The Jurassic of the Circum-Pacific

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11 Eastern Russia

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INTRODUCTION[1]

Diastrophism

The Jurassic of eastern Russia is part of the Mesozoic tectonosedimentary megacycle, from Late Triassic to Neocomian, which formed the Mesozoids of Northeast Asia and laid the foundations of its present structural plan. The Jurassic changed the geodynamic setting from active geoclinal to continentalization, except for the Pacific margin, where new geoclines were initiated at the close of the Jurassic.

Lower and Middle Jurassic deposition occurred during the major cycle of geoclinal evolution of the Mesozoids (North-East Russia: Yukagir cycle), and it comprises a single structural complex together with the Upper Triassic (commonly Norian) deposits. The lower boundary of this complex in the North-East is characterized by hiatuses of differing lengths and minor structural changes (Figure 11.1). In areas of stable down-warping (Oldzhoi and Inyali–Debin Troughs), a weak compressional phase at the beginning of the Yukagir cycle resulted in small thrusts and olistostromes (Parfenov 1984). In Far East Russia, the emplacement of this complex was preceded by a major restructuring accompanied by folding (Figure 11.1).

The upper boundary of the Yukagir cycle is almost ubiquitously marked by angular and stratigraphic uncomformities. This regressive phase was of long duration. In the North-East, uncomformities are most distinct in the Bathonian, and less pronounced in the Oxfordian. In the Far East, the first folding occurred in the middle Bajocian and the main phase in the Callovian; the latter is associated with a total inversion of most of the Amur-Okhotsk Geocline. These uncomformities are regarded as the lower boundary of the late geoclinal cycle (North-East: Kolyma) of Mesozoid evolution that ended at the close of the Neocomian.

Volcanism

Volcanism was most pronounced in the Early and Middle Jurassic of the North-East, particularly along its eastern margin. Three types of volcanic activity are distinguished (Figures 11.1 and 11.2):

1. Viliga suboceanic type of the Early Jurassic: At the upper Indigirka River, the Kobyuma volcanic structure consists of layers of Hettangian to late Pliensbachian subalkaline hyalobasalts (800 m); at the middle Viliga River, the late Toarcian hyalobasalts are up to 250 m thick.
2. Trachybasalts and similar rocks are the prevailing constituents of Early Jurassic rifts (late Sinemurian to early Pliensbachian). This type occurs only in the Omolon Massif, where it is subaerial and subaqueous.
3. The island-arc type, represented by andesitic and andesite-basaltic associations, with associated pyroclastic, occurs throughout the Jurassic of the North-East and is characteristic of the eastern peripheral part of the region (Figure 11.2).

In the Far East, the Early and Middle Jurassic are generally amagmatic, with the exception of eugeoclinal oceanic areas (Figures 11.1 and 11.2). Intense submarine volcanism in the axial zone of the Sikhote-Alin Geocline resulted in spilite-diabase associations, 200–300 m thick, within the Lower to Middle Jurassic siliceous-terrigenous sequences. These formations are now interpreted as suboceanic ophiolite association (Parfenov 1984).

In the Late Jurassic, rift-volcanism occurred in the North-East, with an association of continental olivine basalts and andesite-rhyolite complexes (Iliin–Tas). The South Anyui zone is characterized by spherulitic and ropy lavas of subalkaline and tholelitic basalts and is included in the ophiolite complex (Parfenov 1984) or assigned to the basaltic association of continental rift zones (Gusev et al. 1985).

A rift zone presumably was present in the Late Jurassic of central Sikhote-Alin, east of the Khanko Massif, where Late Jurassic

[1] By I. I. Sey and Y. S. Repin.

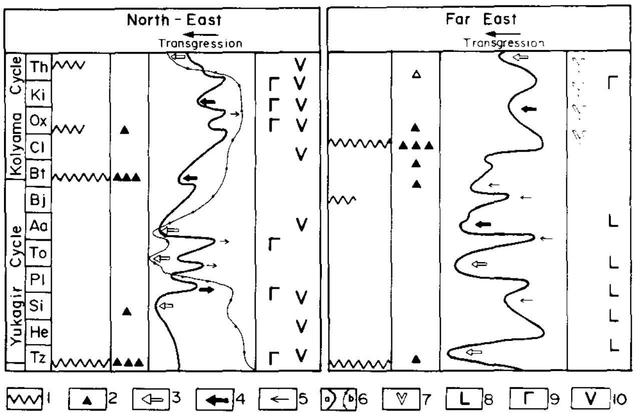


Figure 11.1. Principal geological events in the Jurassic of northeastern Asia: 1, diastrophic phases; 2, levels on which olistostromes are formed. Transgressive–regressive activity: 3, eustatic (global); 4, mixed or of uncertain origin; 5, structural origin (regional); 6, curve of transgression–regression (a, for Far East and North-East; b, for the Siberian Platform). Volcanism: 7, subaerial; 8, eugeoclinal; 9, rift; 10, island arc.

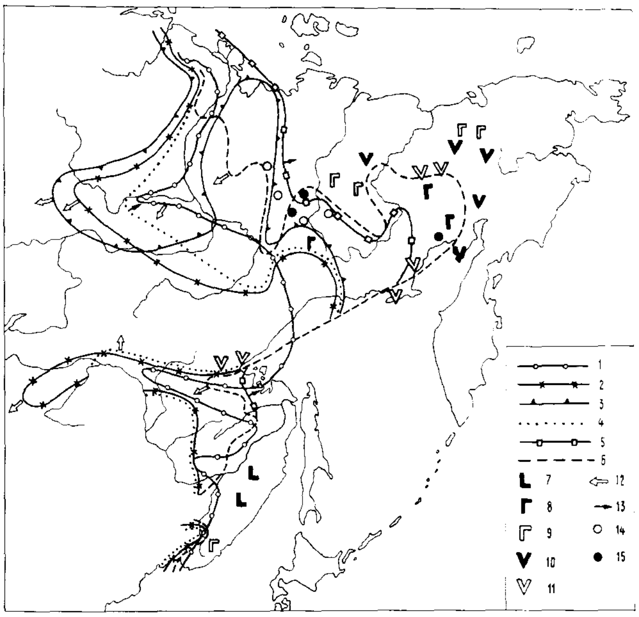


Figure 11.2. Boundaries of major Jurassic transgressions and regressions and areas with volcanics in northeastern Asia. Position of coastline: 1, Hettangian–Sinemurian; 2, late Pliensbachian–Toarcian of Far East and late Pliensbachian of North-East; 3, Toarcian (North-East); 4, Aalenian–Bajocian; 5, Kimmeridgian; 6, Volgian. Volcanism: 7, eugeoclinal; 8, 9, rift zones (8, Early Jurassic; 9, Late Jurassic); 10, island arcs. Coastline position: 11, land; 12, transgressions; 13, regressions. Olistostromes: 14, Norian; 15, Bathonian.

flows, dikes, and extrusive alkaline basaltoid bodies are known (Parfenov 1984; Mazarovich 1985). The Late Jurassic in the Far East is noted for its subaerial volcanic activity in the west and north of the region, dominated by andesites. In the North-East, continental-type Late Jurassic volcanism occurred along the northern margin of the Omolon Massif.

Transgressions and regressions

In the North-East, the Norian to early Sinemurian transgression resulted mainly in deepening of the basin and slight extension (Figure 11.1). It was predominantly eustatic, as evident from the extensive occurrence of cosmopolitan ammonite genera (*Psiloceras, Waehneroceras, Schlotheimia,* and *Arietites*) and some Pacific bivalves (i.e., *Otapiria*). In the middle Sinemurian begins a progressive shallowing trend in the North-East, a consequence of the local inversion of some structures.

In the Far East, however, the earliest Jurassic was regressive, with the sea remaining only in the deepest depressions. The transgressive cycle began in the Sinemurian with a small-scale ingression (Figure 11.1). The Early Jurassic transgression in eastern Russia reached its maximum in the late Pliensbachian–early Toarcian, when the margins of the sea basin extended westward to the western Transbaikal area and the eastern Siberian Platform (Figure 11.2). This eustatic transgression provided broad connections between basins and resulted in the dispersion of amaltheids, pandemic dactylioceratids, and hildoceratids. The subsequent regression at the end of the Toarcian was associated with the general uplift of Northeast Asia.

The Middle Jurassic of eastern Russia is characterized by a thalassocratic regime resulting from local geodynamic processes. The extent of the Aalenian-Bajocian transgression was similar to that of the Early Jurassic. Against the background of a generally high sea level, there were repeated coast-line fluctuations, resulting from local uplifting mainly in the west of the area. Whereas the transgressive phase is early Bathonian in the North-East, it is late Bathonian in the Far East.

The close of the Middle Jurassic was marked by a slow regression. It was associated with diachronous upliftings and folding in the North-East and Far East during Bathonian to Oxfordian times.

The Late Jurassic transgression, which in the Far East began in the latest Callovian, reached its first peak in the Oxfordian–early Kimmeridgian, but the marine basin was much smaller than in the preceding epochs. The transgressive peak was in the middle to late Volgian, eustatic in origin, and extensive in northern Eurasia.

Eastern Russia comprises two major regions, the Far East and the North-East, which differ notably in geological structure and history.

FAR EAST RUSSIA[2]

The Russian Far East, south of the Stanovoi Range, reaches from Sakhalin Island, in the east, to the Eastern Transbaikal area, in the west, where the Jurassic structures are closely similar. Within this area of complex structures, the Jurassic deposits are divided into different structural-facies units that are based on specific features of the rock sequences and also their biota. The Jurassic is most widespread within geoclinal-fold systems, that is,

[2] By I. I. Sey, E. D. Kalacheva, and T. M. Okuneva.

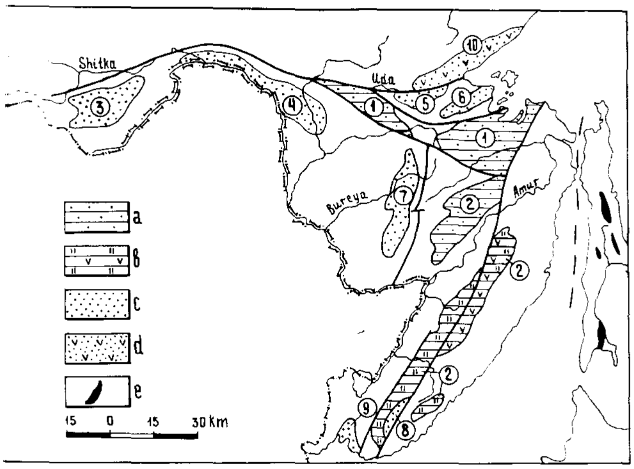


Figure 11.3. Distribution of main types of Jurassic deposits in Far East Russia. Geoclinal-fold systems: 1, Amur-Okhotsk; 2, Sikhote-Alin. Subplatform troughs: 3, East Transbaikal; 4, upper Amur; 5, Uda; 6, Torom; 7, Bureya; 8, Okrainsky; 9, Southern Primorye. Mesozoic structures: 10, Uda-Okhotsk Volcanic Molasse Trough. Rock types: a, miogeoclinal deposits of the Amur-Okhotsk and western Sikhote-Alin geoclinal systems; b, eugeoclinal terrigenous-siliceous-volcanic formations of the central and eastern Sikhote-Alin Geocline; c, terrigenous deposits of subplatform troughs; d, volcanic and volcanosedimentary rocks in zones of Mesozoic activity; e, jasper complex of Sakhalin Island.

the sublatitudinal Amur-Okhotsk and submeridional Sikhote-Alin systems (Figure 11.3), and is up to 10 km thick. The dominant rock types are miogeoclinal sandy to shaley flysch and flyschoid deposits, particularly in the Amur-Okhotsk Geoclinal System. The axial part of the Sikhote-Alin Geocline contains abundant silicovolcanics that mark zones of eugeoclinal sedimentation (Figure 11.4) All these strata are intensely folded, with extensively imbricated overthrust structures and mictite. These probably comprise large structural plates.

The Jurassic geoclinal deposits of relatively deep-sea basins yield very few macrofossils, and the study of microfauna, mainly radiolarians, has just begun. The biostratigraphy of Jurassic geoclinal strata is thus known inadequately and only in general terms.

The second type of deposit corresponds to the so-called subplatform troughs, which, in the Jurassic, formed on the margins of rigid, unconsolidated structures around geoclinal systems. Near the Amur-Okhotsk Geoclinal System are the Eastern Transbaikal, Upper Amur, Uda, and Torom Troughs (from west to east). The Bureya and Southern Primorye Troughs are conjugated with the Sikhote-Alin Geocline (Figure 11.3). The Okrainsky Block, which is presently assumed to be an intrageoclinal uplift (Mazarovich, 1985), has a similar sequence.

These structures are noted for incomplete sections, with unconformities, the presence of coastal-marine and continental facies, and more diverse rock types: sandy to silty sediments dominate, together with coarse-grained and tufogenic rocks. Their thicknesses (to 8,000 m) are comparable to those of the coeval adjacent geoclinal systems (Figures 11.5 and 11.6).

Subplatform troughs have relatively simple geological structures and are, as a rule, large synclinoriums complicated by minor folds and faults with local subhorizontal attitudes.

Paleogeographically, subplatform troughs represent shallow-sea basins, with rich benthic and nektonic fauna that resulted in the relative abundance of fossils. Sections of this type, therefore, predominate in the construction of the detailed stratigraphic scale for the Far East.

The third type of deposit comprises the Jurassic in Sakhalin Island (Figure 11.4). It is part of the Mesozoic Volcanic Jasper Complex, regarded as accumulation of an open-oceanic basin, that is, the Paleopacific (Rikhter 1986).

In addition to these major types, there are also the sedimentary-volcanic formations in volcanic depressions in the north of the region (Dzhugdzhur Ridge) and coarse-clastic molassoid sediments of orogenic intermontane areas of the Bureya Massif and surrounding fold systems.

Lower Jurassic

The Lower Jurassic sections in the Far East all have incomplete fossil records. The outcrops are isolated and the successions separated by uncomformities, so that only a few biostratigraphic units can be distinguished.

Hettangian macrofossils are unknown from the Far East. Sinemurian deposits occur in isolated exposures only in the east of the region. Lower Sinemurian sandstone and siltstone (300 m) with *Otapiria omolonica* and *O. pseudooriginalis* crop out in a tectonic block in the western Sikhote-Alin Geoclin area (Kur River Basin). Upper Sinemurian sandstone, siltstone, and clay (to 260 m) form small exposures in the southern Bureya and South Primorye Troughs and yield *Otapiria limaeformis* and *Pseudomytiloides rassochaensis;* in Primorye occurs also *Angulaticeras* cf. *ochoticum.* This assemblage resembles coeval faunas of the North-East, and the same ammonite zones are recognized: the *Otapiria omolonica* Zone (Lower Sinemurian) and the *Angulaticeras kolymicum* and *Otapiria limaeformis* Zones (Upper Sinemurian).

The so-called Kiselevka Assemblage (lower Amur River), with *Juraphyllites amurensis, Chlamys textoria,* abundant *Cardinia, Plagiostoma,* and other bivalves, gastropods, and corals (Kiparisova 1952) holds a peculiar position among the lower Liassic faunas of the region. (E. V. Krasnov also identified the scleractinians *Anabacia* and *Montlivalcia.*) This fauna is confined to a large limestone lens within a thick (to 2,000 m) sequence of jasper, siliceous-clayey rocks, and volcanics (Kiselevka Formation) that forms a tectonic block among the Upper Jurassic–Lower Cretaceous deposits. The Kiselevka Assemblage may therefore be allochthonous in origin.

Lower Liassic deposits in geoclinal facies appear to be widely distributed in the continental parts of the Far East. They comprise undivided geoclinal complexes that have been dated as Late Triassic–Early Jurassic. Here also belong the Kurnal Formation (sandstone, siltstone, tuff sandstone, gritstone, breccia, basic effusive lenses, 3,500 m), in the central Amur-Okhotsk fold system, and the Sorukan Formation (sandstone, siltstone, 2,000) in the

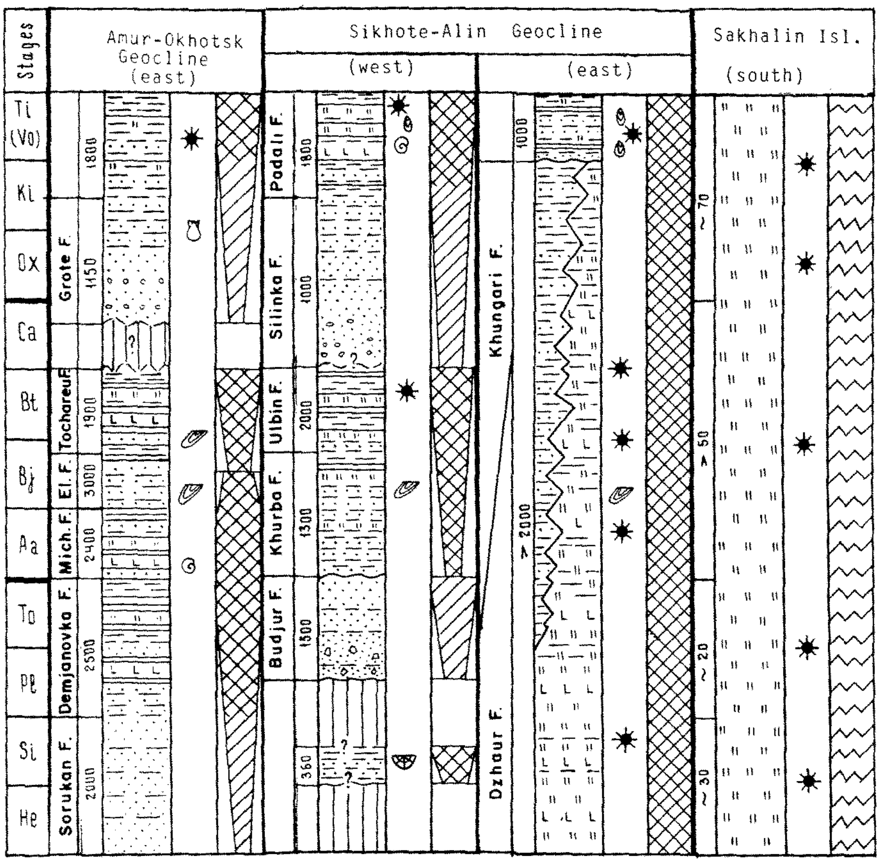


Figure 11.4. Important Jurassic geoclinal sequences in Far East Russia and the oceanic (pregeoclinal) Jurassic sequence of Sakhalin Island. Formations: Mich., Michalitsynskaja; El., Elgon. Legend same as in Figure 11.5.

east of this structure, as well as siliceous-volcanic rocks in the lower part of the Dzhaur Formation in the northern Sikhote-Alin folded area. Their Jurassic age is confirmed in some places by radiolarians (Tikhomirova 1986).

Lower Liassic oceanic facies probably occur in Sakhalin Island (Rikhter 1986), where, according to N. Y. Bragin, jaspers (30 m) in the vicinity of the Yunona Mount (South Sakhalin) contain the Hettangian–Sinemurian radiolarians *Parahsuum simplum, Parahsuum, Dictyomitrella,* and *Lithostrobus.*

Lower Pliensbachian cannot be documented by fossils. The beginning of late Pliensbachian is marked by the peak Jurassic transgression, reaching the Eastern Transbaikal area and forming the base of the sedimentary sequences in all subplatform troughs. Coarse-grained layers (to 400 m) occur ubiquitously at the bases of the sections, yielding abundant *Oxytoma (Palmoxytoma) cygnipes* and *Harpax spinosus.* These deposits are traceable from the Eastern Transbaikal area to Southern Primorye and are distinguished as the *O. cygnipes* and *H. spinosus* Beds.

The most complete Upper Pliensbachian section is recorded in the Bureya Trough from the Desh Formation. Earlier these deposits were placed into the Umalta Formation (Krymholts, Meseshnikov, and Westermann 1988). The latter is at present subdivided into two formations: the Desh (Upper Pliensbachian–Lower Toarcian) and the Sinkaltu (Aalenian–Lower Bajocian) (Sey et al. 1984). It includes (ascending order):

1. *Amaltheus stokesi* Zone – siltstone, with sandstone interbeds, coarse-grained sandstone, breccia, and conglomerate at the base (to 340 m)
2. *A. margaritatus* Zone – siltstone, sometimes sandstone; also with *A.* cf. *complanatus* (160 m)
3. *A. viligaensis* Beds – siltstone, less frequently sandstone (80 m)

Most of the section is characterized by the bivalves *Ochotochlamys bureiensis, Chlamys (Ch.) torulosa, Kolymonectes* ex gr. *staeschei, Amuropecten solonensis,* i.e., the *Ochotochlamys bureiensis* Beds. These units are traceable in the Eastern Transbaikal Trough and Okrainsky Block (Ontagaja and Okrainka Formations, respectively).

In the Okrainsky Block, the upper Pliensbachian, in addition to *Amaltheus,* yields the predominant Tethyan genera *Arieticeras, Fontanelliceras, "Dactylioceras,"* and *Protogrammoceras.* The upper part of the section without amaltheids is distinguished as *"Paltarpites"* Beds.

Toarcian deposits in subplatform troughs are fragmented due to regional pre–Middle Jurassic uplift. In the Bureya (Desh Formation), Uda, and Torom Troughs, sandstone and siltstone (300 m) rest conformably or transitionally on Upper Pliensbachian. In the Eastern Transbaikal area, the Toarcian has a coarse clastic basal horizon (Sivachi Formation, to 600 m), and up the section the

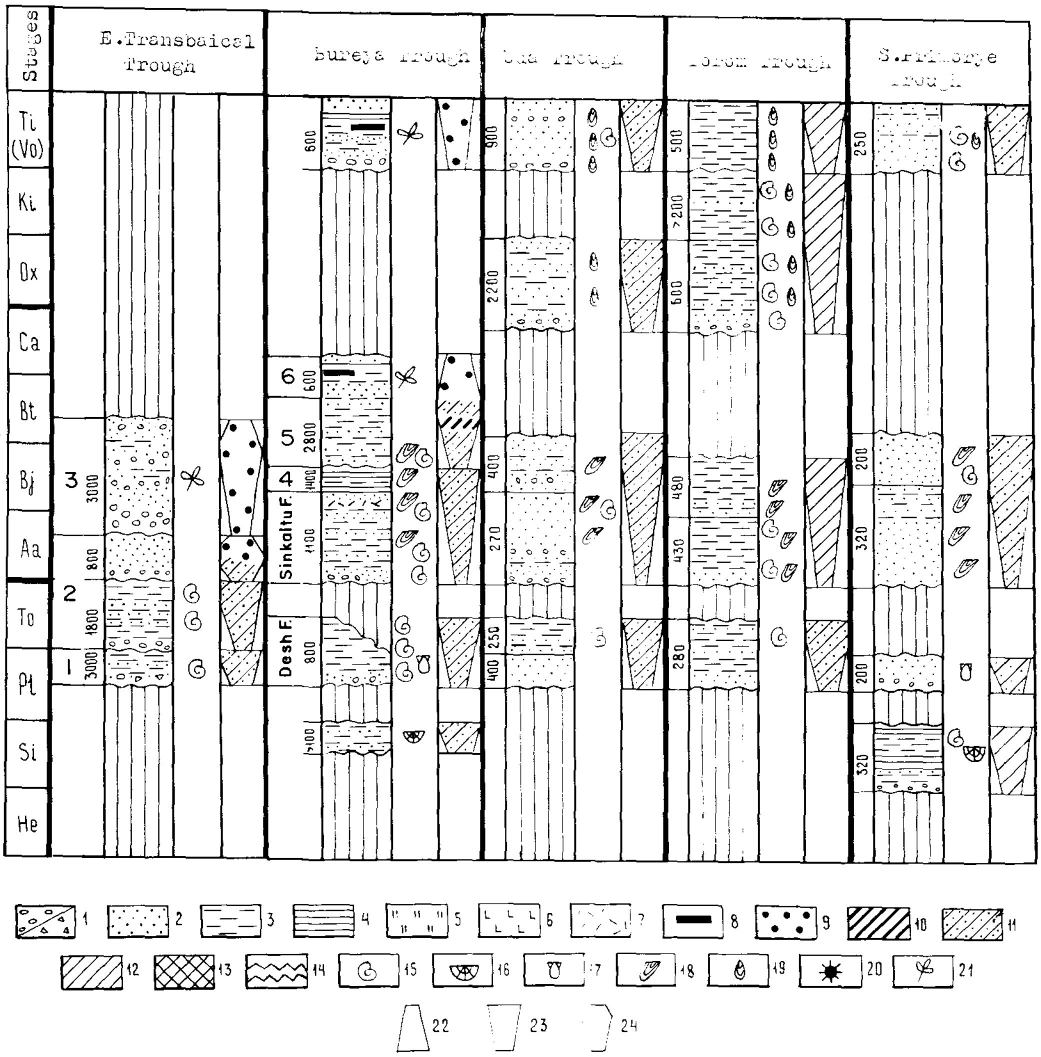


Figure 11.5. Important Jurassic subplatform sequences in Far East Russia. Rock types: 1, conglomerates and breccias; 2, sandstone; 3, siltstone; 4, mudstone and shale; 5, siliceous rocks; 6, basic effusives; 7, acidic effusives; 8, coals. Facies: 9, lacustrine alluvial; 10, coastal marine; 11, upper and middle sublittoral; 12, lower sublittoral; 13, deep sea (pseudoabyssal); 14, oceanic (pelagic). Main groups of fossils: 15, ammonites; 16, otapirias; 17, pectenids; 18, mytiloceramս; 19, buchias; 20, radiolarians; 21, flora. Cycles: 22, regressive; 23, transgressive; 24, more or less symmetric. Formations (with thickness in m): 1, Ontagaja; 2, Sivachi and Onon-Borzja; 3, upper Gazimur; 4, Epikan; 5, Elga and Chagany; 6, Talyndzhan; 7, Dublikan; 8, Komarovka.

sediments are more diverse, from conglomerate to siltstone (Onon-Borzja Formation). The total thickness in this area reaches 2,500 m (Okuneva 1973).

The generalized Toarcian section is divisible into four units of zonal rank: *Harpoceras falciferum* (Eastern Transbaikal area), *Dactylioceras athleticum* (Uda and Bureya Troughs), *Zugodactylites monestieri* (Eastern Transbaikal area, Uda and Torom Troughs), and *Poroceras spinatum* (Bureya Trough). This succession is similar to that of North-East Russia and is correlated with the standard scale. The Upper Toarcian of the Eastern Transbaikal area also contains the ammonite *Pseudolioceras* cf. *rosenkrantzi*, indicating the *P. rosenkrantzi* Zone.

Pliensbachian and Toarcian in geoclinal facies can be distinguished only approximately, proceeding from the continuous character of the strata. In the Amur-Okhotsk Geoclinal Fold System, sandy to silty deposits (2,500 m) (Amkan, Nimelen, and Demyanovka Formations) may be of this age; in the Sikhote-Alin Geoclinal Fold System, both terrigenous and volcanosiliceous rocks are possibly of the same age. The latter occur mainly in northern Sikhote-Alin (Dzhaur Formation). In the south (central Sikhote-Alin), part of the Late Triassic–Middle Jurassic black shale may be Lower Jurassic. This is a structurally complex, sandy to silty sequence with mictite and olistostromes (Mazarovich 1985). In Sakhalin Island, N. Y. Bragin identified the Pliensbachian–Toarcian radiolarian association in the volcanic-jasper oceanic complex (20 m) (Rikhter 1986): *Dultus* aff. *hecattaenus*, *Praeconocaryomina immodica*, *Trillus*, *Canutus*, and *Lupherium*.

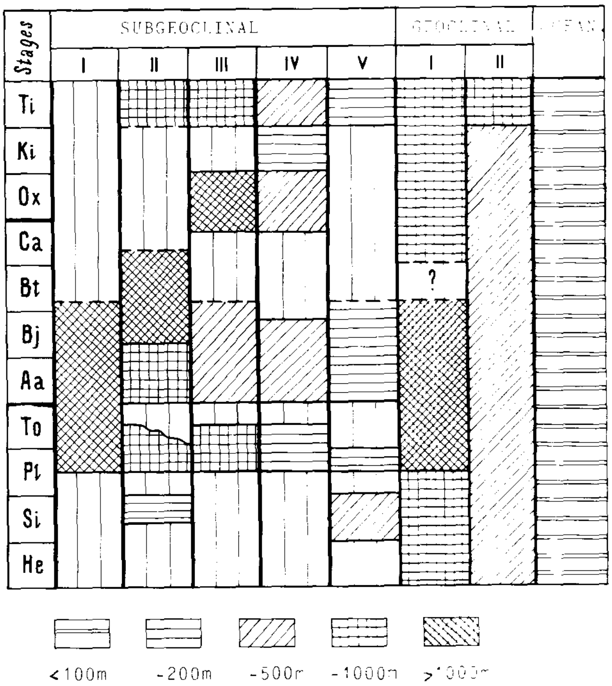


Figure 11.6. Thickness of Jurassic deposits in Far East Russia. Subplatform: I, Eastern Transbaikal Trough; II, Bureya Trough; III, Uda Trough; IV, Torom Trough; V, Southern Primorye Trough. Geoclinal: I, Amur-Okhotsk Geocline (eastern part); II, Sikhote-Alin Geocline (northern part). Oceanic: pregeoclinal, Sakhalin Island. Thickness of deposits per stage: 1, less than 100 m; 2, to 200 m; 3, to 500 m; 4, to 1,000 m; 5, to over 1,000 m.

Middle Jurassic

The beginning of Middle Jurassic in the Far East is marked by a major transgression similar in extent to that in the late Pliensbachian. But it hardly affected the Eastern Transbaikal area, reflecting a gradual area reduction of marine sedimentation from west to east (Figure 11.7). All subplatform troughs have a basal Aalenian unconformity that is also traceable in the marginal parts of geoclinal systems.

The Aalenian transgression favored an extensive distribution of mytiloceramis, which, as dominant Middle Jurassic macrofossils, are used along with ammonites for detailed biostratigraphy of the Middle Jurassic.

The reference Aalenian section in this region is on the western coast of the Tugur Bay in the Okhotsk Sea (Torom Trough), where the zonal stratotypes for eastern Russia are located. This section is as follows (ascending order):

1. *Pseudolioceras beyrichi* Zone – fine-grained sandstone, with some pebbles (64 m); also with *P. (P.)* aff. *beyrichi*, *Mytiloceramus priscus*, and *M. subtilis*.
2. *P. maclintocki* Zone – black, thin-bedded, platy siltstone (100 m); *Mytiloceramus priscus* and *M. quenstedti*; in upper part with accumulations of peculiar *P. (Tugurites)* [*"Grammoceras"*]
3. *P. tugurense* Zone – black, platy, massive siltstone (260 m); *P. (Tugurites) whiteavesi*; in the upper part, *Erycitoides (E.) howelli* and *E. (Kialagvikes) spinatus*; mytiloceram̄s dominated by *Mytiloceramus obliquus*, *M. polyplocus*, *M tugurensis*, *M. anilis*, and, rarely, *M. jurensis* and *M. mori*.

Correlation with the standard scale is accomplished by the ammonites via southern Alaska and Canada (Frebold 1957, 1960, Westermann 1964). The two lower zones (1–2) approximately correspond to the Lower Aalenian, and the *tugurense* Zone (3) to Upper Aalenian. At Tugur Bay are also the stratotypes of Aalenian mytiloceram zones (i.e., *M. priscus* and *M. obliquus* Zones), which approximately correspond to the Aalenian substages. Aalenian ammonite and mytiloceram zonal assemblages are known from almost all subplatform troughs, where Aalenian sandstones and siltstones are up to 700 m thick (lower Sinkaltu Member in Bureya Trough, lower Bonivur Formation in southern Primorye).

The Bajocian of subplatform troughs contains abundant fossils for detailed biostratigraphy. Most stratotypes are in the Bureya Trough (upper Sinkaltu Member), where the Lower Bajocian section along the Bureya River is as follows (ascending order):

1. *Pseudolioceras fastigatum* Zone/*Mytiloceramus jurensis* Zone – equigranular sandstone and siltstone (225 m); in upper part, with rare *P. (Tugurites) costistriatum*; throughout abundant mytiloceramis
2. *Arkelloceras tozeri* Zone/*Mytiloceramus lucifer* Zone – siltstone, with sandstone interbeds (200 m); rare *A. tozeri* and *A. elegans*, abundant *M. lucifer* and *M.* ex gr. *lucifer*

The ages of both ammonite zones are also determined via southern Alaska and western Canada (Westermann 1969; Hall 1984). The *fastigatum* Zone is approximately coeval with the Discites and Laeviuscula Standard Zones (= Widebayense Zone of North America), and the *tozeri* Zone with the Sauzei Zone (= Crassicostatus Zone). The lower boundary of the Bajocian in eastern Russia is drawn at the base of the *fastigatum* Zone.

The stratotype of the superjacent *Mytiloceramus clinatus* Zone is at the Tugur Bay coast (Torom Trough), where deposits with *M. lucifer* are overlain by 230-m-thick siltstone with large *M. clinatus*.

In the Bureya Trough, coeval siltstones along the Soloni River grade into the *Mytiloceramus kystatymenis* Beds. Here, both units are placed in the Epikan Formation (1,400 m). Along the Soloni River, the Bajocian section ends with the *Umaltites era* Beds (horizon), fine-grained sandstone and siltstone (300 m), which overlie siltstone with rare *Liroxyites* cf. *kellumi* (lower Elga Formation).

Dating of the *Umaltites era* Beds presented great difficulties (Sey and Kalacheva 1980). At present, by analogy with similar faunas of western Canada (Frebold and Tipper 1973), they are considered as Late Bajocian, approximately Garantiana and Parkinsoni Standard Zones (Callomon 1984; Sey and Kalacheva 1987). Westermann (personal communication; Sey and Kalacheva 1988) believes that this assemblage is closely akin to the early Late Bajocian *Megasphaeroceras-Liroxyites* assemblage of the Rotundum Zone widely developed in western North America.

The thickness of the Bajocian in the Bureya Trough reaches 2,000 m, probably a maximun for Bajocian subplatform deposits.

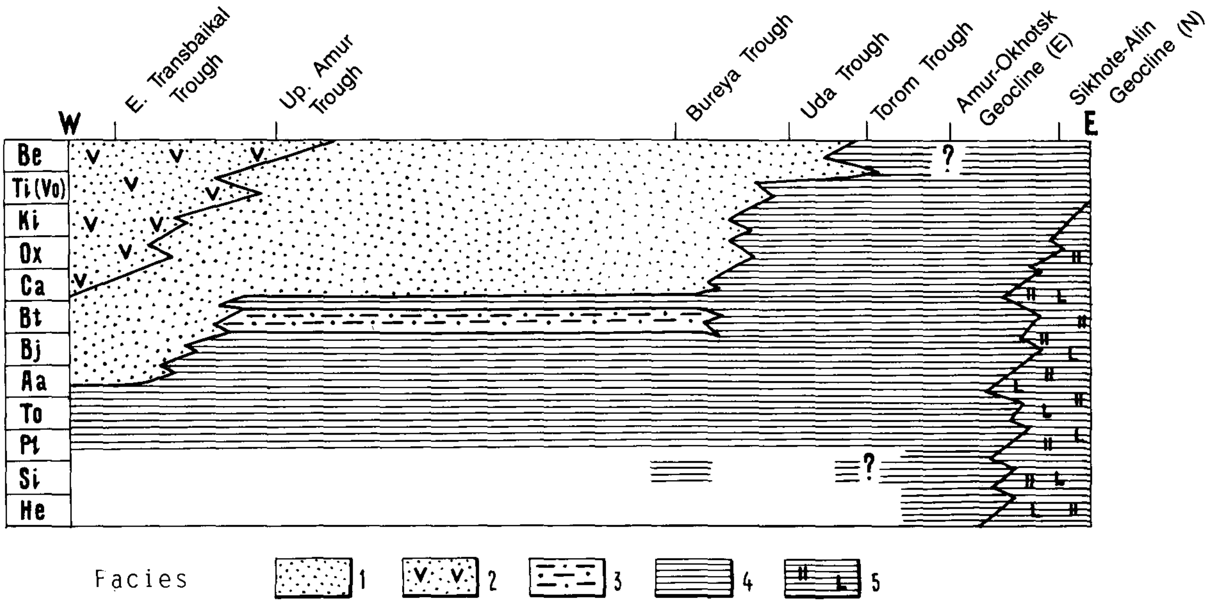


Figure 11.7. Jurassic lithofacies in northern Far East Russia. Facies: 1. continental terrigenous; 2, continental volcanic-terrigenous; 3, coastal marine; 4, marine terrigenous; 5, marine siliceous-volcanic-terrigenous.

The *Mytiloceramus lucifer* Zone is widespread. It is recorded in all subplatform sections (with the exception of the Eastern Transbaikal area, where marine sedimentation apparently ended at the beginning of the Aalenian) and is traceable in geoclinal troughs. It is thus important for intraregional and interregional correlation.

At present, no macrofossils of undisputed Bathonian age are known from the Far East. In the Bureya Trough, the *Umaltites era* Beds are overlain by siltstones with sandstone interbeds (ca. 1,600 m), yielding rare, poorly preserved ammonites that could be Bathonian (upper Elga and Chagany Formations). Marine, coastal-marine, and continental sediments with similar stratigraphic positions are also found in other subplatform troughs. Callovian deposits are known only from the Torom Trough, Tugur Bay coast, where Lower Bajocian is overlain with a distinct angular unconformity by Upper Callovian sandstone and conglomerate (90 m) with *Longaeviceras* cf. *keyserlingi*.

The analysis of the different structural-facies zones of the Far East indicates significant tectonic activity, that is, uplifting and folding, most likely in the Callovian in both the subplatform and geoclinal troughs.

The Middle Jurassic of geoclinal-fold systems, similar to the Lower Jurassic, yields extremely scarce fossils, making biostratigraphy impossible. Local ammonite and mytiloceram levels are known, and the most common among the latter are the Lower Bajocian *Mytiloceramus lucifer* Beds.

The miogeoclinal deposits of the Amur-Okhotsk and western Sikhote-Alin Systems (left bank of Amur River) are subdivided into several formations (i.e., Mikhalitsynskaja, Elgon, and Tochareu in the first area, Churba and Ulbin in the second). They consist of sandy-silty-clayey, flyschoid sediments with siliceous-clayey rock and basic effusive inclusions (over 5,000 m, Figure 11.4). Their Middle Jurassic age is approximately determined by rare finds of ammonites, mytiloceram, and radiolarians (*Resolutions* . . . 1982; Tikhomirova 1986).

In the eugeoclinal zone of the northern Sikhote-Alin Fold System the Middle Jurassic section is still dominated by silicovolcanic rocks of the Dzhaur Formation, which laterally grade into sandy shale accumulations (Khungari Formation). The Middle Jurassic age of both is confirmed by mytiloceram and radiolarians.

In central Sikhote-Alin, clayey rocks of black shale yield the radiolarians *Gorgansium silviensense, Zortus* cf. *jonesi, Aconthocircus* aff. *dicvanocanthus, Parvicingula,* and *Hsuum,* which, according to N. Y. Bragin, indicate Middle Jurassic (Bajocian–Bathonian?) (Mazarovich 1985). Radiolarian assemblages of different (Bajocian–Callovian) ages have been identified from isolated exposures of siliceous, terrigenous rocks in east-central and south Sikhote–Alin (Tikhomirova 1986).

Pre-late Callovian tectonic movements were most distinct in the Amur-Okhotsk Geoclinal System. They are associated with the inversion of its western and central parts and intense folding, complicated by large thrusts, which resulted in an appreciable narrowing of the geoclinal zone and the imbricated thrust structure of the Jurassic (Kirillova and Turbin 1979; Parfenov 1984).

The Middle Jurassic oceanic facies, similar to those of the Lower Jurassic, are part of the volcanic jasper section in Sakhalin Island and yield Middle Jurassic radiolarians. The thickness appears to vary greatly (minimum ca. 50 m) (Rikhter 1986).

Upper Jurassic

Marine Upper Jurassic occurs only in the eastern Far East, indicating continued migration of marine sedimentary basins toward the Paleopacific (Figure 11.7).

In the western Far East, thick continental coal measures (to 5,000 m) follow marine deposits in the upper Amur Trough (Ajak, Dep, and other formations) and Bureya Basin (Dublikan Formation). The narrow fault-bounded depressions surrounding the Amur-Okhotsk Fold System have coarse, continental molasses (over 3,000 m). In the north of the region (Dzhugdzhur Ridge), accumulation of sedimetary volcanics of the Dzhelon Formation (ca. 3,000 m), which started in the Middle Jurassic, continued in the volcanic depressions. At the close of the Jurassic, the destruction of an arched uplift in the central Bureya Massif (lower Zeya River Basin) resulted in a system of intermontane basins filled with molassoid, sandy-pebbly sediments (to 500 m).

Following a hiatus subsequent to folding, Late Jurassic marine sedimentation continued in the Uda and Torom Subplatform Troughs, which have the best Upper Jurassic sections in the Far East. They are supplemented by sections in southern Primorye, where the marine regime was renewed only in the Tithonian (Volgian).

A specific feature of the Upper Jurassic in this region is the scarcity of ammonoids, except in the Tithonian of southern Primorye. The predominant fauna are bivalves, mainly buchiids, which served to define *Buchia* zones commonly with the range of substages (Sey and Kalacheva 1985). The correlation with the ammonite zones is, in most cases, only approximate.

On the Tugur Bay coast (Torom Trough) the following zonal succession is observed (total 1,000 m; ascending order):

1. *Praebuchia impressae* Beds – fine-grained sandstone and siltstone (257 m); *Cardioceras (Scarburgiceras) praecordatum*, *C. (S.)* cf. *gloriosum*, and *Partschiceras pacificum* (= *Scarburgiceras* spp. beds); Lower Oxfordian
2. *Praebuchia lata–Buchia concentrica* Zone – siltstone (233 m); below, *Perisphinctes (Dichotomosphinctes)* cf. *müehlbachi* and *Maltoniceras* aff. *schellwiene;* above, *P. (Dichotomosphinctes)* sp.; Middle-Upper Oxfordian
3. *B. concentrica–B. tenuistriata* Zone – mudstone (220 m); also *B. ochotica*, *B. lindstroemi*, and *Amoeboceras (Amoebites)* cf. *dubium* (= *Amoeboceras* ex. gr. *kitchini* beds); Lower Kimmeridgian
4. *B. tenuistriata–B. rugosa* Zone – siltstone (5 m), possibly with *Ochetoceras elgense;* Upper Kimmeridgian

The Volgian is better represented in the Uda Trough (Urmi and Gerbikan Rivers) (total 3,300 m; ascending order):

5. *B. rugosa–B. mosquensis* Zone – conglomerate, sandstone (over 300 m); Lower–Middle Volgian
6. *B. mosquensis–B. russiensis* Zone – sandstone, siltstone, and coquina interbeds (180 m); rare *B. rugosa* and *B. trigonoides;* Middle Volgian
7. *B. russiensis–B. fischeriana* Zone – sandstone, siltstone (230 m), and coquina; *B. trigonoides*, rare *B. mosquensis* and *B. piochii;* rare ammonites *Durangites* sp. ind. and *Partschiceras schetuchaense;* Middle Volgian
8. *B. terebratuloides–B. piochii* Zone – sandstone, siltstone; *B. fischeriana*, *B. tirgonoides*, *B.* ex gr. *unschensis* and *B. lahuseni* (170 m); Upper Volgian

In Southern Primorye, Upper Jurassic deposits yield Tithonian ammonites and Volgian buchias. Their succession is as follows (ascending order):

1. Upper Lower Tithonian (Promyslovka Village) – calcareous sandstone (30 m), with *Virgatosphinctes* cf. *mexicanus.*

Middle Tithonian (Putyatin Island); calcareous shelly sandstone (80 m):

2. *Pseudolissoceras zitteli* Zone – with abundant Haploceratidae, Oppeliidae, and rare *Subplanitoides*, *Parapallasiceras*, and *Torquatisphinctes*
3. *Aulacosphinctes proximus* Zone – with *Aulacosphinctes*, *Sublithaccoceras*, *Lemencia*, *Subplanitoides*, *Parapallasiceras*, and rare Haploceratidae
4. Upper Tithonian–lower Berriasian (Ussuri Bay coast) – sandstone, rare siltstone, with conglomerate at base (800 m); throughout with *Buchia piochii*, *B. terebratuloides*, *B.* ex gr. *unschenssis*, and *B. fischeriana*, rare *B. volgensis;* middle and upper parts also with early Berriasian ammonites

The Upper Jurassic sections of geoclinal systems resemble the Lower and Middle Jurassic sections. In the strongly reduced Amur-Okhotsk Geocline and western Sikhote-Alin Geocline these terrigenous strata (Grote, Silinka, and Padali Formations, to 3,500 m) yield rare Middle Volgian buchias and Upper Jurassic radiolarians. The axial part of the Sikhote-Alin Geocline is also characterized by silicovolcanics. In northern Sikhote-Alin, silicovolcanic and terrigenous strata are unconformably overlain by sandy-silty-clayey deposits (to 1,500 m) with Middle and Upper Volgian buchias. In central Sikhote-Alin, mainly at its eastern flank, siliceous rocks of the Erdagou Formation (to 2,000 m) and its equivalents yield rich Oxfordian to Valanginian radiolarians (Tikhomirova 1986).

In the oceanic zone, Upper Jurassic (including Kimmeridgian–Tithonian) radiolarian assemblages are known from the upper part of the volcanic jasper section (ca. 70 m) of southern Sakhalin Island (Rikhter 1986). In more northern parts of the island the presumably much thicker volcanic-siliceous-terrigenous strata with limestone lenses (Ostraya Formation and lower Khoe Formation), according to E. V. Krasnov, yield a fauna of reef-building and reefophilic corals. Among these are the Kimmeridgian–Tithonian *Calamophyllia flabellum*, *Cryptocoenia sexradiata*, and *Convexastraed funuzawensis.* According to new radiolarian data, the silicovolcanics surrounding the limestones are of Albian-Cenomanian age (Kazintsova 1987).

The Jurassic–Cretaceous boundary is indistinct in most of the Far East, and in almost all sedimentary basins, from continental to oceanic, the boundary is drawn within continuous, often uniform strata. In marine facies, the boundary is mainly determined by a change in the *Buchia* assemblages, that is, conditionally between the *B. terebratuloides-B. piochii* Zone and the Berriasian *B. okensis* Zone. The find of a lower Berriasian ammonite assemblage in Southern Primorye may permit a more precise definition of the system boundary, in both the *Buchia* and regional ammonite scales.

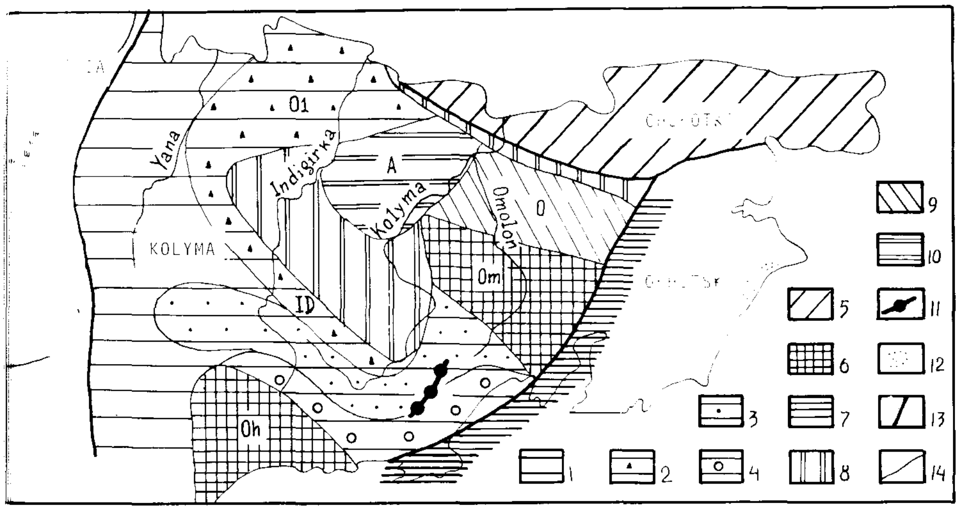


Figure 11.8. Distribution of Jurassic depositional types in North-East Russia. 1–5, terrigenous (miogeoclinal) [1, Verkhoyanye (shelf); 2, Debin (complete); 3, Delinya-Sugoi (discontinuous); 4, Viliga (complete, slightly volcanogenic); 5, Chukotka]; 6, subplatform (Omolon) type; 7–10, volcanoterrigenous (eugeoclinal) [7, Taigonos (island arc); 8, Ilin-Tas and South Anyui (rift zones); 9, Oloi; 10, Alazeya (discontinuous)]; 11, Olyn Island Arc; 12, Jurassic exposures in Koryakia; 13, boundaries of structural blocks; 14, boundaries between depositional types.

NORTH-EAST RUSSIA[3]

North-East Russia is east of the Lena River and north of latitude 59°N. This area is a structurally complex region with heterogeneous geological setting, corresponding in general to the Mesozoic folding area. Distinguished within its limits are the geoclinal folded systems of Verkhoyanye–Kolyma, Chukotka, and Western Kamchatka–Koryak, the Alazeya Fold-Block System, the narrow geoclinal folded zones of Ilin–Tas and South Anyui, the Omolon and Okhotsk Massifs, the Taigonos and Eastern Kamchatka Island-Arc Systems, and a number of other structures (*Geological Structure* . . . 1984). Jurassic deposits are, to varying extents, recorded from all of these major structural areas.

Several types of Jurassic sequences (Figure 11.8) are distinguished on the basis of rock composition, completeness, thickness, biota, and geological evolution.

Terrigenous miogeoclinal sequences

The main occurrence is confined to the Verkhoyanye–Kolyma Geoclinal-Fold System. Lower and Middle Jurassic deposits comprise a geoclinal complex that, together with the underlying Norian rocks, belongs to the Yukagir Complex, formed at the final stage of geoclinal development. Upper Jurassic deposits (sometimes from Volgian) form late geoclinal complexes, together with Lower Cretaceous rocks.

The thick, most nearly complete and continuous, Jurassic sequence of miogeoclinal type is in the Inyali–Debin Megasynclinorium (ID) and Oldzhoj Trough (OL) (Figures 11.9 and 11.10). During the Triassic, the maximum down-warping was farther west (Yana and upper Indigirka Basins), and structures were displaced in the Jurassic (ID and OL). The Lower Jurassic of ID (Kadykchan Formation and lower part of Aren Formation) is represented by fine clastics (mudstone, siltstone), often clayey-siliceous rocks with an admixture of fine volcanic material of intermediate–basic composition (1,000–1,500 m). Most of the Middle Jurassic (Aalenian–Bathonian) consists of 1,800–4,000 m terrigenous three-component flysch (upper part of Aren and Mereduj Formations). Callovian, Oxfordian, and Kimmeridgian sediments (Koster Formation) gradually become less rhythmical and more diverse (to 2,300 m). The total thickness of the Jurassic in ID reaches 7 km. In OL, the Lower Jurassic (2,000 m) consists of sandstone, the Middle Jurassic (1,000–2,500 m) of claystone, and the Upper Jurassic (3,000–5,000 m, Oxfordian–Volgian) of alternating mudstone, siltstone, and sandstone. The total thickness of the section exceeds 8 km.

The terrigenous miogeoclinal type represents sediments of an abyssal trough (pseudoabyssal zone) that during the Jurassic underwent a progressive shallowing. Due to the relatively poor and irregular Jurassic fossil record in ID and OL, lithostratons play the leading role in the subdivision (Figure 11.9). Several formations are distinguished that are traceable over considerable distances. Rare and poorly preserved ammonites make it possible to distinguish only the zones of *Alsatites liasicus, Coroniceras siverti, Angulaticeras kolymicum, Amaltheus viligaensis, Cranocephalites vulgaris, Arctocephalites elegans, Amoeboceras alternans*, and *Cardioceras cordatum*.

To the west, between the Siberian Platform and the ID and OL structures, the Jurassic fills a number of minor synclinal structures in the Verkhoyanye Megaanticlinorium. The total thickness of the Jurassic does not exceed 3.5 km. Presumably, there is a Toarcian hiatus. No Upper Jurassic deposits are recorded. Early (Sakkyryr Group) and Middle (Ulaga Group) Jurassic sediments were accumulated on a broad shelf and are lower to middle sublittoral facies, whereas the Late Jurassic sediments are middle to upper sublittoral.

Rough biostratigraphy is based on rare ammonite finds: Hettangian and Sinemurian on *Psiloceras* sp., *Waehneroceras frigga*, and *Schlotheimia angulata;* Aalenian to Lower Bathonian on *Pseudolioceras beyrichi, Boreiocephalites borealis* (also placed in *Cranocephalites*), *Stephanoceras (Itinsaites)* sp., *Cranocephalites pompeckji, Arctocephalites elegans, Oxycerites jugatus*, and *Longaeviceras keyserlingi*.

Southwestward, at the right banks of the upper Kolyma and Indigirka Rivers, Jurassic exposures again become more extensive,

[3] By Y. S. Repin, K. V. Paraketsov, and I. V. Polubotko.

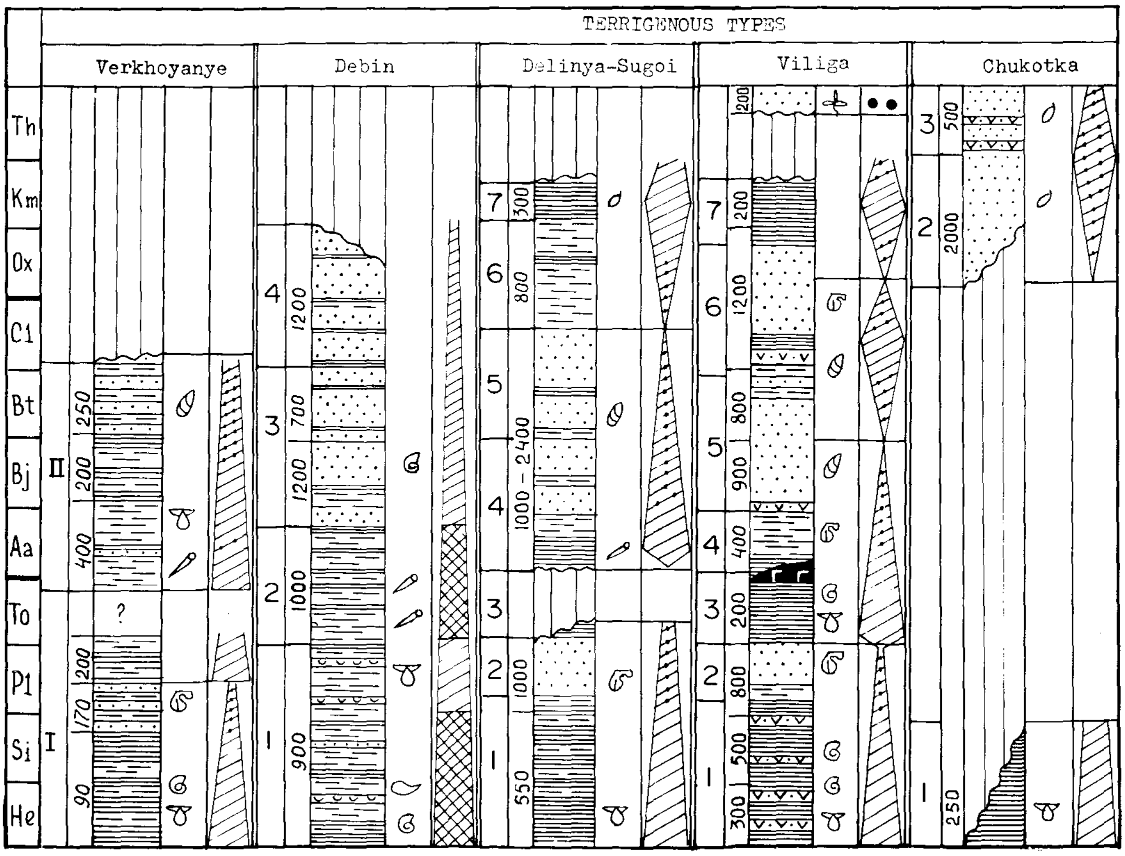


Figure 11.9. Important terrigenous Jurassic sequences in North-East Russia. Legend as in Figure 11.11. Groups and formations: Verkhoyanye: I, Sakkyryr Group; II, Ulaga Groups. Debin: 1, Kadykchan Formation; 2, Aren Formation; 3, Mereduj Formation; 4, Koster Formation. Delinya-Sugoi: 1, Penalti Formation; Tabornyi Formation; 3, Marat Formation; 4, Memechen Formation; 5, Oktyabrina Formation; 6, Kuchukan Formation; 7, Baza Formation. Viliga: 1, Mokhovoj Formation; 2, Makarych Formation; 3, Zazor Formation; 4, Yaschan Formation; 5, Mongke Formation; 6, Viliga Formation; 7, Kalkutty Formation. Chukotka: 1, Kytepveem Formation; 2, Rauchua Formation; 3, Netepneiveem Formation.

with the Delinya–Sugoi depositional type (Figures 11.9 and 11.10). These areas are characterized by continental-crust blocks that subsided during certain Jurassic stages, resulting in thick terrigenous-geoclinal, often flyschoid, sediments. At other times (pre-Aalenian and post-Callovian), down-warping ceased, and troughs were filled by sediments and usually elevated above sea level. Hiatuses at the Lower–Middle and, locally, the Middle–Upper Jurassic boundaries are traceable extensively and sometimes show slight unconformities. These haituses are associated with periods of uplifting or cessation of down-warping.

The Lower Jurassic characterizes the Delinya–Sugoi depositional type: considerable thickness (1,000–2,500 m), flyschoid siltstone–mudstone alternation, extensive subaqueous slumping, and poor fossil record (Penalti and Taborny Formations). Toarcian and part of the Upper Pliensbachian are usually missing over most of the record. The Middle Jurassic is locally reduced, but better developed in other areas, with, below, mudstone (Marat Formation) and above, sandstone (Memechen and Oktyabrina Formations). Upper Jurassic consists of Oxfordian–Kimmeridgian mudstone, siltstone, and terrigenous volcanic sandstone (400–800 m; Kuchukan and Baza Formations).

South of the Delinya–Sugoi-type deposits, in (river) basins of the Sea of Okhotsk, the similar but more complete Viliga depositional type is developed. It has more abundant fossils, particularly Middle Jurassic mytiloceramis. Only the Upper Jurassic is incomplete (i.e., Volgian is lacking). In completeness and thickness, this section is similar to the Debin type. The sediments have admixed volcanics, due to the Early Jurassic Kobjume Rift in the northwest and the Olyn Volcanic Arc in the southeast (Okhotsk–Kolyma divide, boundary between sedimentary types) (Repin 1975).

The Lower Jurassic sandstone and siltstone sequences of the Viliga Basin (1,800 m) have, below, Hettangian–Lower Pliensbachian tufogenic flysch and, at the top, late Toarcian basalt (250 m). The Middle Jurassic (2,800 m) is siltstone and sandstone, flyschoid and tufogenic in the lower part. The Upper Jurassic (ca. 2,000 m) in its lower part consists of sandy-silty rocks, with abundant Lower Oxfordian *Meleagrinella ovalis,* and, in the upper part, of predominantly clayey rocks, with rare Oxfordian–Kimmeridgian buchias. The Viliga sequence is exceptionally complete and fossiliferous and is a reference section for the geoclinal type, with stratotypes and parastratotypes of some zones yielding ammonites and bivalves.

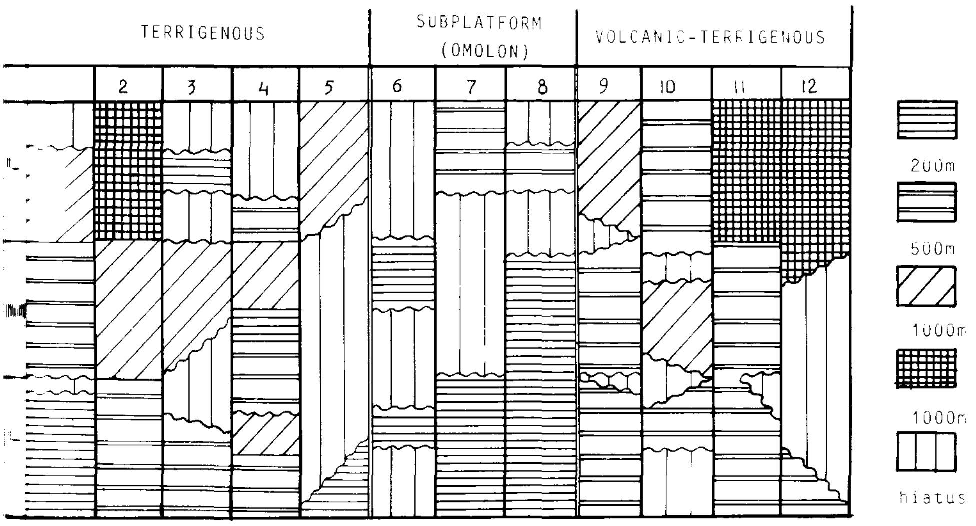


Figure 11.10. Sedimentation rates for the main types of Jurassic deposits in North-East Russia; thicknesses of stages in meters: 1, Verkhoyanye; 2, Debin; 3, Delinya-Sugoi; 4, Viliga; 5, Chukotka; 6, Russian River; 7, Kedon River; 8, Paren River; 9, Oloi; 10, Alazeya; 11, Taigonos; 12, Ilin-Tas.

The Jurassic section of the Chukotka Geoclinal-Fold System (Chukotka type) is terrigenous. Lower Jurassic (Hettangian–Sinemurian) mudstone and clayey siltstone (200–300 m), with rare *Otapiria,* are known only from the small Kytepveem Basin in the west (Kytepveem Formation). Chukotka-type deposition is characterized by Upper Jurassic, filling several late geoclinal depressions that are mainly superposed on an eroded Triassic surface. On the Kolyma–Rauchua Divide, the Myrgovaam Depression is filled with thick arkoses, with single mudstone and siltstone interbeds (to 2,000 m), yielding rare Oxfordian–Kimmeridgian buchias (Rauchua Formation). The large Rauchia Depression along the southwestern coast of Chaun Bay and a number of small depressions farther east were emplaced during the middle Volgian. They are filled by molassoid sediments: polymictic and volcanoterrigenous sandstones, siltstone, and mudstone, with intermediate and acidic tuffite and tuff, tuffaceous gritstone, and conglomerate (600–700 m; Netpneiveem Formation). The deposits yield middle and late Volgian buchias.

Volcanic terrigenous (eugeoclinal) sequences

The Jurassic sequences are volcanic-terrigenous in the Alazeya Fold-Block System, the Oloi Marginal Trough, the Ilin-Tas and South Anyui Suture geoclinal-fold zones, and the Taigonos Island-Arc System, in separate small rift structures, and in the late geoclinal and orogenic Late Jurassic depressions (Figure 11.11). The most complete and thickest Jurassic sequence of this type (Taigonos) is known from the Taigonos Peninsula, which belongs to the Taigonos Island-Arc System (Nekrasov 1976; *Geological Structure* . . . 1984).

The Lower Jurassic (to 1,500 m) consists of andesitic and basaltic tuffs, with sedimentary interbeds (Tikass Group); the Middle Jurassic (3,400 m), of basalts, andesites, tuffs, sandstone, and siltstone; the Upper Jurassic (to 5,400 m), of alternating andesite, basalt, dacite, liparite, tuff, siltstone, and sandstone (Vnutrennyaya Group). The fossil record consists only of levels with *Zugodactylites* sp., *Porpoceras polare, Pseudolioceras beyrichi, Arctocephalites* sp., and *Costacadoceras bluethgeni.*

Southwest of the Taigonos Peninsula, on the Koni and Pyagin Peninsulas and at the Babushkin Bay coast, the Jurassic is generally similar. The upper Middle Jurassic yields the Callovian ammonites *Iniskinites* cf. *magniformis, Costacadoceras* cf. *bluethgeni, Cadoceras,* and, slightly higher, *Longaeviceras* aff. *nikitini.* The Upper Jurassic (ca. 3,000 m) has abundant volcanics and is crowned by flora-bearing Upper Volgian continental beds (Severo-Taigonos Group). Northeast of the Taigonos Peninsula, the structurally complex Western Kamchatka–Koryak Geoclinal-Fold System has only small blocks of the Lower and Middle Jurassic. Silicoterrigenous beds yield a relatively poor fauna resembling the fauna in the remainder of the North-East: *Angulaticeras* ex gr. *kolymicum* (Sinemurian), *Amaltheus* cf. *stokesi* (Upper Pliensbachian), and *Mytiloceramus, Pseudolioceras (Tugurites)* ex gr. *maclintocki,* and *Arkelloceras* (Aalenian–Bajocian). In the Kojverelan Basin (right tributary of the Velikaya River) volcanosiliceous, terrigenous strata (ca. 100 m) have yielded Tethyan Callovian ammonites, unusual for the North-East: *Putealiceras (Zieteniceras?)* cf. *zieteni, Lunuloceras,* and *Choffatia.* Some workers regard this block as allochthonous.

The Upper Jurassic in the Western Kamchatka–Koryak System is represented only by Middle–Upper Volgian. The deposits of some areas (Pekulnei Ridge, Velikaya Basin, Lake Mainits area) are typically eugeoclinal, with spilite, andesite, tuffs with interbeds of jasper, siliceous rocks, sandstone, siltstone, and conglomerate (500–1,000 m). The sediments contain Volgian buchias, whereas the siliceous deposits yield radiolarians. In other areas occur terrigenous or volcanoterrigenous rocks with Volgian buchias.

The Alazeya–Oloi depositional type occurs in the area between the Indigirka River in the west to the Kolyma–Anadyr Divide in the east. Compared with the Taigonos type, it is characterized by hiatuses and reduced thicknesses, and diversity complexity of deposition, sometimes with intergrading marine and continental facies. Lower and Upper Jurassic have the greatest proportion of

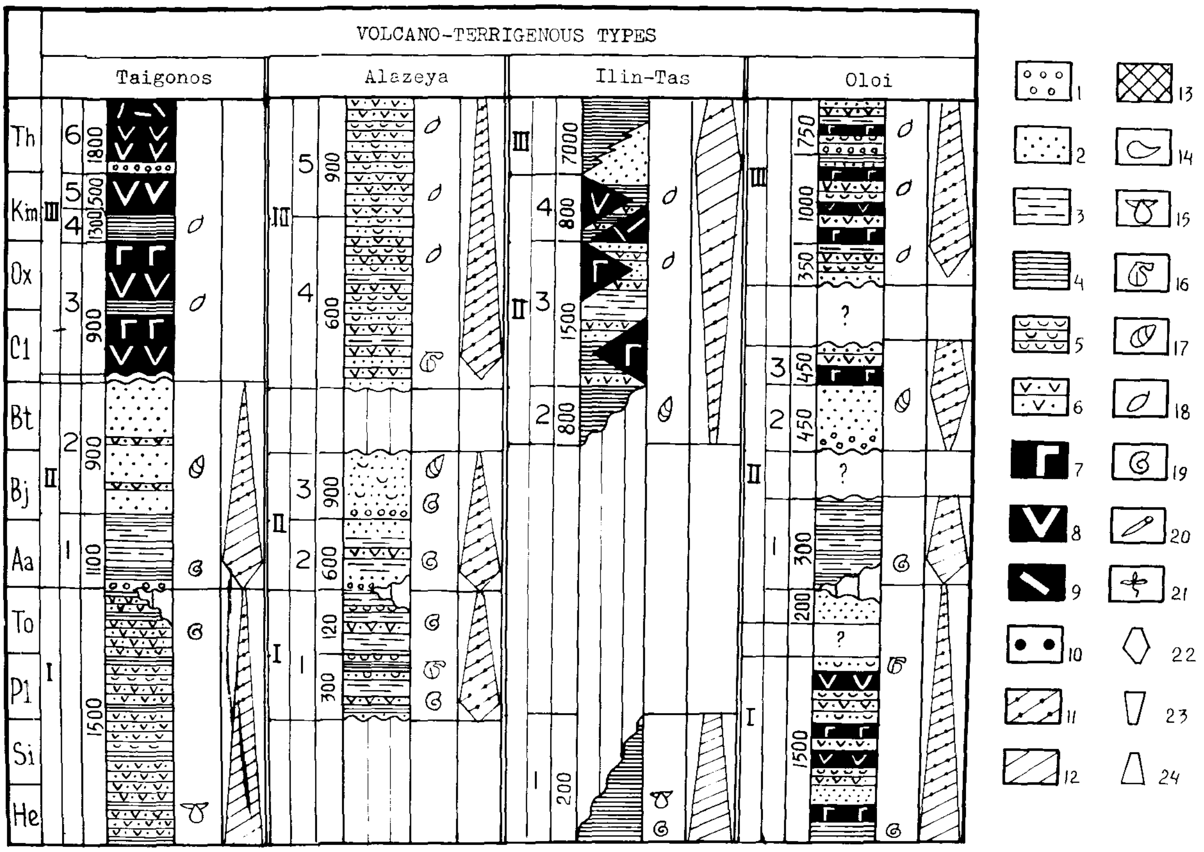


Figure 11.11. Important volcanoterrigenous Jurassic sequences in North-East Russia. Rock types: 1, conglomerate; 2, sandstone; 3, siltstone; 4, mudstone; 5, tuffite and ash tuffs; 6, tuffs and lavas (7, basic; 8, intermediate; 9, acid). Facies: 10, lacustrine alluvial; 11, middle to upper sublittoral; 12, lower sublittoral; 13, deep sea (pseudoabyssal). Benthic bivalves: 14, pseudoabyssal; 15, lower sublittoral [Hettangian-Sinemurian *Otapiria*, *"Pseudomytiloides," Kolymonectes;* Aalenian *Oxytoma, Propeamussium*]; 16, upper sublittoral [late Pliensbachian *"Velata," Radulonectites;* Callovian *Maclearnia*]; 17, mytilocerams; 18, buchias. Nectobenthos: 19, ammonites; 20, belemnites; 21, flora cycles [22, subsymmetric; 23, transgressive; 24, regressive]. Groups and formations: Taigonos: I, Tikass Group; II, Vnutrennaya Group [1, Kuchuveen Formation; 2, Khalpil Formation]; III, Severo-Taigonos Group [3, Talnaveem Formation; 4, Srednij Formation; 5, Gyryangin Formation; 6, Vavachun Formation]. Alazeya: I, Egelyakh Group, upper part [1, Pologij Formation]; II, Fedotikha Group [2, Kurunyur Formation; 3, Syustinnyakh Formation]; III, Khoska Group [4, Abagylakh Formation; 5, Ikki-Kyunnyakh Formation]. Ilin-Tas: 1, Olguya Formation; II, Ilin-Tas Group [2, Taskan Formation; 3, Talbygyr Formation; 4, Kyureter Formation]; III, Bastakh Group. Oloi: I, Krichal Group; II, Privalnaya Group [1, Kojguveem Formation; 2, Losikha Formation; 3, Karkasnaya Formation]; III, Tantyn Group.

volcanics. The Dogger is composed of terrigenous siltstone and sandstone and, locally (Alazeya Plateau), of sandstone and conglomerate. Maximal thickness is in the Oloi Marginal Trough (5.5 km), and somewhat less in the Alazeya System (3.5 km).

The Ilin-Tas depositional type occurs in the middle Indigirka and Kolyma Basins, where it corresponds to the Momo-Zyryan Trough and adjacent Late Jurassic grabens. Lias (Olguya Formation) is represented locally only by Hettangian–Sinemurian fine-clastic, terrigenous deposits (200–1,000 m) that are closely associated with the subjacent Upper Triassic. Above are fine- and coarse-clastic Bathonian–Callovian (600–1,500 m), resting with a considerable hiatus and unconformity on the Hettangian–Sinemurian and older rocks. Malm follows conformably or disconformably. Oxfordian–Kimmeridgian is terrigenous-volcanic, with lateral facies changes (1,000–2,500 m) and with volcanics: basalt, andesite, dacite, liparite, and their tuffs. Volgian is terrigenous-marine in the lower part and lagoonal-continental in the upper, with maximum thickness in the Momo-Zyryan Trough (7–8 km).

In the South Anyui Zone, only the Upper Jurassic can be established: volcanosiliceous strata with spilitic lavas, tuffs, siliceous rocks, and jasperoids. Volgian buchias and radiolarians occur in fine-clastic terrigenous interbeds.

Subplatform (Omolon-type) sequences

The Omolon (subplatform) type of deposition has much more limited distribution than the other types, but is important for Jurassic biozonation in North-East Russia. The principal occurrence is in the Omolon Median Massif (Figure 11.12). This sequence is characterized by relatively low thickness (entire Jurassic, 1,300–2,800 m), hiatuses, and lagoonal-continental

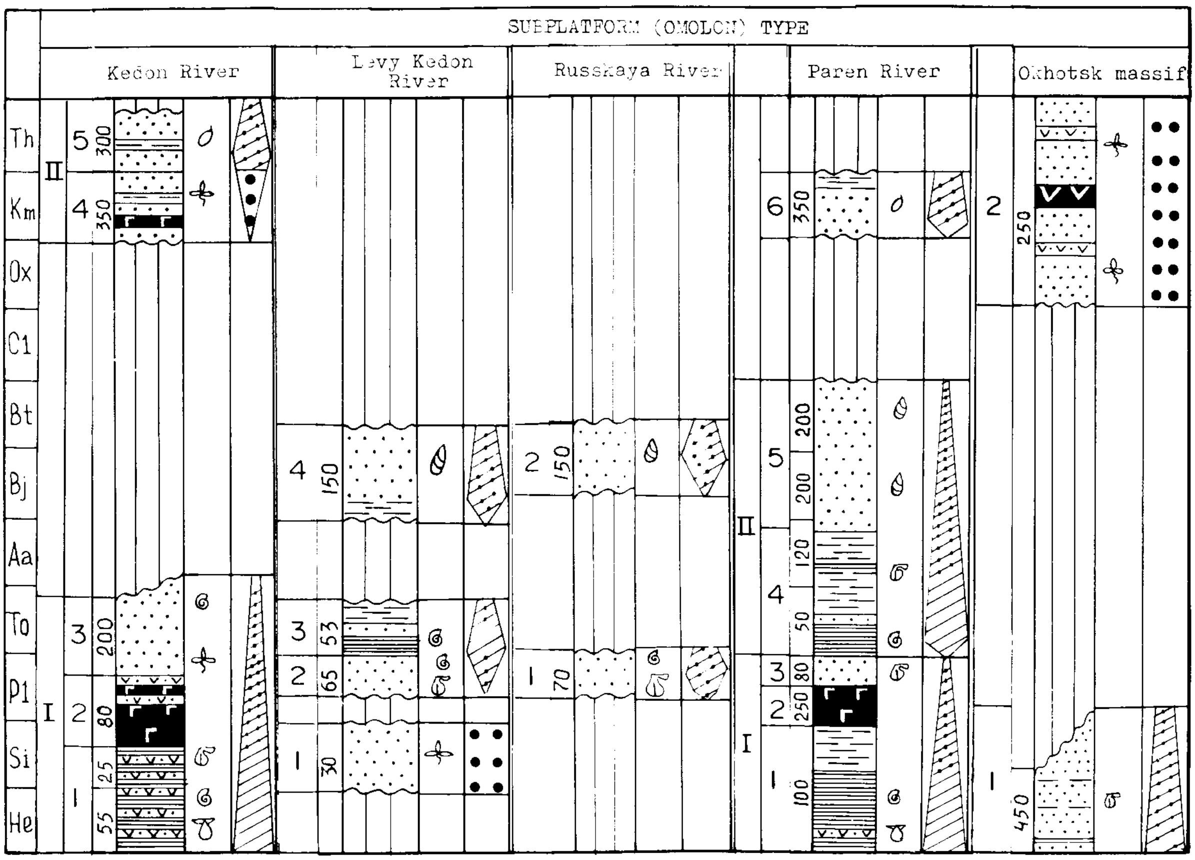


Figure 11.12. Important subplatform-type Jurassic sequences in North-East Russia. Legend as in Figure 11.11. Groups and formations: Kedon River: I, Ust-Finish Group [1, Kinas Formation; 2, Omkuchan Formation; 3, Chirok Formation]; II, Ust-Kedon Group [4, Namyndykan Formation; 5, Ajnene Formation]. Levy Kedon River: 1, Brodnaya Formation; 2, Nalednyi Formation; 3, Start Formation; 4, Emlyndzha Formation. Paren River: I, Uglovaya Group [1, Rybnaya Formation; 2, Tumma Formation; 3, Tokchikin Formation]; II, Chaivaveem Group [4, Eksin Formation; 5, Emlyndzha Formation]; 6, Provorotnyi Formation. Okhotsk Massif: 1, Nyadbaka Formation; 2, Khavakchan Formation.

sediments, as well as marine, predominantly terrigenous rock dominated by sandstone (mainly Upper Pliensbachian and Middle Jurassic), together with basic and intermediate lavas, tuffs, and taphrogenic coarse-clastic rocks (Upper Sinemurian–Lower Pliensbachian, Upper Volgian), in some areas adjacent to fault zones and in late geoclinal Late Jurassic depressions. Abundant fossils include bivalves, ammonites, belemnites, and brachipods in the Lias, mytiloceramss in the Dogger, and buchiids and other bivalves in the Malm. However, as in most regions in the North-East, other taxa (e.g., microfauna) are unknown. Here are the stratotypes of the majority of the Liassic regional ammonite zones.

The thickest (to 2,800 m) subcontinuous section, except for a Callovian–Oxfordian hiatus, is at the northwestern margin of the Omolon Massif, in the Rassokha and Tokur–Yuryakh Basins. Farther northwestward this section becomes geoclinal, with increased thicknesses and impoverished fossil record. Jurassic occurs at the eastern and southeastern margins of the Paren River Massif, where the Lias and Dogger are well developed (900–1,200 m) and the Malm is absent, except for local Kimmeridgian sandstones (to 300 m). Sequences within the massif are more discontinuous and thinner, varying in the different blocks. The most reduced section is in the Russkay River valley (Omolon Basin), in the center of the massif, with only Upper Pliensbachian (Nalednyi Formation, 75 m) resting on Upper Norian and Bathonian (Emlyndzha Formation, ca. 200 m). The Jurassic deposits of the Omolon type are open-shoal facies around an archipelago, connected freely with epicontinental seas and the ocean.

Unlike the Omolon Massif, the Okhotsk Massif has only small incomplete Lower Jurassic (Nyadbaka Formation, Hettangian–Sinemurian and Pliensbachian), with sandstone and siltstone (to 600 m), overlain with a considerable hiatus by the Upper Jurassic (Khavakchan Formation) continental, sedimentary volcanic, flora-bearing strata (ca. 250 m).

Ammonite and bivalve zones

The zonation of Lower Jurassic in North-East Russia is based on the subplatform sections of the Omolon Massif and is supplemented by geocline-type sections (Viliga River, etc.). Most stratotypes and reference sections of zonal units, established on ammonites and bivalves, are in the Omolon Massif.

Hettangian

The best section is on the left bank of the Kedon River, just below the mouth of Omkuchan Creek, where the siliceous, slightly tufogenic Upper Norian (including Rhaetian) mudstones, with *Oxytoma mojsisovicsi* and *Tosapecten efimovae*, are conformably overlain by finely alternating mudstone and tufogenic and siliceous mudstone with lenticular limestone (55 m). The thicknesses of the standard zones are Primulum Zone 9 m, Planorbis Zone 7 m, Liasicus Zone ca. 32 m, and Angulata Zone 5 m (Polubotko and Repin 1972, 1981). The bivalve assemblage consists of *Otapiria originalis, Meleagrinella subolifex, Oxytoma orientalis, Ochotochlamys kiparisovae, "Pseudomytiloides" sinuosus*, and *"P." latus.*

Sinemurian

The zonation is based on several depressions in the central Omolon Massif. The composite sequence is as follows (ascending order):

1. Bucklandi Standard Zone – tuffaceous mudstone (12 m); *Arietites libratus, Paradasyceras* sp.
2. *Coroniceras siverti* Zone – alternation of mudstone and tuffite with carbonite lenses (15 m); also with *Primarietites* cf. *bisulcatus* and *P. reynesi;* upper part with *Eparietites* cf. *denotatus*
3. *Angulaticeras kolymicum* Zone – alternation of tuffaceous mudstone and siltstone and tuffite (35 m); *Angulaticeras (Gydanoceras) ochoticum.*

The two lower zones are characterized by the bivalves *Otapiria omolonica, O. tailleuri, Oxytoma orientalis, "Pseudomytiloides" rassochaensis*, and *Kolymonectes kedonensis* and the brachiopod *Ochotorhynchia omolonensis.* The upper zone contains *Otapiria limaeformis, O. affecta, "Monotis" inopinata, Kolymonectes staeshei, Anomia lemniscata*, and *"Pseudomytiloides" rassochaensis.*

Pliensbachian

Lower Pliensbachian is documented by ammonites finds only in the Bol.-Anyui Basin (*Polymorphites*) (Afitsky 1970) and in the Viliga Basin (Polymorphitidae) (Polubotko and Repin 1974b; Milova 1980). In other areas (Viliga, Bulun, and Gizhiga rivers) the lower substage is distinguished by its bivalve assemblage, including *"Amonotis"* sp., *Kolymonectes staeschei*, and *Chlamys tapensis.*

Upper Pliensbachian is widespread in most of the North-East and is divided into three zones in sections of the Omolon Massif (Brodnaya River in the Levy Kedon Basin) and the Viliga River:

1. *Amaltheus stokesi* Zone – Viliga River; fine quartz-plagioclase sandstone (200 m); also *A. bifurcus* and *A. complanatus*
2. *Amaltheus talrosei* Zone – Brodnaya River; polymictic sandstone and siltstone (13 m); also *A. ventrocalvus* and *A. subbifurcus*
3. *Amaltheus viligaensis* Zone – volcanomictic and tufogenic sandstone (15 m); also *A. brodnaensis, A. extremus*, and *A. orientalis*

The bivalve assemblage of the *stokesi* Zone consists of *"Velata" viligaensis, Kolymonectes mongkensis, Meleagrinella ansparsicosta*, and *Lima philatovi;* that of the *talrosei* and *viligaensis* Zones, of *K. mongkensis, K. levis, Ochotochlamys grandis, Veteranella (Glyptoleda) formosa, Meleagrinella ptchelincevae, M. oxytomaeformis, Harpax laevigatus, Tancredia omolonensis*, etc.

Toarcian

The reference section of the stage and stratotypes of all zones are in the Omolon Massif (upper Levy Kedon River) (Dagis and Dagis 1965; Polubotko and Repin 1966, 1974b; Dagis 1968, 1974 (ascending order):

1. *Tiltoniceras propinquum* Zone – mudstone (12–18 m); *Kedonoceras compactum, K. asperum, Tiltoniceras propinquum, T. costatum, T. capillatum, Arctomercaticeras costatum*, and *A. tenue;* Lower Toarcian
2. *Eleganticeras elegantulum* Zone – mudstone (3 m); *Eleganticeras alajaense, E. planum, E. confragosum*, and *E. connexivum*
3. *Harpoceras falciferum* Zone – mudstone and siltstone (10 m); *Harpoceras falciferum, H. exaratum*, and *Hildoceratoides levisoni*
4. *Dactylioceras athleticum* Zone – polymictic inequigranular sandstone (10 m); *Dactylioceras commune, D. athleticum, D. kanense, D. amplum, Harpohildoceras grande, Kolymoceras cognatum, K. crebrinodum*, and *Hildoceratoides chrysanthemum*
5. *Zugodactylites monestieri* Zone – mudstone and siltstone (5 m); *Zugodactylites braunianus, Z. monestieri, Z. pseudobraunianus, Z. exilis, Z. moratus, Z. latus, Catacoeloceras proprium, C. manifestum, Kolymoceras* ex gr. *viluiense, Pseudolioceras lythense*, and *P. kèdonense*
6. *Porpoceras spinatum* Zone – pisolitic tuffites (1.8 m); *Porpoceras polare, P. spinatum, Collina mucronata, C. orientalis*, and *Pseudolioceras gradatum*
7. *Pseudolioceras rosenkrantzi* Zone – clayey-silty sandstone (5 m); also *Pseudolioceras compactile;* Upper Toarcian

Toarcian bivalves form two assemblages: below (*propinquum, elegantulum*, and *falciferum* Zones), *Meleagrinella substriata, Mytilus mytileformis*, and *"Pseudomytiloides"* aff. *amygdaloides;* above, *Meleagrinella faminaestriata, Oxytoma startensis, Propeamussium pumilum, Pseudomytiloides marchaensis, Vaugonia literata, Protocardia striatula*, and *Goniomya rhombifera*

Aalenian

The reference section of the stage in geoclinal development is in the Viliga Basin (Polubotko and Repin 1974a):

1. *Pseudolioceras maclintocki* Zone – alternating siltstone, mudstone, and dacitic tuffs (90 m); also *P. (P.) replicatum, P. (P.) beyrichi, Mytiloceramus priscus, M. subtilis, Oxytoma jacksoni,* and *Propeamussium olenekense*
2. *Pseudolioceras tugurense* Zone – alternation of siltstone and sandstone (200 m); with *P. (Tugurites) tugurense,* also *Mytiloceramus elegans* and *M. popovi*

Bajocian

The biozones of the lower substage are based on sections in the Omolon Massif (Kegali River), Alazeya Upland (Sededema River), and Anadyr Basin (Repin 1972; *Resolutions* . . . 1978).

1. *Pseudolioceras fastigatum* Zone – also *P. (Tugurites) costistriatum, Mytiloceramus jurensis,* and *M. menneri;* Discites and Laeviuscula Zones (= Widebayense Zone of Southern Alaska)
2. *Arkelloceras tozeri* Zone – *A. elegans, A.* aff. *maclearni, Bradfordia alaseica, Holcophylloceras costisparsum, Zetoceras, Mytiloceramus lucifer,* and *M. omolonensis;* Sauzei Zone (= Crassicostatus Zone)
3. Beds with *Chondroceras* cf. *marshalli* and *Lissoceras* sp. – also *Mytiloceramus porrectus;* Humphriesianum Zone

The base of the Upper Bajocian does not contain ammonites and is defined by the *Mytiloceramus clinatus* Assemblage Zone:

4. *Boreiocephalites borealis* Zone – single finds of index species (ed. note: also placed in *Cranocephalites*) in Adycha River area; Upper Bajocian
5. *Cranocephalites vulgaris* Zone – also *C. nordvikensis, C. inconstans,* and *C. furcatus*

Bathonian

1. *Arctocephalites elegans* Zone – only a single zone is recognizable here; also *A. ellipticus, A. stepankovi,* and "*Oxycerites*" *jugatus*
2. Beds with *Arcticoceras–Costacadoceras*

Callovian

1. Beds with *Cadoceras anabarense* – lower Callovian
2. Beds with *Longaeviceras keyserlingi* – upper Callovian

Because of the extreme scarcity of ammonites, the zonation of the Malm in the North-East is based exclusively on buchiids. The first buchiid, *Praebuchia anyuensis,* occurs in the Dogger, probably directly above the last mytilocerams (*anyuensis* Beds, upper Bathonian). The *Buchia* succession is most complete in the exceptionally continuous Malm section of the Bolshoi Anyui Basin. Here is also the majority of stratotypes of regional *Buchia* zones.

Oxfordian

1. Beds with *Praebuchia? impressae* – tufogenic sandstone with conglomerate, tuff, siltstone, and mudstone (ca. 300 m); dated by stratigraphic position and analogy with the Far East, where *P.? impressae* is associated with *Scarburgiceras;* Lower Oxfordian
2. *Praebuchia kirghisensis* (= *P. lata*)–*Buchia concentrica* Zone – mudstone and siltstone, sometimes silicified (to 430 m); *B. linstroemi, B. mosquensis tenuistriata,* and *B. jeropolensis;* in other areas of the North-East, also *Cardioceras* sp.

Underlain by beds with *Quenstedtoceras;* overlain by sediments with *Amoeboceras* ex gr. *glosense* and *Amoebites* sp.; Middle–Upper Oxfordian.

Kimmeridgian

1. *Buchia concentrica–B. mosquensis tenuistriata* Zone – alternation of mudstone, siltstone, sandstone, tuffaceous sandstone, and tuffite (ca. 200 m); also *B. jeropolensis, B. lindstroemi,* and *B. vuquaamensis,* as well as *Oxytoma (O.) expansa, Meleagrinella ovalis, Isognomon embolicus, Maclearnia broenlundi, Pseudolimeaa borealis,* and *Amoeboceras (Amoebites)* ex gr. *kitchini* throughout the zone; Lower Kimmeridgian
2. *Buchia rugosa–B. mosquensis paradoxa* Zone – siltstone, sandstone, agglomerate, and tuffs (to 200 m); also *B. vuquaamensis* and *B. mosquensis tenuistriata;* remainder of bivalve assemblage similar to that found below; Upper Kimmeridgian

Volgian

1. *Buchia mosquensis mosquensis–B. russiensis* Zone – tufogenic rocks and tuffs (ca. 200 m); also *B. rugosa;* Lower Volgian
2. *Buchia russiensis–B. fischeriana* Zone – siltstone, mudstone, and sandstone, frequently tufogenic (to 200 m); rare *B. mosquensis mosquensis, B. rugosa;* in upper part, *B. flexuosa;* age based on *Dorsoplanites* cf. *transitorus* and *Partschiceras schetuchaense* in this zone and by correlation with adjacent regions; Middle Volgian
3. *Buchia tenuicollis–B. terebratuloides* Zone – alternation of basic and intermediate tephroids, tuffaceous sandstone, siltstone, mudstone, gritstone, and conglomerate (over 1,500 m); also *B. flexuosa, B. lahuseni, B. obliqua,* and endemic *B. circula;* age based on stratigraphic position and ?*Chetaites;* Upper Volgian

PALEOGEOGRAPHY AND GEODYNAMICS OF NORTHEAST ASIA[4]

Paleogeography

Mesozoic eastern Russia was part of the Pacific Mobile Belt. This implies diverse paleoenvironments, from mountainous areas in the west to ocean in the east.

[4] By Y. S. Repin and I. I. Sey.

During the Hettangian and Sinemurian the sea flooded the margin of the Siberian landmass from the east. It comprised platforms and basins with different depths and sediments. A belt of continental shelf, bounded in the northeast by the Debin Linear Suboceanic Basin, extended parallel to the Siberian landmass, with moderate relief. The Anyui Basin separated the Chukotka and Kolyma Blocks. In the central parts of the region, major island systems (Kolyma, Omolon) were surrounded by shelf seas and relatively deep basins. Along the northern and eastern margins of the Kolyma Block, volcanic archipelagoes existed throughout the Jurassic (Taigonos, Anyui).

In all marine areas, accumulation of clays and silts proceeded mainly in lower-sublittoral environments. The principal sources of sediments were the Siberian landmass and the Okhotsk Peninsula. Local provenances were also significant, providing volcanogenic constituents.

In most of Far East Russia, continental regimes began in the earliest Jurassic, subsequent to the Late Triassic transgressive cycle. Marine environments continued only in the linear Amur-Okhotsk and Sikhote-Alin deep-sea depressions, which were paleogeographically stable throughout most of the Jurassic.

In the Early and Middle Jurassic, the intracratonic Amur-Okhotsk Marine Basin, far inland, was filled with sandy-silty-clayey rhythmites, siliceous silts, and volcanites.

The perioceanic Sikhote-Alin Basin apparently corresponded to the continental slope and was separated from the ocean by a series of nonvolcanic marginal uplifts. During most of the Jurassic, volcanosiliceous strata accumulated in the basin, with the maximum amount of volcanites in the Early Jurassic. This sea was surrounded by a denudation plain, which in the west and north graded into the Bureya and Stanovoi uplands, the main sources of clastics during the Jurassic.

In late Pliensbachian–early Toarcian time, a eustatic rise resulted in transgression, especially in the Far East, where the sea covered the Eastern Transbaikal area (Figure 11.13). In the North-East, the Vilyui Lowland was flooded. Mainly fine sand and silt were deposited in the shallow-sea basins under upper and middle sublittoral conditions, generally with low relief of the surrounding land.

The early Toarcian transgression was modified by the development of several geanticlines. This resulted in the drainage of extensive areas in the Lena–Yana interfluve, forming a peninsula, and in extension of the Kolyma Archipelago. The Lena–Yana Peninsula separated the Yakutsk Sea from the markedly reduced Kolyma Basin.

The late Toarcian in eastern Russia was a time of regional uplift and regression, when seaways to the northwestern European sea and to the Paleopacific were absent or reduced.

The transgressive cycle in the Aalenian–early Bajocian greatly enlarged the sea in eastern Russia (Figures 11.13 and 11.14). In some cases the sea deepened slightly, but remained mainly upper–middle, rarely lower, sublittoral. The prevailing sandy-silty sediments indicate weak denudation, rather than a deepening of the basins. This is confirmed by the character of the benthos, the presence of plant remains, and the sedimentary textures.

Beginning with the late Bajocian, gradual shoaling and regression occurred, with repeated coastline fluctuations. The lithofacies are therefore diverse, from deep sea to littoral and continental. Suboceanic basins were filled by sediments and shoaled. The Yakutsk Sea became an area of continental sedimentation. The contrasting thicknesses in sedimentary basins, increased height and relief of the land, and new source areas resulted from increased tectonic activity.

The latest Middle Jurassic and earliest Late Jurassic are noted for major tectonic and geographic changes in the region: some structures were reversed, resulting in the drainage of extensive areas.

In the Late Jurassic, the continentalization of northeastern Asia continued, interrupted by Oxfordian–early Kimmeridgian and middle–late Volgian (Tithonian) transgressions. The area of marine sedimentation was displaced toward the northern and eastern margins of the region, with the maximum transgression during the Volgian (Figures 11.1 and 11.3). Relatively deep sea was retained in the reduced Amur-Okhotsk and Sikhote-Alin Basins, but terrigenous sediments increased in abundance and coarseness. During the earliest Volgian, the Momo-Zyryan deep-sea depression was formed and the Anyui linear oceanic basin appeared, which was open to the Paleopacific. In other basins, upper-sublittoral conditions prevailed, often extremely shallow and with sandy-silty and sandy-pebbly sediments. Subaqueous volcanic activity intensified, particularly peripheral to the Kolyma Block.

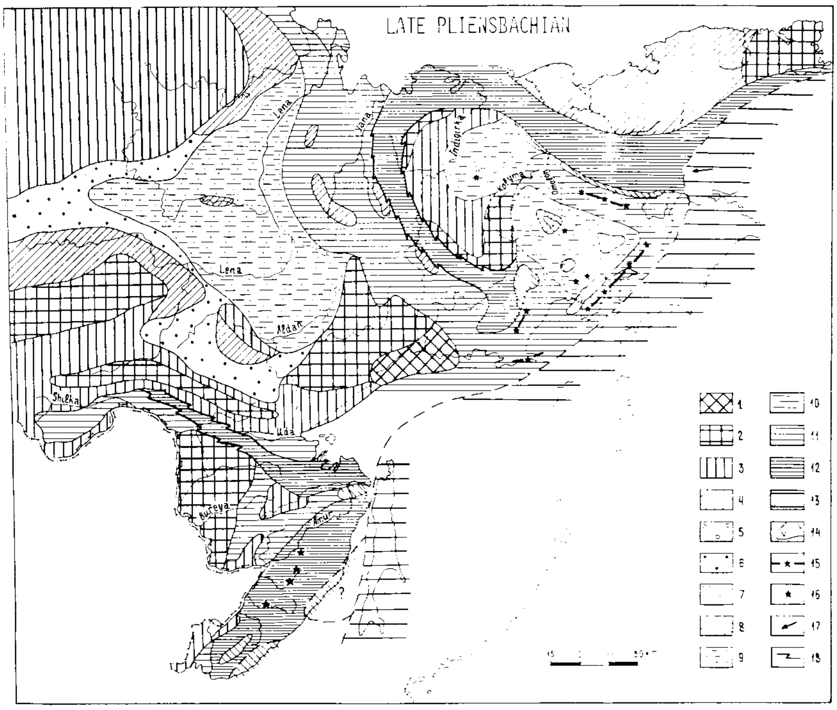
Uplifting resulted in increased elevation and relief of the land. In the south of the region, the Stanovye Mountains formed and included molassoid and volcanic depressions. Several, briefly marine, molassoid depressions also formed in North-East Russia. Coastal and lacustrine alluvial plains were widespread and included coal measures.

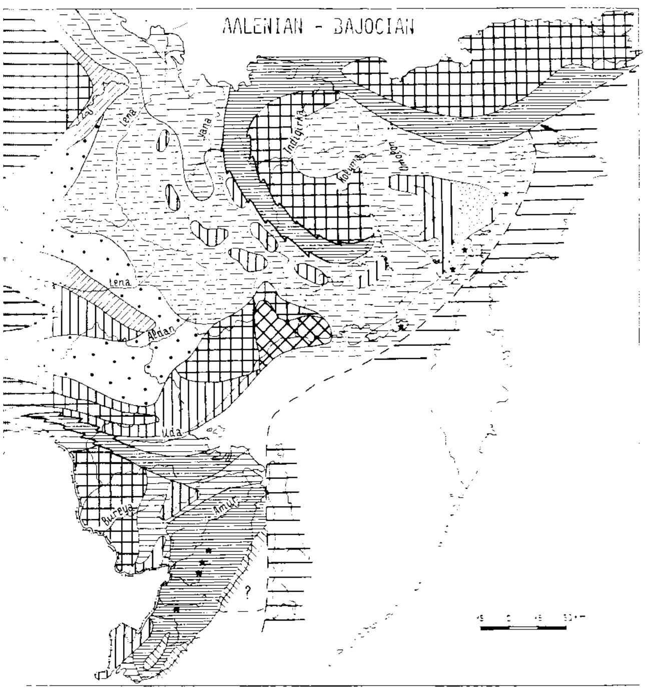
Continentalization of eastern Russia was completed in the Hauterivian, when almost the entire area became land. An aqueous regime was retained only at the eastern margin of the region (Sakhalin Island, Kamchatka, Koryak Upland), which throughout the Jurassic was peripheral to the Paleopacific. Accumulation of siliceous silts and terrigenous siliceous sediments proceeded on the abyssal plains and on intraoceanic uplifts of the Paleopacific.

Geodynamics

The proposed scheme of geodynamic evolution of Eastern Russia in Jurassic time is based on the ideas and notions of several workers who have studied the problems of geodynamics of northeastern Asia in the Mesozoic: Gusev et al. (1985), Zonenschain, Kuzmin, and Natapov (1987), Karasik, Ustritsky, and Khramov (1984), Mazarovich (1985), Parfenov (1984), Rikhter (1986), Stavsky (1988), Khanchuk, Panchenko, and Kemkin (1988), Chudinov (1985). The geological and biogeographic data available to the authors make it necessary to give a slightly modified model.

The geodynamic setting in northeastern Asia by the beginning of the Jurassic had formed under the influence of major riftogenic processes, which started as far back as the Early Paleozoic, followed by subsequent restructuring. Significant restructuring





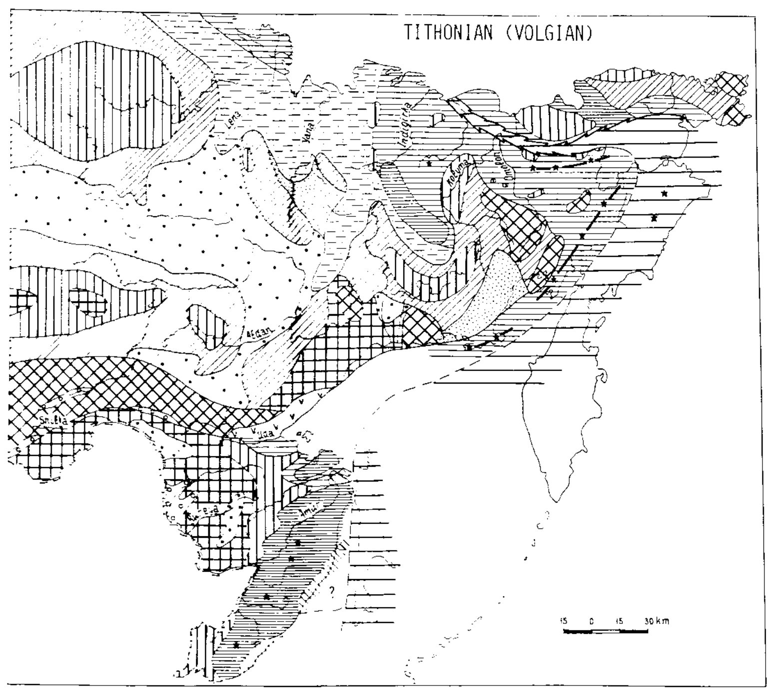


Figure 11.13. Paleogeographic maps of northeast Asia (on the Present globe). Land: 1, high mountains; 2, low mountains; 3, denudation elevation; 4, denudation plains; 5, intermontane depressions; 6, lacustrine alluvial plains; 7, coastal marine plains. Sea: 8, submarine rises; 9, upper sublittoral; 10, lower sublittoral; 11, sublittoral without differentiation; 12, deep sea (pseudoabyssal); 13, oceanic basin (pelagic). Other symbols: 14, areas of subaerial volcanic activity; 15, volcanic island arcs; 16, centers of submarine volcanic activity; 17, direction of main currents; 18, boundaries of compression and rift zones.

occurred in the Norian, when deep-sea troughs of suboceanic basins were formed and surrounded the eastern extremity of the Siberian Continent, and island-arc systems were emplaced.

Along the eastern margin of the Siberian Continent was the rather broad Verkhoyanye Shelf (Figure 11.14), which in turn was surrounded by the Debin Deep-Sea Trough (a pull-apart suboceanic basin). The steep flanks of the trough, which represented the continental slope, are noted for the development of olistostromes (Gusev et al. 1985), whereas the western boundary of the trough in modern plan is traced by the Adycha-Taryn Tectonic Suture. The Debin Deep-Sea Trough was emplaced in late Norian.

The Debin Basin in the east adjoined a system of smaller basins, which separated a number of blocks and microcontinents. Along the northeastern boundary, a linear chain of blocks was lo-

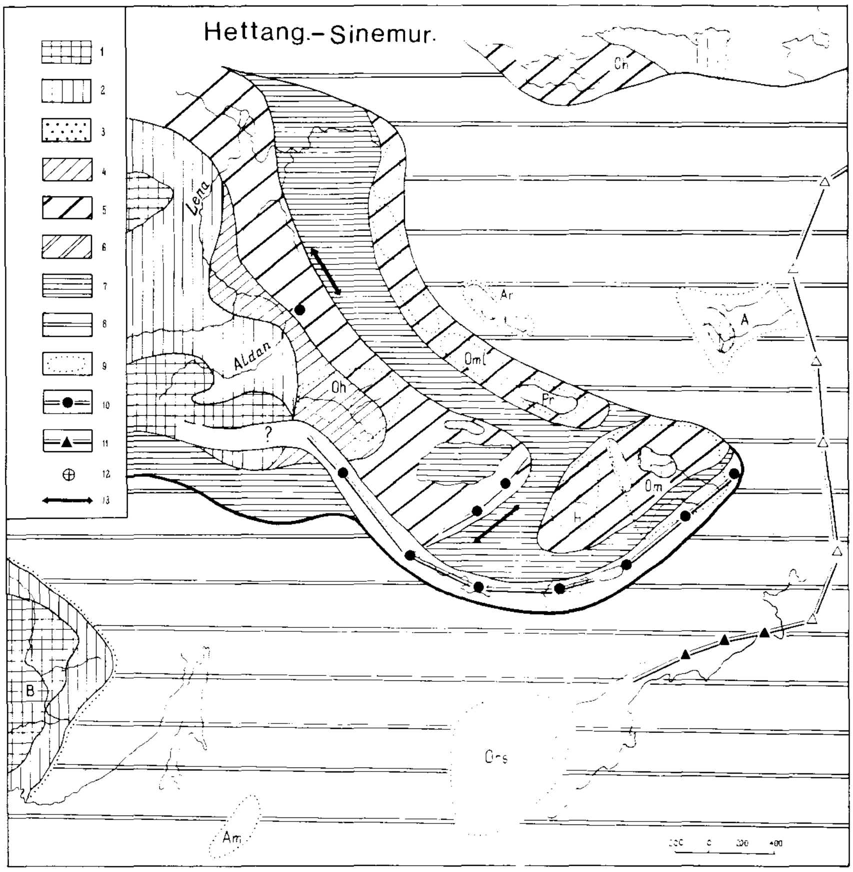
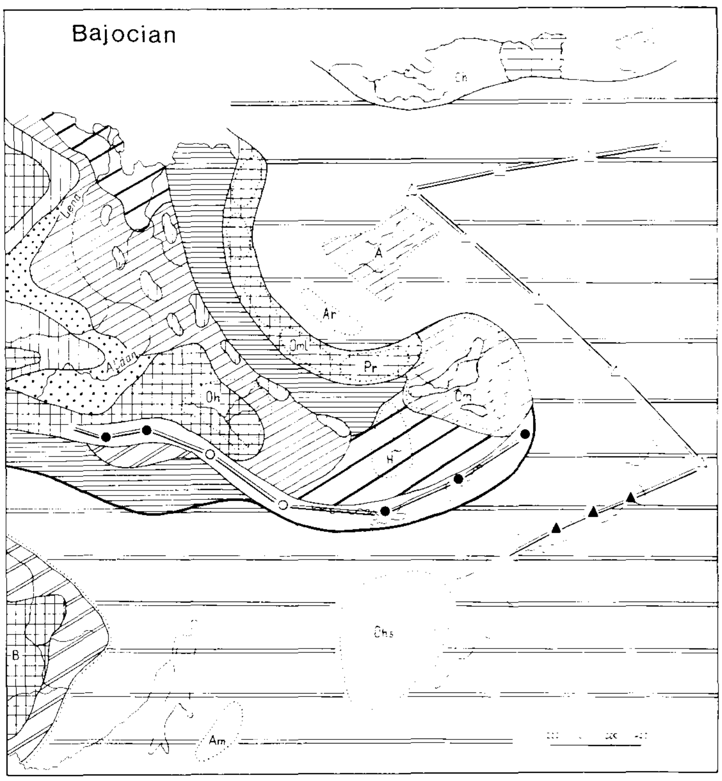
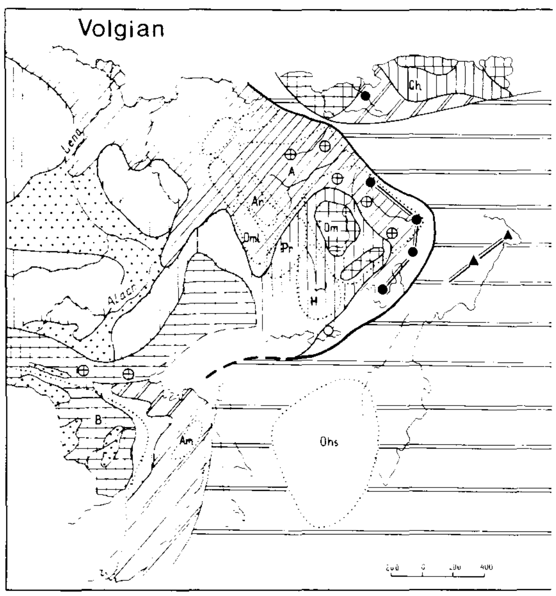


Figure 11.14. Palinspastic reconstructions of northeastern Asia. Land: 1, mountains; 2, uplifts; 3, accumulation plains and intermontane depressions. Sea: 4, shallow shelf (upper sublittoral), sandy sediments predominate; 5, deep shelf (low sublittoral), silty sediments predominate; 6, undivided shelf, sandy-silty sediments; 7, deep-sea troughs on a thinned continental and partly oceanic crust, sandy-silty-clayey flyschoid deposits; 8, deep-sea basins of oceanic type. Other symbols: 9, contours of blocks and microcontinents, later subject to displacement and collision; 10, volcanoes and volcanic arcs on continental crust (black) and their presumed extensions; 11, volcanic arcs on oceanic crust (black) and their presumed extensions; 12, volcano-plutonic belts; 13, contour currents. Microcontinents and blocks: A, Alazeya; Am, Amur; Ar, Arga-Tas; B, Bureya-Khanka; Ch, Chukotka; H, Khetagchan; Oh, Okhotsk; Ohs, Sea of Okhotsk; Om, Omolon; Oml, Omulevka; Pr, Prikolymje.





blocks (Kolyma, Omulevka, Tas-Khayakhtak, etc.), with the continental crust making up a peculiar foreland of the Siberian Continent. Its marginal, southern member was the Omolon Microcontinent. The southeastern margin of the Siberian Continent was bounded by the Taigonos Volcanic Arc emplaced in the late Norian due to under-thrusting of the Pacific oceanic plate under the continent. The same process also caused the emplacement of the Olyn Volcanic Arc during its short evolution.

Chukotka was separated from the Siberian Continent by the Anyui Intercontinental Oceanic Basin, whose possible fragment is the Argatas Range. Alazeya, apparently, represented a continental block. This is consistent with the Late Triassic and Early and Middle Jurassic shallow-water facies and faunas. According to Gusev et al. (1985, p. 138, Fig. 36), the trend of the Carboniferous and Early Mesozoic basalts on the Alazeya Upland is similar to that of the Siberian Platform traps. This block was most remote from its present location. It is represented by distinct early Middle Jurassic biota, including the Subtethyan and East-Pacific element *Bradfordia* and the Bering element *Erycitoides*. Pliensbachian bivalve communities are characterized by the presence of *Weyla*, a characteristic Tethyan element, widespread along the eastern Pacific coast. *Pinna* is also found, a representative of relatively thermophilic faunas, not recorded in coeval Aalenian communities of other structures of North-East Russia.

The Siberian Continent was bounded in the south by the Amur-Okhotsk (Mongolo-Okhotsk) Intracontinental Oceanic Basin, whose emplacement was in the Early Paleozoic, and which was revived by rifting in the early Norian. The southern extremity of the continent was taken up by the Uda Volcanic Zone, which represented a continental extension of the Uda–Murgal or Taigonos Volcanic Arc. In this area, the Siberian Continent was surrounded by the Uda and Torom Troughs, which joined the continental slope at a deep-sea trench.

The southern extremity of the Amur-Okhotsk Basin was the Bureya Land (Bureya–Khanka Megablock), around whose periphery in the Early and Middle Jurassic periodically appeared a system of marginal epicontinental seas (upper Amur, Bureya, etc.).

East of the Bureya-Khanka Megablock was an oceanic basin, the margin of the Paleopacific. Parallel to the Bureya-Khanka Land, in place of the axial part of the Sikhote-Alin Fold System, extended a deep-sea trench in which Jurassic sedimentation was accompanied by emplacement of olistostrome sequences. Eastward, including Sakhalin Island, was an oceanic plate with oceanic-type sedimentation throughout the Jurassic (i.e., deposition of extremely thin siliceous and siliceous-terrigenous sediments).

Thus, the Jurassic of northeastern Asia included a large spectrum of paleogeographic settings.

The Hettangian and Sinemurian of the eastern Siberian Continent were characterized by a moderately rugged topography. Adjacent seas were mainly sublittoral (Verkhoyanye Shelf, Omolon and Kolyma Archipelagoes), with clayey-silty sediments. Similar sediments also deposited on the shelf east of the Bureya Land, which probably had slightly higher elevations.

The late Pliensbachian–early Toarcian transgression resulted from a eustatic rise in sea level on the Siberian Continent; the Vilyui Lowland was flooded. Around the periphery of the Bureya Land, including the Eastern Transbaikal area, a chain of shallow marginal seas was formed. An extensive basin of continental sedimentation appeared on the eastern Siberian Continent (Vilyui and South Yakutsk Lacustrine-Alluvial Plains). Simultaneously, the topography became more dissected in eroded areas. Generally, in the late Pliensbachian, middle and upper sublittoral, sandy-clayey sediments were deposited, sometimes with coarse-clastic rocks. In the early Toarcian, the development of transgression in the northeast was weakened by the growth of geoanticlinal structures, which resulted in the formation of a large peninsula in the Lena-Yana interfluve.

Throughout the Early Jurassic, in suboceanic basins and deep-sea trenches, thick, often flyschoid, sandy-silty-clayey and siliceous-clayey sequences are formed.

The late Toarcian in eastern Russia was a time of regional uplifts, reduction, and segregation of margin areas. At the beginning of the Middle Jurassic, a regional phase of folding occurred on the Alazeya Upland. Apparently, this event was caused by collision of the Chukotka Continent with the Alazeya Block. In adjacent areas this event is indicated by conglomerates.

A new transgressive cycle in the Aalenian–early Bajocian considerably revived the marine basins of northeastern Asia (Figure 11.14) and favored stabilization and leveling of the late Toarcian disturbances. In the late Bajocian, a progressive continentalization of the territory started; the area of shelf and epicontinental seas was reduced and shallowing proceeded; suboceanic basins became shallower and were filled by sediments.

The end of the Middle Jurassic is noted for a major geodynamic and paleogeographic restructuring. In North-East Russia, the major phase of folding was in the Bathonian. It was the result of complicated interactions between the Chukotka Continent, the Alazeya Block, the foreland of the Siberian Continent, and the Pacific plate with the Omolon Microcontinent. Thus, the Alazeya and Omolon Microcontinents formed the main structural constituents in this part of the region.

The subduction along the southern front of the Uda-Murgal Volcanic Arc and the southern boundary of the Siberian Continent in the Middle Jurassic resulted in the northward movement of the Bureya-Khanka Massif. Apparently, at the Middle–Late Jurassic boundary, the Amur-Okhotsk Oceanic Basin became closed, and most of its marine regime was eliminated, though the collisional processes doubtless occurred through the entire Late Jurassic.

In the Late Jurassic the process of continentalization of eastern Russia continued, complicated by marine transgressions in the Oxfordian–early Kimmeridgian and in the middle–late Volgian. The area of marine sedimentation was displaced toward the northern and eastern margins of the region (Figure 11.14). Uplifting was accompanied by a further rise of elevation and a more contrasting land topography; a system of molassoid depressions was emplaced; subaerial volcanic activity was intensified. In the Oxfordian–Kimmeridgian–early Volgian, volcanic belts were formed: Uyanda–Yasachnaya, in front of the Alazeya Block, and

Uda on the southern margin of the Siberian Continent within the Stanovoy Arched Uplift. Over all of northeastern Asia, coastal and lacustrine alluvial plains were developed, where coal-bearing deposits accumulated.

The shelf area in the Sikhote-Alin Oceanic Basin increased. However, the deep-sea trench, with thick terrigenous sedimentation, continued to exist there up to the end of the Neocomian, when, because of subduction, the oceanic plate was thrust over the terrigenous complexes of the paleotrench. In Sakhalin, the abyssal-plain setting was retained to the end of the Early Cretaceous. Probably at the close of the Jurassic, the Amur (Kiselev) Block, associated with the exotic Early Jurassic fauna, was accreted. The fauna included Tethyan or Subtethyan elements (*Juraphyllites, Ctenostreon,* numerous *Cardinia*) and had no equivalents among coeval communities of northeastern Asia.

The opposite direction in the movement of the Pacific plate and the Chukotka Continent, which continued in the Late Jurassic, promoted a further piling-up of blocks and microcontinents and ended in the collision of the Siberian Continent and Chukotka in the Neocomian.

Modern Koryakiya apparently is a microblock (terrane) mosaic, part of which is characterized by exotic (extra-Boreal) invertebrate communities. In the Norian of the Kenkeren Range, shallow-water faunas practically lack bivalve genera and species in common with similar fauna in the inner region of North-East Russia. *Costatoria, Cassianella, Septocardia, Pinna, and Maoritrigonia,* as well as the hermatypic coral *Astraemorpha,* were reported from there (Bychkov 1985). The Callovian sediments in the Koiverelen Basin contain representatives of the Tethyan ammonite genera *Lunuloceras, Zieteniceras,* and *Choffatia* (Sey and Kalacheva 1985). Accretion of Koryakiya probably took place in post-Jurassic time.

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PLATE 15

EASTERN RUSSIA, HETTANGIAN

Figs. 1, 2, 6. *Psiloceras viligense* Chud. & Polub. (1, complete; 2, phragmocone; 6, nucleus); from Planorbis Zone, North-East Russia, Viliga River (coll. Polubotko & Repin).

Fig. 3. *Waehneroceras angustum* A. Dagis, complete; from Liasicus Zone, North-East Russia, Arman River.

Fig. 4. *Waehneroceras frigga* (Waehner), phragmocone?; from Liasicus Zone, North-East Russia, Yana River basin (coll. Repin).

Fig. 5. *Schlotheimia* ex gr. *angulata* (Schloth.), phragmocone?; from Angulata Zone, North-East Russia, Omolon River basin (coll. Polubotko & Repin).

Fig. 7. *Psiloceras olenekense* (Kiparisova), phragmocone?; from Planorbis Zone, North-East Russia, Olenek River basin (coll. Knjazev).

Fig. 8. *Primapsiloceras primulum* (Repin), phragmocone?; from *P. primulum* Zone, North-East Russia, Omolon River basin (coll. Polubotko & Repin).

Fig. 9. *Alsatites*(?) sp. indet., complete?; from Liasicus Zone, North-East Russia, Omolon River basin (coll. Polubotko & Repin).

Fig. 10. *Waehneroceras armanense* Repin, complete; from Liasicus Zone, North-East Russia, Arman River.

Fig. 11. *Waehneroceras portlocki* (Wright), phragmocone?; from Liasicus Zone, North-East Russia, Omolon River basin. These specimens are kept in Central Scientific Research Geological Museum (CNIGR Museum), St. Petersburg, and in the Geological Museum of the Geological Survey of North-East Russia, Magadan.

(Compiled by Repin, Sey, & Kalacheva.)

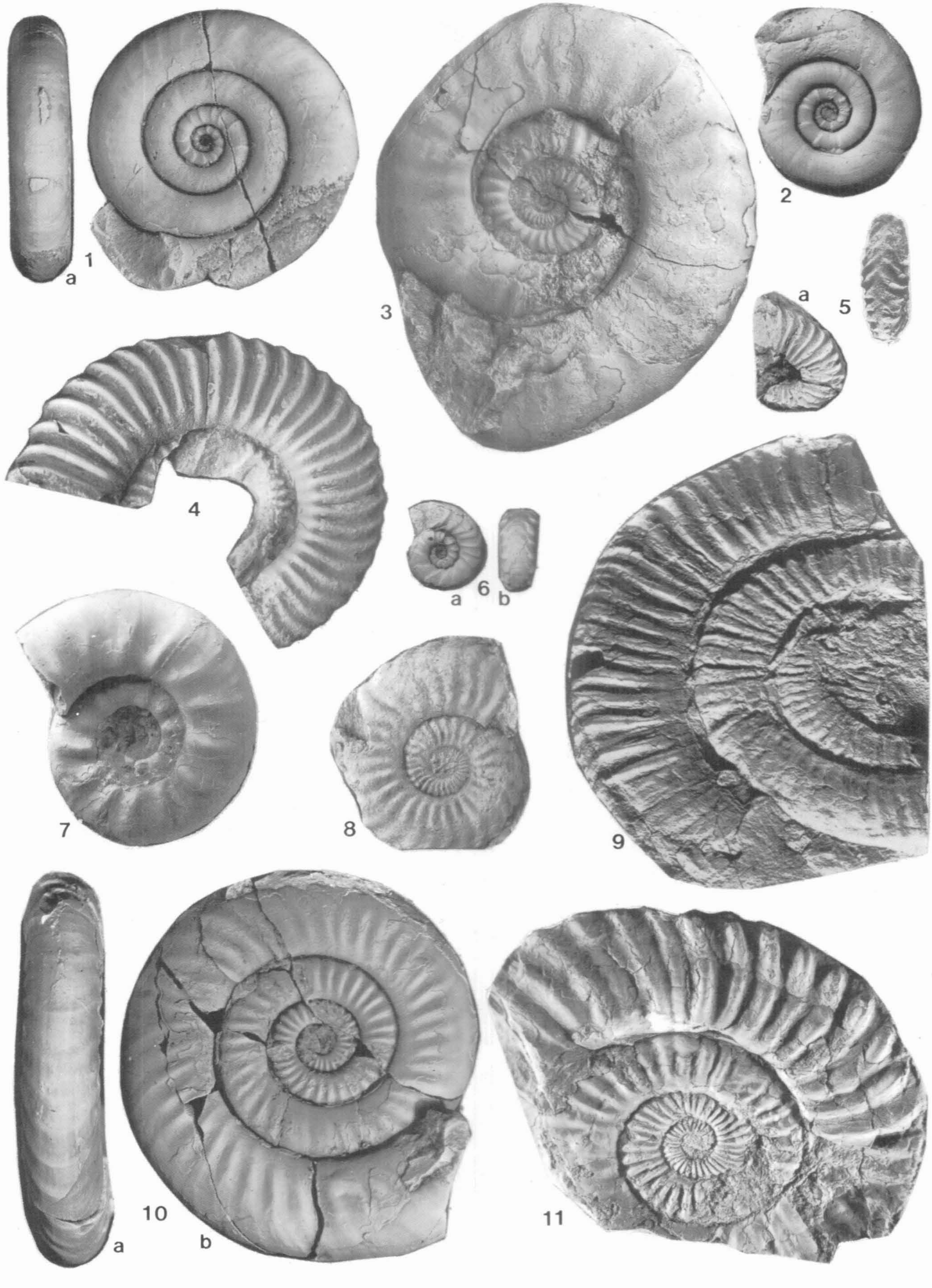
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PLATE 16

EASTERN RUSSIA, SINEMURIAN

Figs. 1, 2. *Arietites libratus* Repin (1, complete; 2, juv.); from Bucklandi Zone, North-East Russia, Omolon River basin (coll. Polubotko & Repin).

Figs. 3–6. *Angulaticeras (Gydanoceras) ochoticum* Repin (3, complete; 4, body chamber; 5, juv. (×2); 6, phragmocone); from *A. kolymicum* Zone, North-East Russia, Ghyzhiga River basin, Buynda River basin, (coll. Polubotko & Repin).

Fig. 7. *Coroniceras (Paracoroniceras) siverti* (Tuchkov), phragmocone (×0.4); from *C. siverti* Zone, North-East Russia, Omolon River basin.

Fig. 8. *Coroniceras (Primarietites) reynesi* (Spath), complete; from *C. siverti* Zone, North-East Russia, Omolon River basin (coll. Polubotko & Repin).

Fig. 9. *Angulaticeras (Gydanoceras)* cf. *ochoticum* Repin; from Upper Sinemurian, Far East Russia, southern Primorye, Trudny Peninsula (coll. Sey & Kalacheva).

Fig. 10. *Angulaticeras (Gydanoceras) kolymicum* Repin, complete; from *A. kolymicum* Zone, North-East Russia, Korkodon River basin (coll. Polubotko & Repin).

(Compiled by Repin, Sey, & Kalacheva.)


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PLATE 17

EASTERN RUSSIA, UPPER PLIENSBACHIAN

Fig. 1. *Amaltheus (Amaltheus) stokesi* (Sow.), complete; from Stokesi Zone, North-East Russia, Sededema River basin.

Fig. 2. *A. (Amaltheus) subbifurcus* Repin, complete; from Stokesi Zone, North-East Russia, Omolon River basin.

Figs. 3, 6. *A. (Amaltheus) margaritatus* (Montf.); from Margaritatus Zone [3, North-East Russia, Lena River (coll. Repin); 6, Far East Russia, Bureya River basin] (coll. Sey & Kalacheva).

Fig. 4. *A. (Amaltheus) talrosei* Repin, complete; from *A. talrosei* Zone, North-East Russia, Korkodon River basin (coll. Repin).

Figs. 5, 7. *Amaltheus (Nordamaltheus) viligaensis* (Tuchkov); from *A. (N.) viligaensis* Zone, North-East Russia, Viliga River (coll. Repin).

Fig. 8. *A. (Amaltheus) extremus* Repin, phragmocone; from *A. (N.) viligaensis* Zone, North-East Russia, Omolon River basin (coll. Repin).

Fig. 9. *Protogrammoceras* cf. *serotinum* (Bettoni); from upper Pliensbachian, Far East Russia, Southern Sikhote-Alin, Izvilinka River basin (coll. Sey & Kalacheva).

Fig. 10. *Fontanelliceras* cf. *fontanellense* (Gemm.), complete; from upper Pliensbachian, Far East Russia, Sikhote-Alin (coll. Sey & Kalacheva).

Figs. 11, 12, 14. "*Dactylioceras*" *simplex* Fucini; from upper Pliensbachian, Far East Russia, Southern Sikhote-Alin (coll. Sey & Kalacheva).

Fig. 13. "*Dactylioceras*" *polymorphum* Fucini, phragmocone?; from Upper Pliensbachian, Far East Russia, Southern Sikhote-Alin (coll. Sey & Kalacheva).

Figs. 15, 16. *Arieticeras japonicum* Matsumoto, complete; from upper Pliensbachian, Far East Russia, Southern Sikhote-Alin (coll. Sey & Kalacheva).

Fig. 17. *Protogrammoceras* sp. indet.; from upper Pleinsbachian, Far East Russia, Southern Sikhote-Alin (coll. Sey & Kalacheva) [= *Paltarpites* sp. indet.].

(Compiled by Repin, Sey, & Kalacheva.)

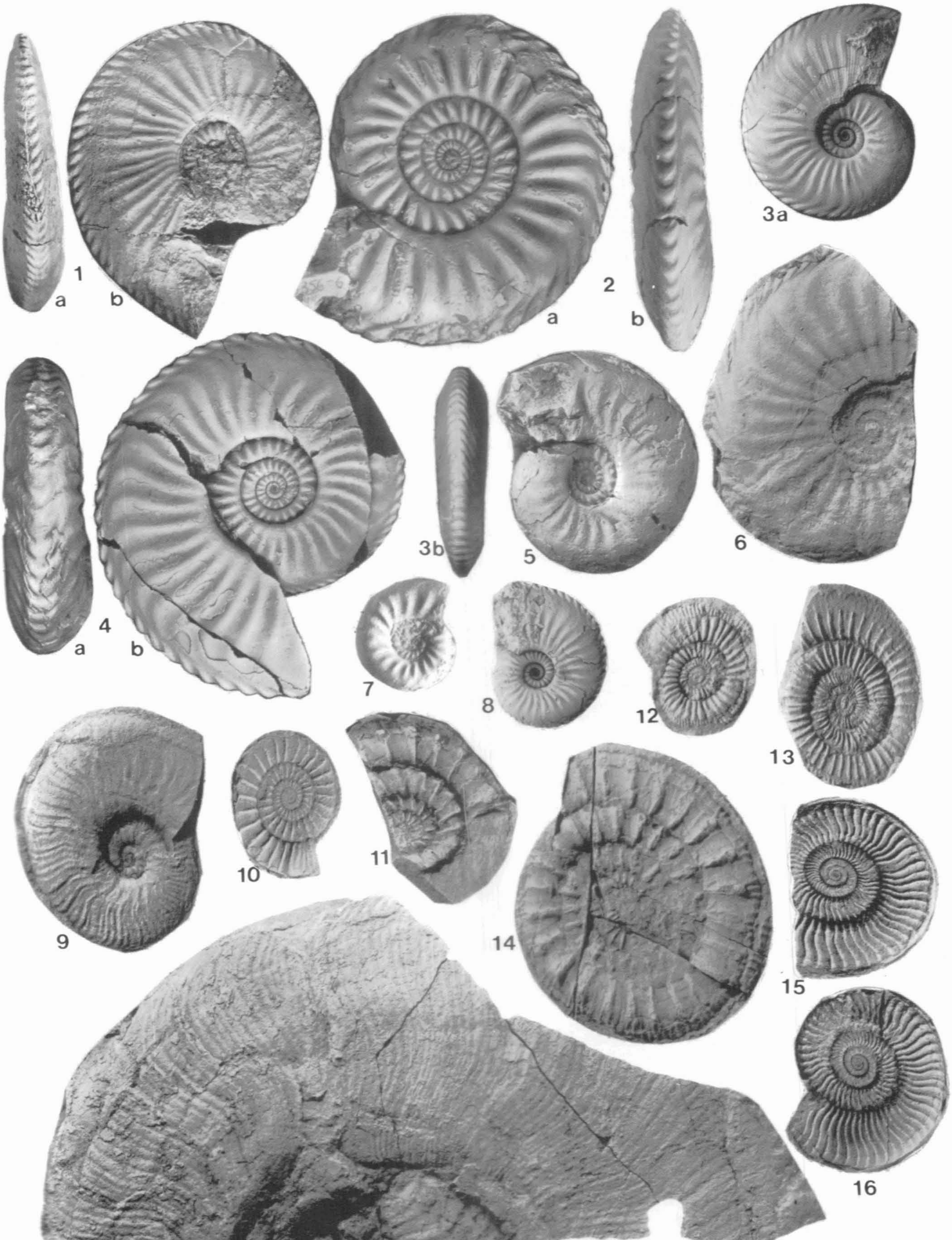
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PLATE 18

EASTERN RUSSIA, TOARCIAN

Figs. 1, 3. *Tiltoniceras propinquum* (Whit.) (1, phragmocone; 3, complete); from *T. propinquum* Zone, North-East Russia, Omolon River basin.

Fig. 2. *Arctomercaticeras costatum* Repin, complete; from *T. propinquum* Zone, North-East Russia, Omolon River basin.

Fig. 4. *Harpoceras exaratum* (Young & Bird), complete; from Falciferum Zone, North-East Russia, Omolon River basin (coll. Polubotko & Repin).

Fig. 5. *Eleganticeras alajaense* (Repin), phragmocone?; from *E. elegantulum* Zone, North-East Russia, Omolon River basin (coll. Polubotko & Repin).

Figs. 6, 8. *Eleganticeras elegantulum* (Y. & B.), complete; from *E. elegantulum* Zone, North-East Russia, Omolon River basin (coll. Repin).

Fig. 7. *Hildaites chrysanthemum* (Yok.), complete; from *D. athleticum* Zone, North-East Russia, Omolon River basin (coll. Repin).

Fig. 9. *Eleganticeras planus* Repin, complete; from *E. elegantulum* Zone, North-East Russia, Omolon River basin.

Figs. 10, 13. *Pseudolioceras kedonense* Repin, complete; from *Z. monestieri* Zone; 10, Far East Russia, Tugur Bay (coll. Sey & Kalacheva); 13, North-East Russia, Omolon River basin (coll. Repin).

Fig. 11. *Harpoceras falciferum* (Sow.), complete; from Falciferum Zone, North-East Russia, Omolon River basin (coll. Repin).

Fig. 12. *Dactylioceras commune* (Sow.), complete; from *D. athleticum* Zone, North-East Russia, Omolon River basin (coll. Polubotko & Repin).

Fig. 14. *Dactylioceras athleticum* (Simps.), complete; from *D. athleticum* Zone, North-East Russia, Omolon River basin.

(Compiled by Repin, Sey, & Kalacheva.)

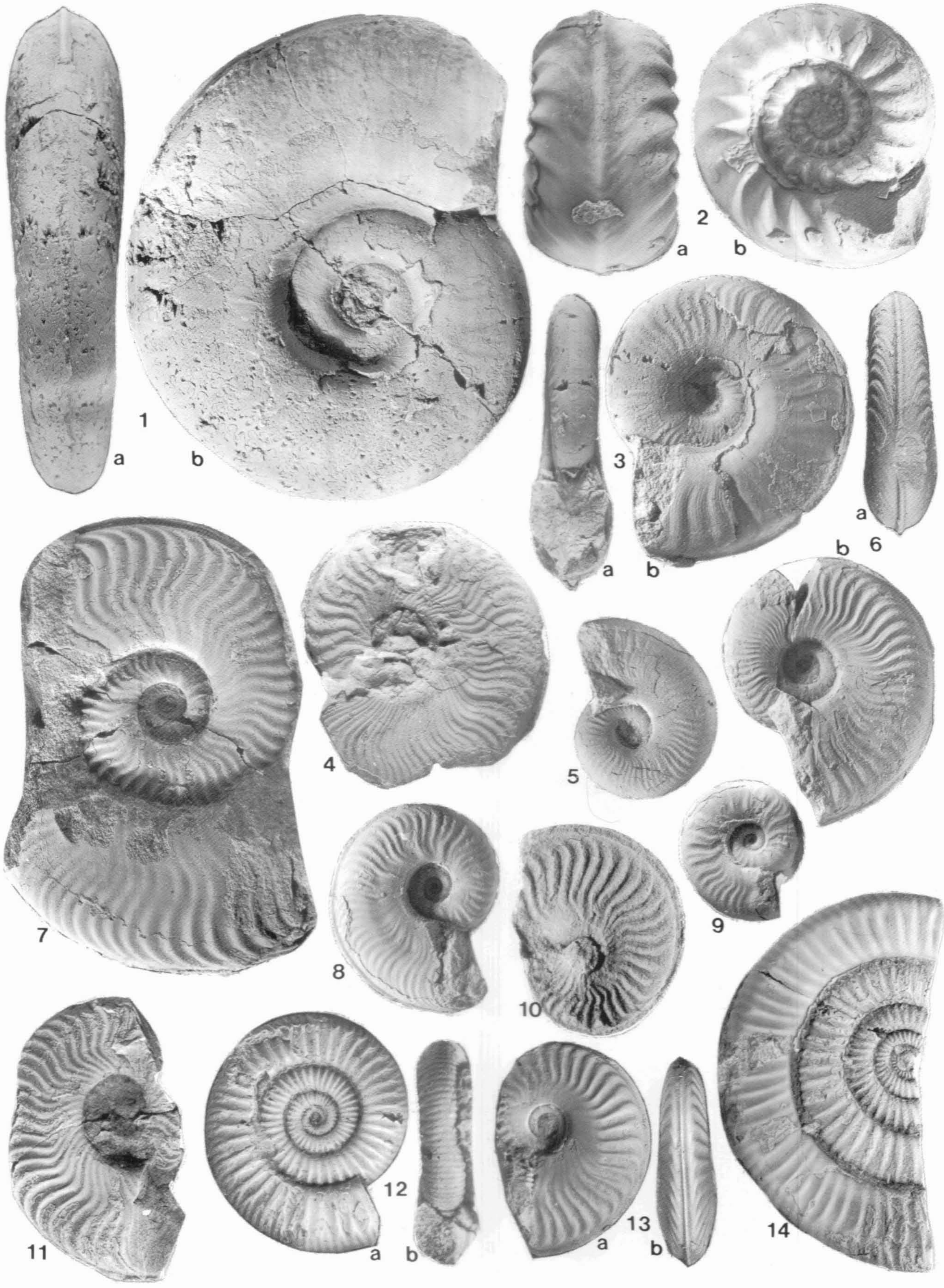

PLATE 19

EASTERN RUSSIA, TOARCIAN

Fig. 1. *Porpoceras spinatum* (Frebold), complete; from *P. spinatum* Zone, North-East Russia, Korkodon River basin.

Figs. 2, 5. *Pseudolioceras lythense* (Y. & B.); 2, complete (×0.64); 5, phragmocone?; from *Z. monestieri* Zone; 2, North-East Russia, Omolon River basin (coll. Polubotko & Repin); 5, Far East Russia, Tugur Bay (coll. Sey & Kalacheva).

Figs. 3, 9, 15. *Zugodactylites braunianus* (Orb.); 3, complete; 9, 15, phragmocone; from *Z. monestieri* Zone; 3, North-East Russia, Korkodon River basin (coll. Repin); 9, 15, Far East Russia, Tugur Bay (coll. Sey & Kalacheva).

Fig. 4. *Pseudolioceras gradatum* Buckman, complete; from *P. spinatum* Zone, North-East Russia, Omolon River basin.

Figs. 6, 16. *Pseudolioceras rosenkrantzi* A. Dagis, complete; from *P. rosenkrantzi* Zone, North-East Russia, Omolon River basin (coll. Repin).

Fig. 7. *Zugodactylites exilis* A. Dagis, phragmocone; from *Z. monestieri* Zone, North-East Russia, Korkodon River basin (coll. Repin).

Fig. 8. *Kolymoceras* aff. *viluiense* Krimholz; from *Z. monestieri* Zone, North-East Russia, Omolon River basin (coll. Polubotko & Repin).

Fig. 12. *Porpoceras polare* (Freb.), phragmocone; from *P. spinatum* Zone, North-East Russia, Paren River basin (coll. Repin).

Fig. 13. *Collina* aff. *orientalis* A. Dagis, complete; from *P. spinatum* Zone, North-East Russia, Paren River basin (coll. Repin).

Fig. 14. *Pseudolioceras replicatum* Buckman, complete; from *P. rosenkrantzi* Zone-*P. beyrichi* Zone, North-East Russia, Olenek River basin (coll. Polubotko & Repin).

(Compiled by Repin, Sey, & Kalacheva.)

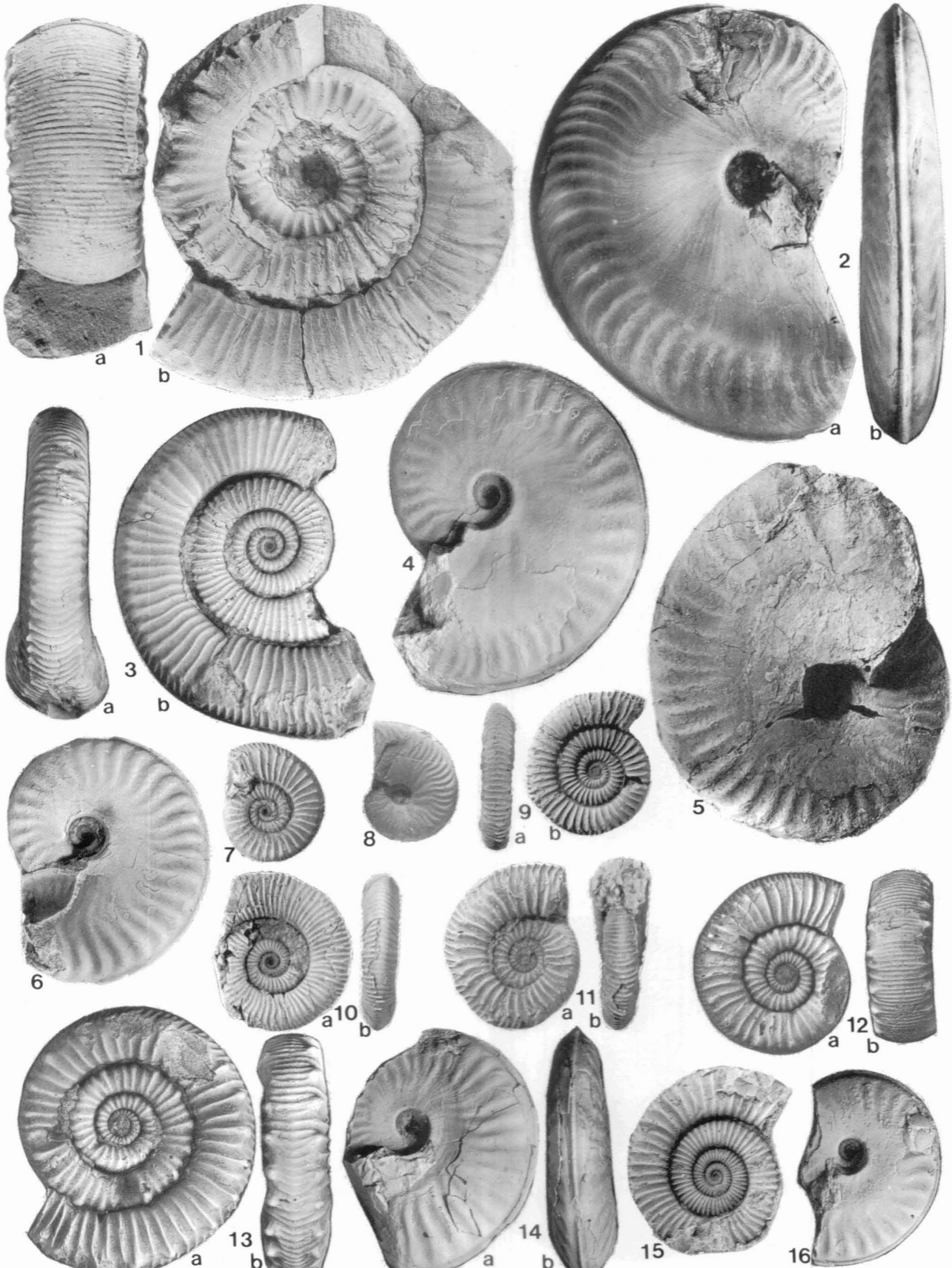
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PLATE 73

EASTERN RUSSIA, AALENIAN

Figs. 1, 6. *Pseudolioceras (Pseudolioceras) beyrichi* (Schloenbach), phragmocone; from *P. (P.) beyrichi* Zone; 1, Far East Russia, Tugur Bay (coll. Sey & Kalacheva); 6, North-East Russia, Sededema River basin (coll. Repin).

Figs. 2, 3, 17. *Pseudolioceras (Tugurites) whiteavesi* (White); 2, 3, phragmocone; 17, complete; from *P. (Tugurites) tugurense* Zone; 2, North-East Russia, Paren River basin (coll. Repin); 3, 17, Far East Russia, Tugur Bay (coll. Sey & Kalacheva).

Figs. 4, 15, 16. *Pseudolioceras (Tugurites) maclintocki* (Haughton), phragmocone; from *P. (T.) maclintocki* Zone; 4, 16, Far East Russia, Bureya River basin, Tugur Bay (coll. Sey & Kalacheva); 15, North-East Russia, Kegali River basin (coll. Repin).

Fig. 5. *Erycitoides* sp., phragmocone (×2.5); from *P. (T.) tugurense* Zone, North-East Russia, Penzhina River basin (coll. Repin).

Fig. 7. *Erycitoides howelli* (White), phragmocone; from *P. (T.) turgurense* Zone, Far East Russia, Tugur Bay (coll. Sey).

Figs. 8–10. *P. (Tugurites) tugurense* Kalach. & Sey, phragmocone; from *P. (T.) tugurense* Zone, Far East Russia, Tugur Bay (coll. Sey & Kalacheva).

Figs. 11–13. *P. (Tugurites)* sp. (= "*Grammoceras*" sp. indet.); from *P. (T.) maclintocki* Zone; 11, North-East Russia, Sugoy River basin (coll. Repin); 12, 13, Far East Russia, Tugur Bay (coll. Sey).

Fig. 14. *Erycitoides (Kialagvikes) spinatum* Wester., complete; from *P. (T.) tugurense* Zone, Far-East Russia, Tugur Bay (coll. Sey & Kalacheva).

(Compiled by Repin, Sey, & Kalacheva.)

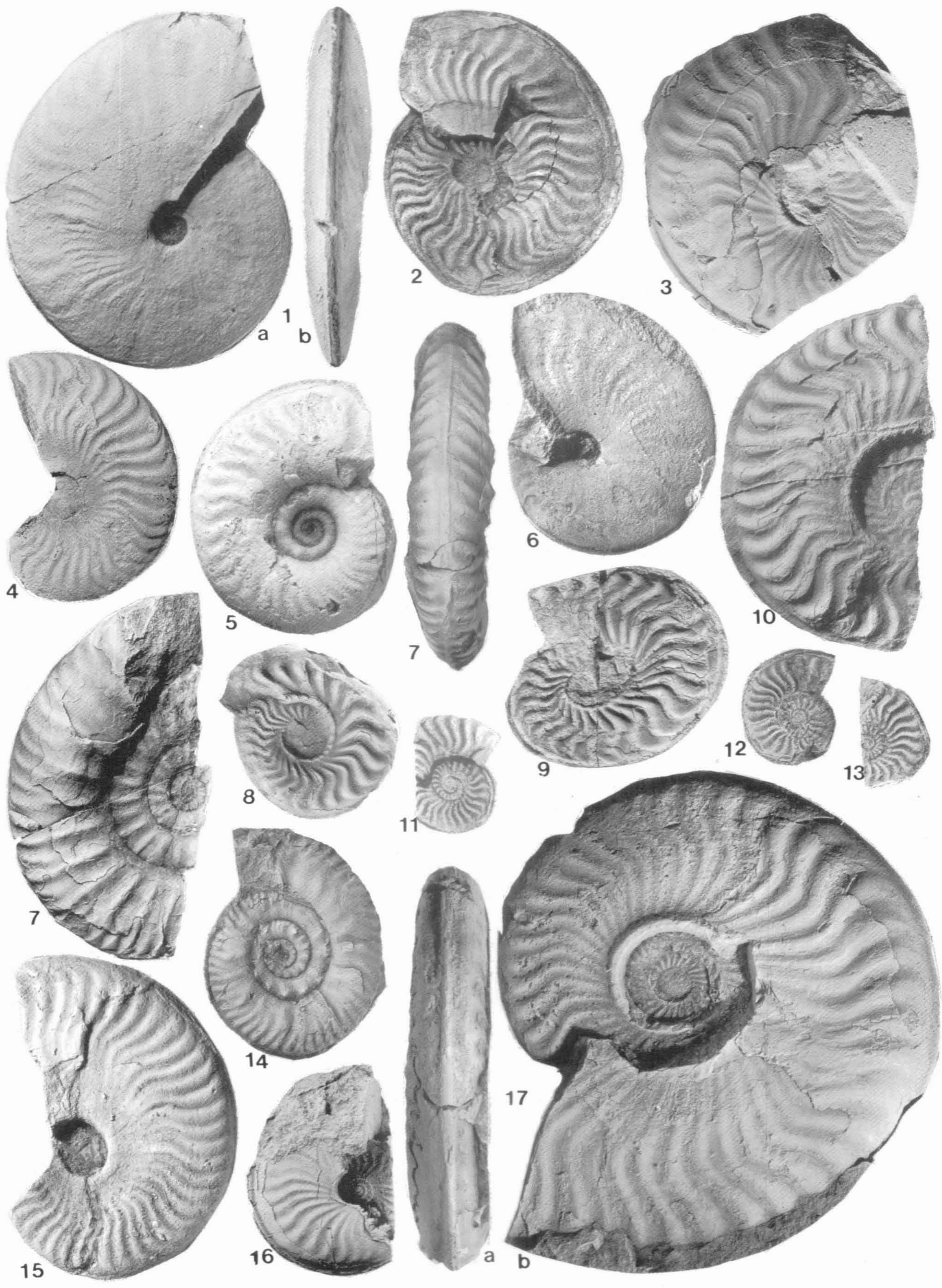
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PLATE 74

EASTERN RUSSIA, BAJOCIAN

Figs. 1, 2, 5. *Pseudolioceras (Tugurites) fastigatum* Wester., phragmocone; from *P. (T.) fastigatum* Zone; 1,2, Far East Russia, Bureya River basin (coll. Sey & Kalacheva); 5, North-East Russia, Kegali River basin (coll. Repin).

Figs. 3, 4. *P. (Tugurites) costistriatum* Wester., phragmocone?; from *P. (T.) fastigatum* Zone; 3, Far East Russia, Bureya River basin (coll. Sey); 4, North-East Russia, Paren River basin (coll. Repin).

Fig. 6. *Arkelloceras tozeri* Frebold, phragmocone?; from *A. tozeri* Zone, Far East Russia, Bureya River basin (coll. Sey & Kalacheva).

Figs. 7, 13. *Arkelloceras elegans* Frebold, phragmocone, complete; from *A. tozeri* Zone; 7, Far East Russia, Bureya River basin (coll. Sey & Kalacheva); 13, North-East Russia, Anadyr River basin (coll. Repin).

Fig. 8. *Oppelia (Liroxyites)* cf. *kellumi* Imlay; from Upper Bajocian, Far East Russia, (coll. Sey & Kalacheva).

Fig. 9. *Bradfordia alaseica* Repin, complete; from *A. tozeri* Zone, North-East Russia, Sededema River basin (coll. Repin).

Fig. 10. *Arkelloceras* cf. *maclearni* Freb.; from *A. tozeri* Zone; Far East Russia, Shilka River basin (coll. Sey).

Fig. 11. *Chinitnites*(?) sp. (= *Umaltites era* [m]), complete; from Upper Bajocian, *Umaltites era* Beds, Far East Russia, Bureya River basin (coll. Sey).

Figs. 12, 14, 15. *Umaltites* (= *Megasphaeroceras*) *era* (Krimholz); 12,14, complete; 15, phragmocone; from Upper Bajocian, *Umaltites era* Beds, Far East Russia, Bureya River basin (coll. Sey). [*Editor's comment: Umaltites* closely resembles the coeval genus *Megasphaeroceras,* in which it should be included as a subgenus, if not synonym.]

Fig. 16a–c. *Chondroceras* cf. *marshalli* (McLearn), complete?; a (×3); b,c (×2); from Lower Bajocian, *C. marshalli* Beds, North-East Russia, Anadyr River basin (coll Repin).

(Compiled by Repin, Sey, & Kalacheva.)

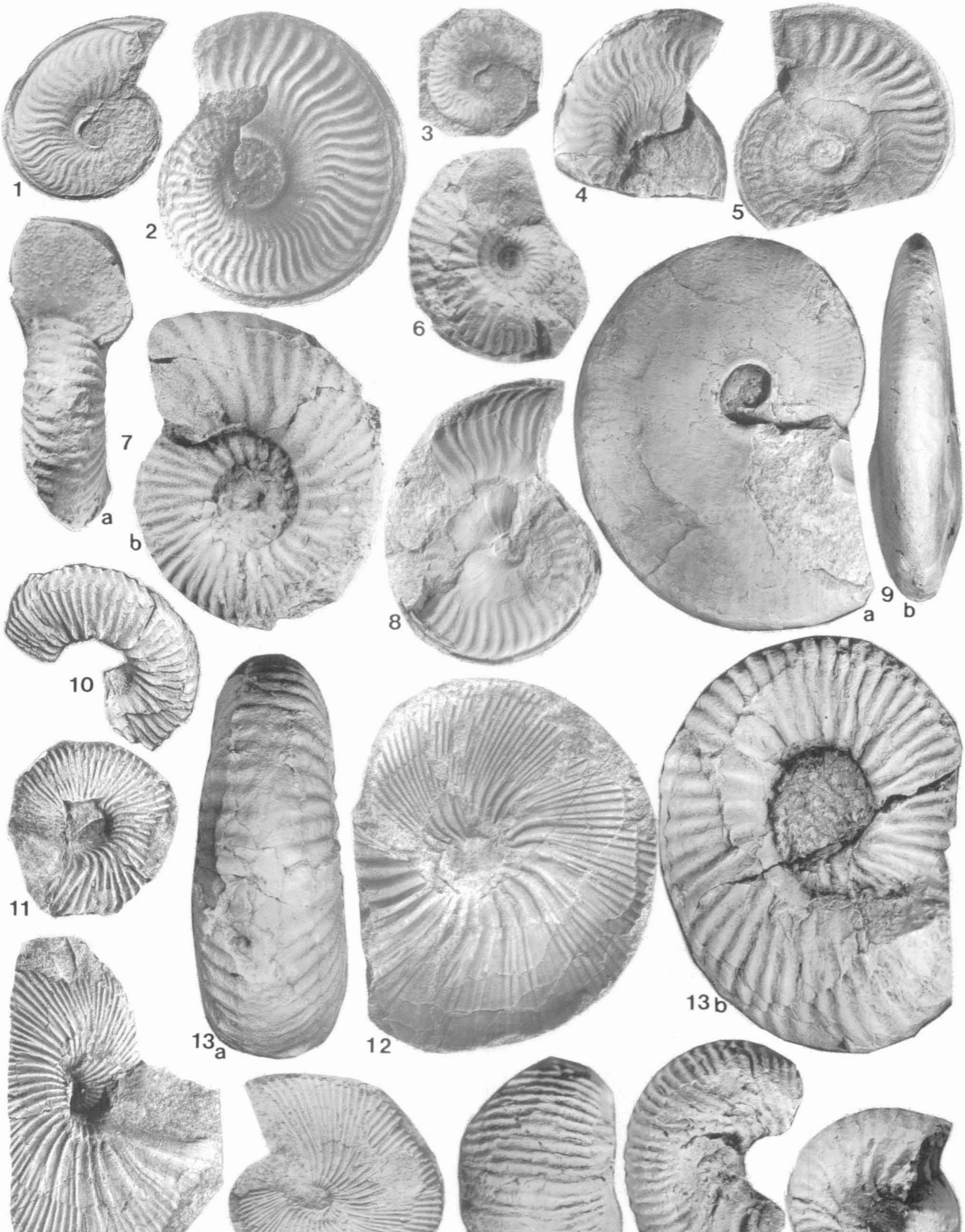
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PLATE 75

EASTERN RUSSIA, BAJOCIAN–BATHONIAN

Fig. 1. *Itinsaites*(?) sp.; from Bajocian, North-East Russia, Yana River basin (coll. Repin).
Fig. 2. *"Oxycerites" jugatus* Ersch. & Meledina, phragmocone (×2); from Lower Bathonian, *A. elegans* Zone, North-East Russia, Takhtoyama River basin (coll. Polubotko & Repin).
Fig. 3. *Cadoceras*(?) sp.; from Upper Bathonian, North-East Russia, Bolshoi Anyui River basin (coll. Repin).
Fig. 4. *"Cobbanites" talkeetnanus* Imlay, complete; from Upper Bajocian, Far East Russia, southern Primorye (coll. Sey & Kalacheva).
Fig. 5. *Cranocephalites furcatus* Spath, complete?; from *C. vulgaris* Zone, North-East Russia, Takhtoyama River basin (coll. Polubotko & Repin).
Fig. 6. *Costacadoceras*(?) cf. *bluethgeni* Rawson; from Upper Bathonian, North-East Russia, Okhotsk Sea, Babushkin Bay (coll. Paraketzov).
Fig. 7. *Iniskinites* cf. *magniformis* (Imlay); from Upper Bathonian, North-East Russia, Okhotsk Sea, Babushkin Bay (coll. Paraketzov).
Fig. 8. *Umaltites*(?) sp. (= *Megasphaeroceras*),[2] complete?; from Upper Bajocian, North-East Russia, Indigirka River basin (coll. Nikonov).
Figs. 9, 10. *Arctocephalites elegans* Spath, phragmocone; from Upper Bathonian, *A. elegans* Zone, North-East Russia, Viliga River.
Fig. 11. *Cranocephalites vulgaris* Spath; from Upper Bajocian, *C. vulgaris* Zone, North-East Russia, Takhtoyama River basin (coll. Polubotko & Repin).
(Compiled by Repin, Sey, & Kalacheva.)

[2] See caption to Plate 74.

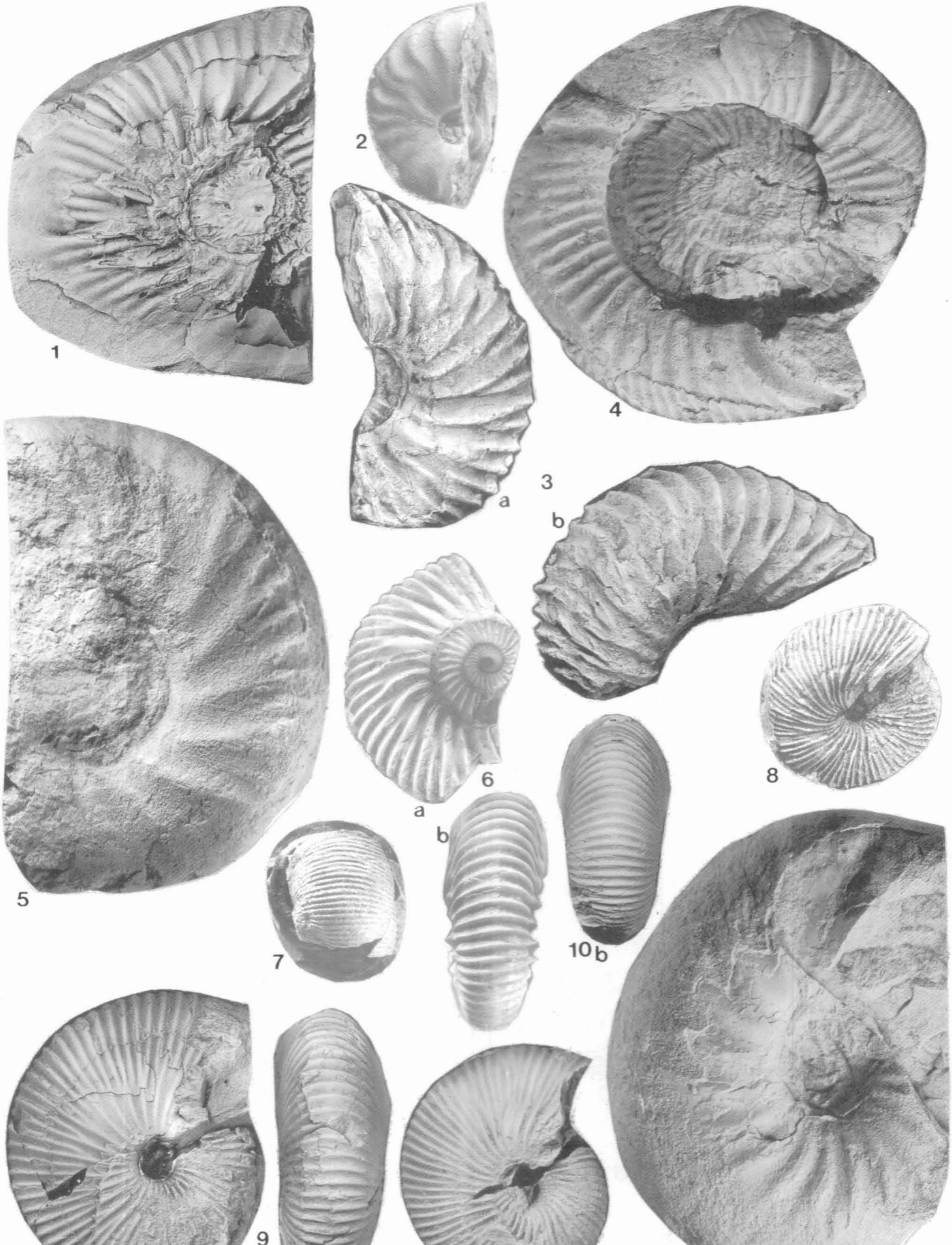
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PLATE 76

EASTERN RUSSIA, CALLOVIAN

Figs. 1–3. *Longaeviceras* cf. *keyserlingi* (Sok.); from Upper Callovian; 1, North-East Russia, Yana River basin (coll. Repin); 2,3, Far East Russia, Tugur Bay (coll. Sey & Kalacheva).

Fig. 4. *Lunuloceras*(?) sp. indet.; from Callovian, North-East Russia, Koryak Upland (coll. Terekhova).

Figs. 5, 6. *Choffatia* cf. *leptonota* Spath; sense 6, fragment of body chamber; from Callovian, North-East Russia, Koryak Upland (coll. Terekhova).

Figs. 7, 8. *Zieteniceras* sp. indet.; from Callovian, North-East Russia, Koryak Upland (coll. Terekhova) (coll. Sey & Kalacheva).

Fig. 9. *Cadoceras* (*Paracadoceras*) cf. *anabarense* Bodyl., phragmocone; from Lower Callovian, North-East Russia, Korkodon River basin.

(Compiled by Repin, Sey, & Kalacheva.)

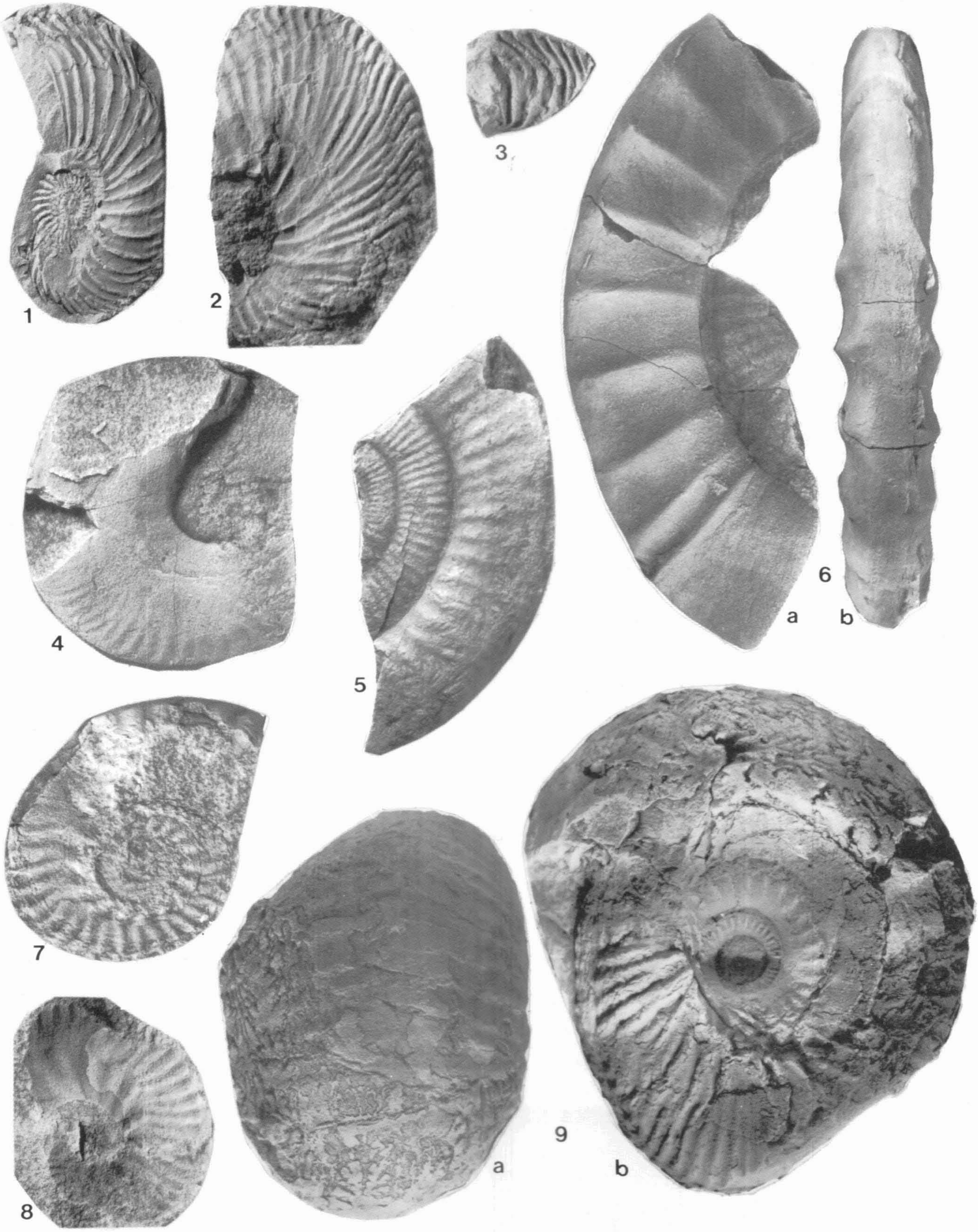
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PLATE 89

EASTERN RUSSIA, OXFORDIAN–KIMMERIDGIAN

Figs. 1, 3. *Cardioceras* (*Scarburgiceras*) *praecordatum* R. Douville; from lower Oxfordian, *Scarburgiceras* Beds, Far East Russia, Tugur Bay (coll. Sey & Kalacheva).

Fig. 2. *C.* (*Scarburgiceras*) cf. *gloriosum* Arkell; from lower Oxfordian, *Scarburgiceras* Beds, Far East Russia, Tugur Bay (coll. Sey & Kalachéva).

Fig. 4. *Cardioceras* (*Maltoniceras*) aff. *schellwieni* Boden, complete?; from Middle Oxfordian, Far East Russia, Tugur Bay (coll. Sey & Kalacheva).

Figs. 5–7. *Ochetoceras elgense* Chudoley & Kalacheva; from Upper Kimmeridgian–?Lower Tithonian, Far East Russia, Uda River basin (coll. Sey & Kalacheva).

Figs. 8–10. *Amoeboceras* (*Amoebites*) ex gr. *kitchini* (Salfeld); 9, (×2); from Lower Kimmeridgian, *A.* (*A.*) ex gr. *kitchini* Beds; 8,9, Far East Russia, Tugur Bay (coll. Sey & Kalacheva); 10, North-East Russia, Korkodon River basin.

Fig. 11. *Perisphinctes* (*Dichotomosphinctes*) cf. *mühlbachi* Hyatt, from Middle Oxfordian, Far East Russia, Tugur Bay (coll. Sey & Kalacheva).

(Compiled by Repin, Sey & Kalacheva.)

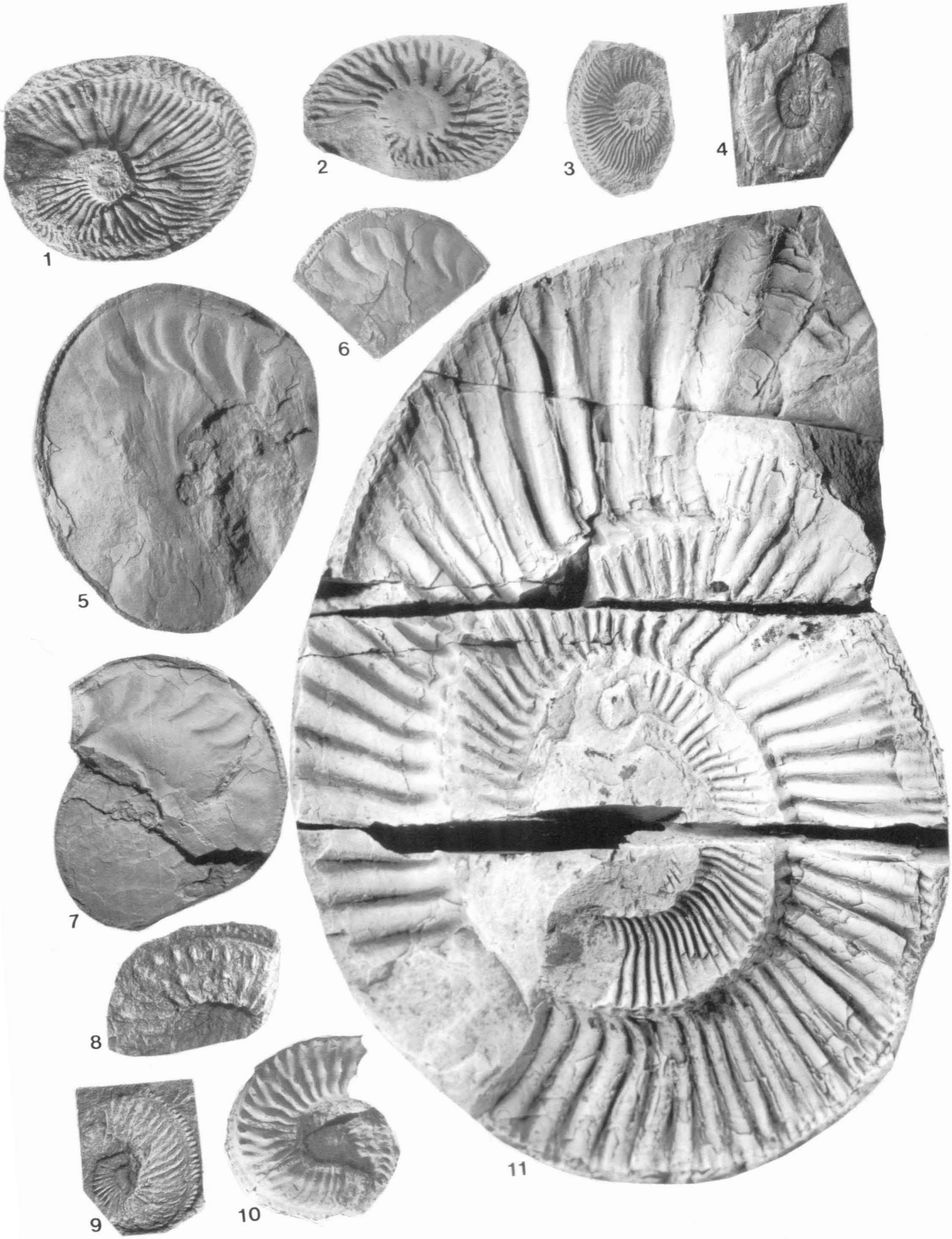
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PLATE 90

EASTERN RUSSIA, TITHONIAN

Fig. 1. *Subplanitoides* aff. *tithonicum* Zeiss, phragmocone?; from middle Tithonian, *Pseudolissoceras zitteli* Zone, Far East Russia, southern Primorye, Putiatin Island (coll. Sey & Kalacheva).

Figs. 2, 17. *Subplanitoides* ex gr. *altegyratum* Zeiss; from middle Tithonian, *P. zitteli* Zone, Far East Russia, Putiatin Island (coll. Sey & Kalacheva).

Fig. 3. *Subplanitoides putiatinensis* (Chudoley); from Middle Tithonian, Far East Russia, Putiatin Island.

Fig. 4. *Haploceras* cf. *elimatum* (Oppel), complete; from middle Tithonian, *P. zitteli* Zone, Putiatin Island (coll. Sey & Kalacheva).

Figs. 5, 6, 10–12, 15. *Glochiceras jollyi* (Oppel); from *P. zitteli* Zone, Putiatin Island (coll. Sey & Kalacheva).

Figs. 7–9, 13, 14. *Pseudolissoceras* ex gr. *zitteli* (Burckhardt); from *P. zitteli* Zone, Putiatin Island (coll. Sey & Kalacheva).

Fig. 16. *Virgatosphinctes* cf. *mexicanus* (Burckh.), phragmocone [= *Subplanites* (*Parapallasiceras*) *contiguus* (Zittel)]; from Lower Tithonian, Far East Russian, southern Primorye.

Figs. 18, 19. *Subplanitoides*(?) sp.; from *P. zitteli* Zone, Putiatin Island (coll. Sey & Kalacheva).

Fig. 20. *Sublithacoceras*(?) sp.; from *Aulacosphinctes proximus* Zone, Putiatin Island (coll. Sey & Kalacheva).

(Compiled by Repin, Sey, & Kalacheva.)

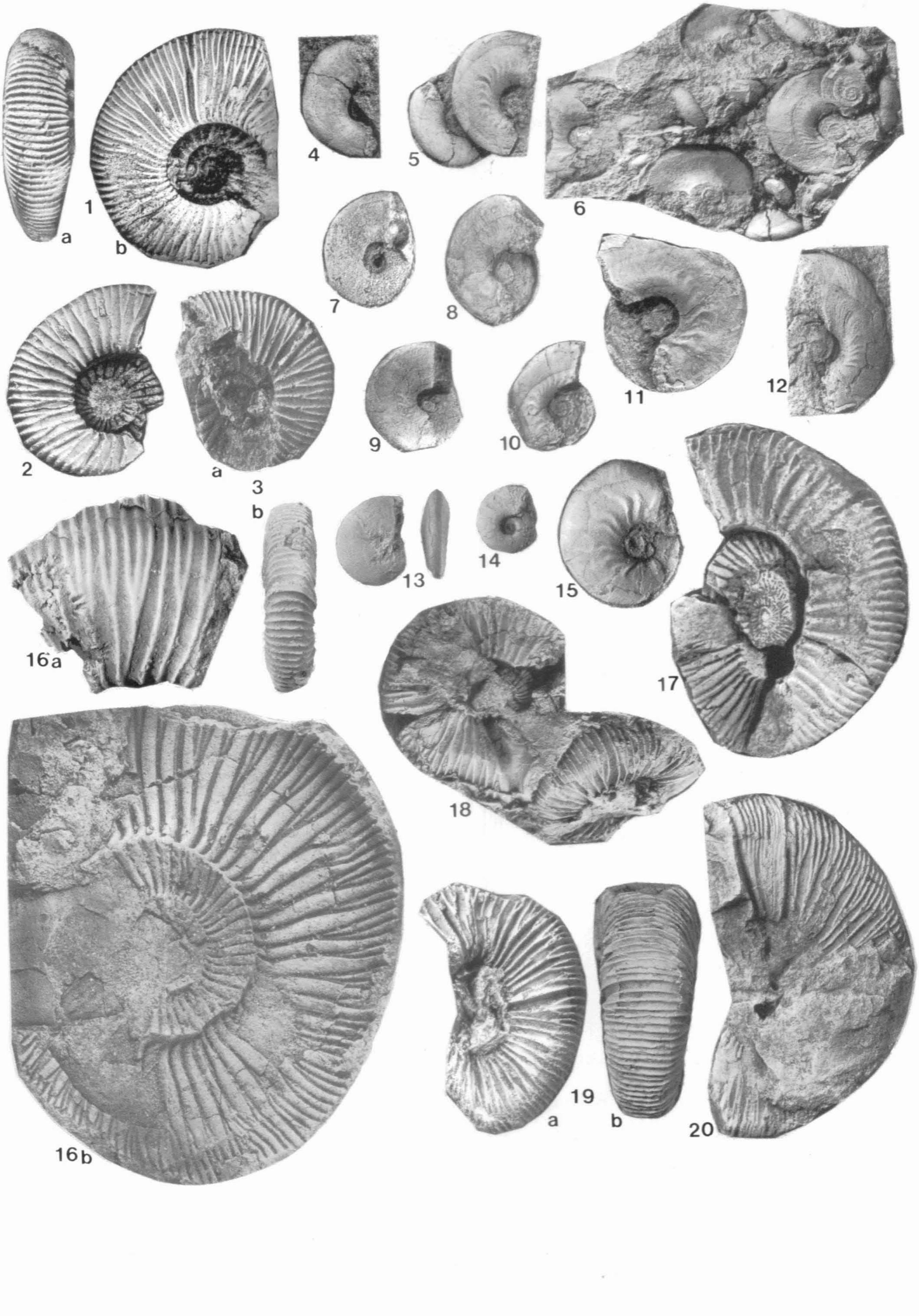
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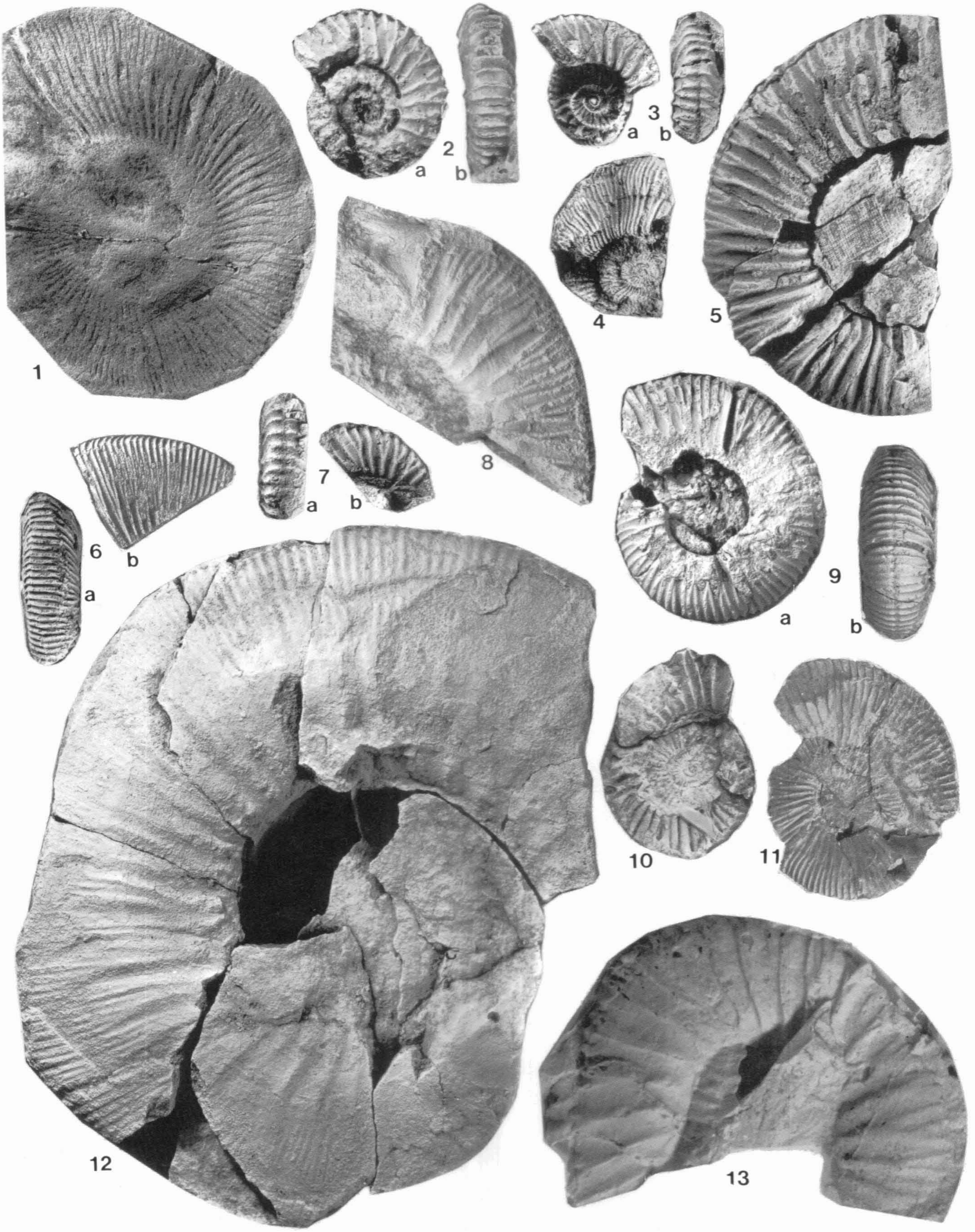
PLATE 91

EASTERN RUSSIA, TITHONIAN/VOLGIAN

Fig. 1. *Lemencia* aff. *adeps* (Schneid); from middle Tithonian, *Aulacosphinctes proximus* Zone, Far East Russia, southern Primorye, Putiatin Island (coll. Sey & Kalacheva).
Fig. 2, 3, 7. *Aulacosphinctes proximus* (Steuer); from *A. proximus* Zone, Putiatin Island (coll. Sey & Kalacheva).
Fig. 4. *Lemencia* sp.; from *A. proximus* Zone, Putiatin Island (coll. Sey & Kalacheva).
Fig. 5. *Subplanitoides* ex gr. *subpraecox* (Donze & Enay); from *Pseudolissoceras zitteli* Zone, Putiatin Island (coll. Sey & Kalacheva).
Fig. 6. *Sublithacoceras* sp. juv.; from *A. proximus* Zone, Putiatin Island (coll. Sey & Kalacheva).
Fig. 8. *Parapallasiceras* sp., fragment of body chamber; from *P. zitteli* Zone, Putiatin Island (coll. Sey & Kalacheva).
Fig. 9. *Subplanitoides* sp., phragmocone; from *A. proximus* Zone, Putiatin Island (coll. Sey & Kalacheva).
Fig. 10. *Durangites* sp. indet.; from Middle Volgian, Far East Russia, Uda River basin.
Fig. 11. *Chetaites*(?) sp. indet.; from Upper Volgian, North-East Russia, Bolshoi Anyui River basin.
Fig. 12. *Sublithacoceras* cf. *penicillatum* (Schneid), complete?; from middle Tithonian, *A. proximus* Zone, Far East Russia, Putiatin Island (coll. Sey & Kalacheva).
Fig. 13. *Dorsoplanites* cf. *transitorius* Spath, phragmocone; from Middle Volgian, North-East Russia, Bolshoi Anyui River basin (coll. Paraketzov).
(Compiled by Repin, Sey, & Kalacheva.)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