

The Bivalve *Buchia* and the Jurassic–Cretaceous Boundary in the Boreal Province

V. A. Zakharov

Institute of Geology and Geophysics, Academy of Sciences of the U.S.S.R., Novosibirsk, 630090, U.S.S.R.

Received 9 July 1986 and in revised form 13 November 1986

V. A. Zakharov. The Bivalve *Buchia* and the Jurassic–Cretaceous Boundary in the Boreal province. *Cretaceous Research* (1987) **8**, 141–153. Eight successive *Buchia* zones (buchiazones) are recorded in the stratigraphic interval from the base of the Middle Volgian substage (Late Jurassic), up to the base of the Early Valanginian (Early Cretaceous). These zones, reading from the base upwards include: *mosquensis*, *russiensis*, *taimyrensis*, *obliqua*, *unschensis*, *okensis*, *jasikovi* and *tolmatschowi*. The lower boundary of each of these zones was examined to choose one of them as the most suitable for recognising the Jurassic–Cretaceous boundary. Preference was given to the base of the *okensis* zone, because it corresponds to the base of the ammonite zone of *Hectoroceras kochi*, and it is situated near the boundary between the Volgian and the boreal Berriasian stages. *B. okensis* is very easily recognised in field sections, and also is good for boreal-tethyan correlation. The base of the *inflata* zone and of its North Pacific chronostratigraphic analogue, the *pacifica* zone, is also ideal for correlation, but is too young and corresponds to the base of the Valanginian stage. The bases of other buchiazones are assessed and found unsatisfactory.

Institute of Geology and Geophysics, Academy of Sciences of the U.S.S.R., Novosibirsk, 630090, U.S.S.R.

KEY WORDS: Bivalve; *Buchia*; Jurassic–Cretaceous boundary; Volgian; Boreal Berriasian; Valanginian.

1. Introduction

Bivalves of the family Buchiidae Cox, 1953, are widely distributed from the Late Triassic to the Early Cretaceous (Early Neocomian) marine environments on most continents of the Earth (Zakharov, 1981). The genus *Buchia* Rouillier, 1845, is known from Late Oxfordian (Late Jurassic) to Hauterivian (Early Cretaceous) strata, and is restricted to the northern hemisphere. Over thirty species are recognised (Zakharov, 1981). Closely related, but different, genera occur in the southern hemisphere. Today fossil *Buchia* is particularly abundant north of latitude 50°N at all stratigraphic levels in the Late Jurassic and Early Cretaceous, and is sometimes still abundant at 40°N (Zakharov, 1981, figure 89). The origin, growth and evolution of the genus took place in the circumboreal realm, where species of *Buchia* are biogeographically distributed. Some differences in the assemblages are observed for palaeoseas with different regimes e.g. shallow epicontinental platform and deeper basinal areas.

Buchia is characterised by a high rate of evolution. This can be recognised through four main ontogenetic trends which are related to time. These trends

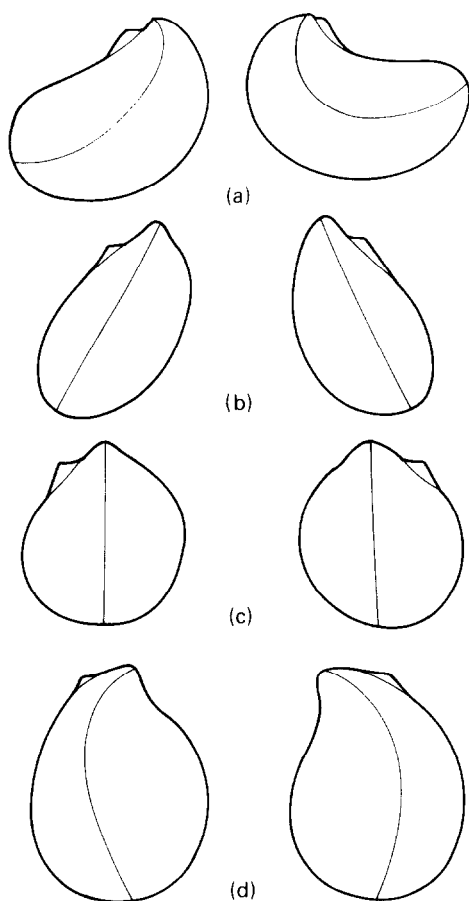


Figure 1. Ontogenetic types of the genus *Buchia*: (a)—curvoid; (b)—obliquoid; (c)—orthoid; (d)—inversoid.

are curvoid, obliquoid, orthoid and inversoid and are the plots of the successive positions of the point of highest curvature on the distal point of the commissure. These are illustrated in Figure 1.

The biostratigraphic value of *Buchia* is based on the high rate of evolution, the wide geographic distribution of most species, the limited influence of local facies, the abundance in different types of facies and the ease of taxonomic determination. Thus a zonal scheme is established that is independent of other biozonal schemes for the boreal Late Jurassic and Early Cretaceous. Buchiazones have been established both in North America and northern Eurasia. In the U.S.S.R., *Buchia* has had important stratigraphic significance since publication of the monographic studies of Pavlov (1907) and D. Sokolov (1908; 1910; 1912; 1913; 1916; 1928), works largely on the Far Eastern U.S.S.R. by Bodylevsky (1928a; 1928b; 1937; 1943; 1963) and latterly by Paraketsov (1965; 1968; 1972; Paraketsov & Paraketsova, 1973), in Siberia by Bodylevsky and Shulgina (1958) and the Russian Platform by Gerasimov (1955; 1969). However regional autonomous zonal sequences

were only established in the late seventies (Zakharov, 1977; 1978; 1979; 1981; Konovalov, 1977; Paraketsov 1980). The *Buchia* zonal scheme for northern Siberia has proved to be satisfactory for use in North and East Greenland (Håkansson, Birkelund, Piasecki and Zakharov, 1981; Surlyk and Zakharov 1982) and for northern Norway (Zakharov, Surlyk and Dalland, 1981). The *Buchia* sequence allows correlation beyond strictly boreal limits into the subtethyan realm (Zakharov and Bogomolov, 1984). During the last 27 years various zonal schemes based on *Buchia* have been proposed for California, Oregon and northern Alaska (Imlay, 1959; 1961), and for British Columbia and boreal parts of Canada and Greenland (Jeletzky; 1960; 1965; 1966; 1973). Jeletzky (1965) proposed a zonal scheme for California and Oregon. Its reliability was confirmed by Jones, Bailey and Imlay (1969) and Imlay and Jones (1970).

The sequence of buchiazones is based mainly on the evolution of a single taxonomic lineage. In the late Middle and early Late Jurassic there existed the genus *Praebuchia*, which gave rise to *Buchia* in the Late Oxfordian. This means that at any one time there existed only a single biological species. Schindewolf (1970) considered that such stratigraphic schemes based on successive changes of monotaxonomic zones of a mutational nature are the most reliable base for biochronology. The present author believes that both the first appearance of each *Buchia* species in sections and the beginning of its abundance to be practically isochronous throughout the boreal and subtethyan realms. As the lineage spans the Jurassic-Cretaceous boundary, then there must be a point in the sequence which can be recognised as the boundary between these two Periods, and the aim of this article is to recognise that boundary.

2. The buchiazones of the Jurassic-Cretaceous boundary

Some geographical distributions of *Buchia* species discussed below are given in Figures 2, 3 and 4. The palinspastic basis of these maps is the Hauterivian, Early Cretaceous map of 120 my of Smith, Hurley and Briden (1981).

2.1 Base of the *Russiensis* Buchiazone

The lower boundary of the *russiensis* buchiazone is defined by the appearance of the index species, and the disappearance of *B. rugosa* (Table 1). The zone is situated at the base of the *Virgatites virgatus* ammonite zone on the Russian Platform, and the *Dorsoplanites maximus* zone in northern Siberia (Table 2). In this zone buchias with an obliquoid ontogenetic growth curve in the right valve appear for the first time. Below this buchiazone only the curvoid ontogenetic type occurs in both left and right valves (Zakharov, 1981, p. 89, pls 13-17).

B. russiensis appears to be facies controlled. In sections in the central epicontinental basins in Central and West Siberia, where deep water conditions are recognised, the species is rare and dominated by *B. mosquensis*. In the orogenic belt areas of the Pacific region where *B. russiensis* occurs, it is numerically subordinate to *B. piochii*. Thus there is some doubt as to how

Table 1. *Buchia* zonation of the Jurassic-Cretaceous boundary stages of the boreal and subtethyan realms.

Age			E ENGLAND (Kelly 1984 & IGC Report)	E GREENLAND (Surlyk & Zakharov 1982)	SVALBARD (Yershova 1983 modified)	PECHORA RIVER (Mesezhnikov et al. 1979)	VOLGA RIVER REGION (Zakharov 1985)
EARLY CRETACEOUS	Valang.	Early	? volgensis	keyserlingi	keyserlingi	keyserlingi	keyserlingi
				inflata	? inflata	inflata	? inflata
	Berriasian			volgensis	volgensis	? cf. tolmatschowi	volgensis
				?	? okensis	uncitoides	? okensis
LATE JURASSIC	Volgian	Late	Buchia absent ?	unschensis ?	unschensis	unschensis	unschensis ?
			terebratuloides	terebratuloides	obliqua	terebratuloides fischeriana	
			fischeriana	fischeriana	russiensis		
	Middle		russiensis			russiensis ?	
			mosquensis	mosquensis	mosquensis	mosquensis	mosquensis

synchronous the appearance of *B. russiensis* is. The appearance of the species is clearly unsatisfactory for a period boundary.

2.2. Base of the Taimyrensis Buchiazone

The base of the *taimyrensis* buchiazone is defined by the first appearance of the index species. It is distinguished from its immediate ancestor *B. russiensis* by its wide, oval, smooth to sometimes folded sculpture of the shell (Zakharov, 1981, p. 95, p. 18). Shortly above the first appearance of *B. taimyrensis*, the abundance of *B. mosquensis* individuals decreases sharply (Table 1). The base of the *Taimyrensis* buchiazone coincides with the base of the local zone of *Taimyrosphinctes excentricus* (Table 2). Although the phylogenetic sequence from the previous buchiazone is satisfactory, it cannot be recommended as a period boundary because the index species is very rare outside the limits of North Siberia. In most parts of the boreal realm *B. russiensis* continues into this buchiazone (Table 2).

2.3 Base of the Obliqua-Terebratuloides Buchiazone

B. obliqua and *B. terebratuloides* appear together at the base of the buchiazone along with a marked increase in the abundance of *B. fischeriana* (Table 1). At this point there is the first appearance of *Buchia* having inversoid ontogeny in both valves (Zakharov, 1981, Figure 24; p. 98, pl. 20; p. 105, pls 23–25). Both *B. obliqua* and *B. terebratuloides* are derived ancestrally from *B. russiensis*.

(SUBPOLAR URAL) (Zakharov 1981)	NORTHERN SIBERIA (Zakharov 1977)	NE ASIA (Paraksetsov 1980 modified)	NORTHERN CANADA	WESTERN BR. COLUMBIA	NORTHERN CALIFORNIA (Imlay Jones 1970)
			(Jeletzky 1965-1973 modified)		
keyserlingi	keyserlingi	?	keyserlingi	?	keyserlingi
inflata	inflata	inflata	?	pacifica	pacifica
tolmatschowi	tolmatschowi	volgensis ? okensis	aff. volgensis	tolmatschowi	uncitoides
jasikovi	jasikovi		uncitoides	uncitoides	
?	okensis		okensis	okensis	aff. okensis
Buchia absent	unschensis	? unschensis ?	terebratuloides	terebratuloides	?
	obliqua		unschensis ?	aff. okensis	
?		fischeriana ?	fischeriana	?	fischeriana
taimyrensis ? mosquensis	taimyrensis	piochii	piochii	cf. blanfordiana	piochii
	russiensis			russiensis	
	mosquensis				

Individual specimens of this group are easily named, but the species group as a whole is not. *B. obliqua* is unknown on the Russian Platform and in the Pacific Region. In these regions it is replaced by *B. terebratuloides* whose distribution is shown in Figure 2. *B. terebratuloides* first appears rarely in the latest part of Middle Volgian Substage (Gerasimov, 1955). In some localities, like in the Pechora River Basin, in the base of the *obliqua* buchiazone, *B. russiensis* is particularly abundant and replaces the index species. The question concerning the coincidence of the *terebratuloides-obliqua* buchiazones with the Middle/Late Volgian substage boundary needs revision. The boundary may be non-synchronous with regard to buchiazones in different regions and therefore it is not suitable as a boundary between the Jurassic and Cretaceous Periods.

2.4. Base of the Unschensis Buchiazone

The base of the *unschensis* buchiazone is defined on the first appearance of the index species in abundance. This level is somewhat above the first appearance of the species itself (Table 1). The species is probably derived from *B. terebratuloides* (Zakharov, 1981, p. 109, pls 25-30). The valves of *B. terebratuloides* are distinguished by contrasting ontogenetic types: the left is orthoid and the right inversoid. Although there is a clear phylogenetic continuation from below, the boundary is difficult to establish. Single specimens of the species can only be identified if well preserved. The species

Table 2. Biozones and epiboles (thick lines) of the *Buchia* species of the north of the U.S.S.R.

JURASSIC			CRETACEOUS					Period		
Volgian			Boreal Berriasian			Valanginian	Stage			
Middle	Upper						Substage			
<i>rugosa</i> <i>mosquensis</i>	<i>russiensis</i>	<i>taimyrensis</i>	<i>obliqua</i>	<i>unschensis</i>	<i>okensis</i>	<i>jasikovi</i>	<i>tolmatschowi</i>	<i>inflata</i>	<i>keyserlingi</i>	<i>Buchia</i> zonation
<i>Buchia mosquensis</i>										
<i>B. rugosa</i>										
<i>B. russiensis</i>										
<i>B. taimyrensis</i>										
<i>B. fischeriana</i>										
<i>B. obliqua</i>										
<i>B. terebratuloides</i>										
<i>B. unshensis</i>										
<i>B. okensis</i>										
<i>B. jasikovi</i>										
<i>B. volgensis</i>										
<i>B. tolmatshowi</i>										
<i>B. inflata</i>										
<i>B. aff. inflata</i>										
<i>B. keyserlingi</i>										

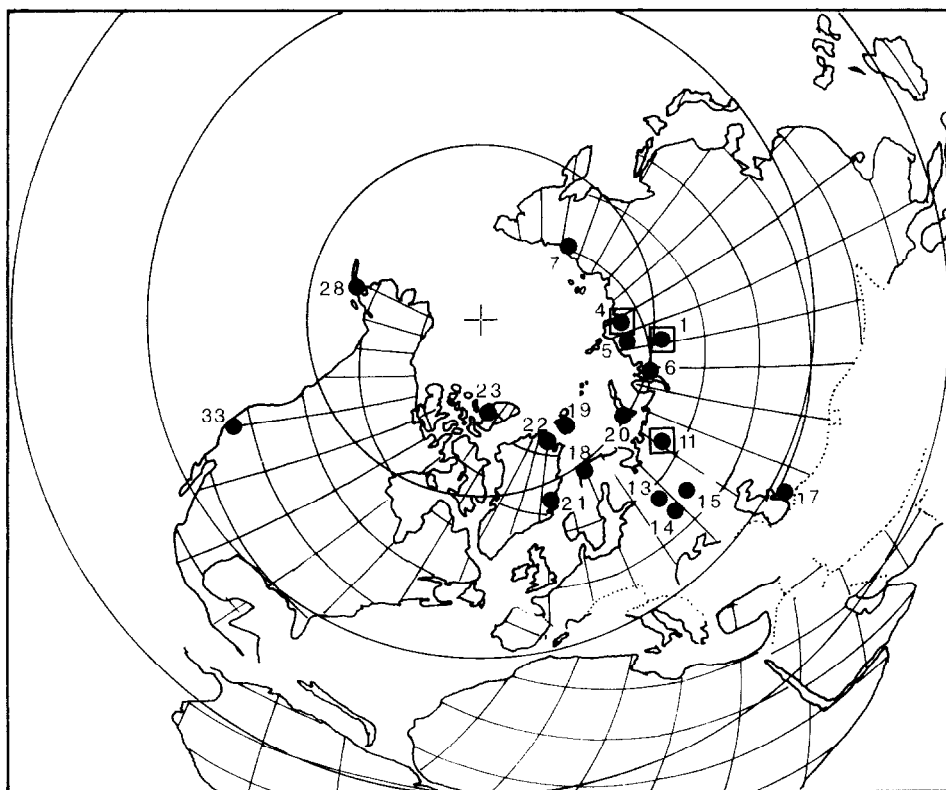


Figure 2. Distribution of *Buchia terebratuloides* (circles) and *B. jaskovi* (squares). North of Siberia: 1—Kheta River basin, 2—Popigay River basin, 3—Anabar River basin, 4—Nordvik Peninsula, 5—Central Taimyr, 6—mouth of Yenisei River (boreholes), 7—Anui River basin, 8—Northern Sikhote-Alin, 9—Southern Primor'ye (Southern Sikhote-Alin); Subpolar Urals; 10—Yatria and Tolya River basins; Russian Platform: 11—Pechora River basin (Izhma River), 12—Sanin Nos Peninsula and Kolguyev Island, 13—Upper Volga River basin, 14—Oka River basin, 15—Middle Volga River basin (villages of Gorodische and Kashpir); Southern U.S.S.R.: 16—Manguyschlak Peninsula, 17—Kopet Dag Mountains; Arctic Islands: 18—Andøy, 19—Svalbard (Spitsbergen and Kong Karls Land), 20—Novaya Zemlya (Southern Island), 21—East Greenland, 22—North Greenland, 23—Ellesmere Island, 24—Axel Heiberg Island; Arctic Canada and U.S.A.: 25—Richardson Mountains, 26—Brook Range, 27—Yukon River Basin, 28—Alaska Peninsula and Aleutian Islands, 29—Southern Alaska, 30—British Columbia (Harrison Lake), 31—Vancouver Island, 32—Oregon, 33—Northern California.

is rare in the Pacific region, where at the same stratigraphic level the narrow, tall and bent *B. piochii* predominates (Table 2; Imlay & Jones, 1970). Thus the base of this buchiazone can be traced only by the correlation with regional buchiazones through the boreal and subtethyan provinces. The base may therefore not be synchronous and must be rejected as a possible period boundary.

2.5. Base of the Okensis *Buchia*zone

The lower boundary of the *B. okensis* buchiazone is defined by the appearance of the index species, whose ancestor may be *B. fischeriana*. At the same level, or may be somewhere close to it, *B. volgensis* also appears (Table 1). *B. okensis* is an unmistakable species, distinguished by its large, broad,

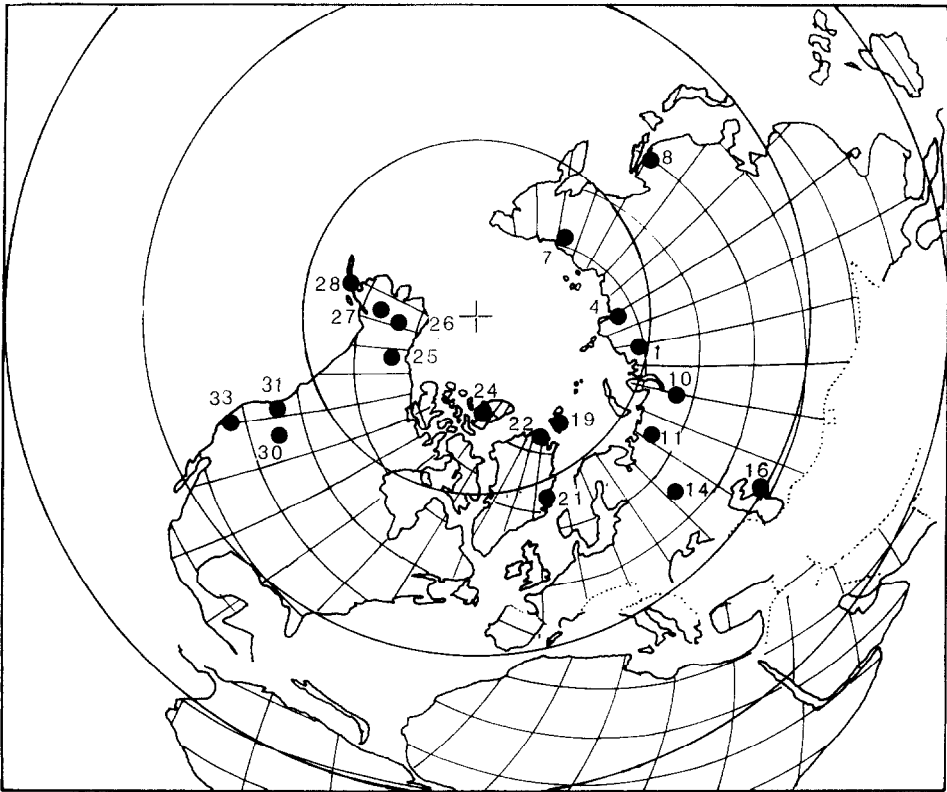


Figure 3. Distribution of *Buchia okensis*. Explanation as for Figure 2.

oval shell covered by spaced out coarse ribs (Zakharov, 1981, p. 116, pls 31–35). The right valve is characterised by inversoid ontogeny, the left by curvoid (Zakharov, 1981, Figure 22). The base of the buchiazone is therefore particularly clear, and has been recognised from all the regions of the boreal realm and from several of the subtethyan, allowing direct boreal-tethyan correlation (Figure 3; Table 2). The base of the *okensis* buchiazone is very near to the base of the ammonite zone of *Hectoroceras kochi*, which is widespread in the boreal region.

Thus the base of the *okensis* buchiazone meets many requirements of a good stratigraphic indicator; it has reliable phylogenetic control, is easily determined in sections, has good correlation possibilities both for intraboreal and boreal-tethyan sequences. It is also important to indicate that the base of the *okensis* buchiazone is situated close to the traditional boundary between the Jurassic and Cretaceous Periods at the base of the *kochi* zone (subzone) in the boreal region, and possibly the *occitanica* zone of Tethys. Because of these factors the base of the *okensis* buchiazone is the most suitable horizon at which to draw the base of the Cretaceous period.

2.6. Base of the Jasikovi (–Uncitoides) Buchiazone

The base of the buchiazone is defined by the abundance of the index species and in the sharp reduction of the number of *B. okensis* representatives (Table

1). Both index species are characterised by inversoidal ontogeny of both left and right valves (Figure 1) and have similar, small sized, tall, narrow, usually smooth shells (Zakharov, 1981, p. 121, pls 36–37). Less significant differences include the ratio and character of the prominence of the valves (Mesezhnikov *et al.*, 1979, pl. 3, Figure 4). The phylogenetic control of the base of the zone is not established as the ancestor is not known. It is also possible that in different sections the epibole of the species is at slightly different stratigraphic levels within buchiazones, its base cannot be proved synchronous (Table 2).

Thus the base of the *jasikovi* buchiazone is not reliable as it is not easily recognised and may not be synchronous.

2.7. Base of the Tolmatschowi *Buchia*zone

The base of the *tolmatschowi* buchiazone is defined by the first appearance of the index species. The species is distinguished by large tall shells with a pronounced inversoidal ontogeny in both valves (Zakharov, 1981, p. 11, pl. 41–743; text-figure 13). The species is believed to be derived from *B. volgensis* which becomes abundant near the base of the buchiazone (Zakharov, 1981, p. 125, pl. 37–40) (Table 1). Typical representatives of *B. tolmatshowi* are easily recognised even in single specimens, thus there is good phylogenetic control, and the base of the buchiazone is easily recognised. However there are correlation problems because the index species has not been recognised in Greenland, Spitsbergen, central Russian Platform (Volga River), eastern U.S.S.R., Arctic Canada and north California. Only the *B. volgensis* biozone, which covers most of the Berriasian is found in many of those regions. Even where it does occur in British Columbia, northern Siberia, Polar Urals and the Pechora River basin, at several horizons including at the base of the buchiazone, *B. tolmatshowi* is numerically subordinate or rare in comparison to *B. volgensis*.

The stated problems therefore make this buchiazone unsatisfactory for the base of the Cretaceous Period.

2.8. Base of the Inflata *Buchia*zone

The lower boundary of the base of the *inflata* buchiazone is defined by the first appearance of the index species relative to *B. aff. inflata* and the first rare *B. keyserlingi* (Table 1). The index species is recognised easily in most well preserved single specimens by the moderate size and the usually bulbous valves characterised by inversoidal ontogeny (Zakharov, 1981, p. 135, pls 43–47; text-figure 14). It is possible that *B. inflata* is descended from *B. volgensis*, the biozone of which overlaps with the base of the *B. inflata* biozone.

Therefore the base of the *inflata* buchiazone is easily recognised in sections, although the phylogenetic control is not clear. Correlation potential is high and this buchiazone is recognised in most boreal regions, although in the north Pacific ones it is replaced by the *pacifica* buchiazone (Figure 4; Table 2). *B. pacifica* is considered to be a variant of *B. inflata*. The fact that the *pacifica* buchiazone in British Columbia and the *inflata* biozone in North

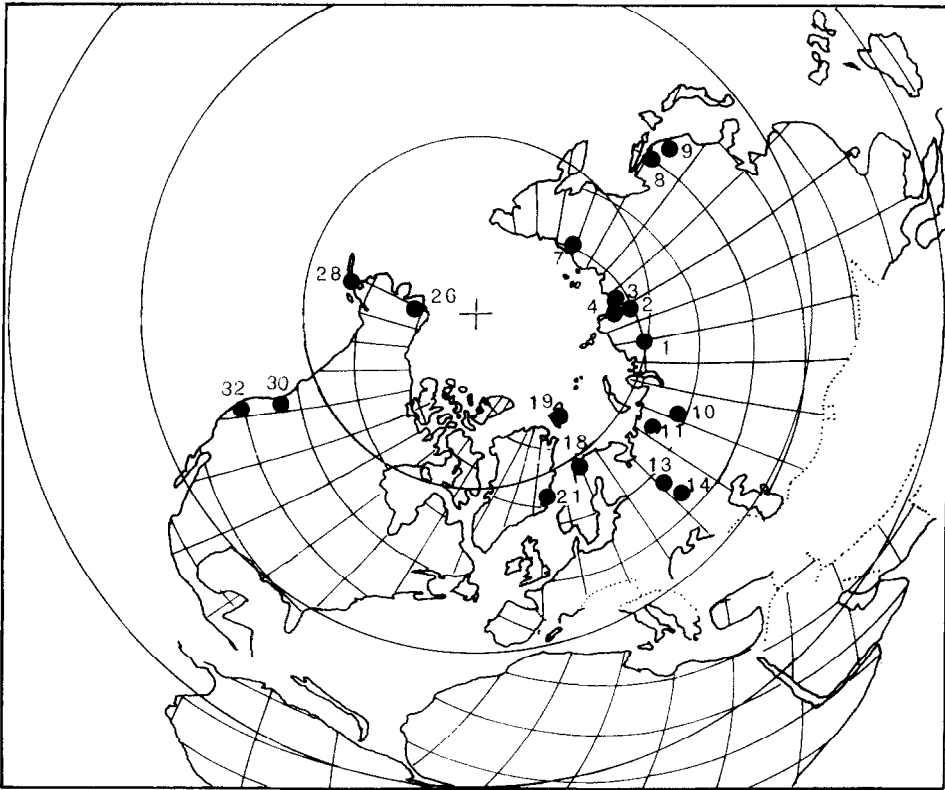


Figure 4. Distribution of *Buchia inflata*. Explanation as for Figure 2.

Siberia are both immediately above the *tolmatschowi* biozone indicates that the lower boundaries of these two buchiazones are nearly synchronous in their respective provinces. A further point is that the base of the *inflata* buchiazone is very close to or coincident with the junction of the Berriasian and Valanginian stages. It can therefore be considered as a possible contender for the Jurassic–Cretaceous boundary.

2.9. The base of the Keyserlingi Buchiazone

The lower boundary of this buchiazone is defined in sections by the abundance of the index species and a sharp reduction in numbers of *B. inflata* (Table 1).

The species is easily recognised in assemblages by its subtriangular-rounded shell, ornament of regular lamellose ribs and near inversoid ontogeny of the left valve (Zakharov, 1981, p. 141, pls 50–55; text-figure 15). *B. keyserlingi* is an exceptionally widespread species both in boreal and subtethyan regions, therefore its correlation potential is particularly high (Table 2; Zakharov, 1981, Figure 73).

The main disadvantage of this buchiazone is the absence of phyletic control because the biozone of the index species (Early Hauterivian to Early

Valanginian) ranges far beyond the limits of the buchiazone. Also it is difficult to determine the base of the buchiazone in discontinuous sections, because the epibole of *B. keyserlingi* can be asynchronously placed within the buchiazone.

3. Conclusions

As can be seen in Table 2, the boundaries of only two buchiazones coincide with the boundaries of substages. The base of the *obliqua-terebratuloides* buchiazones coincides with the junction of the Middle and Upper Volgian Substages and the base of the *inflata-pacifica* buchiazones with the junction between the Berriasian and Valanginian Stages. However when examined in detail, these boundaries do not coincide. The Volgian/boreal Berriasian boundary, between the *Chetaites chetae* and *C. sibiricus* zones, lies within the *unschensis* buchiazone (Saks, 1972).

It has been shown above that the bases of the *taimyrensis*, *unschensis*, *jasikovii* and *tolmatschovi* buchiazones are all completely unsatisfactory as indicators of the Jurassic/Cretaceous boundary. The *russiensis*, *terebratuloides* and *keyserlingi* buchiazones are more widespread and have a high correlation potential, but there is doubt over the synchronicity of their bases in different regions, therefore these are also unsuitable.

Two buchiazone base boundaries deserve most attention, namely those of *okensis* and *inflata*. The former is preferred as indicator of the base of the Cretaceous for several reasons, but mainly because the base of the *okensis* buchiazone practically coincides with the base of the *Hectoroceras kochi* zone in boreal regions, which in turn correlates closely to the base of the *occitanica* zone of Tethys near the traditional boundary between the Tithonian and Berriasian (Casey, Mesezhnikov & Shulgina 1977). Also *B. okensis* is easy to recognise in the field, and is widespread in both boreal and tethyan regions, extending into Primor'ye and north California.

Although the *inflata* buchiazone is also easily recognised, widespread in boreal regions and reaching into Tethys, it is less satisfactory. It occurs at the junction of the boreal Berriasian and the Valanginian stages. Some investigators consider the boundary between the Berriasian and the Valanginian as the most suitable as the Jurassic-Cretaceous boundary (Druschits, 1968; Druschits & Vakhrameev, 1976; Wiedmann, 1967; 1968; 1975; 1980). Because of the doubt concerning the synchronous correlation between the boreal *inflata* buchiazone and the boreal-pacific (subtethyan) *pacifica* buchiazone, this boundary can only be regarded as secondary in relation to that of the *okensis* buchiazone.

Acknowledgment

Simon Kelly (Department of Earth Sciences, University of Cambridge) is thanked for commenting on and improving the original manuscript and figures.

References

- Bodylevskiy, V. I. 1928a. Notice concerning aucellas from Taimyr in Middendorf's collection from Taimyr. *Doklady AN SSSR* **14/15**, 285–288 [In Russian].
- Bodylevskiy, V. I. 1928b. *Auciella* from the Suruktakh River Basin in the Cherskiy Range. *Izvestiya Geologicheskogo Komiteta AN SSSR* **46**, 705–710 [In Russian].
- Bodylevskiy, V. I. 1937. About some Cretaceous faunas from the Kolyma country and western Kamchatka. In *fauna and flora of the Mesozoic and Caenozoic sections of the Okhotsk-Kolyma country*. NKTR pp. 51–56 [In Russian].
- Bodylevskiy, V. I. 1943. Concerning the Lower Cretaceous fauna of the Suchan coal basin. *Doklady AN SSSR* **41**, 226–268 [In Russian].
- Bodylevskiy, V. I. 1963. Arkhangelsk, Vologda districts, Komi ASSR. 1. Geological description. In *Geology of the USSR*, 2, Jurassic and Cretaceous systems. Moscow: Gosgeoltekhizdat pp. 631–682 [In Russian].
- Bodylevskiy, V. I. & Shulgina, N. I. 1958. *Jurassic and Cretaceous faunas of the mouth of the Yenisei River*. Moscow: Gosgeoltekhizdat. 1–196 [In Russian].
- Casey, R., Mesezhnikov, M. S. & Shulgina, N. I. 1977. The correlation of the Jurassic-Cretaceous boundary beds of England, the Russian Platform, the Subpolar Ural and Siberia. *Izvestiya Akademii Nauk SSSR, Seriya Geologicheskaya* **7**, 14–13 [In Russian].
- Cox, L. R. 1953. Lower Cretaceous gastropods, lamellibranchia and annelids from Alexander Island (Falkland Islands Dependencies). *Scientific report of the British Antarctic Survey* **4**, 1–14.
- Druschits, V. V. 1968. Concerning the stratigraphical position of the Berriasian Stage. In *Memorial collection of the Geological Institute of the Bulgarian Academy of Science*. Sofia. [In Russian].
- Druschits, V. V. & Vakrameev, V. A. 1976. The boundary between the Jurassic and Cretaceous Systems. In *Boundaries of the geological system*. Moscow: Nauka, 1985–224 [In Russian].
- Gerasimov, P. A. 1955. *Index fossils of the Mesozoic of the central province of the European part of the USSR*. 1. Moscow: Gosgeoltekhizdat, 1–274 [In Russian].
- Gerasimov, P. A. 1969. *Upper substage of the Volgian stage of the central part of the Russian Platform*. Moscow: Nauka, 1–144 [In Russian].
- Håkansson, E., Birkelund, T., Piasecki, S. & Zakharov, V. A. 1981. Jurassic–Cretaceous boundary of the extreme Arctic (Peary Land, North Greenland). *Bulletin of the Geological Society of Denmark* **30**, 11–42.
- Imlay, R. W. 1959. Succession and speciation of the pelecypod *Aucella*. *Geological Survey professional paper* **314-D**, 1–14.
- Imlay, R. W. 1961. Characteristic Lower Cretaceous megafossils from northern Alaska. *Geological Survey professional paper* **335**, 1–76.
- Imlay, R. W. & Jones, D. L. 1970. Ammonites from the *Buchia* Zones in northwestern Oregon. *Geological Survey professional paper* **647-B**, 1–59.
- Jeletzky, J. A. 1960. Uppermost Jurassic and Cretaceous rocks, east flank of Richardson Mountains between Stoney Creek and Lower Donna River Northwest Territories. *Geological Survey of Canada, Paper* **59-14**, 1–31.
- Jeletzky, J. A. 1965. Late Upper Jurassic and early Lower Cretaceous fossil zones of the Canadian Western Cordillera. *Bulletin Geological Survey Canada* **103**, 1–70.
- Jeletzky, J. A. 1966. Upper Volgian (Latest Jurassic) ammonites and buchias of Arctic Canada. *Bulletin Geological Survey Canada* **128**, 1–72.
- Jeletzky, J. A. 1973. Biochronology of the marine boreal latest Jurassic, Berriasian and Valanginian in Canada. In *The Boreal Lower Cretaceous* (Eds. Casey, R. C. & Rawson, P. F.) *Geological Journal, Special Issue* **5**, 41–80.
- Jones, D. L., Bailey, E. H. & Imlay, R. W. 1969. Jurassic (Tithonian) and Cretaceous *Buchia* zones in northwestern California and southwestern Oregon. *Geological Survey professional paper* **647-A**, 1–24.
- Kelly, S. R. A. 1984. Bivalvia of the Spilsby Sandstone and Sandringham Sands (Late Jurassic–Early Cretaceous of Eastern England). Part 1. *Monograph Palaeontographical Society* 1–94.
- Konovalov, V. P. 1977. The genus *Buchia* in the Pacific realm. In *Evolution of the Pacific biota*. Vladivostok, 139–154 [In Russian].
- Mesezhnikov, M. S., Golbert, A. V., Zakharov, V. A., Klimova, I. G., Kravets, V. S., Saks, V. N., Shulgina, N. I., Alekseev, S. N., Bul'nikova, S. P., Kuzina, V. I. & Yakovleva, S. P. 1979. New data on the stratigraphy of the Jurassic–Cretaceous boundary strata in the Pechora River Basin. In *Upper Jurassic and its Boundary with the Cretaceous System* (Ed. Saks, V. N.) Novosibirsk: Nauka, 66–71 [In Russian].
- Paraketsov, K. V. 1965. Description of the genus *Aucella*. In *Field atlas of the Cretaceous Fauna of Northeastern USSR*. Magadan, 15–25 [In Russian].
- Paraketsov, K. V. 1968. Family Aucellidae Fischer. In *Field atlas of the Jurassic Fauna and Flora of Northeastern USSR*. (Ed. Bodylevskiy, V. I.) Magadan, 50–59 [In Russian].

- Paraketsov, K. V. 1972. Volgian stage at the northeast of the Kolyma River. In *Materials on Geology and Minerals of the Northeast of the USSR*. Magadan: SVKNII Akademiya Nauk SSSR, 131–136 [In Russian].
- Paraketsov, K. V. 1980. The problem of zonation of the Upper Jurassic and Lower Cretaceous of the northeast USSR by buchias. In *Biostratigraphy and correlation of the deposits of the northeastern USSR*. Magadan, pp. 91–114 [In Russian].
- Paraketsov, K. V. & Paraketsova, G. I. 1973. Lower Cretaceous sections of the Yeropol River Basin. *Doklady Akademiya Nauk SSSR* **209**, 665–667 [In Russian].
- Pavlov, A. P. 1907. Enchainement des aucelles et aucellines du Crétacé Russe. *Nouvelles Mémoires de la Société impériale des Naturalistes de Moscou* **17**, 1–93.
- Rouillier, C. 1845. [Untitled article in which *Buchia* is proposed for *Avicula mosquensis*]. *Bulletin de la Société Impériale des Naturalistes de Moscou* **18**, 289.
- Saks, V. N. 1972. *The Jurassic-Cretaceous boundary and the Berriasian stage in the boreal realm*. Novosibirsk, Nauka, 1–371. [In Russian; English translation: 1975. Jerusalem: Israel Program for Scientific Translations, 1–391].
- Schindewolf, O. 1970. *Stratigraphie und stratotypus*. Mainz: Akademie der Wissenschaften und der Literatur, 1–134.
- Smith, A. G., Hurlley, A. M. & Briden, J. C. 1981. *Phanerozoic paleocontinental world maps*. Cambridge: Cambridge University Press. 1–102.
- Sokolov, D. N. 1908. Ueber Aucellen aus dem Norden und Osten von Sibirien. *Mémoires de la Société impériale des Sciences Naturelles de St. Petersbourg* **21**, 1–18.
- Sokolov, D. N. 1910. *Mesozoic fossils from Preobrazheniya and Begichev islands*. *St. Petersburg*, 41–54 [In Russian].
- Sokolov, D. N. 1912. Über Akad. Fr. Schmidt's Fossiliensammlungen aus den Amurlande. *Trudy geologicheskogo Muzeya Petra Velikago. Imperatorskoi Akademiya Nauk* **6**, 153–166.
- Sokolov, D. N. 1913. Petrifications from boulders from Novaya Zemlya. *Trudy geologicheskogo Muzeya Petra Velikago* **7**, 59–92.
- Sokolov, D. N. 1916. Collection of fossils from Preobrazheniya and Begichev islands. *Trudy geologicheskogo Muzeya Rossiskoi Akademiya Nauk* **8**, 15–62 [In Russian].
- Sokolov, D. N. 1928. Mesozoic fossils from Bolshezemeliskaya tundra and Kashpir. *Trudy geologicheskogo Muzeya, Leningrad* **3**, 15–62 [In Russian].
- Surlyk, F. & Zakharov, V. A. 1982. Buchiid bivalves from the Upper Jurassic and Lower Cretaceous of East Greenland. *Palaeontology* **25**, 727–753.
- Wiedmann, J. 1967. Die Jura-Kreide-Grenze und Fragen stratigraphischer Nomenklatur. *Neues Jahrbuch für Geologie und Paläontologie. Monatshefte* **1967**, 736–746.
- Wiedmann, J. 1968. Das problem stratigraphischer Grenzziehung und die Jura Kreide-Grenze. *Eclogae Geologicae Helveticae* **1**, 321–336.
- Wiedmann, J. 1975. The Jurassic-Cretaceous boundary as one of the Mesozoic system boundaries. In *Colloque sur la limite Jurassique-Crétacé. Mémoires de recherches géologiques et minières* **86**, 358–362.
- Wiedmann, J. 1980. El limite Jurassico-Cretacico: problema y soluciones. In *Actas II Congreso Argentino Paleontologia y biostratigraphia. I Congreso Latinoamericano Paleontologia, Buenos Aires* **5**, 103–120.
- Yershova, E. S. 1983. *Explanatory note to Jurassic and Lower Cretaceous stratigraphical chart of the Spitsbergen Archipelago*. Leningrad: PGO "SEVMORGEO", 1–88 [In Russian].
- Zakharov, V. A. 1977. The experiment of zonation for the Upper Jurassic and Lower Cretaceous Boreal deposits by buchias. In *International colloquium on the Upper Jurassic and Jurassic-Cretaceous boundary. Abstracts of the Papers*. (Ed. Saks, V. N.) Novosibirsk: Institute of Geology & Geophysics, Sibirskoye Otdelenie Akademiya Nauk SSSR, 48–49 [In Russian; English translation p. 133].
- Zakharov, V. A. 1978. Buchiazones in the stratotypes region. In *New data on stratigraphy and fauna of the Jurassic and Cretaceous of Siberia*. Novosibirsk: Institute of Geology and Geophysics, 97–128 [In Russian].
- Zakharov, V. A. 1979. Zonal division of the Boreal Upper Jurassic and Neocomian deposits by buchias. In *The Upper Jurassic and its boundary with the Cretaceous system*. (Ed. Saks, V. N.) Novosibirsk: Nauka, 122–130 [In Russian].
- Zakharov, V. A. 1981. *Buchiidae and biostratigraphy of the Boreal Upper Jurassic and Neocomian*. *Trudy Institut Geologii Geofiziki*, **458**, 1–270 [In Russian].
- Zakharov, V. A. & Bogomolov, J. I. 1984. The correlation of the Boreal and Subtethyan Valanginian on buchias and ammonites. In *Boundary stages of Jurassic and Cretaceous Systems*. Moscow: Nauka, 18–27 [In Russian].
- Zakharov, V. A., Surlyk, F. & Dalland, A. 1981. Upper Jurassic-Lower Cretaceous *Buchia* from Andøy, northern Norway. *Norsk Geologisk Tidsskrift* **66**, 261–269.