part of the *Hectoroceras kochi* zone.

PLATE VII

Figures 1–3. *Subcraspedites (Ronkinites) rossicus* Schulgina n. sp. 1) specimen 14/10118: 1a) lateral; 1b) view from venter. Boyarka River, exposure 16, in a talus of beds with *Hectoroceras kochi*,. 2) specimen 15/10118, lateral, with the body chamber. Boyarka River. *Surites analogus* zone. 3) specimen 16/10118, holotype: 3a) view from right side of outer whorl; 3b) view from left side; 3c) view from ventral side of inner whorl. Boyarka River. *Surites analogus* zone.

PLATE VIII

Figure 1. *Paracraspedites stenomphaloides* Swinnerton. Specimen 17/10118. 1a) view from right side; 1b) view from venter. Kheta River. *Chetaites sibiricus* zone.

Figure 2. *Paracraspedites* cf. *stenomphaloides* Swinnerton. Specimen 18/10118. Cast with imprint. Maimecha River. *Surites analogus* zone.

PLATE IX

Figure 1. *Surites (Surites) spasskensis* (Nikitin). Specimen 10/10118. 1a) view from right side; 1b) view from venter; 1c) view from left side. Boyarka River. *Hectoroceras kochi* zone.

Figure 2. *Surites (Surites) subanalogus* Schulgina n. sp. Specimen 21/10118. 2a) lateral; 2b) view from venter. 2c) view from aperture. Boyarka River. *Surites analogus* zone.

PLATE X

Figure 1. *Surites (Surites) spasskensis* (Nikitin). Specimen 22/10118. 1a) view from left side; 1b) from right side. Boyarka River. *Hectoroceras kochi* zone.

PLATE XI

Surites (Surites) spasskensis (Nikitin). Specimen 23/10118. Lateral view. Levaya Boyarka River, in a talus of beds with *Hectoroceras kochi.*

PLATE XII

Figure 1. *Surites (Surites) subanalogus* Schulgina n. sp. Specimen 24/10118. Lateral view. Boyarka River. *Surites analogus* zone.

Figure 2. *Surites (Surites) subanalogus* Schulgina n. sp. Specimen 25/10118. 2a) view from right side; 2b) view from venter. Boyarka River. *Surites analogus* zone.

Figure 3. *Surites (Surites) subanalogus* Schulgina n. sp. Specimen 26/10118, holotype. 3a) view from left side; 3b) view from aperture; 3c) view from venter. Boyarka River. *Surites analogus* zone.

PLATE XIII

Figures 1, 2. *Surites (Surites)* ex gr. *analogus* (Bogoslovsky). 1) specimen 27/10118: 1a) view from left side; 1b) view from venter. 2) specimen 28/10118: 2a) lateral; 2b) view from venter: 2c, d) inner whorl, photographed from two sides. Boyarka River. *Surites analogus* zone.

PLATE XIV

Figures 1–4. *Bojarkia mesezhnikowi* Schulgina. 1) specimen 29/10118, lateral. 2) specimen 30/10118: 2a) lateral; 2b) view from venter. 3) specimen 31/10118, inner whorl of large specimen, photographed from three sides. 4) specimen 32/10118, lateral. Boyarka River. Zone of the same name.

PLATE XV

Figure 1. *Argentiniceras* (?) n. sp. Specimen 36/10118. 1a) view from right side; 1b) view from venter; 1c, d, e) inner whorls photographed from three sides. Kheta River. *Chetaites sibiricus* zone.

Figure 2. *Bojarkia mesezhnikowi* Schulgina. Specimen 33/10118. Lateral view. Boyarka River. Zone of the same name.

Figure 3. *Bojarkia* sp. juv. (cf. *payeri* Toula). Specimen 34/10118. 3a) lateral; 3b) view from venter. *Bojarkia mesezhnikowi* zone.

PLATE XVI

Figures 1, 2. *Bojarkia bodylevskii* Schulgina n. sp. 1) specimen 35/10118, holotype: 1a) view from left side; 1b) view from venter. 2) specimen 35a/10118: 2a) lateral; 2b) view from venter. Boyarka River. *Bojarkia mesezhnikowi* zone.

PLATE XVII

Figure 1. *Tollia tolli* Pavlow. Specimen 38/10118. 1a) lateral; 1b) view from aperture. Anabar River. *Neotollia klimovskiensis* (?) zone.

PLATE XVIII

Figure 1. *Tollia* aff. *tolli* Pavlow. Specimen 39/10118. 1a) view from right side of outer whorl; 1b, c) inner whorls. Paks Peninsula (Cape Urdyuk-Khaya). *Bojarkia mesezhnikowi* zone.

Figure 2. *Tollia tolli* Pavlow. Specimen 40/10118. 2a) view from left side; 2b) from venter; 2c) from aperture. Paks Peninsula (Cape Urdyuk-Khaya). *Bojarkia mesezhnikowi* zone.

Figure 3. *Neotollia klimovskiensis* (Krimholz). Specimen 43/10118, shown from two sides. Bol'shaya Romanikha River. Zone of the same name.

PLATE XIX

Figure 1. *Tollia emeljanzevi* Voronez. Specimen 41/10118. Lateral view. Paks Peninsula (Cape Urdyuk-Khaya). *Bojarkia mesezhnikowi* zone.

Figure 2. *Tollia pakhsaensis* Voronez. Specimen 42/10118. 2a) view from right side; 2b) from venter. Paks Peninsula (Cape Urdyuk-Khaya). *Bojarkia mesezhnikowi* zone.

PLATE XX

Figures 1, 2. *Neotollia maimetschensis* Schulgina n. sp. 1) specimen 44/10118 in a sand concretion. Outer whorl destroyed. Boyarka River, in a talus of beds of *Neotollia klimovskiensis* zone. 2) specimen 45/10118, holotype: 2a) view from right side; 2b) from aperture. Maimecha River. Lower part of the *Polyptychites stubendorffi* zone.

PLATE XXI

Figure 1. *Neotollia klimovskiana* Bodylevsky and Schulgina n. sp. Specimen 46/10118. 1a) view from right side; 1b) from aperture. Anabar River (possibly the Klimovskii ravine). Sample from Kiselev's collection, deposited with Bodylevskii, sampling site not indicated.

Figure 2. *Neotollia maimetschensis* Schulgina n. sp. Specimen 41/10118. 2a) view from left side; 2b) fragment of outer whorl, photographed from the right side. Bol'shaya Romanikha River. *Neotollia klimovskiensis* zone.

PLATE XXII

Figure 1. *Neotollia klimovskiana* Bodylevsky and Schulgina n. sp. Specimen 48/10118, holotype. Lateral view. Outer whorl of this specimen shown in Plate XXIII, Figure 1. Anabar River. *Neotollia klimovskiensis* (?) zone.

Figure 2. *Neotollia klimovskiensis* (Krimholz). Specimen from Bodylevskii's collection. 2a) lateral; 2b) view from venter. Place of occurrence unknown.

PLATE XXIII

Neotollia klimovskiana Bodylevsky and Schulgina n. sp. Specimen 48/10118, holotype. Lateral view. Inner whorl shown in Plate XXII. Anabar River. *Neotollia klimovskiensis* (?) zone.

PLATE XXIV

Figures 1, 2. *Virgatoptychites trifurcatus* Schulgina n. sp. 1) specimen 50/10118, holotype: 1a) lateral; 1b) view from aperture. Boyarka River. *Neotollia klimovskiensis zone.* 2) specimen 51/10118: 2a) lateral; 2b) view from aperture; 2c) inner whorl. Boyarka River. *Bojarkia mesezhnikowi* zone.

Figure 3. *Hectoroceras kochi* Spath. Specimen 52/10118. 3a) lateral; 3b) view from aperture. Paks Peninsula. Zone of the same name.

PLATE XXV

Figure 1. *Hectoroceras kochi* Spath. Specimen 52/10118. 1a) view from venter; 1b) lateral. Boyarka River. Zone of the same name.

PLATE XXVI

Figure 1. *Menjaites imperceptus* I. Sasonova. Venter shown in Plate XXVII, Figure 2. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 1/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 2. *Surites (Caseyiceras) caseyi* I. Sasonova. Right bank of the Oka near Chevkino, layer 5, sample 5/10223. Upper Berriasian, *Surites spasskensis* zone.

Figure 3. *Surites (Caseyiceras) caseyi* I. Sasonova. Holotype. Right bank of the Menya River near Pekhorka, Abal exposure, layer 5, sample 2/10223. Upper Berriasian, *Surites spasskensis* zone.

PLATE XXVII

Figure 1. *Menjaites imperceptus* I. Sasonova. Holotype. 1a) view from right side; 1b) view from venter; 1c) view from venter in section; 1d) view from right side of large whorl, showing the inner whorls covered with fine ribs with two constrictions; 1e) view from right side of inner whorls, three constrictions clearly visible; 1f) view from left side of inner whorls; 1g) view from ventral side of inner

whorls shown in 1e, 1f. Right bank of Menya River near Pekhorka, Abal exposure, layer 6, sample 3/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 2. *Menjaites imperceptus* I. Sasonova. View from venter. For a picture of the shell drawn from the side see Plate XXVI, Figure 1.

Figure 3. *Menjaites magnus* I. Sasonova. Inner whorls of specimen shown in Plate XXVIII, Figure 3a, 3b.

PLATE XXVIII

Figure 1. *Menjaites magnus* I. Sasonova. Holotype. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 4/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 2. *Menjaites magnus* I. Sasonova. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 9/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 3. *Menjaites magnus* I. Sasonova. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 7/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 4. *Menjaites imperceptus* I. Sasonova. Juvenile whorls with distinctly expressed constrictions. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 6/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 5. *Menjaites imperceptus* I. Sasonova. Juvenile whorls. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 8/10223. *Pseudogarnieria undulato-plicatilis* zone.

PLATE XXIX

Figure 1. *Peregrinoceras pressulum* (Bogoslovsky). Right bank of the Oka River near Chevkino, layer 5, sample 19/10223. Upper Berriasian, *Surites spasskensis* zone.

Figure 2. *Peregrinoceras bellum* I. Sasonova. Right bank of the Oka River near Chevkino, layer 5, sample 11/10223. Upper Berriasian, *Surites spasskensis* zone.

Figure 3. *Peregrinoceras subpressulum* (Bogoslovsky). Right bank of the Oka River near Chevkino, layer 5, sample 14/10223. Upper Berriasian, *Surites spasskensis* zone.

Figure 4. *Subpolyptychites distinctus* I. Sasonova. Type species and holotype. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 17/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 5. *Peregrinoceras* ind. sp. Right bank of the Oka River near Chevkino, layer 4, sample 20/10223. Upper Berriasian, *Surites spasskensis* zone.

PLATE XXX

Figure 1. *Menjaites fidus* I. Sasonova. Holotype. 1a) lateral; 1b) venter. Right bank of the Menya River near Pekhorka, Abal exposure, lower part of layer 6, sample 38/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 2. *Bogoslovskia pseudostenomphala* I. Sasonova. Holotype. Right bank of the Menya River, near Pekhorka, Abal exposure, layer 6, sample 21/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 3. *Surites pervulgatus* I. Sasonova. Holotype. Right bank of the Oka River near Chevkino, layer 5, sample 30/10223. Upper Berriasian, *Surites spasskensis* zone.

Figure 4. *Subpolyptychites orbicularis* I. Sasonova. Holotype 4a) lateral; 4b) venter; 4c) side of shell on inner whorls; 4d) view from ventral side of inner whorls. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 40/10223. *Pseudogarnieria undulato-plicatilis* zone.

PLATE XXXI

Figure 1. *Stchirowskiceras tumefactum* I. Sasonova. Holotype. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 35/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 2. *Stchirowskiceras principale* I. Sasonova. Holotype. Right bank of the Menya River near Pekhorka, Abal exposure, layer 4, sample 32/10223. *Pseudogarnieria undulato-plicatilis* zone.

PLATE XXXII

Figure 1. *Proleopoldia menensis* (Stchirowsky). Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 23/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 2. *Proleopoldia stchirowskii* I. Sasonova, Holotype. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 24/10223. *Pseudogarnieria undulato-plicatilis* zone.

Figure 3. *Surites simplex* (Bogoslovsky). Lectotype chosen by Sazonova. Photograph of the original published by Bogoslovskii (1902, pl. XIV, fig. 6a). Mouth of the Usa River, from a boulder. Sample 149, collection No. 301 of the Chernyshev Museum, Leningrad.

PLATE XXXIII

Figure 1. *Pseudogarnieria securis* I. Sasonova. Holotype. Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 27/10223. *Pseudogarnieria undulato-plicatilis* zone. Cross section shown in Plate XXXIV, Figure 3.

Figure 2. *Proleopoldia kurmyschensis* (Stchirowsky). 2a) cross section; 2b) view from venter. Side of shell shown in Plate XXXIV, Figure 1.

PLATE XXXIV

Figure 1. *Proleopoldia kurmyschensis* (Stchirowsky). Right bank of the Menya River near Pekhorka, Abal exposure, layer 6, sample 31/10223. *Pseudogarnieria undulato-plicatilis* zone. Cross section shown in Plate XXXIII, Figure 2.

Figure 2. *Menjaites imperceptus* I. Sasonova. Part of inner whorl of the shell shown in Plate XXVII, Figure 1 at a shell diameter of 45 mm (x3). On the photograph thin fascicles of threadlike ribs are seen on the shell, but the internal mold shows no imprints of such ribs (its surface is smooth).

Figure 3. *Pseudogarnieria securis* I. Sasonova. Cross section of the specimen shown in Plate XXXIII, Figure 1.

PLATE XXXV

Figures 1, 2. *Borealites radialis* Klimova n. sp. Berriasian, *Hectoroceras kochi* zone. 1a) holotype, middle whorls, view from left side; 1b) fragment of outer whorl from left side; 1c) from venter; 1d) suture line of holotype. 2a) crushed clay mold, from right side; 2b) its suture line. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

Figure 3. *Borealites mirus* Klimova n. sp. Holotype. Berriasian, *Hectoroceras kochi* zone. 3a) middle whorl from left side; 3b) fragment of outer whorl from left side; 3c) suture line, not drawn in full, at a shell diameter of 51 mm; 3d) suture line, not drawn in full, at a shell diameter of 111 mm. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

PLATE XXXVI

Figures 1, 2. *Borealites explicatus* Klimova n. sp. Berriasian, *Hectoroceras kochi* zone. 1a) holotype, view from left side; 1b) cross section. 2a) incom›lete large specimen, from left side; 2b) its suture line. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

PLATE XXXVII

Figures 1–12. *Tollia* cf. *payeri* (Toula). Berriasian, *Tollia payeri* zone. 1–4) densely ribbed specimen, view from left side; 5) sparsely ribbed specimen, from right side; 6) incomplete densely ribbed specimen, from left side; 7) two incomplete inner whorls of densely ribbed specimens; 8) fragment of outer whorl, from left side; 9) fragment of sparsely ribbed specimen, from right side; 10) fragment of middle whorl, from left side; 11) suture line of outer whorl; 12) densely ribbed specimen, from right side. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

Figures 13–15. *Neotollia densa* Klimova n. sp. 13) holotype, view from right side; 14) inner whorl, from right side; 15) suture line of holotype. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

PLATE XXXVIII

Figure 1. *Neotollia venusta* Klimova n. sp. Holotype. Lower Valanginian, *Temnoptychites insolutus* zone. 1a) inner whorl from left side; 1b) inner whorl from outer side; 1c) middle whorl from left side; 1d) middle whorl from ventral side; 1e) outer whorl from left side. See Plate XXXIX. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

PLATE XXXIX

Figure 1. *Neotollia venusta* Klimova n. sp. Holotype. Lower Valanginian, *Temnoptychites insolutus* zone. 1a) view from left side; 1b) suture line. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

PLATE XL

Figures 1–4. *Hectoroceras tolijense* (Nikitin). Berriasian, *Hectoroceras kochi* zone. 1a) medium-sized specimen, view from right side; 1b) cross section; 1c) view from venter; 1d) suture line of this specimen. 2a) juvenile specimen, view from right side; 2b) from venter. 3a) fragment of juvenile specimen, from right side; 3b) from venter. 4) incomplete specimen of medium size, from right side. Right bank of the Yatriya River, 1.8 km below the mouth of the Bol'shaya Lyul'ya.

PLATE XLI

Figure 1. *Liostrea uralensis* Zakharov n. sp. Holotype No. 410/1. 1a) left valve; 1b) right valve. Lower Cretaceous, Berriasian, *Hectoroceras kochi* zone. Cis-Polar Urals, Mauryn'ya River, right-hand tributary of the Tol'ya, 8 km from the mouth as the crow flies, layer 5 (talus).

PLATE XLII

Figures 1–8. *Liostrea lyapinensis* Zakharov n. sp. Holotype No. 410/7. 1a) left valve; 1b) right valve; 2) No. 410/8, left valve; 3) No. 410/9, left valve; 4) No. 410/11, left valve; 5) No. 410/12, right valve; 6) No. 410/10, left valve; 7) No. 410/30, left valve: 7a) inside; 7b) outside; 8) No. 410/13, left valve. Lower Cretaceous, Berriasian, *Hectoroceras kochi* zone. Cis-Polar Urals, Yatriya River, exposure 1, layer 2.

Figure 9. *Liostrea uralensis* Zakharov n. sp. No. 410/1, left valve. Occurrence as for the holotype (see legend to Plate XLI).

PLATE XLIII

Figures 1–4. *Cylindroteuthis (Cylindroteuthis) luljensis* Sachs n. sp. 1) holotype No. 86–1: 1a) view from ventral side; 1b) from left side. Cis-Polar Urals, Yatriya River, Berriasian, *Surites analogus* zone. 2) rostrum of No. 86–2: 2a) from ventral side; 2b) from left side. Cis-Polar Urals, Yatriya River, Berriasian. 3) rostrum of No. 86–3, longitudinal section. Cis-Polar Urals, Yatriya River, Berriasian. 4) rostrum of No. 86–6, cross section at the alveolar apex. Cis-Polar Urals, Yatriya River, Berriasian, *Surites analogus* zone.

Figure 5. *Liostrea uralensis* Zakharov n. sp. No. 410/2, view from right valve of the specimen shown in Plate XLII, Figure 9.

PLATE XLIV

Figures 1–10. *Lenticulina sossipatrovae* Gerke and E. Ivanova n. sp. x 60. Khatanga Depression, Berriasian stage. 1) holotype No. 250/3. 2) paratype No. 250/4: 2a) lateral; 2b) view from peripheral margin; 2c) from aperture. Boyarka River, *Bojarkia mesezhnikowi* zone. 3) paratype No. 1009/354: 3a) lateral; 3b) view from peripheral margin. Nordvik area, Kozhevnikovo (borehole K–133, depth 151–157 m), *Chetaites sibiricus* and *Surites analogus* zones, beds with *Haplophragmoides infracretaceous.* 4–6) paratypes Nos. 250/172, 250/173, and 250/174: a) lateral; b) from peripheral margin. Boyarka River, *Bojarkia mesezhnikowi* zone. 7–10) paratypes Nos. 250/175, 250/176, 250/177, and 250/178, Maimecha River, beds with *Surites* spp.

PLATE XLV

Figures 1, 3. *Lenticulina nivalis* Schleifer and Gerke n. sp. x 60. Khatanga Depression. Nordvik area (Kozhevnikovo). Berriasian stage, *Hectoroceras kochi* and *Surites analogus* zones, beds with *Haplophragmoides infracretaceous.* 1) paratype No. 1009/358. 3) holotype No. 1009/356: 3a) lateral; 3b) view from peripheral margin. Borehole K–119, depth 170–175 m.

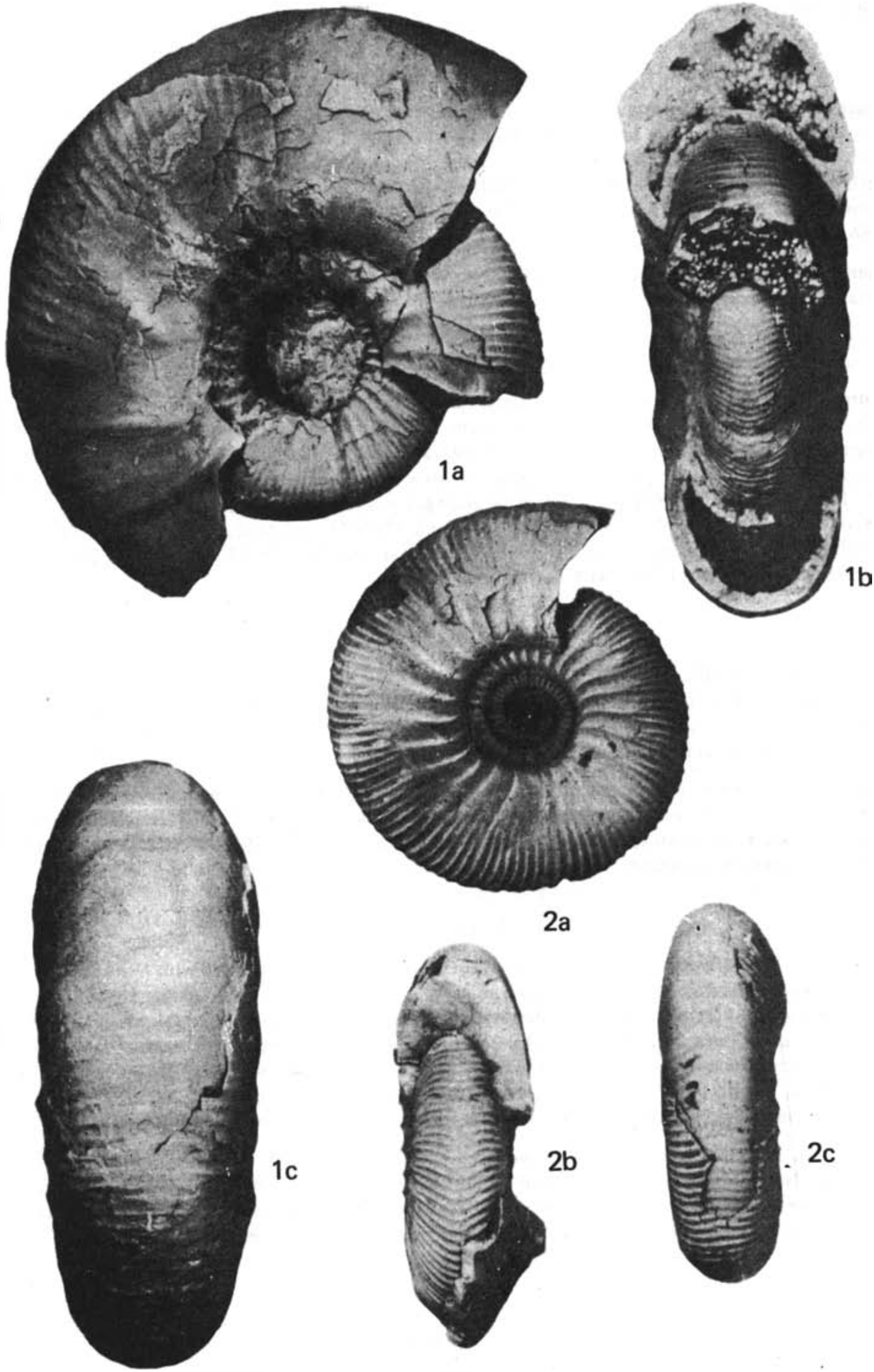
Figures 2, 4–6. *Lenticulina perspicua* E. Ivanova n. sp. x 60. Khatanga Depression, Boyarka River. Berriasian stage, *Bojarkia mesezhnikowi* zone. 2) holotype No. 250/167: 2a, 2b) lateral; 2c) view from peripheral margin; 2d) from aperture. 4–5) paratypes Nos. 250/168, 250/169, and 250/171: a) lateral; b) view from peripheral margin.

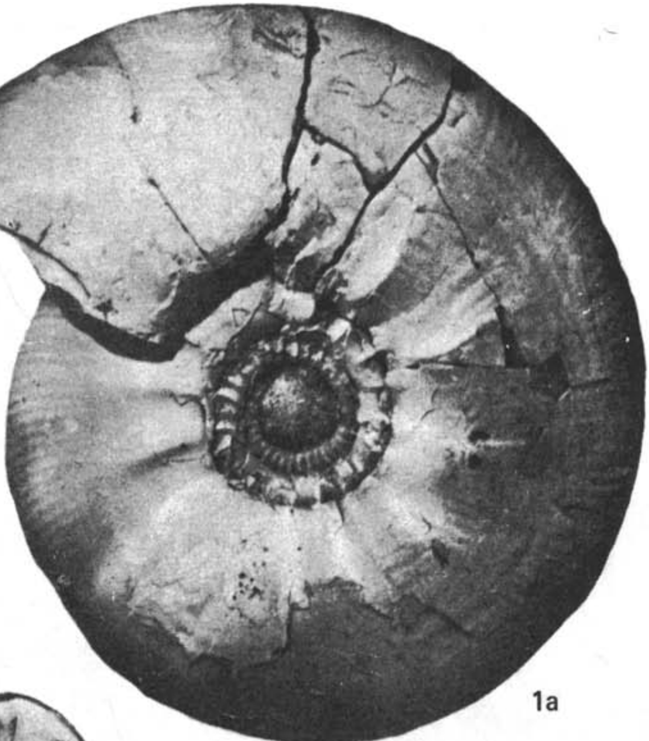
PLATE XLVI

Figures 1–5, 7, 8. *Marginulina corneolus* Vassilenko. x 80. Valanginian, beds with *Haplophragmoides infracretaceous.* Nordvik area. 1) lectotype, microspherical generation: 1a) lateral; 1b) ventral. Cape Il'ya (borehole K–1, depth 234 m). 2) megaspherical generation A_1, Cape Il'ya (borehole K–1, depth 193 m). 3) same, Cape Il'ya (borehole K–2, depth 114 m). 4) juvenile specimen of megaspherical generation from the same beds. 5) microspherical generation (?), mud volcano of Kozhevnikovo (borehole K–119, depth 187–192 m). 7) megaspherical generation A_1 (borehole K–119, depth 184–187 m). 8) megaspherical generation A_2, same locality. Figures 1–4 after Vasilenko (1951).

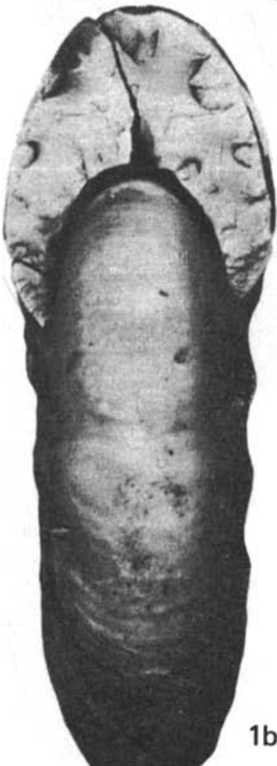
Figures 6, 9. *Marginulina* ex gr. *gracilissima* (Reuss). Valanginian, beds with *Haplophragmoides infracretaceous.* Nordvik area. 6) microspherical generation: 6a) lateral; 6b) ventral; 6c) view from oral end. Cape Il'ya (borehole K–163, depth 156 m). 9) megaspherical generation A_1: 9a) lateral; 9b) ventral; 9c) view from oral end. Nordvik borehole K–144, depth 13 m). After Gerke (1964).

PLATE I





1a

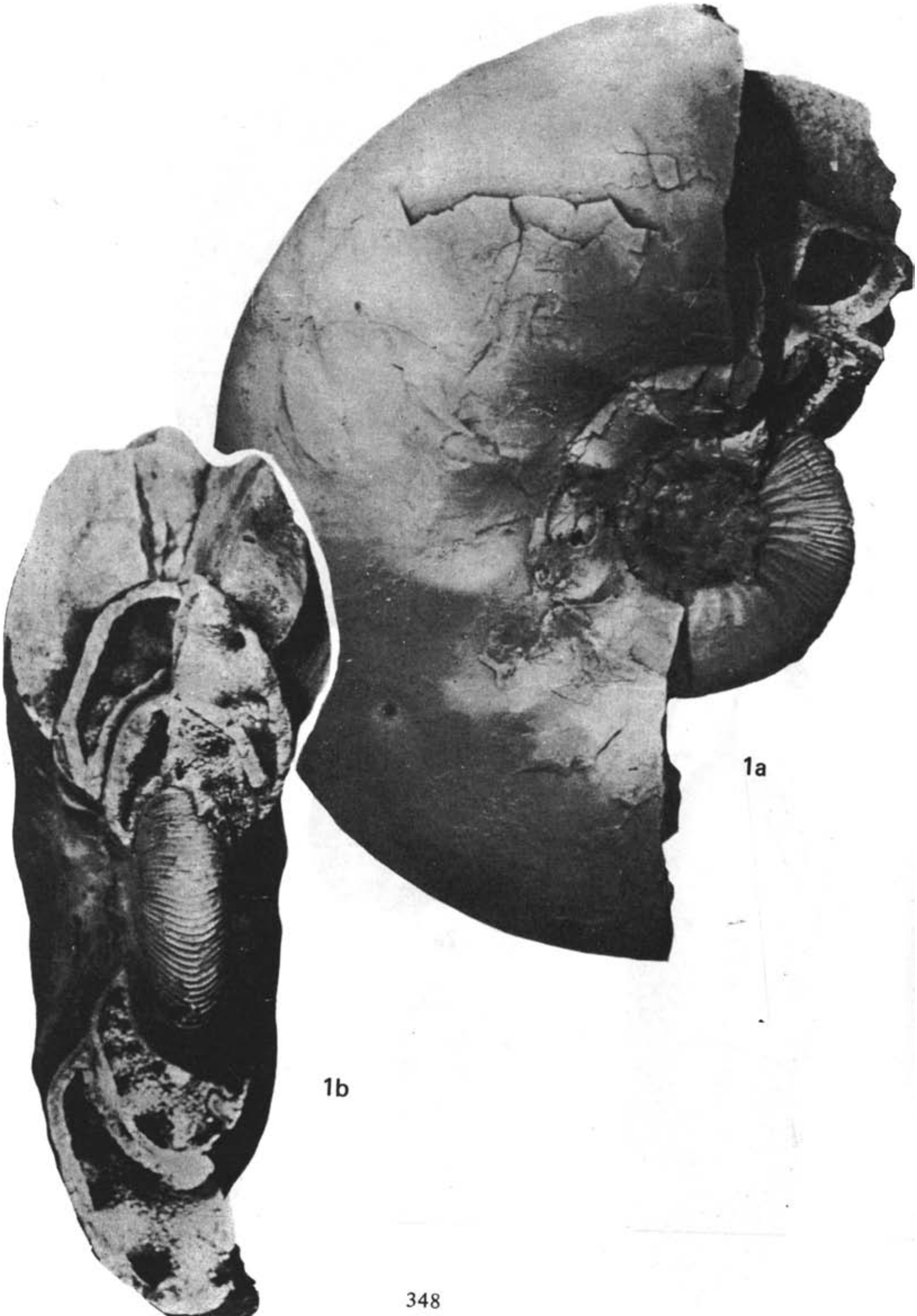


1b

2a

2b

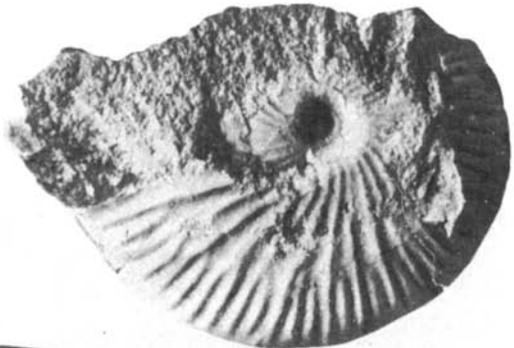
1c



1a

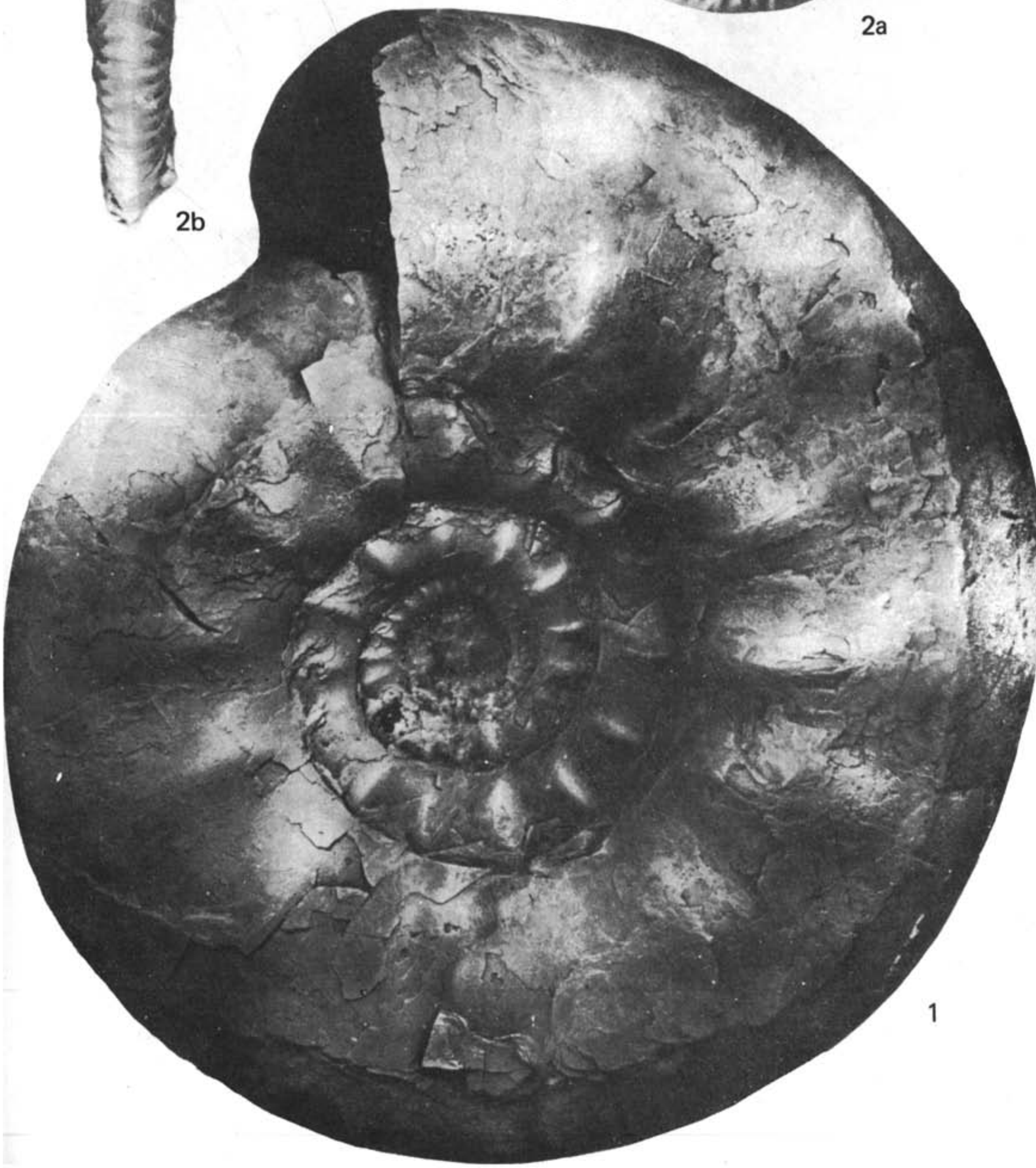
1b

PLATE IV

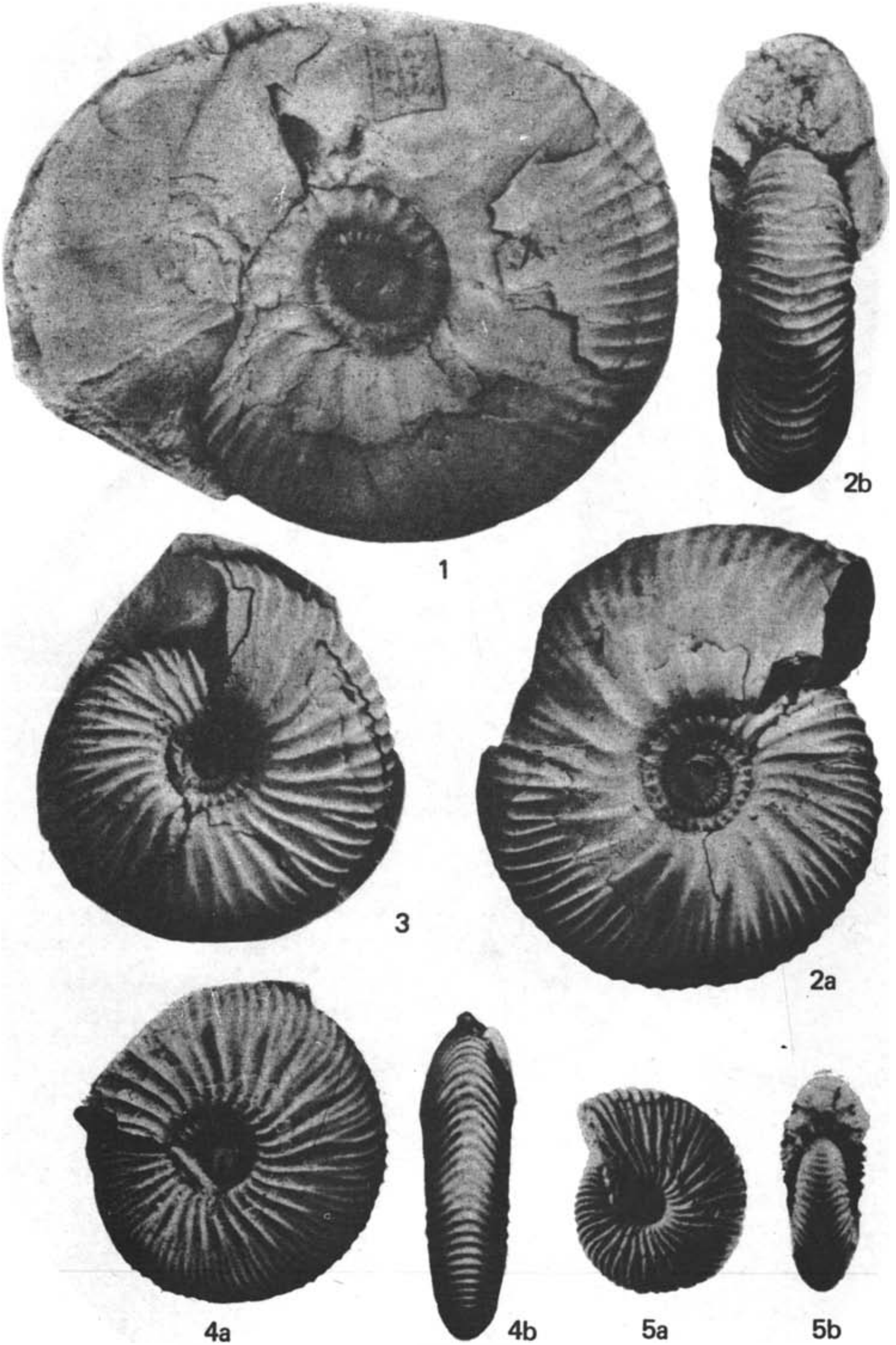


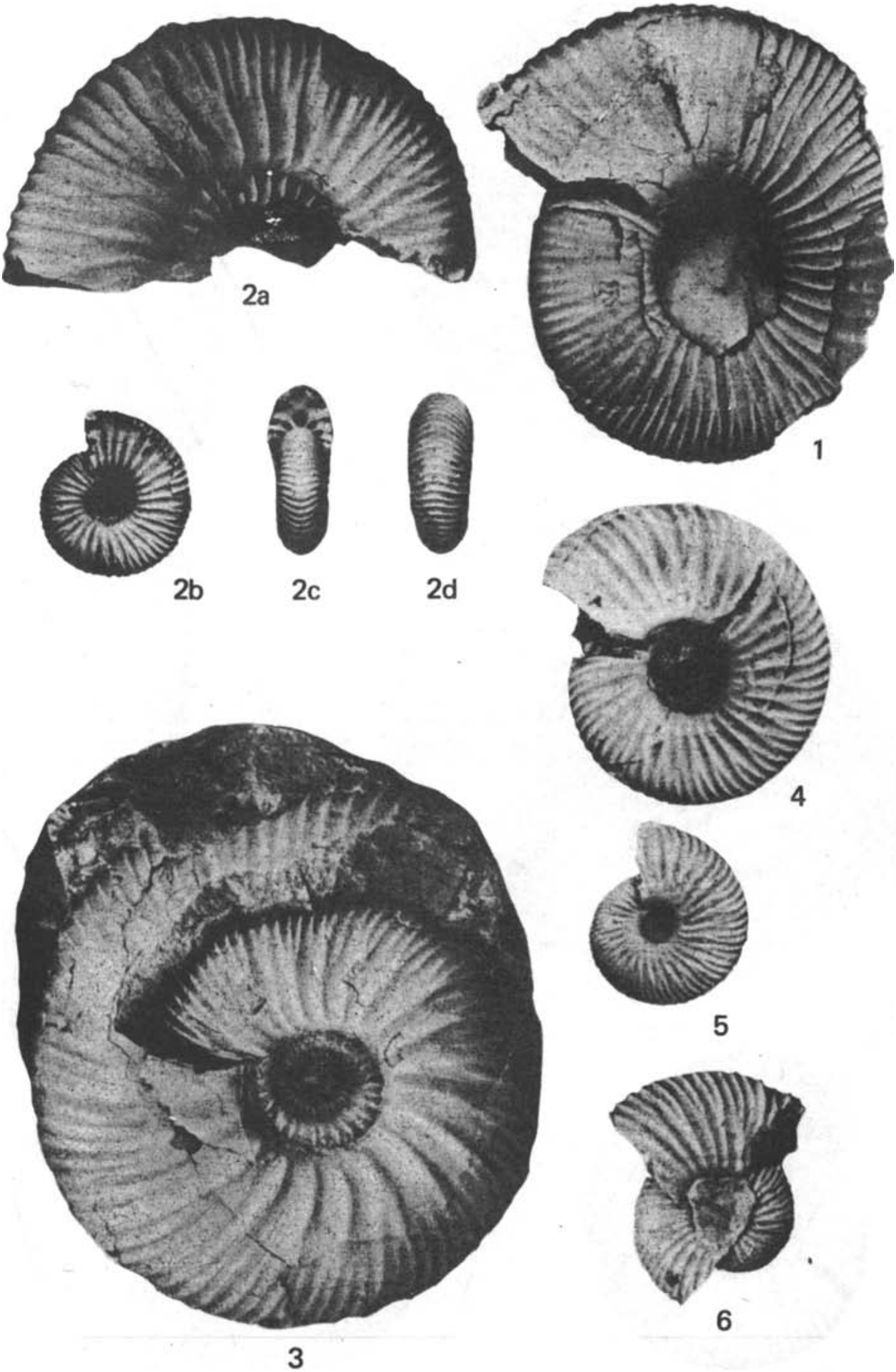
2a

2b



1


1
2b
3
2a
4a
4b
5a
5b

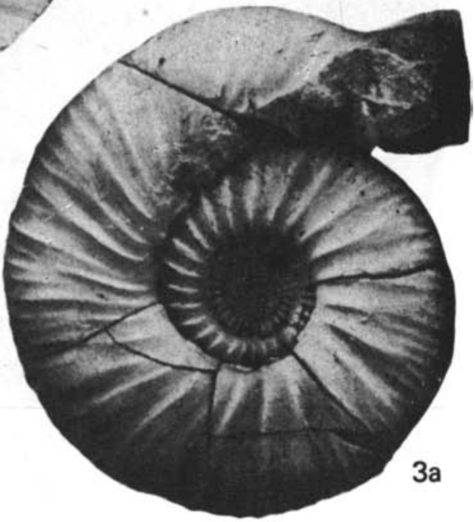

2a
1
2b
2c
2d
4
3
5
6

1a

1b

2

3c



3a

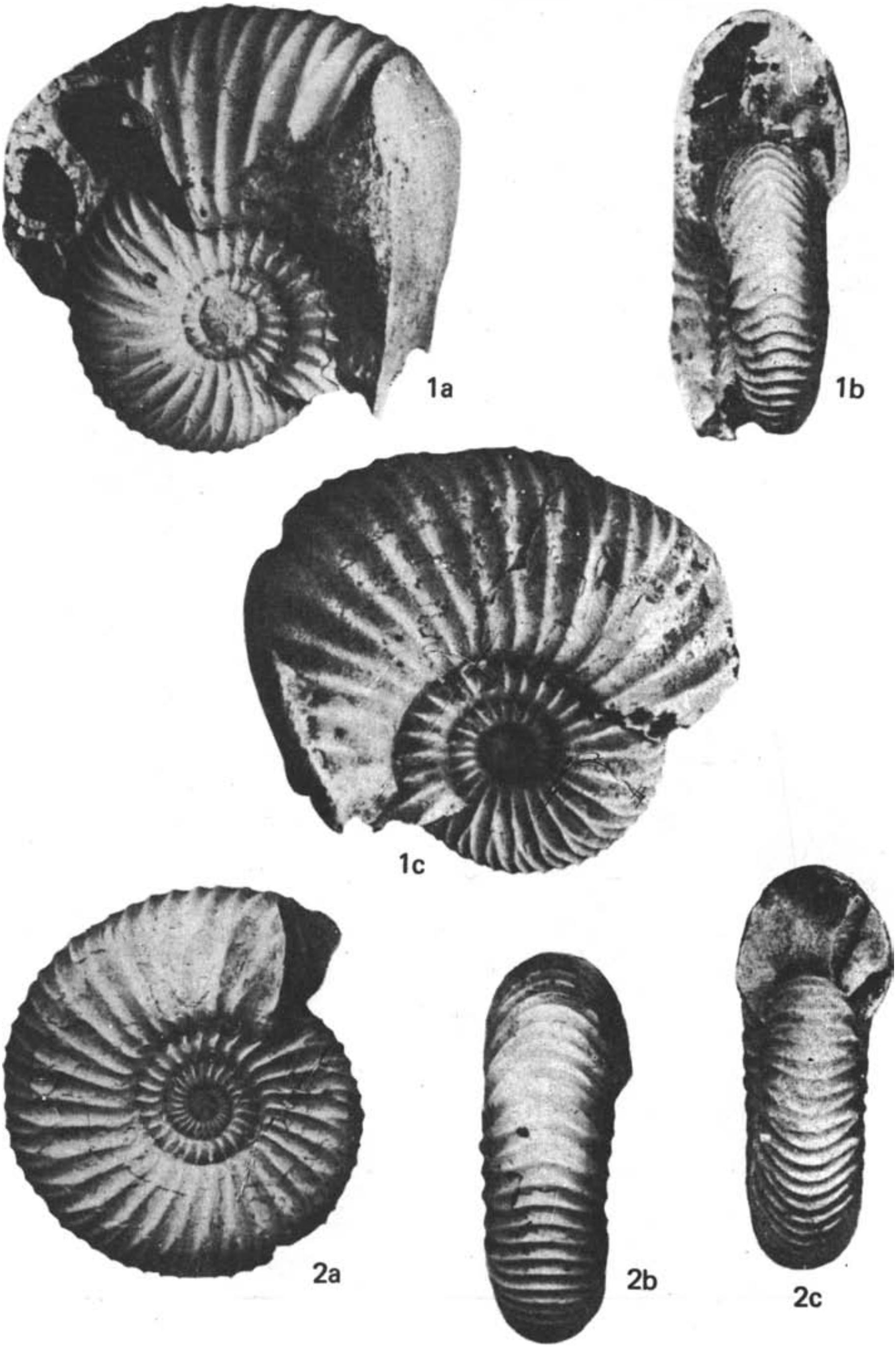
3b

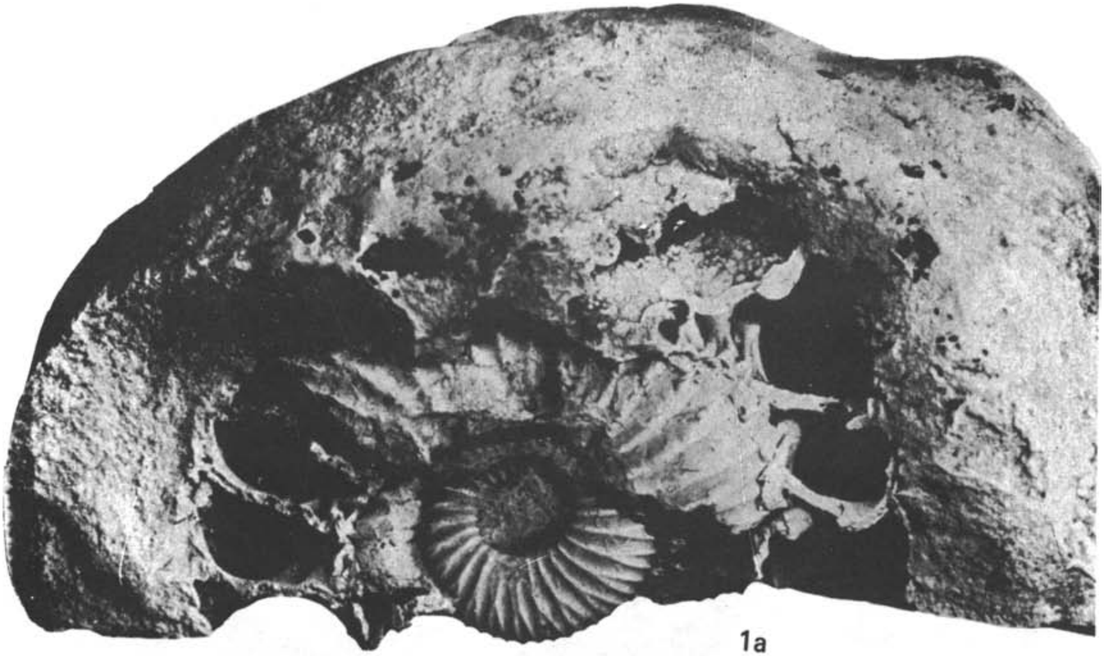
1a

1b

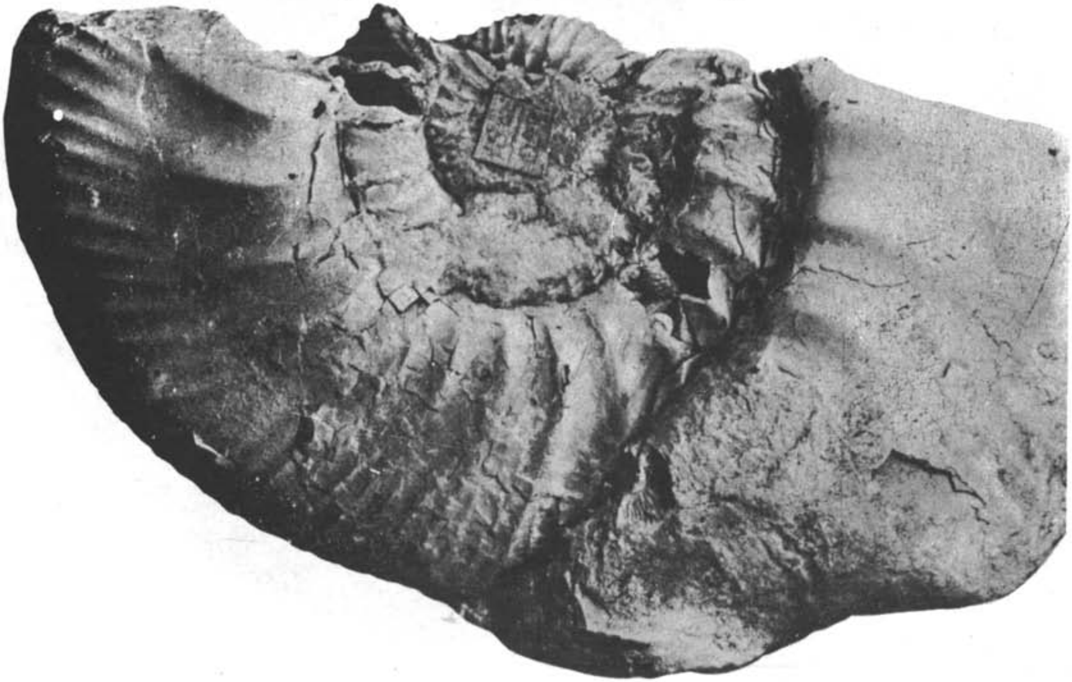
2

PLATE IX





1a



1b

1

3a

3b

3c

2a

2b

PLATE XIII

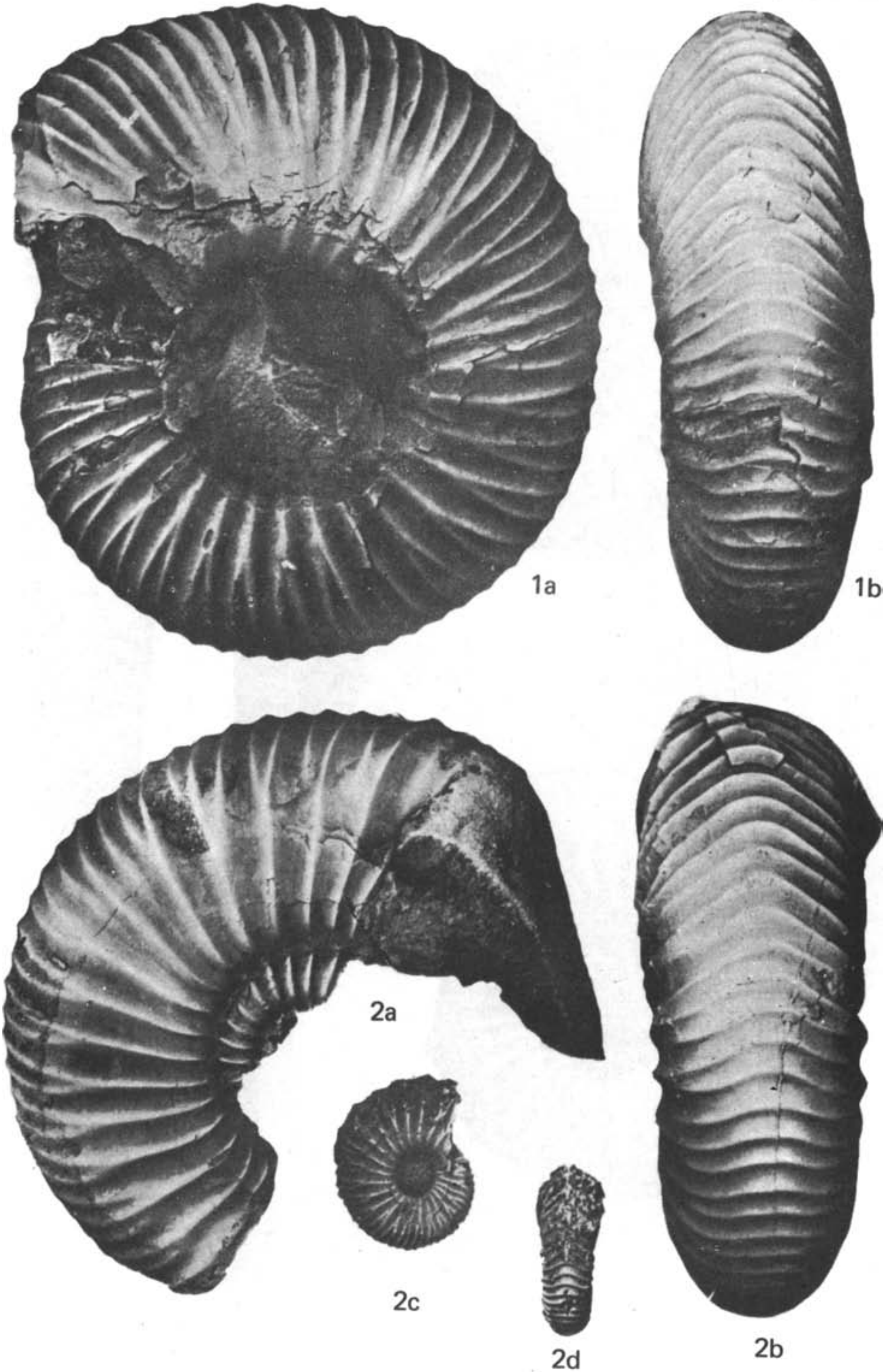


PLATE XIV

PLATE XV

1a

1b

1c

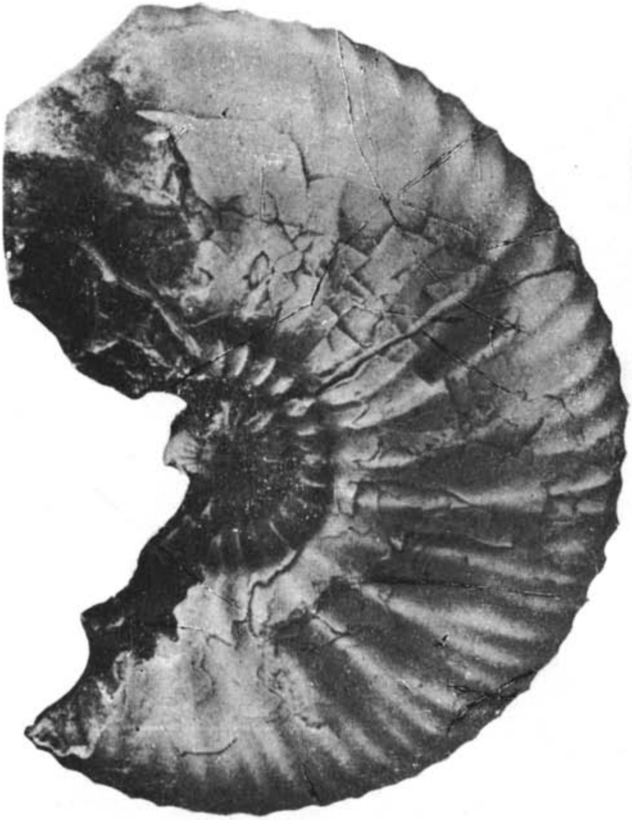
1d

1e

2

3a

3b

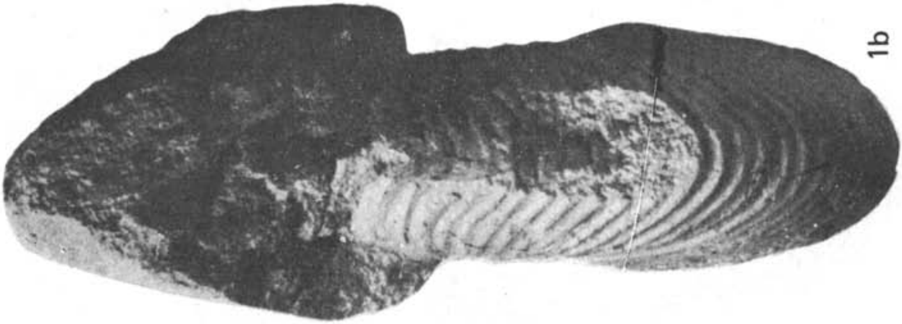


1b

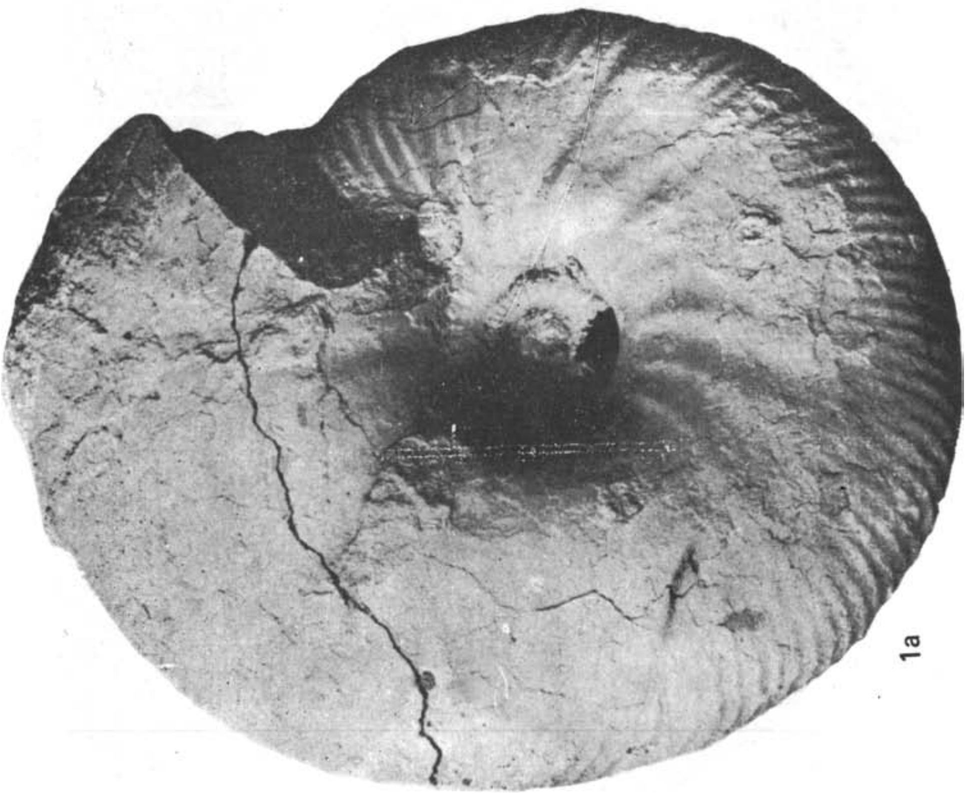
1a

2b

2a



1b



1a

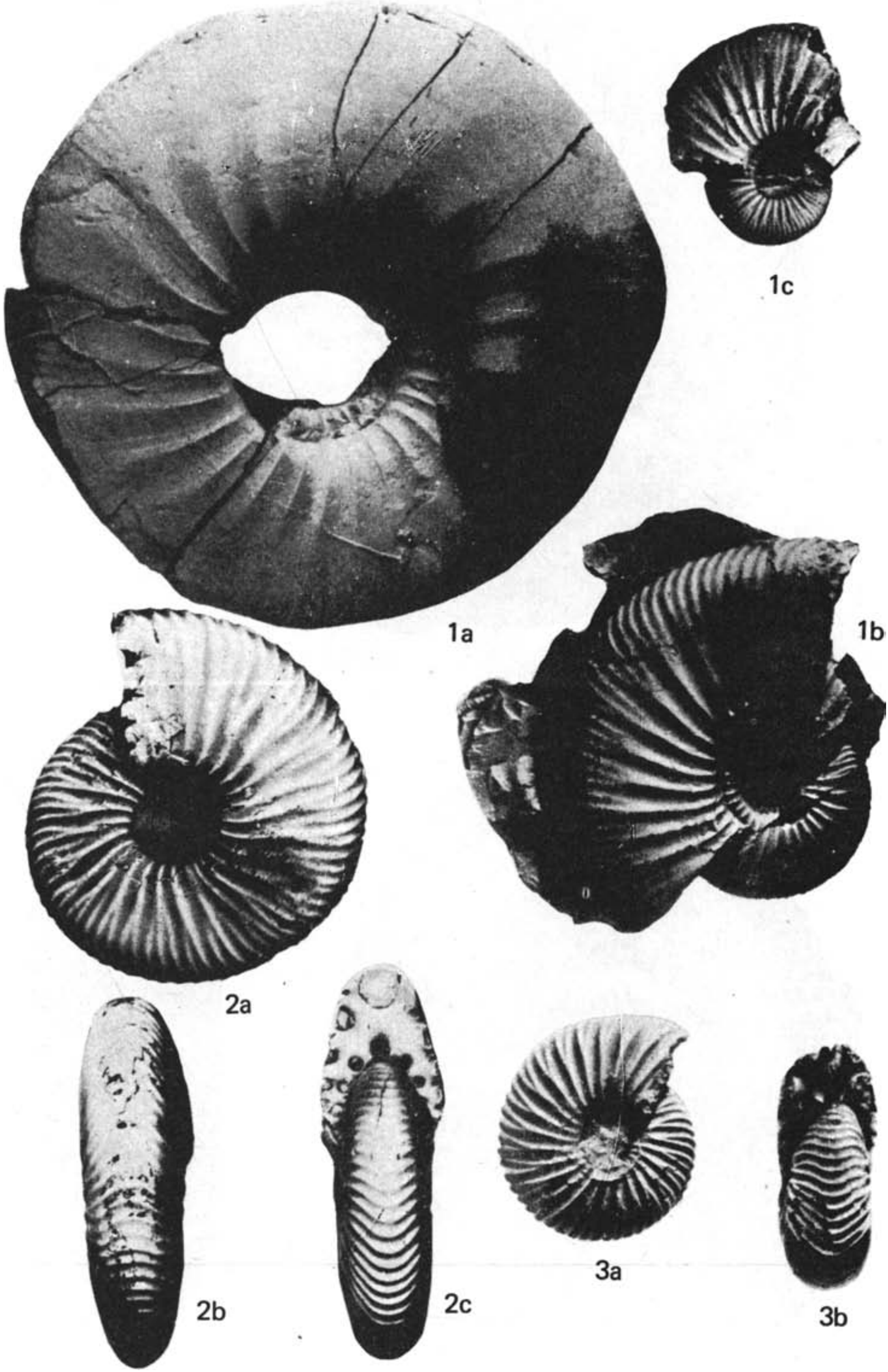
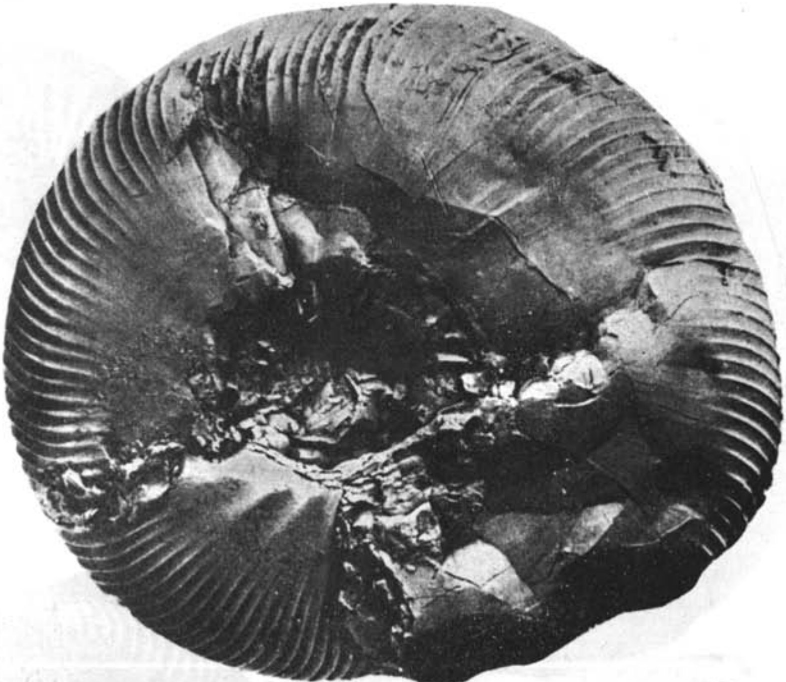

1a
1b
1c
2a
2b
2c
3a
3b

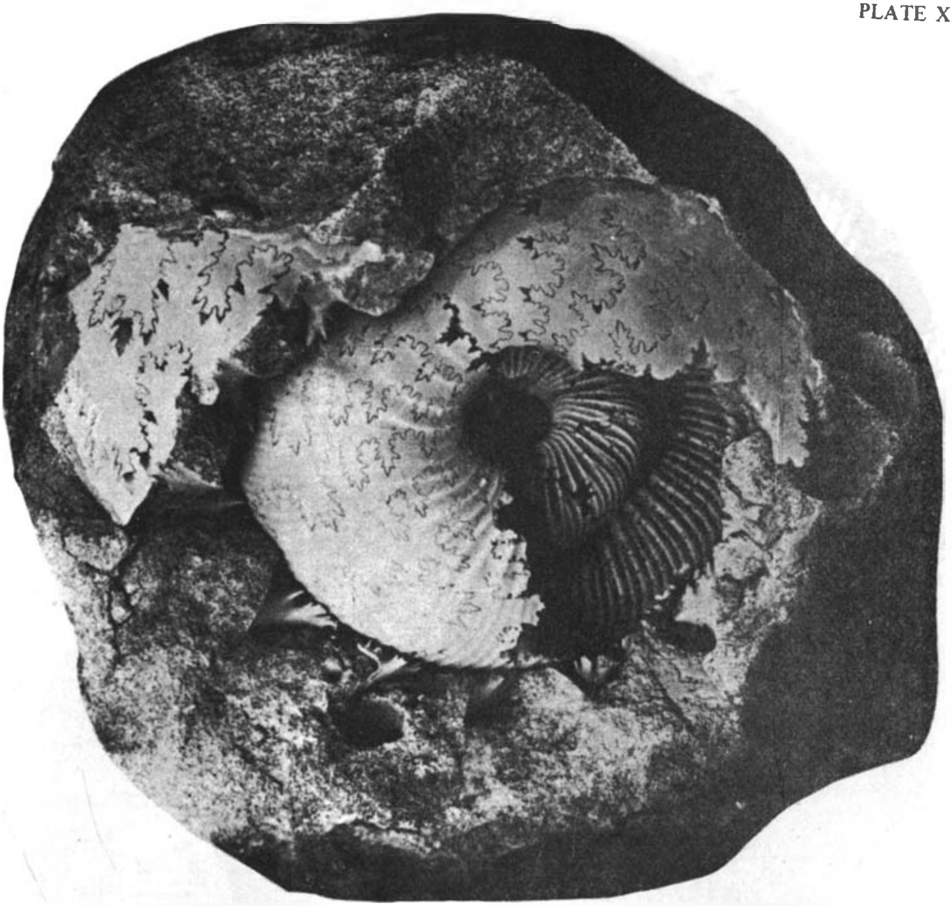
PLATE XIX



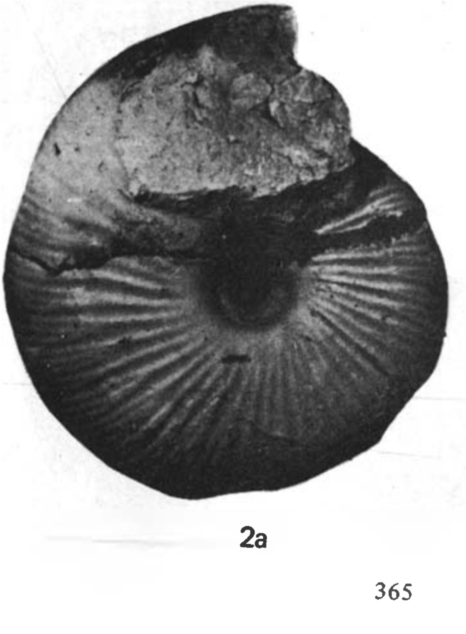
1

2a

2b



1



2a

2b

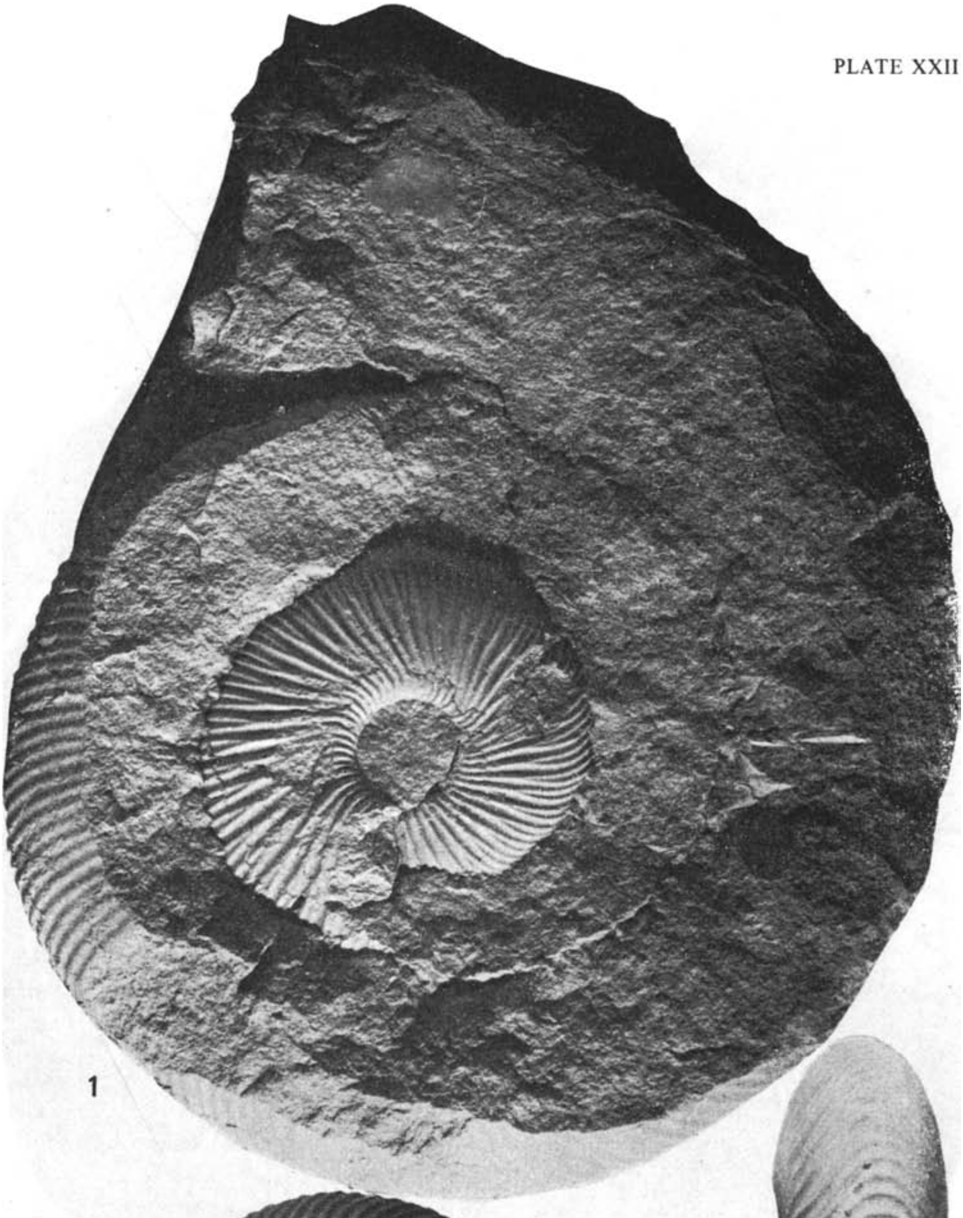
PLATE XXI

1a

2a

2b

1b



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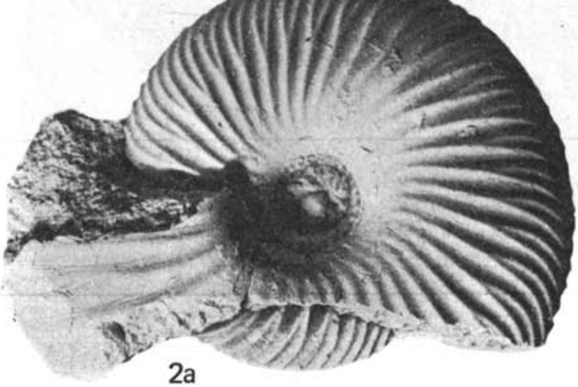


2a

2b

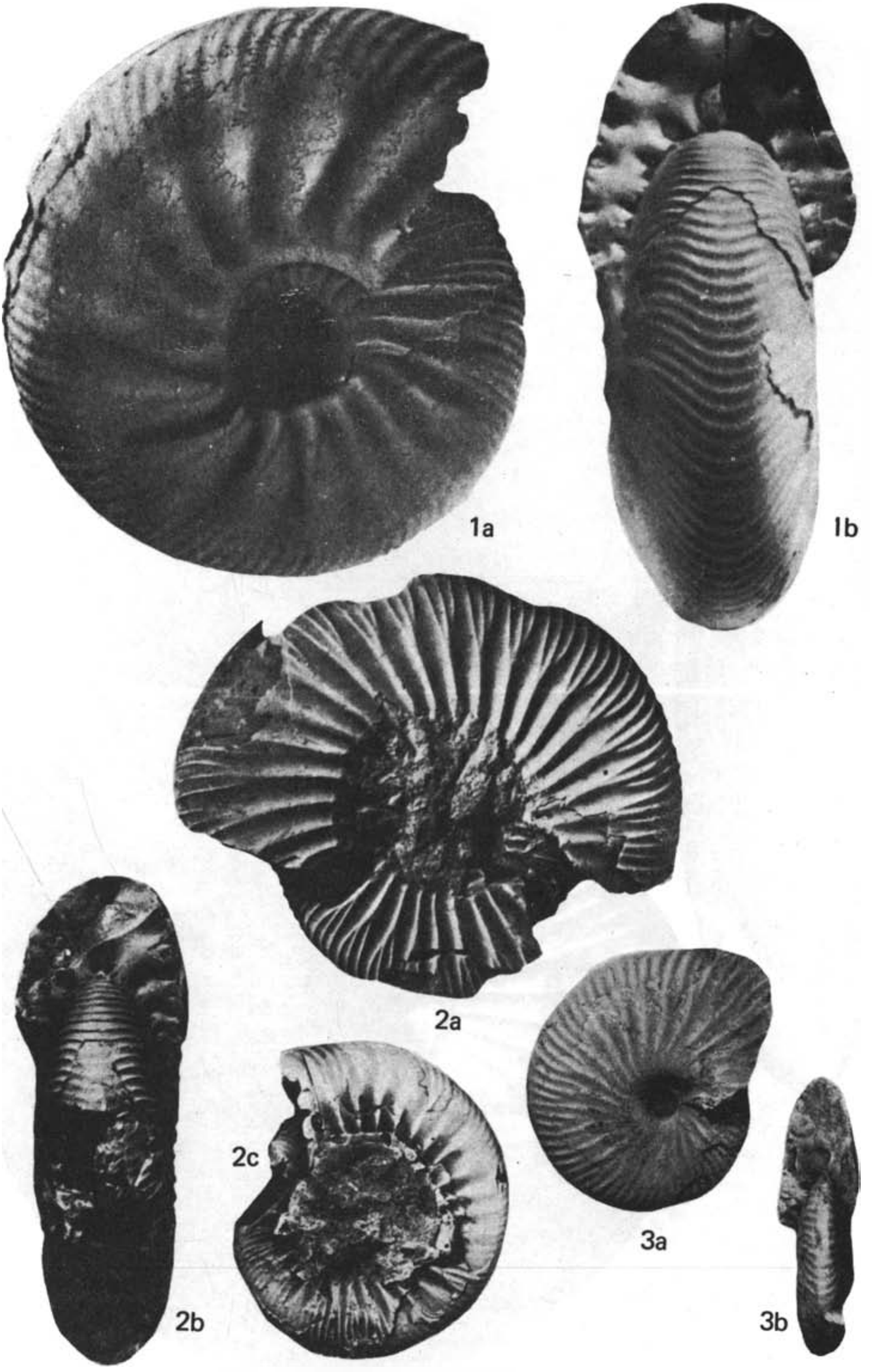
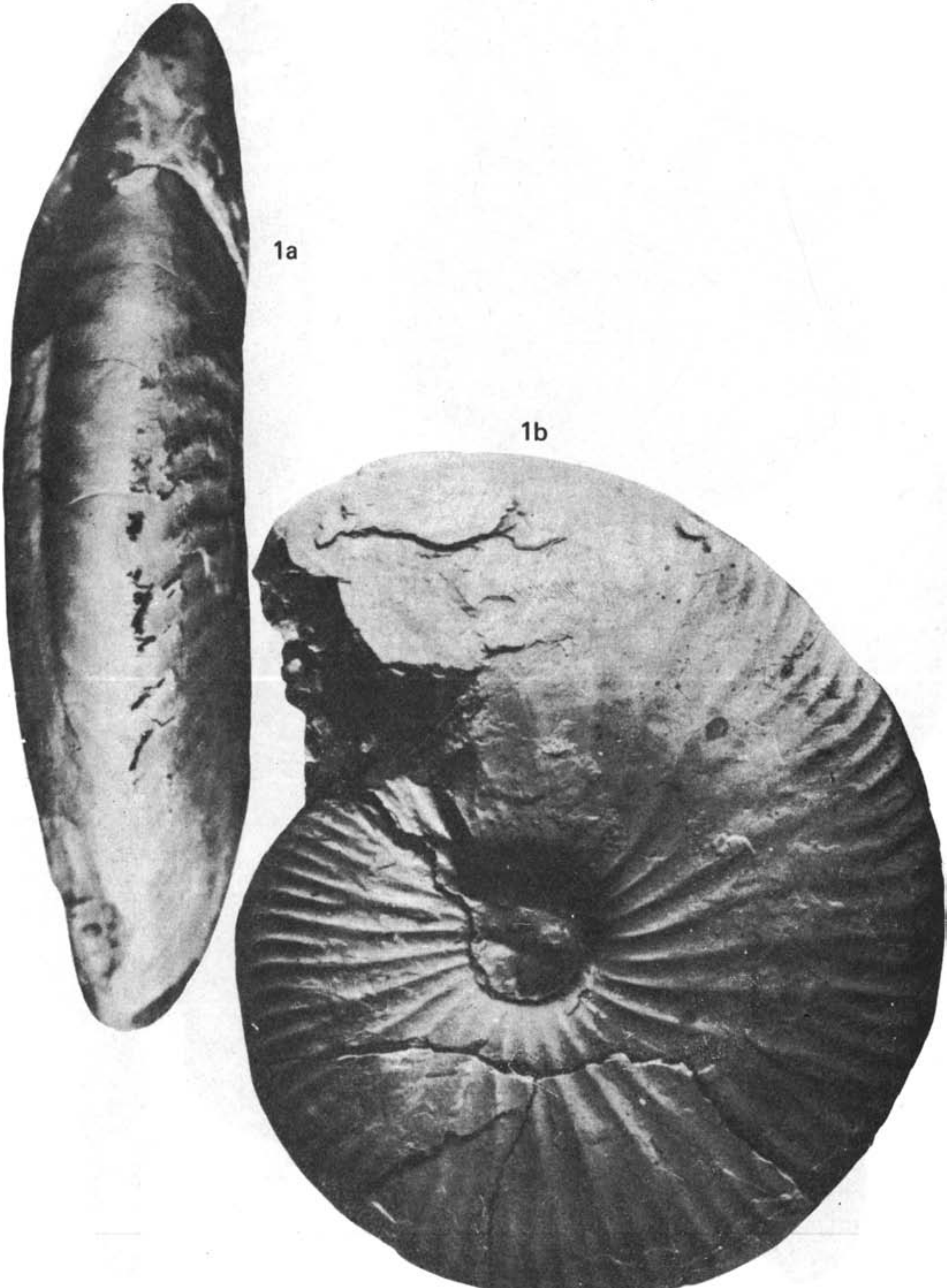
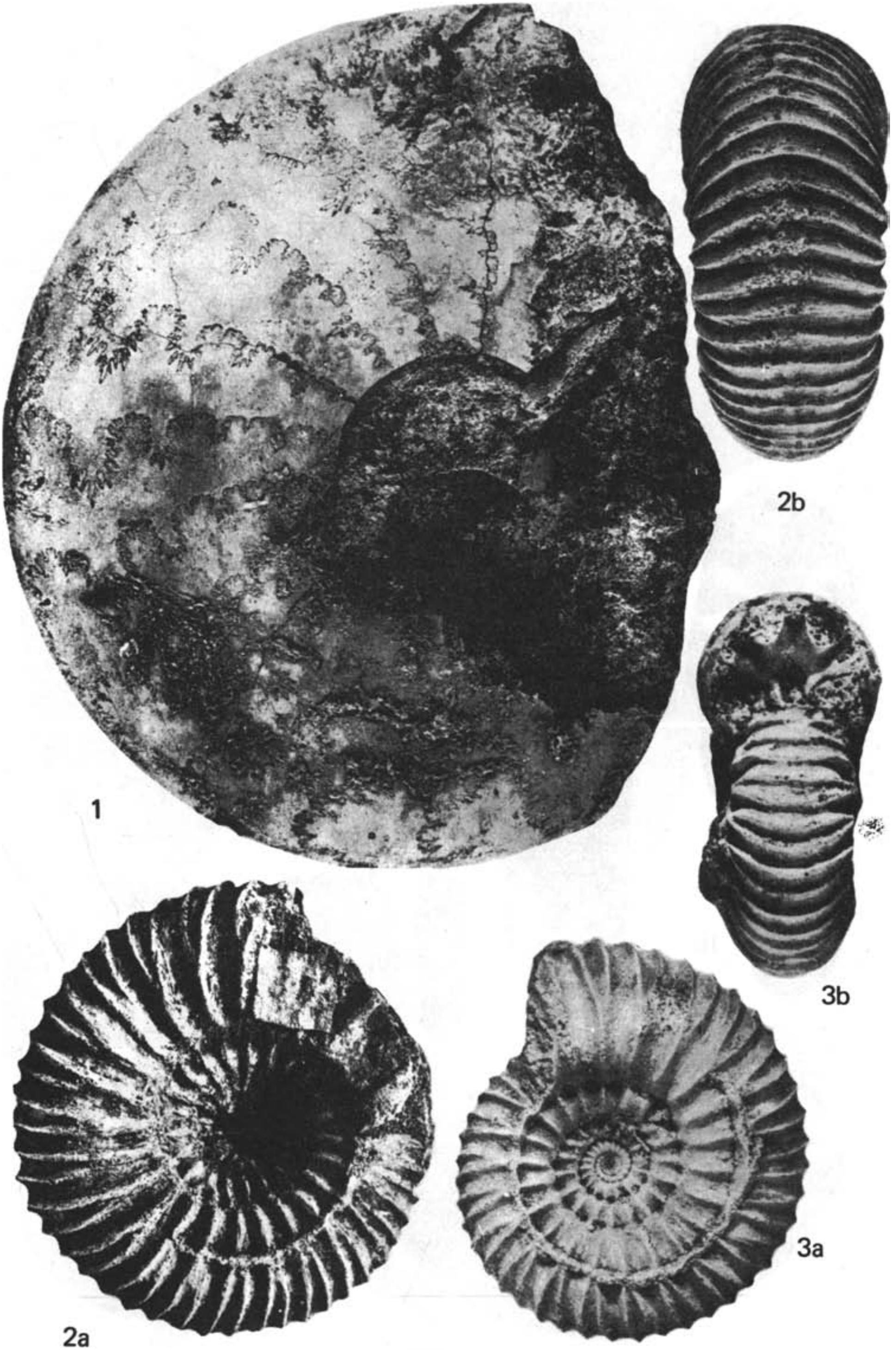
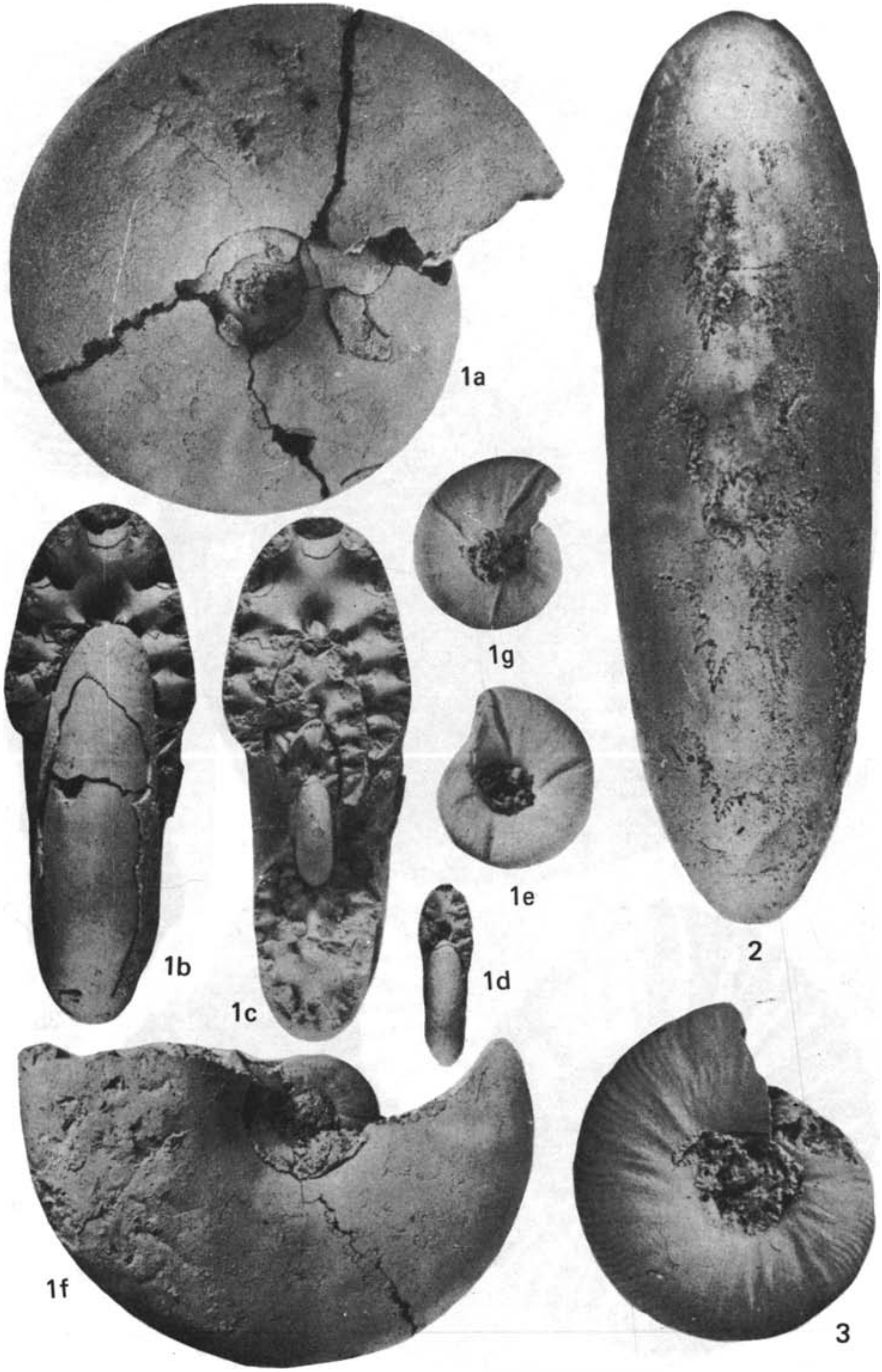

1a
1b
2a
2b
2c
3a
3b

PLATE XXV





2b
3b
1
3a
2a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1c
1d
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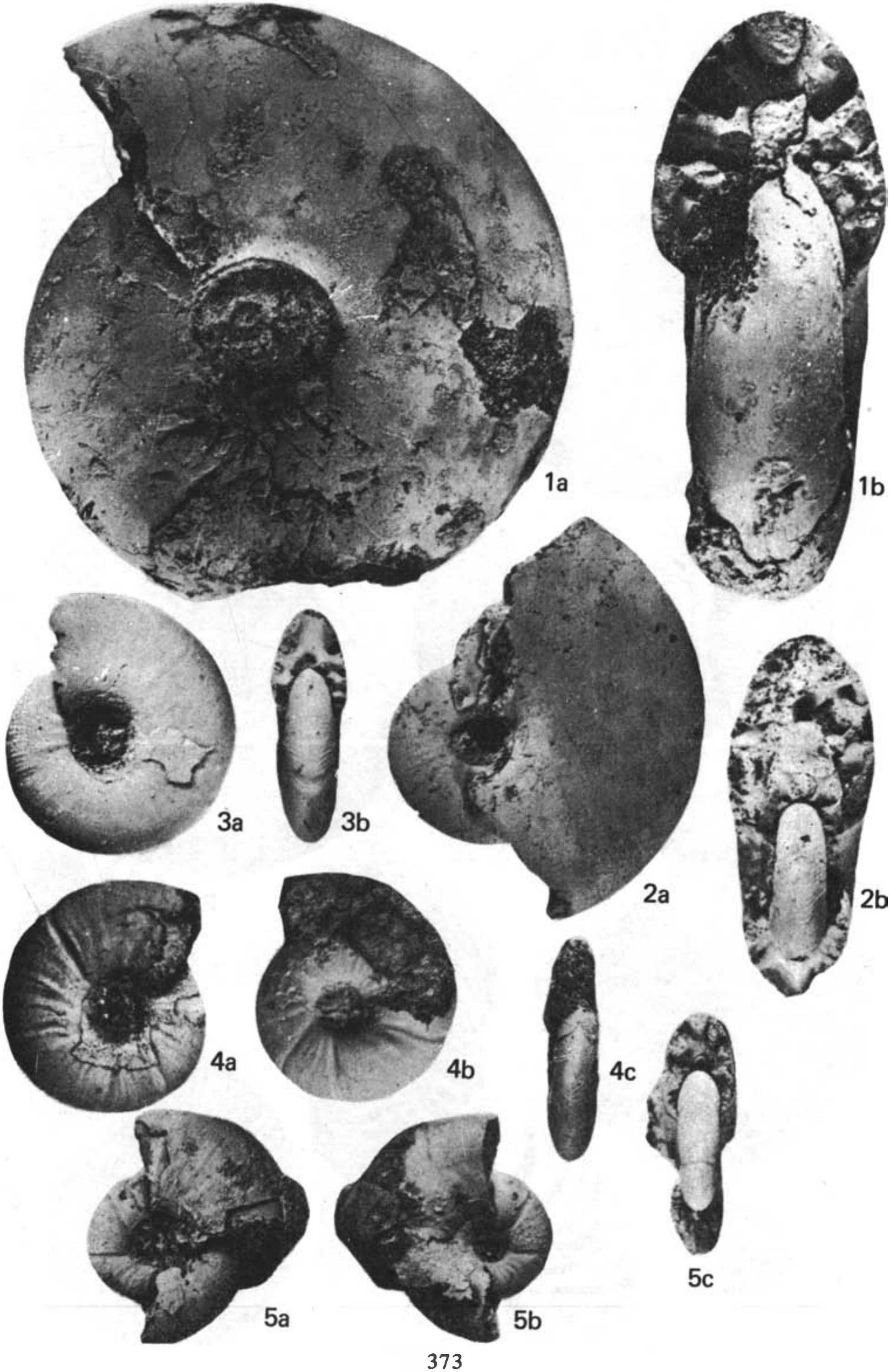
1f
1g
2
3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2b
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4b
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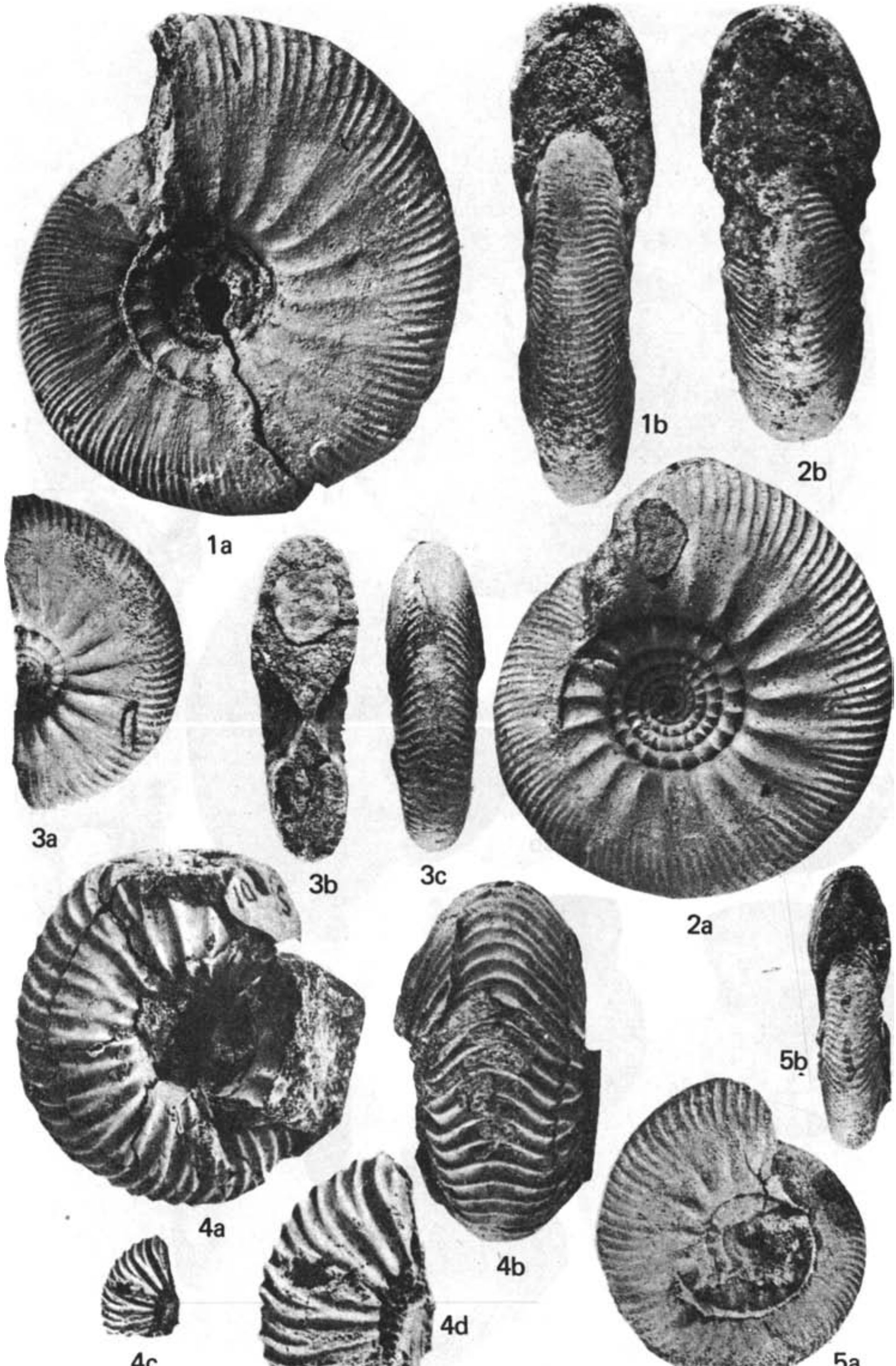
5c
5a
5b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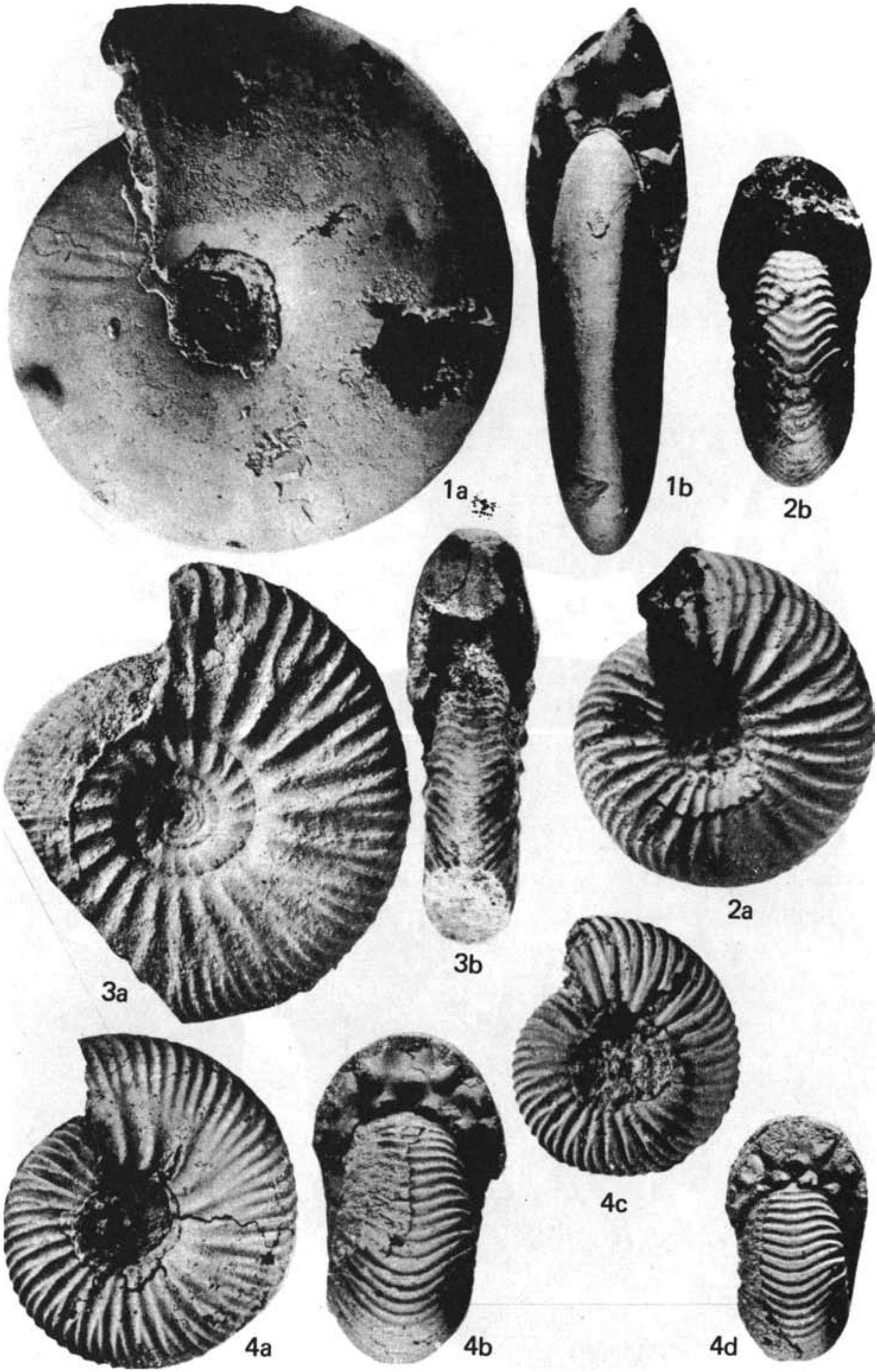
2a
4a
4b
5b
5a
4c
4d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2b
3a
3b
2a
4c
4a
4b
4d

PLATE XXXI

1a

1b

2a

2b

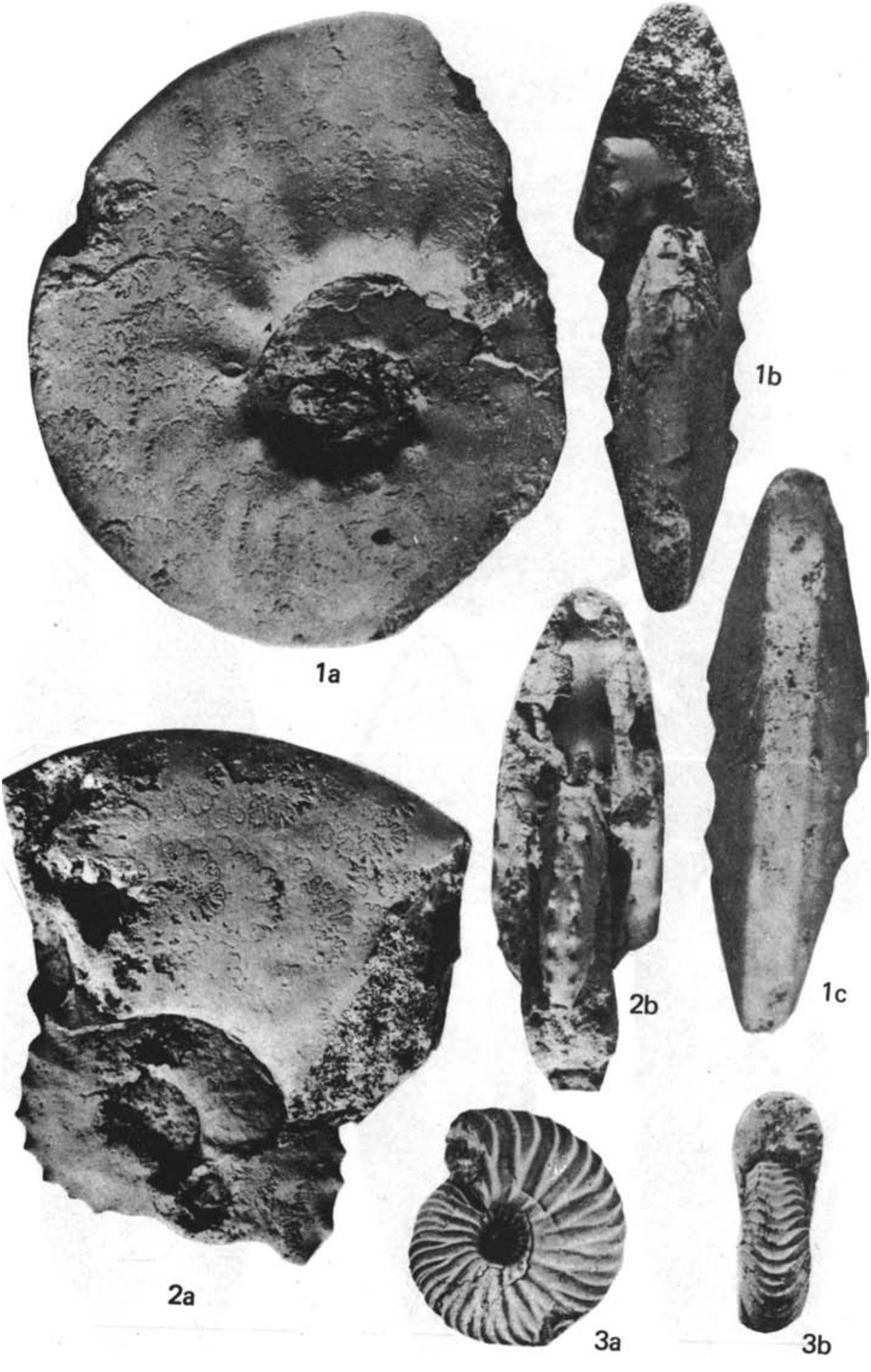
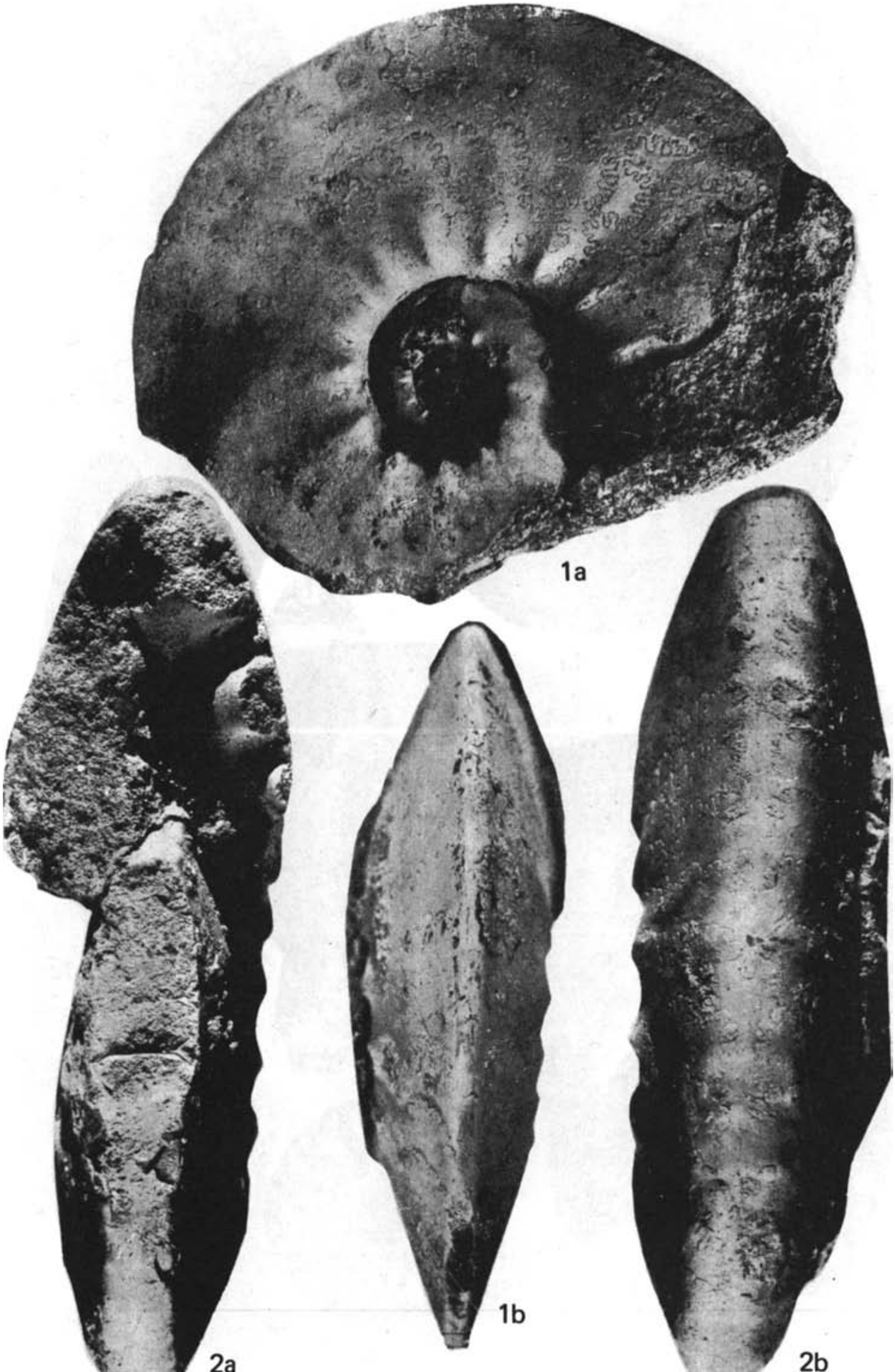

1a
1b
1c
2a
2b
3a
3b

PLATE XXXIII



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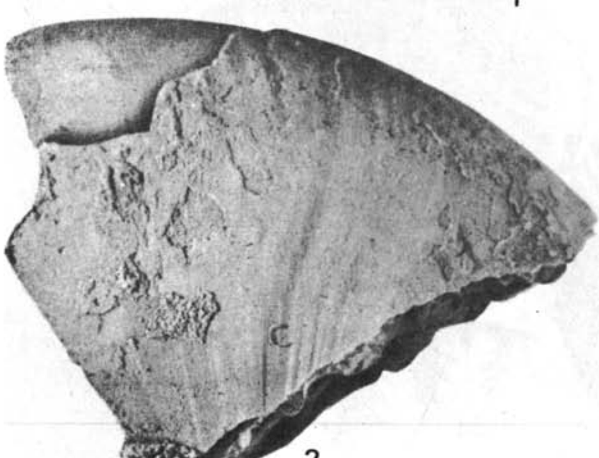
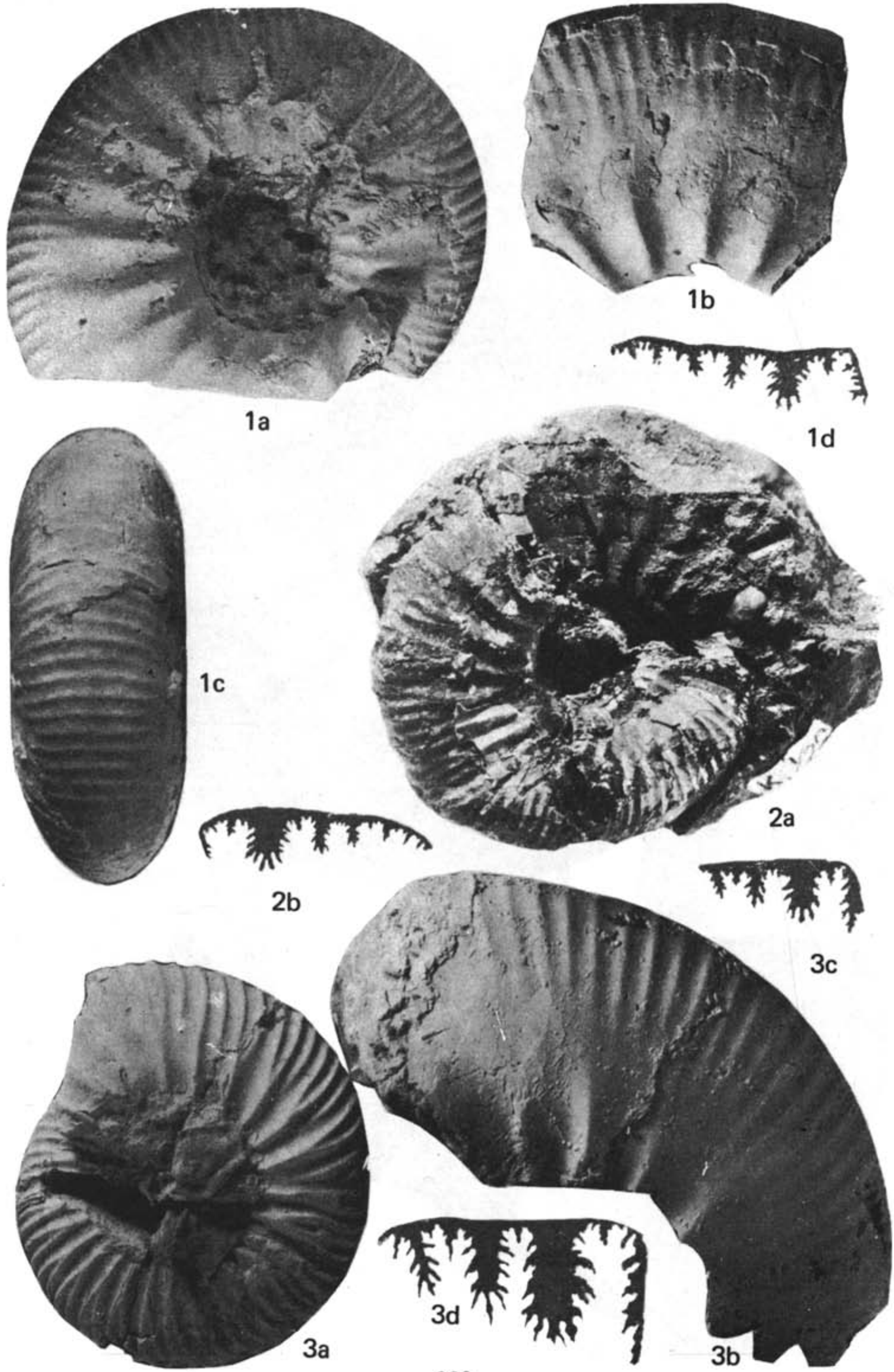


2

3

PLATE XXXV



1a

1b

2a

2b

PLATE XXXVII

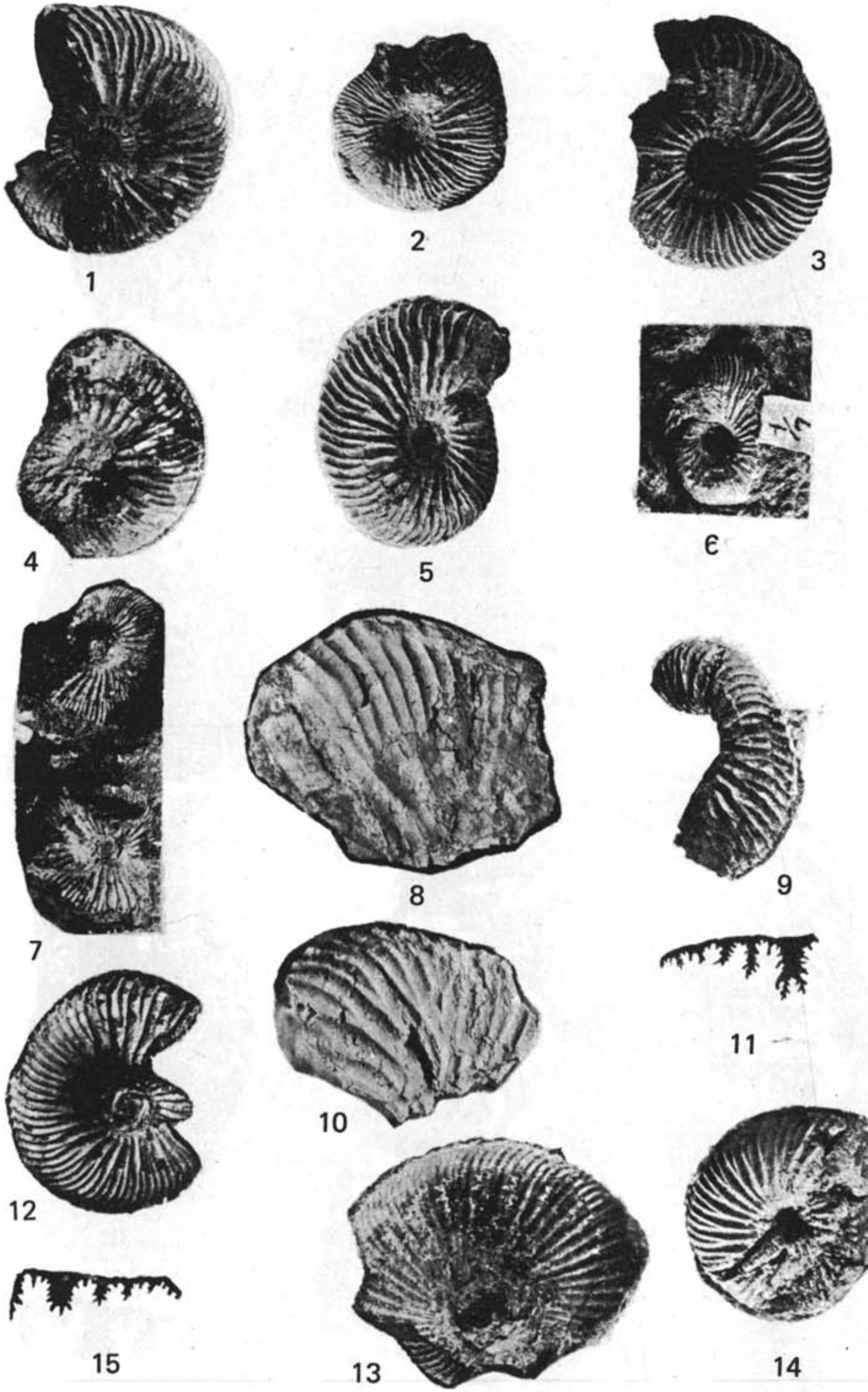


PLATE XXXVIII

1a

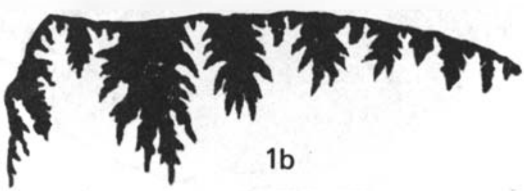
1b

1c

1d

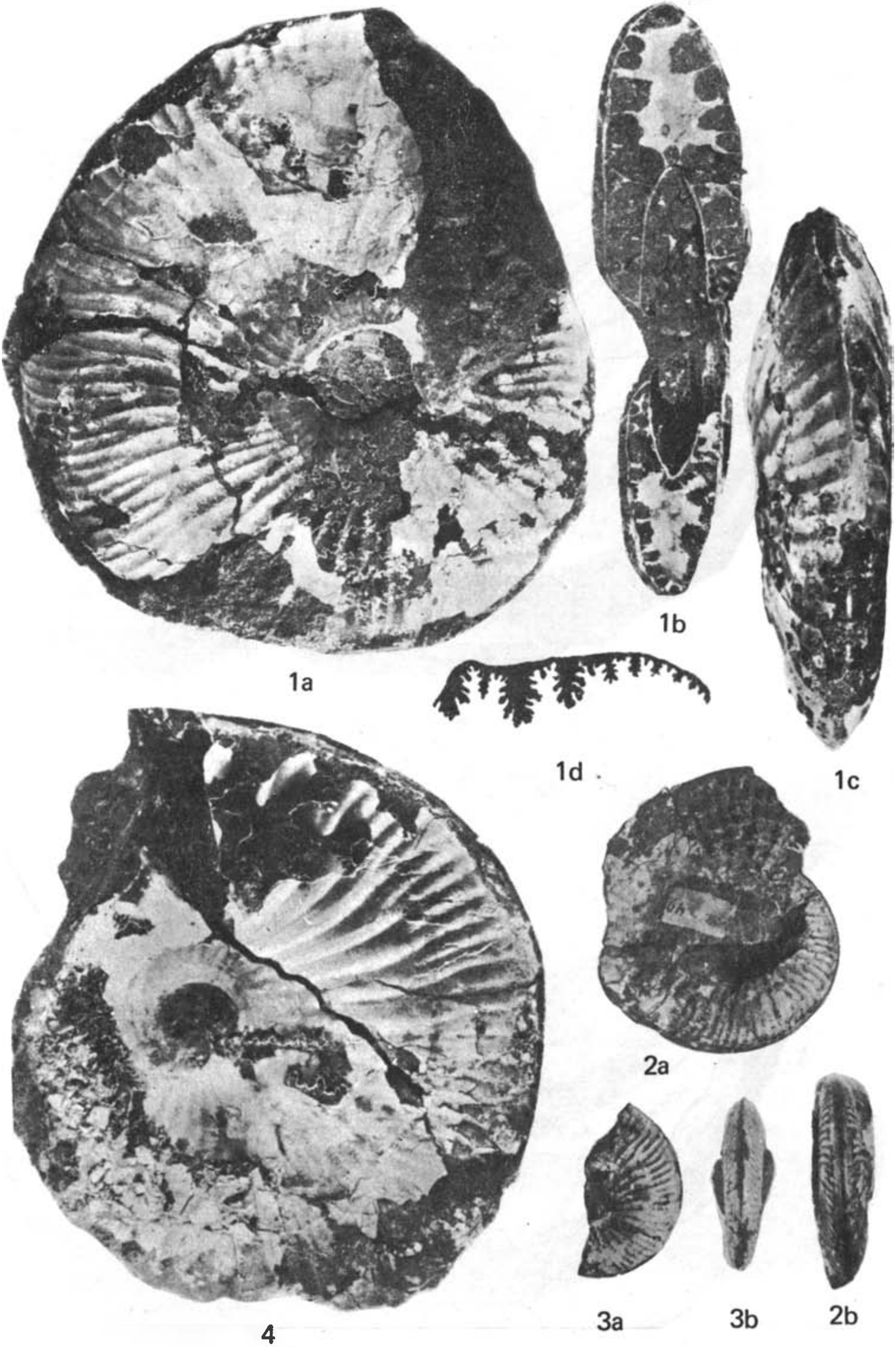
1e

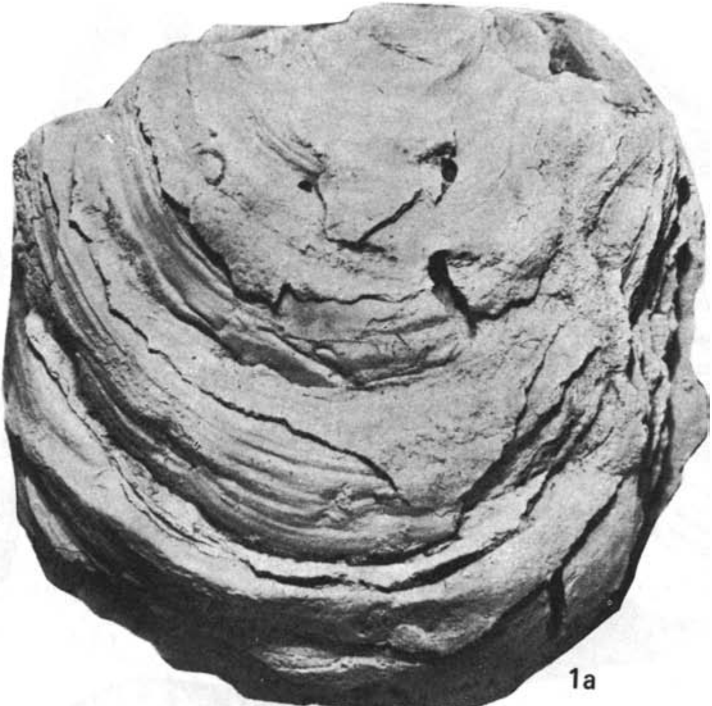
1a



1b

PLATE XL





1a

1b

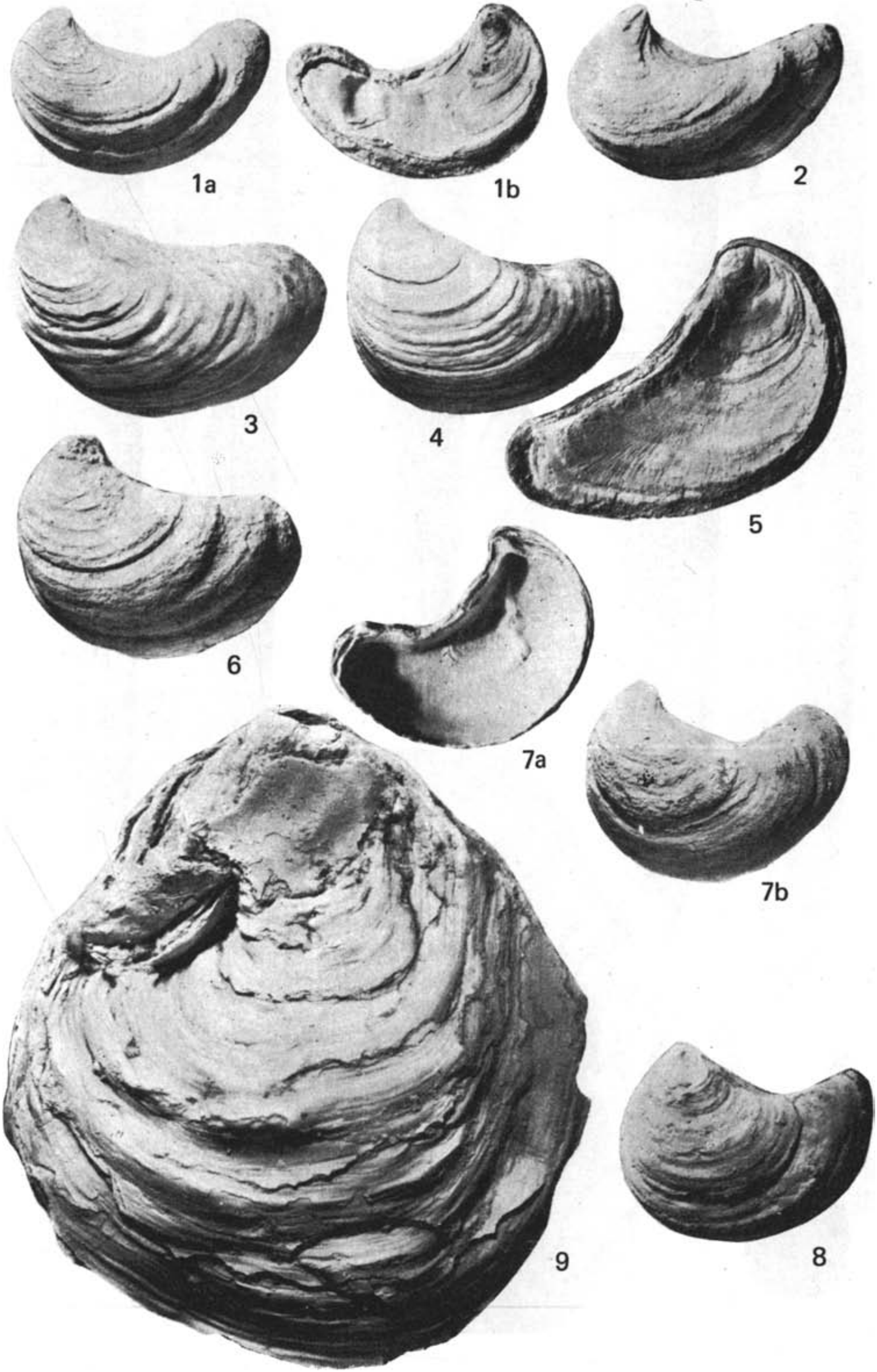
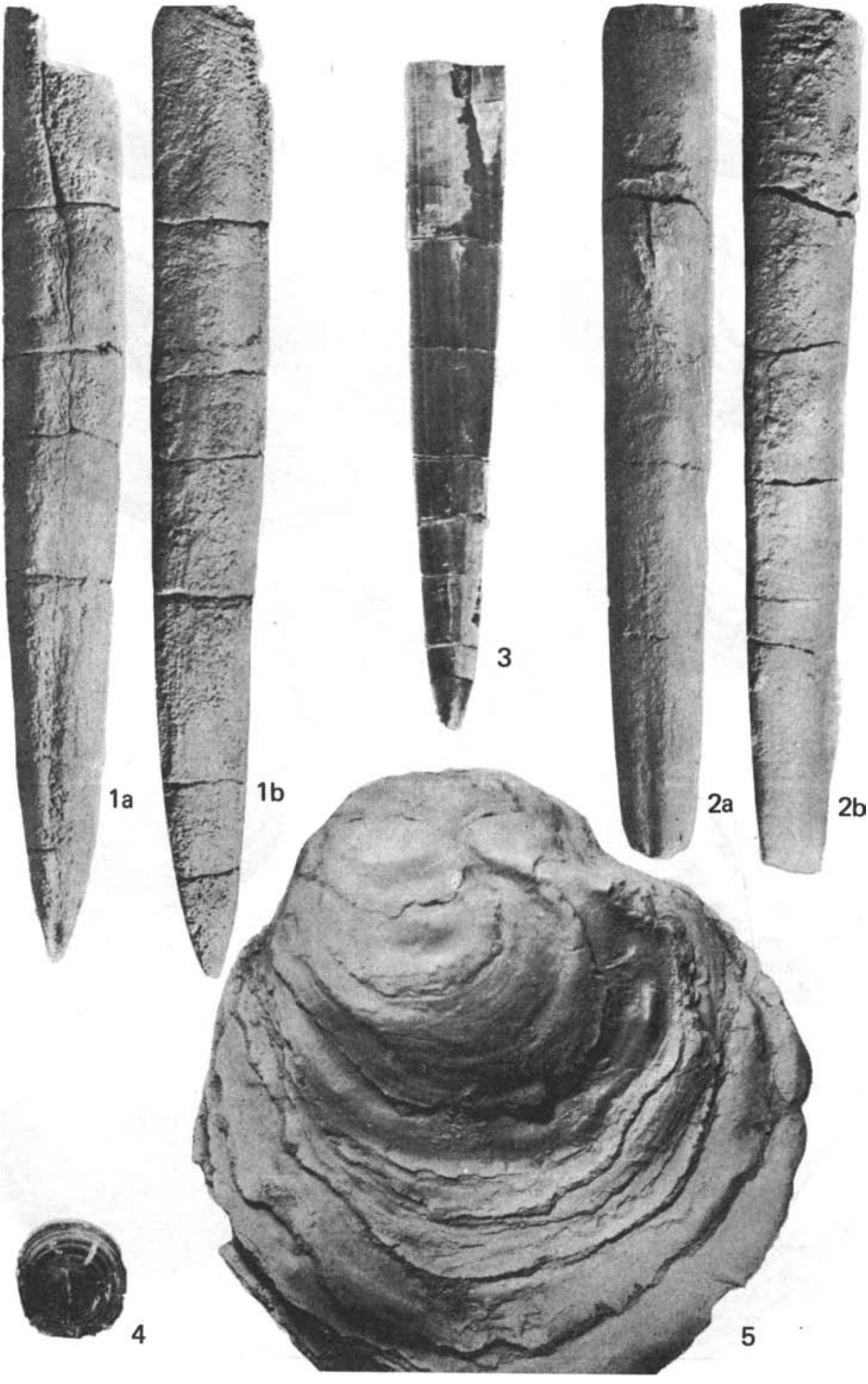
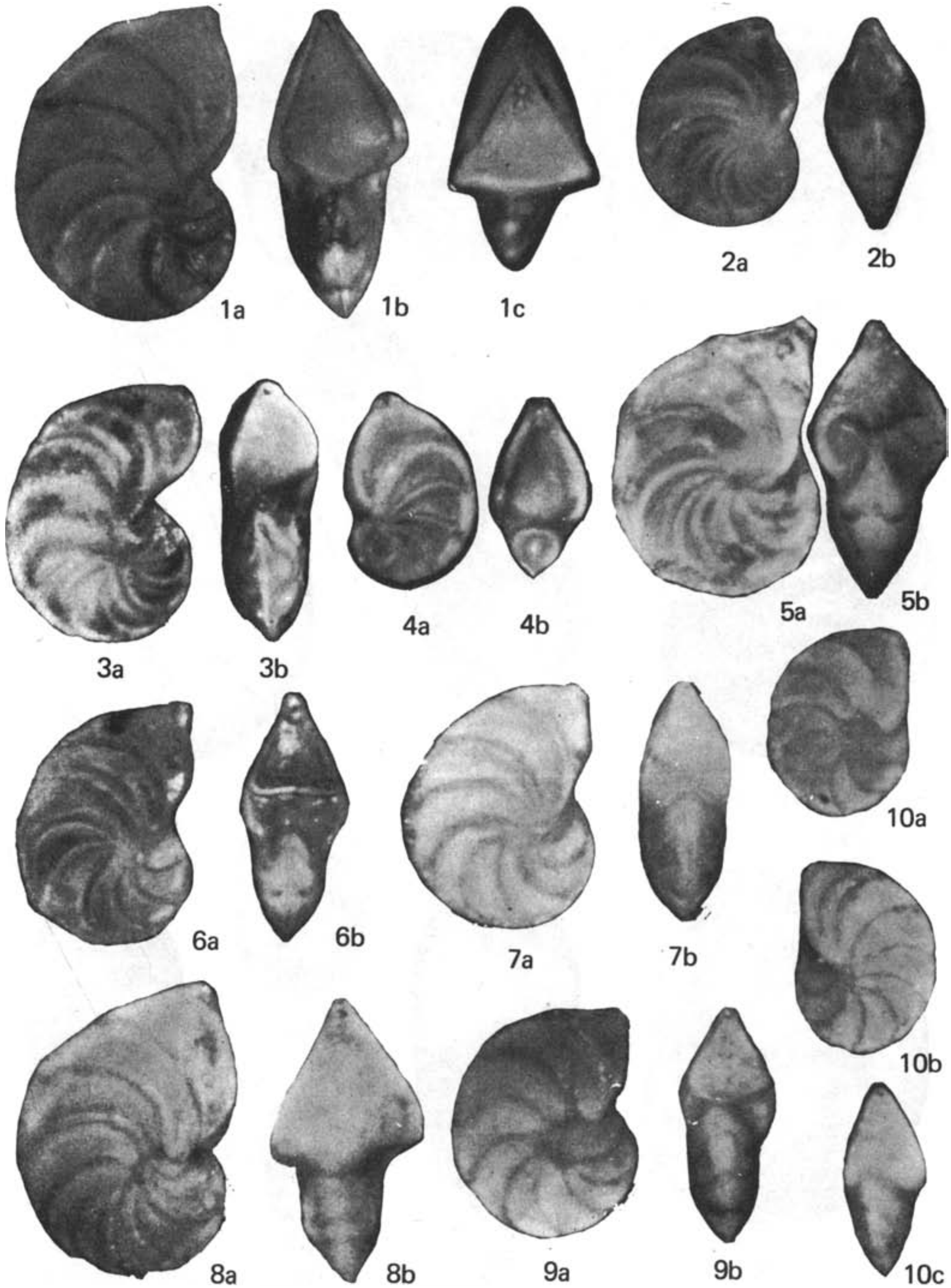

1a
1b
2
3
4
5
6
7a
7b
8
9

PLATE XLIII




1a
1b
1c
2a
2b
3a
3b
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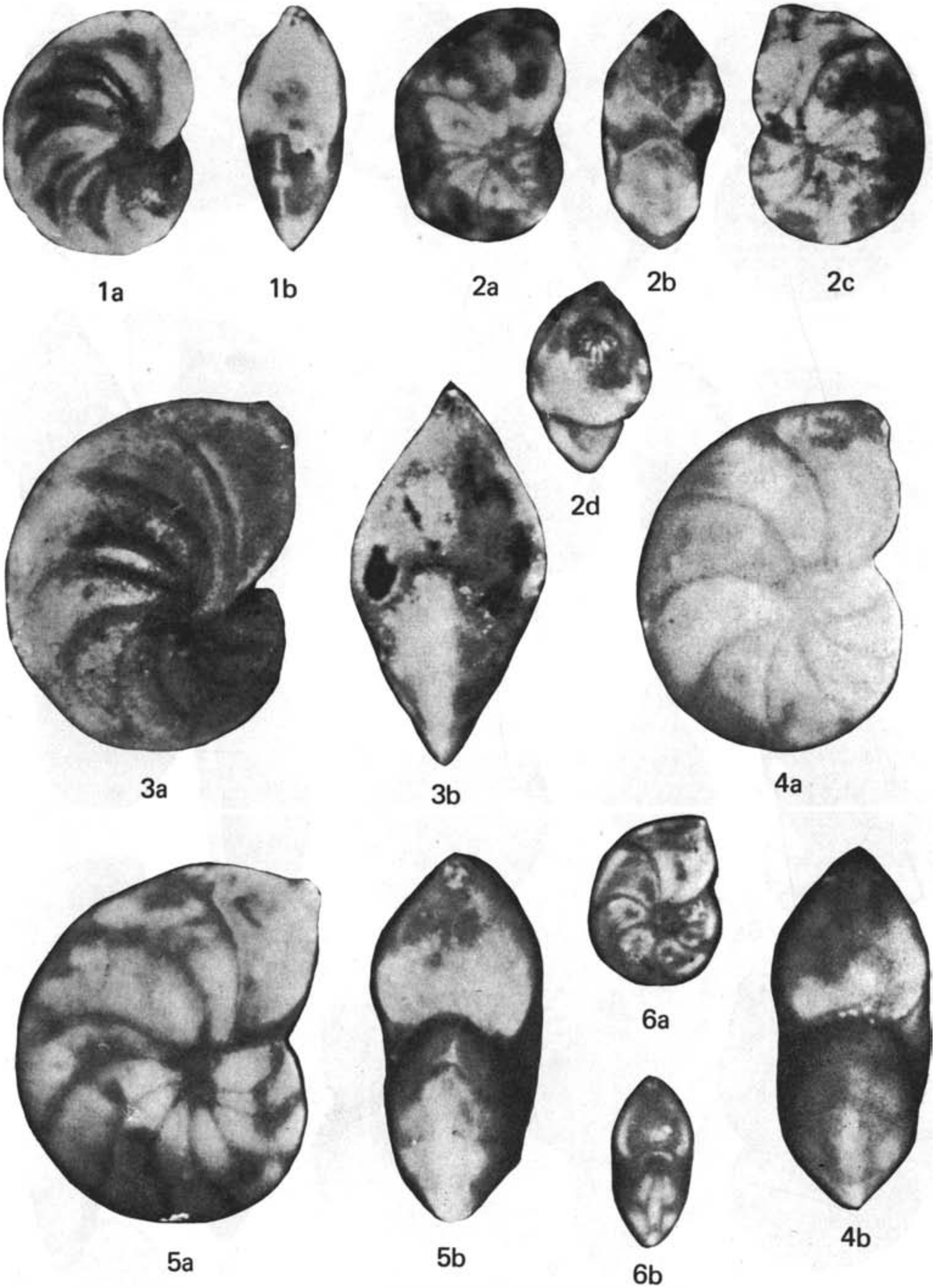
4b
5a
5b
6a
6b
7a
7b
8a
8b
9a
9b
10a
10b
10c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2b
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3b
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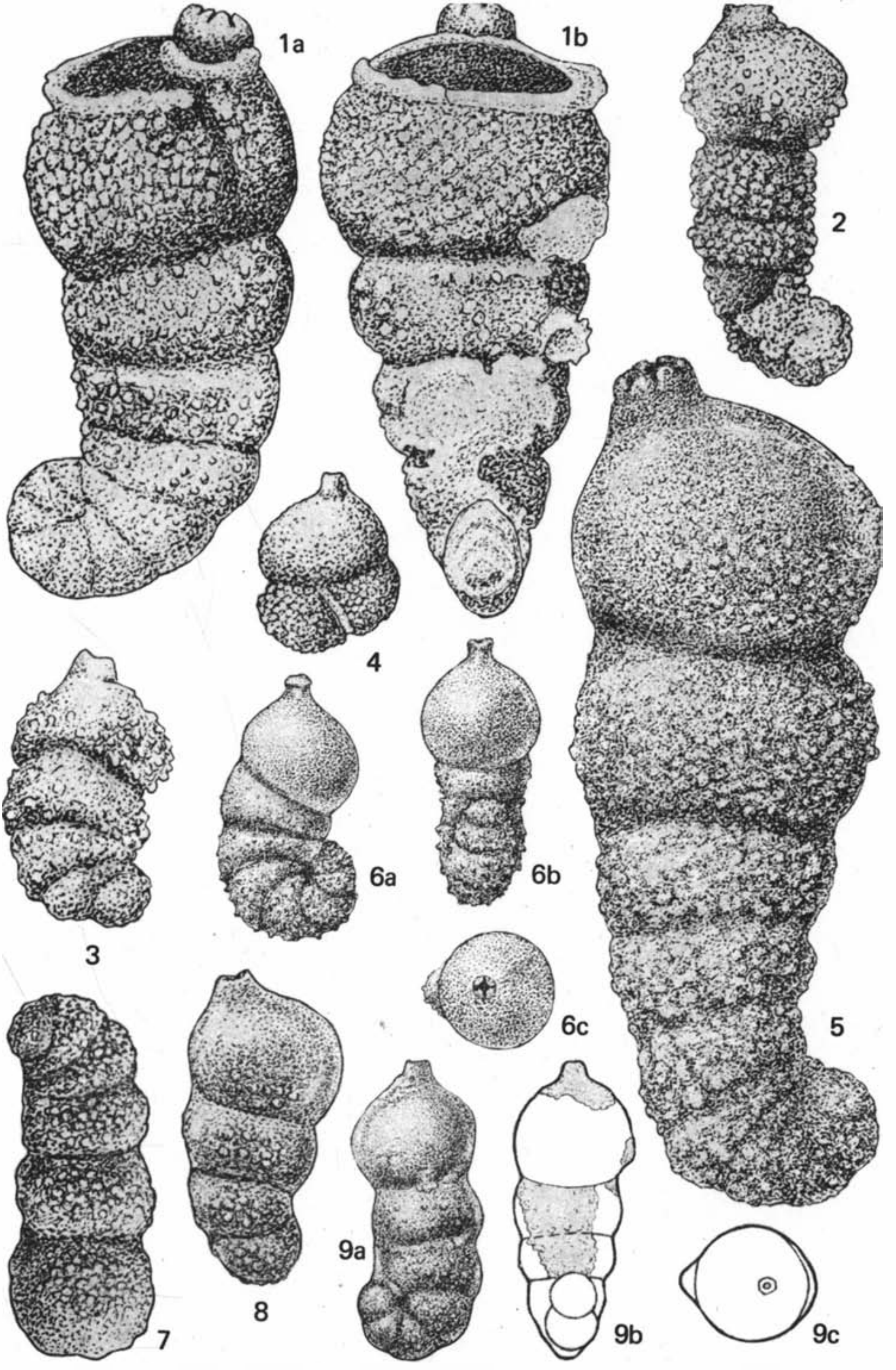
5a
5b
6a
6b
4b


1a
1b
2
3
4
5
6a
6b
6c
7
8
9a
9b
9c

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