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## Lower Berriasian of Southern Primorye (Far East Russia) and the problem of Boreal–Tethyan correlation

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## Abstract

Jurassic/Cretaceous boundary deposits in the Far East of Russia are characterized by fauna of a mixed type, including Tethyan ammonites and Boreal species of *Buchia*. In the north of the region (Western Okhotsk area), the middle Volgian deposits comprise the upper Tithonian *Durangites*. In Southern Primorye, the lower Berriasiyan ammonites *Pseudosubplanites* cf. *grandis*, *P. aff. combesi*, *Berriasella* ex gr. *jacobi*, *Dalmasiceras* etc. occur on the Ussuri Bay coast, together with upper Volgian *Buchia* species. Hence, the notion of non-correspondence between the Tithonian and Volgian is confirmed, as well as that a part of the Volgian belongs to the Cretaceous. A description of the lower Berriasiyan ammonites and the upper Volgian *Buchia* is given, including one new ammonite species: *Dalmasiceras orientale* sp. nov. © 1999 Elsevier Science B.V. All rights reserved.

**Keywords:** Russia; Far East; Volgian; Tithonian; Berriasiyan; biostratigraphy; ammonites; buchias; correlation; Boreal; Tethyan

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## 1. Introduction

The problem of the Jurassic–Cretaceous boundary is of paramount importance in Mesozoic stratigraphy and has been discussed for a long time. In 1973 at Lyon–Neuchâtel, the boundary between the Jurassic and Cretaceous was placed beneath the Berriasiyan at the base of the *Jacobi/Grandis* Zone. However, determination of the boundary in the Mediterranean region has not solved the entire problem. Sharp differentiation of marine faunas in the Late Jurassic and Early Cretaceous stimulated distinguishing different stages: the Tithonian and Berriasiyan in the Tethyan

Realm, and the Volgian, Portlandian and Ryazanian stages in the Boreal and Subboreal realms. Thus, the problem of the Boreal–Tethyan correlation and the level of the Jurassic–Cretaceous boundary in the Boreal Realm assumes particular prominence. The Volgian stage for a long time has been considered to correspond to the Tithonian. Beginning in the sixties, a number of researchers (Casey, 1973; Barthel, 1975; Kutek and Zeiss, 1974, 1988; Sasonova and Sasonov, 1983) suggested that the Tithonian and Volgian stages are inadequate in their ranges and that the upper Volgian substage belongs to the Berriasiyan. Mesezhnikov also admitted that the uppermost of the upper Volgian substage (*Craspedites nodiger* Zone) could belong to the Cretaceous (Krymhols et al., 1988). However, many workers dealing with the Bo-

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real Jurassic and Cretaceous maintain the traditional view of equivalence of the Tithonian and Volgian stages and attribute the entire Volgian stage to the Jurassic (Zakharov et al., 1997). A more detailed history of the problem has been presented earlier (Sey and Kalacheva, 1997).

The key to the problem is found in the regions with mixed Boreal–Tethyan faunas. Mixed ammonite faunas of central Poland, northern Caucasus, Crimea, Mangyshlak, and the Russian Platform are usually involved in the discussion of the issues of the Boreal–Tethyan correlation. Major emphasis is also placed on mixed faunas of another type in which Tethyan ammonites are associated with Boreal species of *Buchia*. Such faunas are known in California, Oregon, and western Canada. Their significance for the Boreal–Tethyan correlation has been considered by Zeiss (1979, 1986), Jeletzky (1984), and Hoedemaeker (1987). In Russia, comparable mixed faunas are recorded in the uppermost Jurassic and lowermost Cretaceous in the Far East.

## 2. Stratigraphy, fauna assemblages, age

In the Far East, Upper Jurassic and Lower Cretaceous deposits with Boreal *Buchia* and Tethyan ammonites occur mostly in the Western Okhotsk area and Southern Primorye. We have studied these sediments for several years.

The most complete sections exist in Western Okhotsk in the north of the Far East, where the zonal *Buchia* scale has been developed (Sey and Kalacheva, 1988, 1993). This scale agrees well with similar scales of the Russian Platform and northern Siberia. One specimen of *Durangites* was found there in the upper middle Volgian (*Buchia russiensis*–*Buchia fischeriana* Zone). This ammonite closely resembles *Durangites* aff. *D. rarifurcatus* Imlay from the upper Tithonian of Mexico (Verma and Westermann, 1973; Sey and Kalacheva, 1983). The genus *Durangites* determines the upper zone of the upper Tithonian of southern Europe (Tavera, 1985). The middle Volgian deposits in Western Okhotsk sections are conformably overlain by the upper Volgian sediments (*Buchia piochii* s.l.–*Buchia terebratuloides* Zone).

Southern Primorye is another area where uppermost Jurassic and lowermost Cretaceous with Tethyan

ammonites and Boreal *Buchia* are also known. There, mainly in the Putyatin Island, the Upper Jurassic comprises the lower? and middle Tithonian sediments with abundant ammonites: '*Virgatosphinctes*', *Pseudolissoceras*, *Haploceras*, *Glochiceras* (?), *Semiformiceras*, *Lemencia*, *Subplanitoides*, *Parapalasiceras*, *Aulacosphinctes*, *Sublithacoceras*, *Himalayites* (?) (Sey and Kalacheva, 1996). The authors have distinguished there '*Virgatosphinctes cf. mexicanus*' beds (lower Tithonian?) and *Pseudolissoceras zitteli* and *Aulacosphinctes proximus* zones (middle Tithonian). The two latter units yield rare *Buchia mosquensis* (Buch) and *B. rugosa* (Fischer).

Of great interest in Southern Primorye is the outcrop along the Ussuri Bay coast (Chigan Formation) (Fig. 1). There, Triassic siltstone underlies a thick (600 m) sandstone sequence. At its base there is a packet (200 m) of coarse clastic rocks: conglomerates, gritstones, and coarse-grained cross-bedded sandstones. Most of the section is composed of fine-grained greenish-gray sandstones with rare thin siltstone intercalations and bands of light-coloured medium-grained sandstones. The sequence is unconformably overlain by non-marine Lower Cretaceous deposits. The section, except basal beds, contains abundant *Buchia*; well-preserved ammonites occur in the middle and upper parts of the section (Fig. 2).

The *Buchia* assemblage is dominated by *Buchia piochii* (Gabb) s.l., *B. terebratuloides* (Lahusen) and *B. unschensis* (Pavlow); *B. fischeriana* (Orbigny) and *B. trigonoides* (Lahusen) are less frequent, and *B. volgensis* (Lahusen) is very rare. This association is typical of the upper Volgian and characteristic for the upper Volgian substages of Russia, Greenland, Spitzbergen, and the Canadian Arctic (see below).

One of the main species in the assemblage is *Buchia piochii* s.l. The synonymy of this species has been thoroughly worked out by Imlay (1959). Following Imlay, we include into the synonymy *B. tenuicollis* (Pavlow), *B. hyatti* (Pavlow), *B. krotovi* (Pavlow) and other species with a narrow, high, and slightly incurved shell. These species are widespread in the Russian Platform: they appear at the top of middle Volgian and are most abundant in *Craspedites* beds of the Upper Volgian, particularly in the *Craspedites subditus* Zone (Gerasimov, 1969). At the northern margin of Russia, Arctic Islands, and Greenland, *B. piochii* is almost unknown; how-

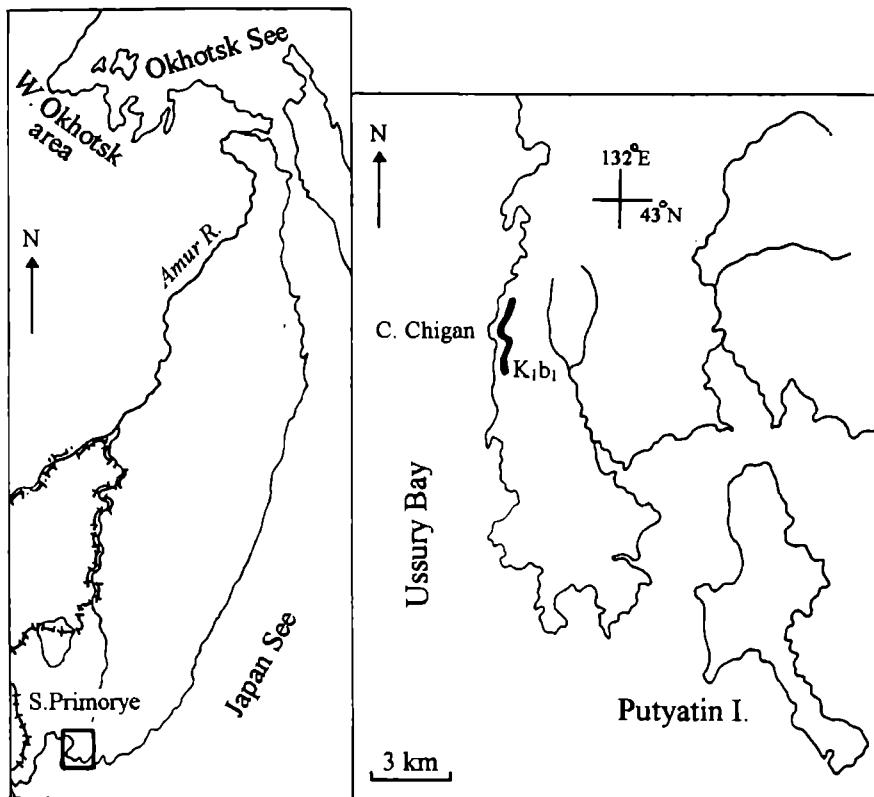


Fig. 1. Location of the lower Berriasian section on the Ussuri Bay coast in Southern Primorye, Far East, Russia.

ever, it is recorded in the northeast of Russia, where the upper Volgian *Buchia tenuicollis*–*B. terebratuloides* Zone has been distinguished (Parakhetzov and Parakhetzova, 1989). Rare *B. piochii* have been found in the lower upper Volgian of the Sverdrup Basin in the Canadian Arctic (Jeletzky, 1984).

*Buchia terebratuloides*, another species also abundant in the assemblage, occurs from the base of the *Kachpurites fulgens* Zone to the lowermost Ryazanian in the Russian Platform (Pavlow, 1907; Gerasimov, 1969). This species has a similar range in northern Siberia, northeastern Russia, Greenland, and Arctic Canada. In northern Siberia *B. terebratuloides* (including *B. obliqua*) can be traced from the base of the *Craspedites okensis* Zone to the upper part of the *Chetaites chetae* Zone (Zakharov, 1990). In Greenland, northern Norway, and Spitzbergen reliable records of its occurrences appear to be known only in the upper Volgian (Håkansson et al., 1981; Zakharov et al., 1981; Surlyk and Zakharov, 1982;

Ershova, 1983). In the Canadian Arctic this species is mostly confined to the upper Volgian (Jeletzky, 1984).

The range of *Buchia unschensis* is slightly higher as compared to two previously mentioned species. In the Russian Platform, Siberia, Greenland, Spitzbergen, and the Canadian Arctic this species mainly occurs at the top of the upper Volgian substage and in the overlying beds, including the bottom of the *Hectoroceras kochi* Zone. Unlike others, *Buchia fischeriana* and *Buchia trigonoides* have a more extensive age range: they appear in the upper middle Volgian and presumably pass into the Ryazanian beds. The assemblage also comprises a few large *Buchia*, tentatively identified as *Buchia volgensis*, though the latter is common at a higher stratigraphic level. Thus, the *Buchia* assemblage is a clear indication of the late Volgian age of the enclosed deposits (*B. piochii* s.l.–*B. terebratuloides* Zone) (Table 1).

Besides *Buchia*, the section on the Ussuri Bay coast contains sporadic Tethyan ammonites, which

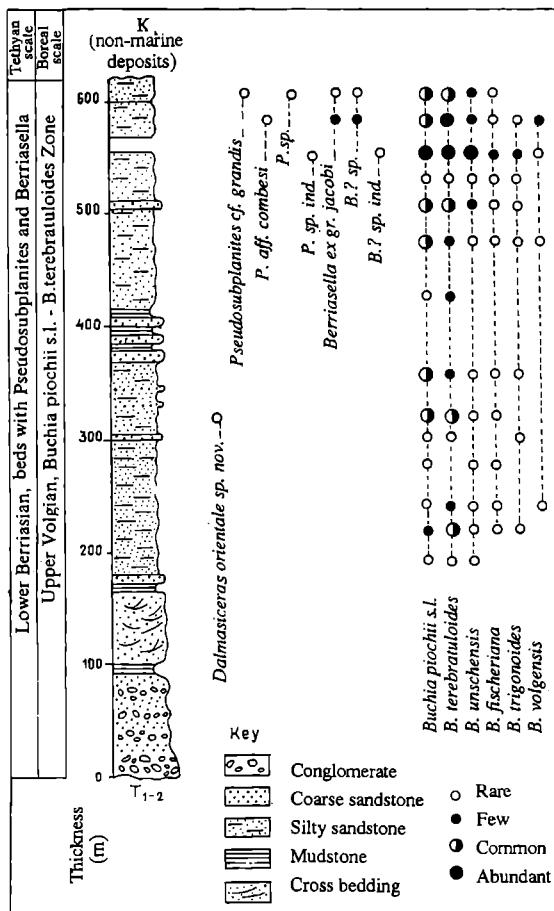


Fig. 2. The section of the lower Berriasian sediments (Chigan Formation) on the Ussuri Bay coast and distribution of ammonites and *Buchia* in this section.

allow refinement of its age. In the middle part of the section (320 m above the base) a peculiar *Dalmasiceras* was recorded, which was assigned to the new species *D. orientale* sp. nov. due to its involute shell and an unusual ornamentation. Among all known *Dalmasiceras*, it is most similar to *D. biplanum* Maz. (Mazenot, 1939; Cecca et al., 1989) from the lower Berriasian (*Jacobi/Grandis* Zone) in southeastern France. At the top of the section (550 m above the base) *Pseudosubplanites* sp. ind. and *Berriasella*? sp. ind. have been recorded. The uppermost part (570–600 m) contains an ammonite assemblage dominated by small adult ammonites (possibly microconchs) assigned to the genus *Berriasella*. Most of them are defined as *B. ex gr. jacobi* Maz. and the rest as

*Berriasella*? sp. Other, rarer ammonites belong to the genus *Pseudosubplanites*. The largest specimen of them has been identified as *Pseudosubplanites cf. grandis* (Maz.) and the others as *P. aff. combesi* Le Heg. and *P. sp.*

As indicated by the ammonite assemblage the deposits of Ussuri section are of early Berriasian age and correspond to the *Jacobi/Grandis* Zone of the Mediterranean scale.

### 3. Systematic paleontology

Family NEOCOMITIDAE Salfeld, 1921

Subfamily BERRIASELLINAE Spath, 1922

Genus *Pseudosubplanites* Le Hegarat, 1973

*Pseudosubplanites* cf. *grandis* (Mazenot, 1939); Plate I, fig. 3

*Material.* One specimen, fragment of a body chamber.

*Description.* Very large, evolute, planulate shell (D about 200 mm) with wide umbilicus. Umbilical wall almost vertical. Whorl section compressed, high oval in shape (H/D = 0.32). The flanks converging gradually into a convex and relatively narrow venter. Ornamentation characterized by strong and dense ribbing. Ribs elevated and narrow, bifurcate and simple, the latter being predominant (10/15). They start on the umbilical wall and extend on the flanks radially. Ribs cross the venter without a break.

*Remarks.* By the nature of its large shell with rapidly increasing high volution and type of ornamentation our specimen is closely similar to specimens of *Pseudosubplanites grandis* from the lower Berriasian of southeast France (Le Hegarat and Remane, 1968, p. 25, pl. 5, figs. 6, 7; Le Hegarat, 1973, p. 38, pl. 2, figs. 3, 4) and Bulgaria (Nikolov, 1982, p. 38, pl. 1, figs. 2, 3; pl. 2, fig. 5; pl. 3, figs. 1, 2; pl. 4, fig. 1). It differs by thinner and denser ribbing and a greater number of simple ribs on body chamber.

*Distribution.* Lower Berriasian. Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

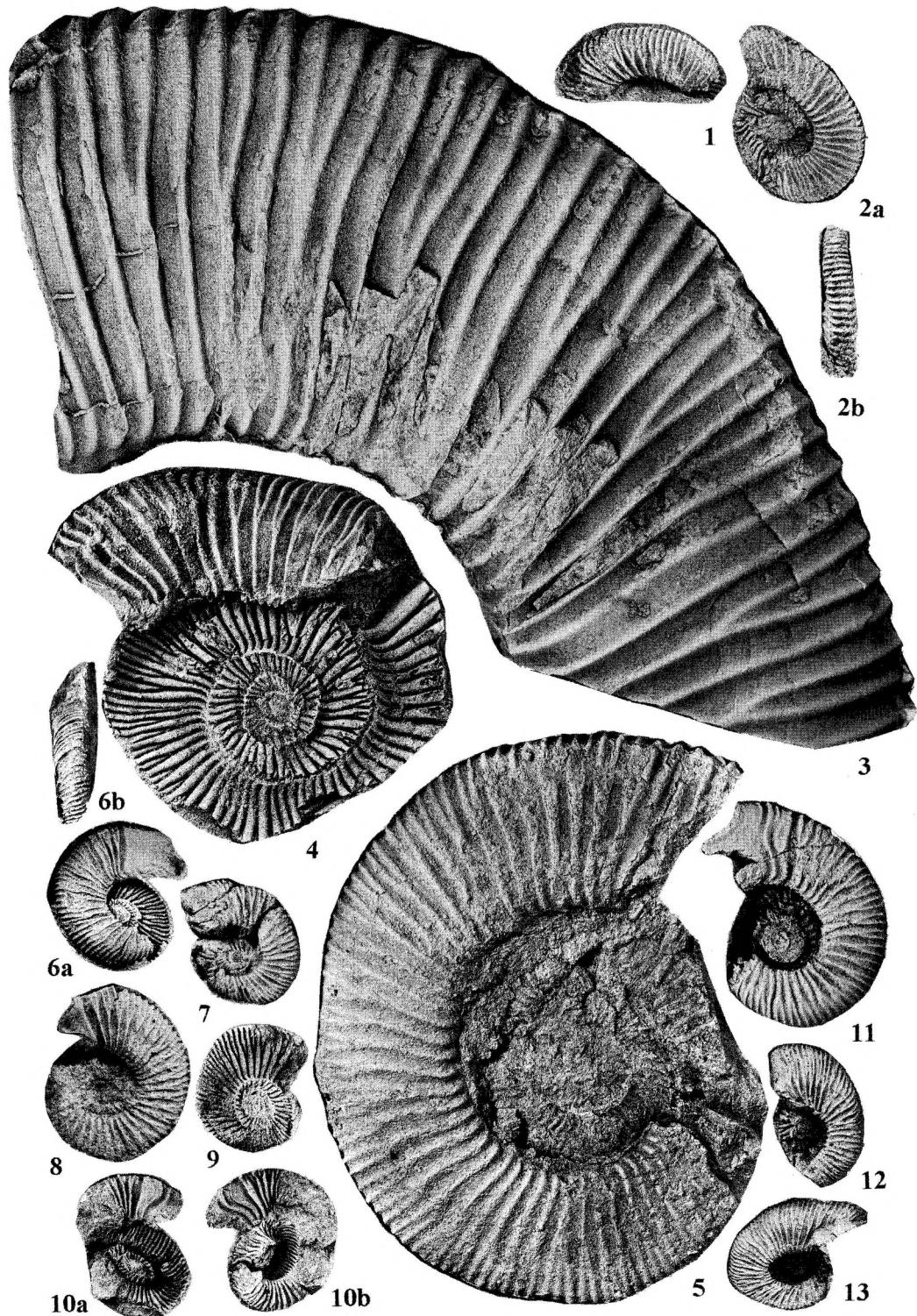
*Pseudosubplanites* aff. *combesi* Le Hegarat, 1973; Plate II, figs. 8, 9

*Material.* Three specimens, one specimen with body chamber (D about 120 mm), two not well preserved.

Table 1  
Correlation chart of the Jurassic–Cretaceous boundary faunas of the Russian Far East and the west of North America

Far East of Russia		Southern Primorye		Western Canada		North America		California	
Western Okhotsk area Sey and Kalacheva, 1993		Sey and Kalacheva, 1996		Jeletzky, 1984		Jones et al., 1969; Imlay and Jones, 1970		California	
Buchiias	Ammonites	Buchiias	Ammonites	B. uncicoides	Buchiias	Ammonites	Buchiias	Neocosmoceras	Ammonites
B. okensis Zone	"Berriasian"			B. okensis Zone	B. uncicoides	Neocosmoceras	B. uncicoides Zone	Spiliceras? Proniceras?	
					B. terebratuloides Zone	Parodontoceras Substeuroceras	B. aff. Bokensis Zone	Parodontoceras Substeuroceras	
				B. piocchii– B. terebratuloides Zone	Pseudosubplanilites, Bernasella, Dalmasiceras	B. Fischeriana Zone	B. Fischeriana Zone	Spiliceras Parodontoceras Aulacosphinctes?	
				B. russiensis – B. Fischeriana Zone	Durangites	B. piocchii Zone	B. Fischeriana Zone	Durangites, Kossinnaia	
				B. mosquensis – B. russiensis Zone		B. cf. blanfordiana Zone	B. russiensis s.l. Zone	(=B. elderensis) Zone	
						B. mosquensis– B. rugosa Zone	B. rugosa	Aulacosphinctes proximus Zone	
								Pseudolissoceras. zittelii Zone	
								B. mosquensis s.l. Zone	
								"Virgatosphinctes cf. mexicanus"	

## PLATE I



**Description.** Flattened evolute shell with broad ( $U/D = 0.45$ ) and shallow umbilicus; umbilical walls almost vertical. Final body chamber occupies about two thirds of the last whorl. Inner and middle whorls gradually increasing and moderately high ( $H/D = 0.30$ ), the last whorl much higher ( $H/D = 0.33$ ). Flanks almost flat and rapidly converging to comparatively narrow venter. Ornamentation characterized by bifurcate and simple ribs. On the phragmocone ribbing is fine, dense and elevated. On the body chamber the ribs are high, sometimes slightly incurved; beside bifurcate ribs there are simple ribs and one subvirgatotome (polygyrate) rib. They cross the venter without interruption.

**Remarks.** Our specimens approximately resemble specimens of *P. combesi* Le Hegarat (1973, p. 36, pl. 1, fig. 2; pl. 37, fig. 1) from southeast France in its evolute large shell ( $D$  about 100–120 mm) with almost flat flanks and having bifurcate ribbing. They differ from French specimens in having a greater number of finer ribs, a lot of simple ones and only one subvirgatotome rib, whereas *P. combesi* has several subvirgatotome ribs on the body chamber and on the phragmocone. Another similar species, *P. berriasiense* Le Hegarat (1973, p. 33, pl. 1, fig. 1; pl. 37, fig. 2), has numerous subvirgatotome ribs.

**Distribution.** Lower Berriasian. Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

#### *Pseudosubplanites* sp.; Plate I, figs. 4, 5

**Material.** Two poorly preserved specimens.

**Description.** Evolute flattened shell ( $D = 88$  mm) with gradually increasing, moderately high whorls ( $H/D = 0.28$ ), a broad shallow umbilicus ( $U/D = 0.45$ ) with almost vertical walls. Flanks slightly convex and the venter narrow and flattened. Body chamber occupies about two thirds of the last whorl. Ornamentation is characterized by dense (about 60 on the outer whorl), rather fine and slightly incurved,

bifurcate ribs; however, on the body chamber there are four subvirgatotome ribs. Bifurcation occurs at a level about the middle of the flanks. Ribs cross the venter without interruption.

**Remarks.** These ammonites could not be identified with any of the known species of *Pseudosubplanites*. Our specimens differ from the specimens described as *P. ponticus* Retowski (1893, p. 51, pl. 2, fig. 9), *P. berriasiense* Le Hegarat (1973, p. 33, pl. 37, fig. 2) and *P. combesi* Le Hegarat (1973, p. 36, pl. 37, fig. 1), by a less height of the outer whorls, more numerous, finer and denser ribs.

**Distribution.** Lower Berriasian. Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

#### Genus *Berriasella* Uhlig, 1905

*Berriasella* ex gr. *jacobi* Mazenot, 1939; Plate I, figs. 1–2, 6–13

**Material.** Thirteen specimens (microconchs) in general well preserved, five of them complete with aperture and lappets.

**Description.** Shells are very small ( $D = 20$ –35 mm), evolute, flattened; at early stages whorls not very high and a shallow umbilicus. The whorls become higher at later stages, the umbilicus moderately wide. The umbilical wall is almost vertical; the flanks and the umbilical walls form the rectangle with rounded border. The flanks are gently convex and rapidly converge to a rounded or slightly flattened venter. Body chamber occupies approximately two thirds of the whorl. Ornamentation is characterized by fine and dense (19 per half a whorl), mostly bifurcate (rarely simple) ribs. Towards the end of the body chamber the ribs are sometimes slightly incurved. The aperture margin is slightly thickened in certain specimens and ends in a small rounded lateral lappet. In other specimens it has a more complex structure with two constrictions and elongated lappet. On the

#### PLATE I

All specimens represented in Plates I–III were collected by authors. They are kept in the Central Scientific Research Geological Museum (CGM), St.-Petersburg, Russia. Collection No. 12951.

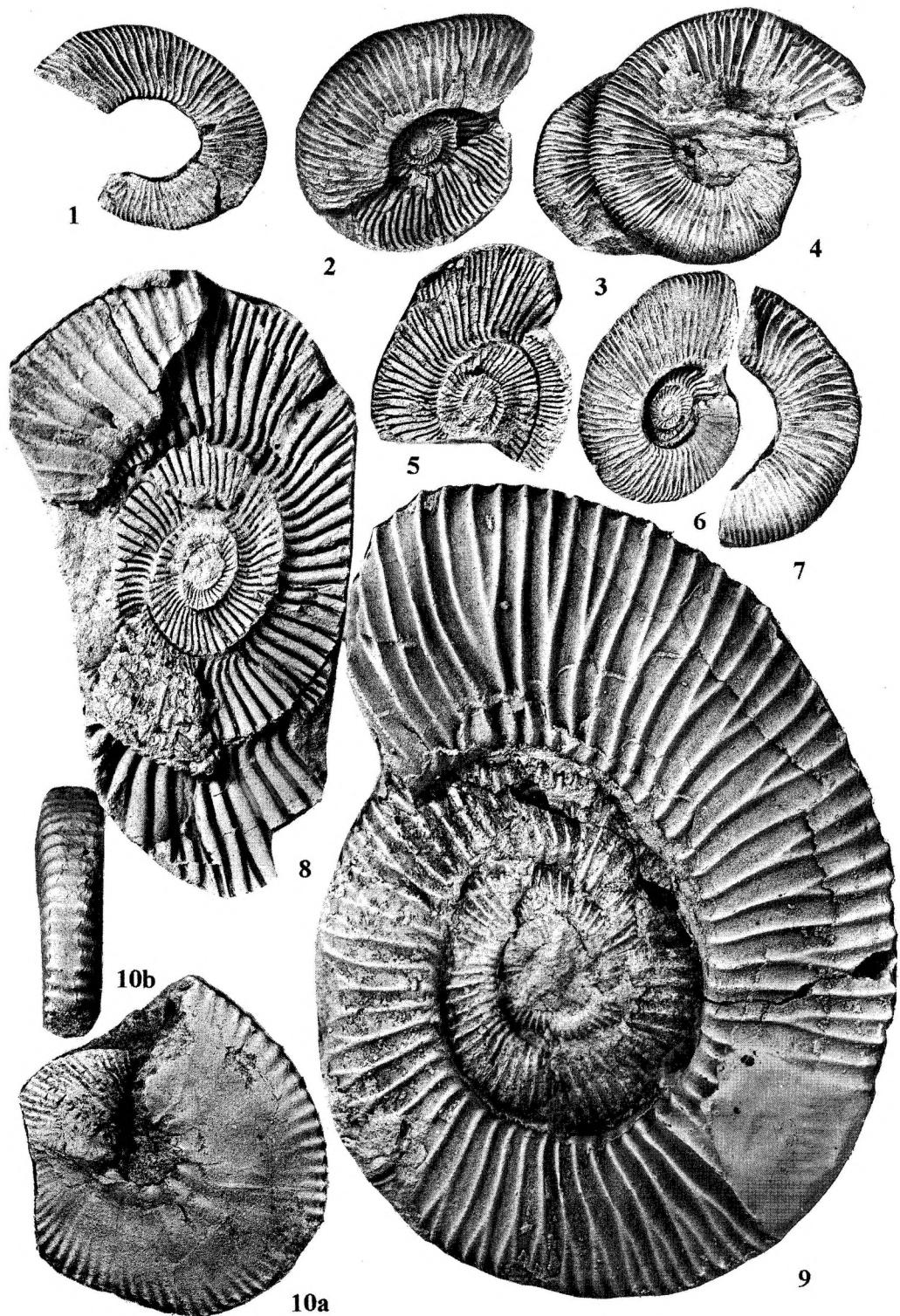
1, 2, 6–13. *Berriasella* ex gr. *jacobi* Mazenot. CGM: 1 = 11/12951; 2a, b = 14/12951; 6a, b = 9/12951; 7 = 19/12951; 8 = 10/12951; 9 = 15/12951; 10a, b = 12/12951; 11 = 8/12951; 12 = 17/12951; 13 = 13/12951.

3. *Pseudosubplanites* cf. *grandis* (Mazenot). CGM: 2/12951.

4, 5. *Pseudosubplanites* sp. CGM: 4 = 7/12951; 5 = 6/12951.

All specimens  $\times 1$ . Lower Berriasian. Chigan Formation, Ussuri Bay, Southern Primorye.

## PLATE II



phragmocone ribs cross the venter with interruption; on the body chamber interruption is absent.

**Remarks.** These specimens are most similar to drawing specimens of *Berriasella jacobi* Mazenot (1939, p. 54, pl. 4, figs. 1–4); however, the very small size does not make it possible to identify them with the holotype. We compare them with one of the topotypes of the Chomerac (Mazenot, 1939, pl. 4, fig. 4) as well as with the specimens from Spain (Tavera, 1985, pl. 33, figs. 7–11) and Tunisia (Arnould-Saget, 1951, pl. 4, fig. 11; pl. 5, fig. 1). It should be noted, that the shape of the aperture in representatives of *B. jacobi* is unknown.

**Distribution.** Lower Berriasian. Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

#### *Berriasella?* sp.; Plate II, figs. 1–7

**Material.** Ten specimens (microconchs?), mostly internal moulds and well preserved fragments.

**Description.** Shell is small ( $D$  about 40 mm), evolute, flattened, with moderately wide umbilicus:  $U/D$  ratio range 0.35–0.38. Umbilical wall is almost vertical, but not high. The flanks are subplanate and rapidly converge to rounded venter. Body chamber occupies about two thirds of the last whorl. Ornamentation consists of very dense (60 on the last whorl) and fine bifurcate ribs. On the body chamber ribs cross the venter without interruption.

**Remarks.** Peculiar character of ribbing distinguishes our specimens from the majority of known *Berriasella* s.l. As compared to specimens of *B. jacobi* Maz. (1939, p. 54, pl. 4, figs. 1–4), *B. oppeli* (Kilian) (Mazenot, 1939, p. 49, pl. 3, figs. 1–3) and other species, these specimens have almost double number of finer ribs with a very distinct and regular bifurcation.

**Distribution.** Lower Berriasian. Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

#### Genus *Dalmasiceras* Djanelidze, 1922

##### *Dalmasiceras orientale* sp. nov.; Plate II, fig. 10

**Holotype.** *Dalmasiceras orientale* Sey et Kalacheva sp. nov., figured in Plate II, fig. 10a,b; Central Geological Museum (CGM) No. 1/12951, St.-Petersburg, Russia.

**Locus typicus.** Eastern coast of Ussuri Bay, Southern Primorye, Far East of Russia.

**Stratum typicum.** Lower part of the Lower Berriasian, Chigan Formation. *Derivatio nominis.* After the location in eastwern Russia.

**Material.** One specimen, CGM, No. 1/12951: internal mould, phragmocone with body chamber (microconch), but aperture not preserved.

**Description.** Shell is of medium size ( $D = 60$  mm), compressed and involute with a high outer whorl ( $H/D = 0.48$ ), three fourths of which occupies the body chamber. The umbilicus is narrow ( $U/D = 0.14$ ) with elevated umbilical border. The flanks are flat, rapidly converging to strongly flattened venter. The ornamentation consists of tubercles near the umbilical border and numerous ribs. The tubercles on the phragmocone are small. Several (2–3) fine ribs diverge from them, forming indistinct bundles. On the body chamber tubercles are rather large; middle parts of the flanks are smoothed. Short and coarse ribs are retained only near the venter. Ratio of tubercles and ribs on the body chamber is 10:60. On the venter the ribs are separated by a distinct smooth band.

**Remarks.** *Dalmasiceras orientale* sp. nov. differs from most of typical *Dalmasiceras* by much more involute shell with a narrow umbilicus and high, rapidly increasing whorls. By the shape of the shell it is similar only to *D. biplanum* Mazenot (1939, p. 170, pl. 26, fig. 8; Cecca et al., 1989, p. 73, pl. 4, figs. 1, 2) of southeast France. However, the latter has a larger size (macroconch) and almost lacks ornamentation on the phragmocone, whereas our ammonite

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#### PLATE II

##### See also Plate I.

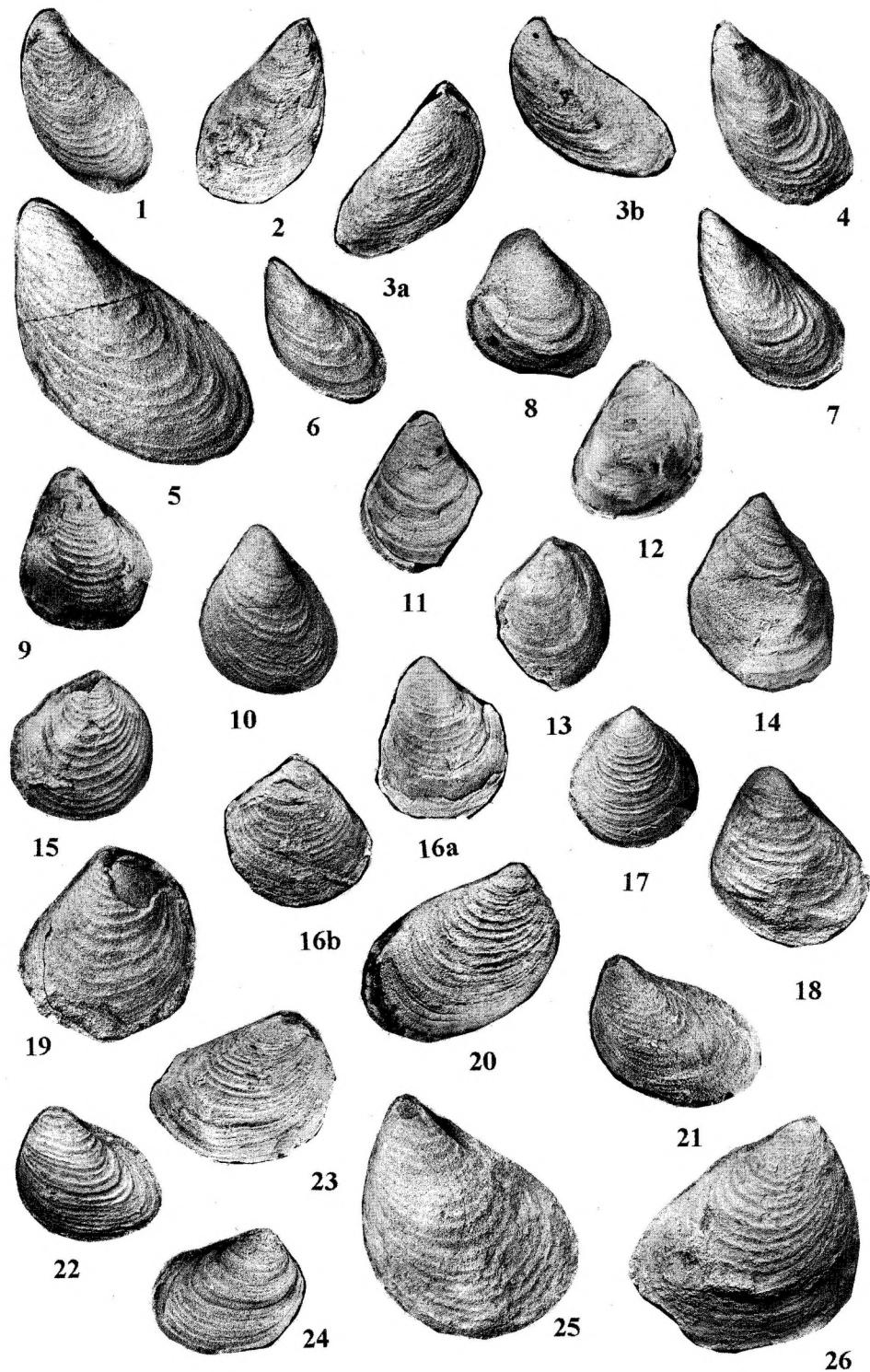
1–7. *Berriasella?* sp. CGM: 1 = 24/12951; 2 = 23/12951; 3 = 21/12951; 4 = 20/12951; 5 = 22/12951; 6 = 25/12951; 7 = 26/12951.

8, 9. *Pseudosubplanites* aff. *combesi* Le Hegarat. CGM: 8 = 4/12951; 9 = 3/12951.

10a, b. *Dalmasiceras orientale* sp. nov. CGM: 1/12951.

All specimens  $\times 1$ . Lower Berriasian. Chigan Formation, Ussuri Bay, Southern Primorye.

## PLATE III



retains ribbing on the flanks up to the beginning of the body chamber. Beside *D. orientale* sp. nov. has less numerous more coarse tubercles.

**Distribution.** Lower Berriasian. Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

#### Family BUCHIIDAE Cox, 1953

##### Genus *Buchia* Rouillier, 1845

*Buchia piochii* (Gabb, 1864) s.l.; Plate III, figs. 1–7

1864 *Inoceramus piochii*: Gabb, pl. 25, figs. 173,? 174 (see White, 1888, pl. 4, figs. 1,? 2).

1895 *Aucella piochii*: Stanton, p. 42, pl. 4, figs. 2–9.

1959 *Aucella piochii*: Imlay, p. 157, pl. 17, figs. 7–10, 12–29.

1961 *Aucella piochii*: Imlay, p. 3, pl. 7, fig. 11.

1969 *Buchia piochii*: Imlay, p. A10, pl. 2, fig. 16, pl. 3, figs. 20–29.

1984 *Buchia piochii*: Jeletzky, pl. 4, fig. 2 (only).

1984 *Buchia aff. piochii*: Jeletzky, pl. 4, fig. 11 (only).

1984 *Buchia ex gr. lahuseni*: Jeletzky, pl. 4, figs. 9, 13

(Full synonymy see Stanton, 1895; Imlay, 1959, p. 158; Imlay, 1961).

**Material.** More than 70 specimens — internal moulds of left and right valves, rarely — bivalve specimens from Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

**Description.** Shell mainly small to medium sized for genus, inequivaled, narrow and elongate posteriorly, much longer than wide. Left valve moderately inflated, slender and slightly incurved, obliquely suboval to trigonally suboval in outline; beak long, narrow and usually strongly incurved backward. Suboval right valve smaller than left valve, weakly inflated, with short and small beak. Surface ornament consist of concentric, fine, closely spaced ribs, some specimens have coarser, widely spaced ribbing.

**Remarks.** *Buchia piochii* closely resembles *B. russiensis* (Pavlow). It differs from the latter by more narrow, slender and incurved shell with narrow, long and coiled backward beak.

**Occurrence.** Upper Volgian of Russian Platform, Northeast and western Okhotsk area of Russia; lower Berriasian of Southern Primorye (Russian Far East), California, and western Canada.

*Buchia terebratuloides* (Lahusen, 1888); Plate III, figs. 8–14

1988 *Aucella terebratuloides*: Lahusen, p. 18, pl. 4, figs. 1–11.

1981 *Buchia terebratuloides*: Zakharov, p. 105, pl. 23, figs. 4–6, pl. 24, figs. 1–4, pl. 25, figs. 1–10.

1982 *Buchia terebratuloides*: Surlyk and Zakharov, p. 738, pl. 14, figs. 7–10.

1984 *Buchia terebratuloides*: Jeletzky, pl. 1, fig. 8, pl. 3, fig. 8.

1989 *Buchia terebratuloides*: Paraketzov and Paraketzova, p. 227, pl. 9, figs. 10–14.

(Full synonymy see Zakharov, 1981, p. 105).

**Material.** More than 50 specimens — internal moulds of left and right valves from Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

**Description.** Shell mostly small sized, inequivaled, relatively high and almost equilateral, not extending posteriorly; both valves nearly equal convexity. Left valve trigonal with high, elongate and strongly projecting beak, overhanging right valve. The latter subtrigonal to suboval in outline, its beak small and not prominent. Concentric ornament from fine to strong, variably spaces ribs; weak constrictions common, there are almost smooth specimens.

**Remarks.** This species is distinguished from closely resembling *Buchia unschensis* (Pavlow) (see below) by subtrigonal, high shell with narrow, strongly projecting beak and more diverse ornamentation.

**Occurrence.** Upper Volgian to lowermost Ryazanian of the Russian Platform and East Greenland; upper Volgian of Petshora River basin, northern Siberia, Northeast and western Okhotsk area of Russia; lower Berriasian of Southern Primorye, western Canada, and California.

#### PLATE III

##### See also Plate I.

1–7. *Buchia piochii* (Gabb.) s.l. CGM: 29–35/12951; 3a = right valve, 3b = left valve.

8–14. *Buchia terebratuloides* (Lahusen). CGM: 36–42/12951.

15–19. *Buchia unschensis* (Pavlow). CGM: 43–47/12951; 16a = left valve, 16b = right valve.

20, 21. *Buchia fischeriana* (Orbigny). CGM: 48, 49/12951.

22–24. *Buchia trigonoides* (Lahusen). CGM: 50–52/12951.

25, 26. *Buchia volgensis* (Lahusen). CGM: 53, 54/12951.

All specimens  $\times 1$ . Lower Berriasian. Chigan Formation, Ussuri Bay, Southern Primorye.

*Buchia unschensis* (Pavlow, 1907); Plate III, figs. 15–19

1907 *Aucella unschensis*: Pavlow, p. 61, pl. 6, fig. 12 (only).  
 1981 *Buchia unschensis*: Zakharov, p. 109, pl. 23, fig. 5, pl. 25, figs. 11–13, pl. 26, figs. 1–3, pl. 27, figs. 1–6, pl. 28, figs. 1–5, pl. 29, figs. 1–4, pl. 30, figs. 1–5.

1982 *Buchia unschensis*: Surlyk and Zakharov, p. 740, pl. 74, figs. 11–14.

1984 *Buchia unschensis*: Jeletzky, pl. 1, fig. 9, pl. 5, figs. 2, 6.

(Full synonymy see Zakharov, 1981, p. 109).

**Material.** About 50 specimens — internal moulds of left and right valves, rarely — bivalve specimens from Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

**Description.** Shell small to medium sized, moderately inequivaled and nearly equilateral, rounded, non-oblique in outline. Left valve subtrigonal to trigonally oval, moderately inflated; beak relatively short, wide, and weakly projecting. Right valve moderately or weakly inflated, suborbicular to orbicular; beak very small and non-projecting. Sometimes small posterior wings are observed. The surface is covered by well-defined concentric ribs, variable in strength and spacing. Rarely one or two weak constrictions are present.

**Remarks.** *Buchia unschensis* shows great resemblance to *B. terebratuloides* (see above). This species is also close to *B. okensis* (Pavlow). The latter differs by large size, suboval oblique shape of shell and more coarse and widely spaced ribs.

**Occurrence.** Upper Volgian and lowermost Ryazanian of the Russian Platform, Petshora River basin, Siberia, Greenland, Arctic Canada, Northeast Russia and western Okhotsk area; lower Berriasian of Southern Primorye and western Canada.

*Buchia fischeriana* (Orbigny, 1845); Plate III, figs. 20, 21

1845 *Avicula fischeriana*: Orbigny, p. 472, pl. 41, figs. 8–10.  
 1981 *Buchia fischeriana*: Zakharov, p. 101, pl. 21, figs. 1–9, pl. 22, figs. 1–4, pl. 23, figs. 1–3.

1981 *Buchia fischeriana*: Håkansson, Birkelund et al., p. 23, pl. 3, figs. 7–11.

1981 *Buchia fischeriana*: Surlyk and Zakharov, p. 736, pl. 74, figs. 5, 6.

1984 *Buchia fischeriana*: Jeletzky, pl. 3, fig. 6, pl. 4, fig. 15.

1989 *Buchia fischeriana*: Parakhetzov and Parakhetzova, p. 223, pl. 8, figs. 1–7.

1981 *Buchia taimyrensis* sp. nov.: Zakharov, p. 95, pl. 18, figs. 3, 4, 6–8, pl. 19, figs. 2–7.

(Full synonymy see Zakharov, 1981, p. 101)

**Material.** Fifteen specimens — internal moulds of right and left valves from Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

**Description.** Shell predominantly medium sized, inequivaled and strongly inequilateral. Both valves are obliquely oval, sometimes slightly incurved shape with long rounded anterior margin and more short and straight posterior one. Left valve moderately inflated with short, relatively narrow, and moderately prominent beak. Right valve weakly inflated, its beak small and nearly non-projecting. Ornamentation mainly consists of regular spaced concentric ribs of equal size, although specimens with irregular ribbing and nearly smooth surface are present.

**Remarks.** *B. fischeriana* is very close to *B. trigonoides* (Lahusen) (see below). This species also bears similarities to *B. russiensis* (Pavlow), but it differs from the latter by obliquely oval wide shell, shorter, less projecting beak and more regular concentric ornamentation.

**Occurrence.** Middle Volgian to basal Ryazanian of the Russian Platform; middle and upper Volgian of northern Siberia, East Greenland, western Okhotsk area of Russia; upper Volgian of Northeast Russia and Arctic Canada; lower Berriasian of Southern Primorye, California, and western Canada.

*Buchia trigonoides* (Lahusen, 1888); Plate III, figs. 22–24

1888 *Aucella trigonoides*: Lahusen, p. 14, pl. 2, figs. 21, 22 (only).

1907 *Aucella trigonoides*: Pavlow, p. 55, pl. 4, figs. 23, 24.

1968 *Aucella trigonoides*: Parakhetzov, p. 57, pl. 102, fig. 3.

1965 *Buchia aff. fischeriana*: Jeletzky, pl. 7, fig. 6; 1966, p. 29, pl. 7, figs. 3, 7.

1981 *Buchia taimyrensis* sp. nov.: Zakharov, p. 45, pl. 18, figs. 2, 5, 6 (only).

(Full synonymy see Jeletzky, 1965; Parakhetzov, 1968).

**Material.** Twelve specimens — internal moulds of right and left valves from the Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

**Description.** Shell small to medium sized, inequivaled, strongly inequilateral and oblique, with nearly equal height and length. Left valve subtrigonal to trigonally suboval, beak displaced to anterior margin, wide, weakly to moderately prominent. Right valve suboval with long rounded anterior margin

and small, nearly non-projecting beak. Both valve elongate and flattened posteriorly. Ornament diverse: from regular fine concentric ribbing to nearly smooth with rare strong ribs and constrictions.

**Remarks.** *Buchia trigonoides* strongly resembles *B. fischeriana*. A number of workers regard these species as synonyms (e.g. Zakharov, 1981). However *B. trigonoides* differs from *B. fischeriana* by well-defined subtrigonal shape of shell with nearly equal height and length, more prominent beak of left valve and more diverse ornament.

**Occurrence.** Middle Volgian to lowermost Ryazanian of the Russian Platform; middle and upper Volgian of northern Siberia and western Okhotsk area of Russia; upper Volgian of northeast Russia and Canadian Arctic; lower Berriasian of Southern Primorye and western Canada.

*Buchia volgensis* (Lahusen, 1888); Plate III, figs. 25, 26

1888 *Aucella volgensis*: Lahusen, p. 16, pl. 3, figs. 1–17.

1981 *Buchia volgensis*: Zakharov, p. 125, pl. 37, figs. 5–7, pl. 38, figs. 1–3, pl. 39, figs. 1–4, pl. 40, figs. 1–2.

1984 *Buchia (Buchia) volgensis*: Kelly, p. 58, pl. 10, figs. 1, 3, 4, 7, 8.

1988 *Buchia volgensis*: Luppov, Bogdanova et al., p. 140, pl. 18, figs. 1–7.

1989 *Buchia volgensis*: Paraketzov and Paraketzova, p. 229, pl. 11, figs. 1–3.

(Full synonymy see Zakharov, 1981, p. 125; Kelly, 1984, p. 58; Luppov et al., 1988).

**Material.** Ten specimens — internal moulds of right and left valves from Chigan Formation, eastern coast of Ussuri Bay, Southern Primorye.

**Description.** Shell medium to large, inequivaled and inequilateral, obliquely elongate, relatively high. Left valve moderately inflated, subtrigonal to trigonally suboval, in the last case it is strongly increasing posteriorly. Left beak high, narrow to moderately wide, projecting. Right valve weakly inflated, trigonally suboval in outline with small, wide, slightly projecting beak. The surface is covered by regularly spaced, fine to strong concentric ribs.

**Remarks.** *Buchia volgensis* can be distinguished from the closest *B. okensis* (Pavlow) by its higher subtrigonal shell with more narrow and prominent left beak and usually finer ribbing. Several of our specimens having more wide, rounded shells are transitional between both species.

**Occurrence.** Upper Volgian to Ryazanian of the Russian Platform; Ryazanian of northern Russia, England, North and East Greenland, Norway, and Arctic Canada; lower Berriasian of Southern Primorye and California; upper Berriasian of northern Caucasus and Mangyshlak; Berriasian of Sikhote-Alin.

#### 4. Conclusion

Ammonites from the Ussuri Bay section, including *Dalmasiceras*, *Pseudosubplanites*, and *Berriasella*, are of Early Cretaceous age and correspond to the lower part of lower Berriasian. According to the *Buchia* scale these deposits are of late Volgian age and correspond to the upper Volgian *Buchia piochii* s.l.–*B. terebratuloides* Zone. The same situation exists in North America — in California, Oregon, and Western Canada, where the upper Volgian *Buchia* is also associated with Tethyan ammonites (Jones et al., 1969; Imlay and Jones, 1970; Jeletzky, 1984). There the *Buchia* assemblage is also dominated by *Buchia piochii* s.l. (including *B. lahuseni*, *B. lahuseni* var. *tenuicollis* sensu Jeletzky), *B. fischeriana*, and *B. terebratuloides*. The latter, according to Jeletzky (1984, p. 196), is the main upper Volgian marker. A small number of *B. unschensis*, *B. volgensis* (= *B. trigonoides* sensu Imlay in Jones et al., 1969), and peculiar *Buchia* aff. *B. okensis* is also present. The ammonite assemblage, occurring with buchias includes *Spiticeras*, *Proniceras*, *Groebericeras*? *Parodontoceras*, *Substeuroceras*, etc. (see Table 1). It is presently dated as the lower Berriasian, corresponding to the *Jacobi/Grandis* (= *Euxinus*) and *Occitanica* zones of the European scale (Zeiss, 1986; Tavera et al., 1986; Hoedemaeker, 1987).

As a result, the mixed *Buchia*-ammonite faunas of eastern Russia and western North America illustrate a discrepancy between the Tithonian and Volgian and suggest that the Volgian belongs partly to the Cretaceous. *Durangites* and *Kossmatia* in the middle Volgian beds with *Buchia russiensis* (= *Buchia elderensis*) in the western Okhotsk area and California suggest that the Jurassic/Cretaceous boundary in Boreal sections lies at the base of the upper Volgian. These findings support the opinion earlier expressed by a number of workers.

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