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Some Albian-Cenomanian Monomorphic Ammonites of the Northwestern Sector of the Paleo-Pacific and Aspects of Their Distribution

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Abstract—This paper analyses the taxonomic composition and geographic distribution of Albian–Cenomanian monomorphic ammonites in the northwestern Paleo-Pacific. The study is based on a unique collection of 350 specimens collected over more than 70 years in northeastern Russia and Russian Far East, as well as a review of published data. Overall, the presence of 14 ammonoid families was established in the Albian and 8 in the Cenomanian, reflecting a significant reduction in biodiversity and a reorganization of faunal assemblages at the Lower–Upper Cretaceous boundary, previously described as a boundary faunal-turnover biotic event. Particular attention is paid to the genera *Beudanticeras*, *Cleoniceras*, *Neogastroplites*, *Marshallites*, *Eogunnarites*, *Gaudryceras*, *Anagaudryceras*, *Stoliczkaia*, *Sonneratia*, and *Neophylloceras*. For these genera, stratigraphic ranges and regional distribution patterns are demonstrated. A total of 20 taxa have been identified, including some that are in open nomenclature. Hypotheses have been proposed regarding which of these species can be considered endemic to the Northern Pacific paleobiogeographic realm, while others have a wider distribution and can be used for global correlations. The study also clarifies the ages of several localities and makes some adjustments to the boundaries of the zonal scheme. It is suggested that the Albian–Cenomanian period in the region was characterized by a unique combination of endemic and cosmopolitan forms, reflecting the migration processes between the Paleo-Pacific and Tethys.

Keywords: biotic events, "Middle Cretaceous", Koryak Upland, Penzhina Gulf coast, Sakhalin, Japan

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INTRODUCTION

Late Cretaceous ammonite assemblages differ from Early Cretaceous ones not only in their taxonomic composition, but also in morphotypes. Significant changes seem to have occurred during the so-called "Middle Cretaceous" interval, specifically from the Aptian–Albian boundary to the Cenomanian–Turonian boundary. Near these boundaries, important biological events took place in many groups of marine fauna, including ammonoids (Bengtson and Kakabadze, 2018). The Albian-Cenomanian interval is considered one of the possible options for distinguishing the "Middle Cretaceous". A similar opinion is shared, for example, by M. Hart (Hart, 2021) and V.M. Podobina (2018). A formal proposal for the tripartition of the Cretaceous would require combining data from many chronostratigraphically significant fossil groups, such as ammonoids, inoceramids, foraminifera, nannofossils, as well as dinoflagellates with data on magnetic, event and sequence stratigraphy (Bengtson and Kakabadze, 2018).

This paper is devoted to the study of a large collection of monomorphic ammonoids collected from Albian–Cenomanian sections of the Northwest Paleo-Pacific, as well as consideration of the stratigraphic and geographic distribution of some representatives of this fauna. During the Cretaceous, the Pacific fauna was characterized by a high degree of endemism for most of the time, and this trend increased from the Turonian onwards (Jagt-Yazykova, 2012). This circumstance greatly complicates age determination and biostratigraphic correlation in the study area. However, as in other regions of the world, it is possible to identify biotic events here, such as changes in faunal assemblages, radiation, and migration events, extinctions and the first occurrence of new species, which are associated with abiotic events. The dynamics of the development of different groups is another criterion for global correlation, as biotic events are often associated with global abiotic events that influence changes in habitat conditions. For example, ammonoids, one of the major stratigraphic groups, reacted sensitively to such changes. Their adaptation to new environments and migration of taxa led to the first occurrence of new morphotypes, and the taxonomic composition of faunas in the studied

region changed (Alabushev, 1989; Jagt-Yazykova, 2012). This paper also examines the existing ammonoid-based biostratigraphic scheme of the studied deposits for North-East Russia and the Russian Far East and shows possible levels of regional and global correlations based on both the studied collection and previously published materials.

MATERIAL

The research is based on material collected at numerous sampling sites along the Pacific coast of Russia (Fig. 1) over more than 70 years by various researchers of the Far East. Among them, Yu.G. Mirolyubov, V.P. Pokhialainen, V.F. Belyi, A.F. Mikhailov, I.M. Migovich, M.A. Pergament, L.I. Tikhomirov, T.D. Zonova, and many others.

These unique collections were preserved and transferred by T.D. Zonova to the Karpinsky Geological Institute Museum (TsNIGR Museum) in St. Petersburg with the support of her sister N.D. Zonova. In total, the authors have studied 350 samples. The main objective of this research was to conduct taxonomic analysis, as well as to determine the stratigraphic (Fig. 2) and geographic distribution of the identified taxa and their biostratigraphic significance. This has allowed us to clarify the age of some localities and zonal subdivisions. As a result, the age of some localities and zonal subdivisions was revised and updated.

Additionally, previously studied samples were used, including those described in (Vereshchagin et al., 1965; *Opornyi*..., 1987). The reference review includes published data on the Albian–Cenomanian interval of the Amur River valley and the Pacific coast of Russia: Sikhote-Alin, Sakhalin Island, Koryak Highlands (Pontonean Mountains), the Penzhina Bay coast (Penzhina Bay, Penzhina River basin, Penzhinsky Ridge), and adjacent territories of Japan and other regions. A study was conducted to analyze the geographical distribution of ammonoid taxa in other regions of the world. The work also presents the zonal division of the considered stratigraphic interval (Fig. 3), in which, as already mentioned above, some boundaries were adjusted.

The general taxonomic analysis of ammonoids was carried out without a monographic systematic description, so as not to increase the volume of the present work. Almost all of the taxa mentioned above have already been described previously, and no new taxa for the region were discovered. This paper includes eight plates of the best-preserved specimens from the north-eastern and eastern regions of Russia, as well as a few specimens from the island Sakhalin. All the studied collections are stored in the TsNIGR Museum (nos. 130088 and 13237).

HISTORY OF STUDY

The Albian–Cenomanian deposits are relatively widespread in the regions of the Pacific coast of Russia. They have an average thickness of 700 to 1000 m and are well characterized by the remains of ammonoids and inoceramids, as well as some other bivalves, gastropods, and brachiopods (Vereshchagin et al., 1965; Vereshchagin, 1977; *Opornyy*..., 1987; Zonova et al., 1993; Alabushev and Wiedmann, 1994, 1997; Jagt-Yazykova, 2011; etc.). The Albian fauna was found on the coast of the Penzhina Bay, in the Koryak Highlands, and in the Sikhote-Alin region. However, the lowest Cretaceous (Upper Albian) deposits have only been found on Sakhalin Island (*Opornyi*..., 1987; Zonova et al., 1993). Cenomanian deposits are present throughout North-East Russia and Russian Far East and they conformably overlap the Albian ones. Some representatives of the Early Cretaceous fauna from Sakhalin already have been previously described (Zonova et al., 1986, 1993; *Opornyi*..., 1987), as well as those from the north-eastern regions of the Pacific coast of Russia and the Amur region, including the Sikhote-Alin Mountains and Primorye (Zonova and Yazykova, 2000; Yazykova, 2001; Sey et al., 2004).

CHARACTERISTICS OF IDENTIFIED TAXA OF AMMONOIDS

The eight paleontological plates (I–VIII) in this article present taxa belonging to the six families (Desmoceratidae, Kossmaticeratidae, Hoplitidae, Lyelliceratidae, Gaudryceratidae, Phylloceratidae) and 10 genera of three suborders (Phylloceratina, Lytoceratina, Ammonitina) of monomorphic ammonites. A total of 20 taxa has been identified, mostly to species level, and some specimens have been identified to the generic level in open nomenclature.

The family Kossmaticeratidae is represented by the genera *Marshallites* and *Eogunnarites* (subfamily Marshallitinae). Quite a few specimens in our collection belong to the genus *Marshallites* (Plate I). The four species were identified, including *M. olcostephanoides* Matsumoto (Plate I, figs. 1, 2, 23, 26), *M. compressus* Matsumoto (Plate I, fig. 3), *M. cumshewaensis* (Whiteaves) (Plate I, figs. 4–8, 27), and *M. columbianus* McLearn (Plate I, figs. 9–11, 13–22). The first three species are zonal species dated to the middle and upper Cenomanian, while the Albian zone *Marshallites cumshewaensis* partially overlaps the lower Cenomanian (Fig. 2). The specimens shown in Plate I (figs. 12, 24, 25) and Plate V (fig. 6) have been identified as *Marshallites* sp., since the state of their preservation does not allow a more specific determination. Ammonites of the genus *Marshallites* from Northeastern Russia were first described by G.P. Terekhova (1980). *M. olcostephanoides* and *M. columbianus* were also found in the described collection, but we were unable to find the new species *Marshallites tumefactus* Terechova, which was described by G.P. Terekhova. *Marshallites* can be assigned to the so-called "North Pacific genera," which appeared in the Northeast, Sikhote-Alin, Sakhalin, Alaska, British Columbia, California, and Japan at the end of the Albian (*Mar-*

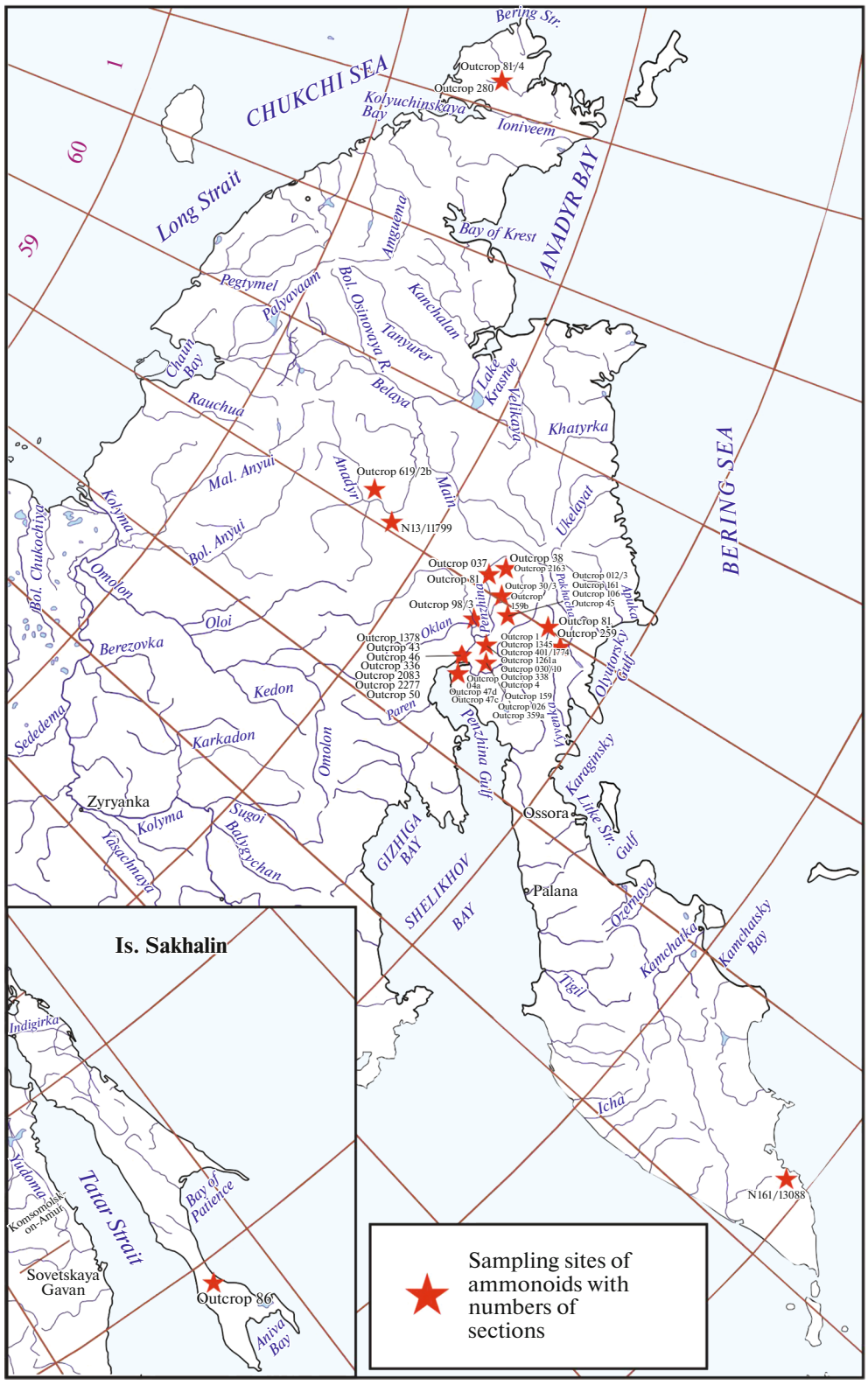


Fig. 1. Map of the distribution of Cretaceous deposits in the northeast and far east of Russia. Stars indicate sampling sites.

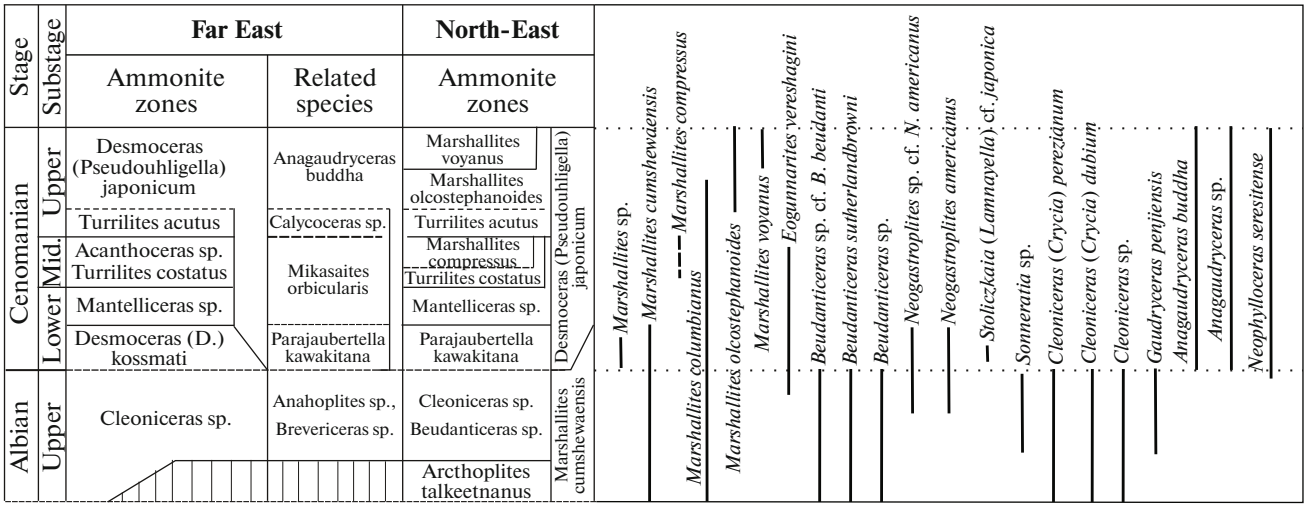
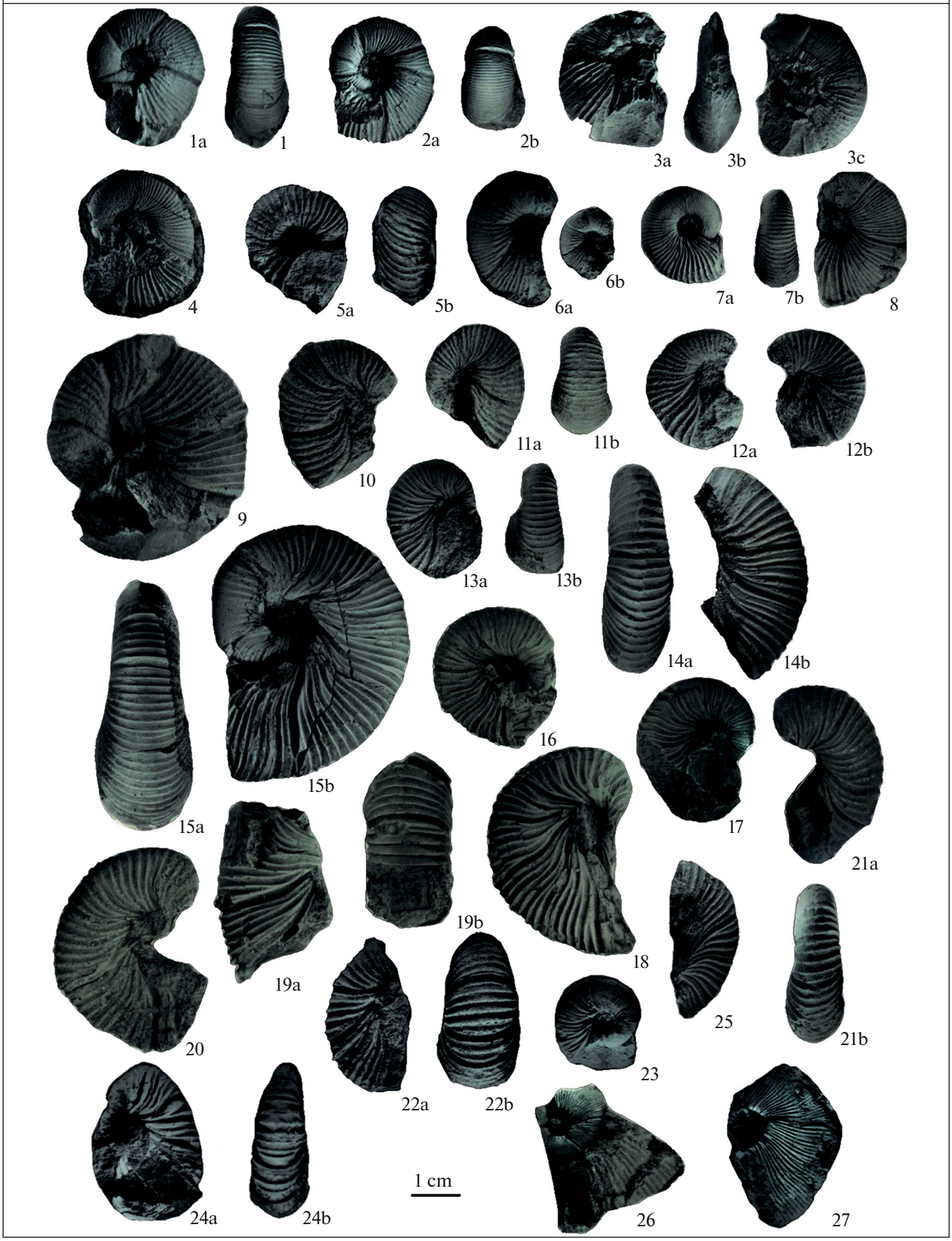


Fig. 2. Stratigraphic distribution of the ammonoid taxa discussed in this paper.

shallites cumshewaensis, *M. columbianus*; Fig. 2) and became widely distributed in the Cenomanian throughout the northern part of the Pacific paleobiogeographic realm (PPR). T. Matsumoto (1991) described nine species of this genus from Japan (*M. cumshewaensis*, *M. olcostephanoides*, *M. miyakoensis*, *M. compressus*, *M. hendersoni*, *M. virgatoides*, *M. involutus*, *M. rotundatus*, and *M. kossmati*). The ammonite assemblage in North-Eastern Russia is less diverse, which may be due to a variety of reasons, such as an insufficient number of finds, or less favorable habitat conditions, such as temperature and depth of the basin, or the need for a taxonomic revision of the subfamily Marshallitinae, etc. Several representatives of *Marshallites* were found in the Upper Albian deposits of southern Sakhalin and Sikhote-Alin (Yazykova, 2001). So far, the Late Albian representatives are the most ancient ones of this genus found in the region. *Marshallites* cf. *miyakoensis* Obata et Futakami from Japan is currently the oldest known representative of the genus *Marshallites* in the Paleo-Pacific. It is found in the upper part of the Aptian stage (Matsumoto and Murakami, 1991).

Plate I. (1, 2, 23, 26) *Marshallites olcostephanoides* Matsumoto: (1) no. 1/13088, (a) lateral view, (b) ventral view, Niklekuyul River, Penzhina River valley, North-East of Russia, collection of Yu.G. Mirolyubov, 1973, outcrop 037; (2) no. 24/13088, (a) lateral view, (b) ventral view, (26) no. 110/13088; Klyuch Golodny River, Penzhina River Valley, North-East of Russia, collection of T.D. Zonova, 1972, outcrop 106; (23) no. 124/13088, Klyuch Skalny River, left tributary of the Klyuch Golodny River, Penzhina River valley, North-East, collections of Yu.G. Mirolyubova, published in 1972, outcrop 012/3; Upper Cenomanian, Marshallites olcostephanoides Zone; (3) *Marshallites compressus* Matsumoto, no. 204/13088, (a) left lateral view, (b) ventral view, (c) right lateral view, Klyuch Vtoroy River, Cape Mamet, coast of Penzhina Bay, North-East of Russia, collections of Yu.G. Mirolyubov, 1971, outcrop 04a; Middle Cenomanian, *Marshallites compressus* Zone; (4–8, 12, 27) *Marshallites cumshewaensis* (Whiteaves): (4) no. 30/13088, (5) no. 126/13088, (a) lateral view, (b) ventral view, Maly Upupkin River, a tributary of the Belaya River, collection of T.D. Zonova, 1972, outcrop 1; (6) no. 29/13088, (a) lateral view (×2), (b) lateral view (×1), Tikhlivayam River, Penzhina River Valley, North-East of Russia, collection of Yu.G. Mirolyubov, 1971, outcrop 30/7; (7) no. 28/13088, (a) lateral view, (b) ventral view, Amytgin River, Penzhina River valley, North-East of Russia, collections of Yu.G. Mirolyubov, 1971, outcrop 026; (8) no. 172/13088, Povorotnaya River, tributary of the Omutnaya River, Penzhina River valley, North-East, collections of T.D. Zonova, 1972, outcrop 38; Upper Albian–Lower Cenomanian, Marshallites cumshewaensis Zone; (12) no. 205/13088, (a) left lateral view, (b) right lateral view; (27) no. 67/13237, Maly Upupkin River, tributary of the Belaya River, opposite the Neprokhodimy stream, Penzhina River valley, North-East of Russia, collections of T.D. Zonova, 1972, outcrop 1345; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (9–11, 13–22) *Marshallites columbianus* McLearn: (9) no. 10/13088, (10) no. 16/13088, (11) no. 12/13088, (a) lateral view, (b) ventral view; Maly Upupkin River, tributary of the Belaya River, opposite the Neprokhodimy stream, Penzhina River valley, North-East of Russia, collections of A.F. Mikhailov, 1955, outcrop 161; collections of T.D. Zonova, 1972, outcrop 1345; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (13) no. 15/13088, (a) lateral view, (b) ventral view; (14) no. 25/13088, (a) ventral view, (b) lateral view; Amytgin River, tributary of the Talovka River, Penzhina River valley, North-East of Russia, collections of Yu.G. Mirolyubov, 1971, outcrop 026; (15) no. 199/13088, (a) ventral view, (b) lateral view, (16) no. 171/13088 = no. 47/11799, (17) no. 198/13088, (18) no. 202/13088, (19) no. 200/13088, (a) lateral view, (b) ventral view, (20) no. 197/13088, (21) no. 196/13088, (a) lateral view, (b) ventral view, (22) no. 26/13088, (a) lateral view, (b) ventral view; Amytgin River, tributary of the Talovka River, Penzhina River valley, North-East of Russia, A.F. collections of A.F. Mikhailov, 1955, outcrop 359a; collections of Yu.G. Mirolyubov, 1971, outcrop 30/7; Upper Albian–Lower Cenomanian, Marshallites cumshewaensis Zone; (24, 25) *Marshallites* sp.: (24) no. 189/13088, (a) lateral view, (b) ventral view, Klyuch Skalny River, left tributary of the Klyuch Golodny River, Penzhina River valley, North-East, collections of Yu.G. Mirolyubov, 1972, outcrop 012/3; (25) no. 111/13088, Klyuch Golodny River, Penzhina River valley, North-East of Russia, collections of T.D. Zonova, 1972, outcrop 45; Lower Cenomanian, Marshallites cumshewaensis Zone.

Plate I


1a
1
2a
2b
3a
3b
3c
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5a
5b
6a
6b
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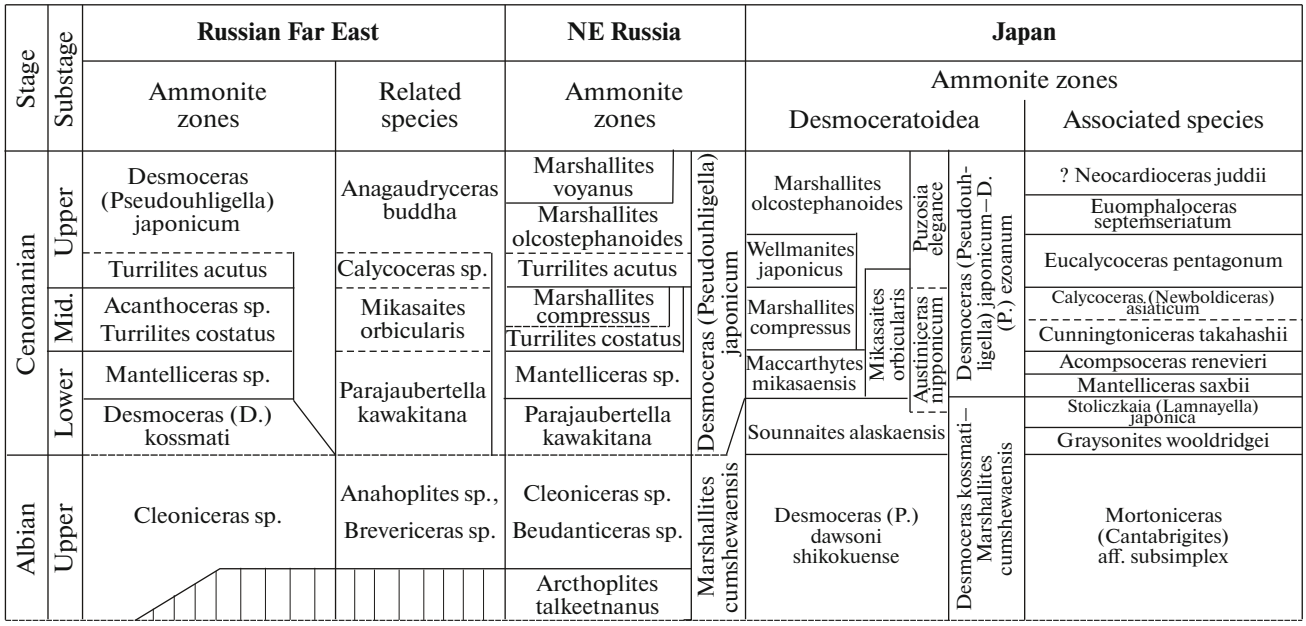


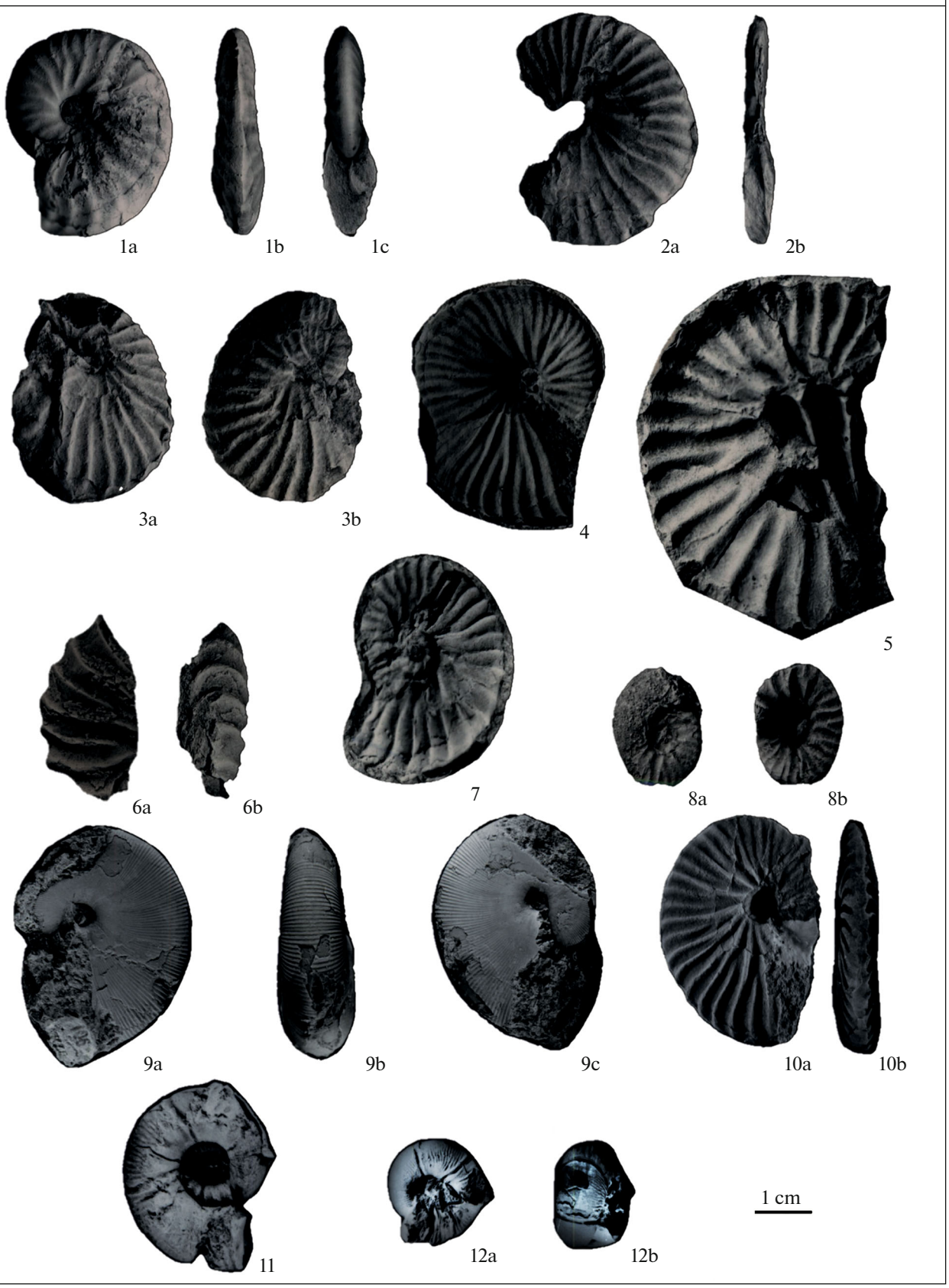
Fig. 3. Zonal subdivision of Albian–Turonian deposits in the Russian Far East based on ammonoids (Jagt-Yazykova, 2011; this paper) and comparison with the zonal scheme of Japan (Toshimitsu et al., 1995).

In the Cenomanian deposits of southern Sakhalin, in the Naiba River basin, only one species was found (*M. olcostephanoides* Matsumoto) (*Opornyi*..., 1987; Yazykova, 2001). Two species, *M. cumshewaensis* and *M. columbianus*, are also known from Cenomanian deposits of British Columbia, Alaska, and California (Matsumoto, 1959, 1991).

Thus, it can be considered that *Marshallites* is a typical North Pacific genus, which appeared here in the late Aptian–Albian and became widespread in the Cenomanian. Terekhova (1980) distinguished the beds with *Marshallites* ex gr. *voyanus* in the Cenomanian–Turonian of Ugolnaya Bay of Anadyr Gulf. Later, E.A. Jagt-Yazykova and T.D. Zonova (2012) limited the age of Beds with *Marshallites voyanus* to the upper Cenomanian. The subfamily Marshallitinae did not survive the Cenomanian–Turonian boundary. On the other hand, Matsumoto (1991) noted that some ammonites from the Campanian and even Maastrichtian of South India, for example "Gunnarites kalika" (Kennedy and Klinger, 1985, figs. 34a–34c) may belong to the genus *Marshallites*. The above authors also described *Marshallites* cf. *cumshewaensis* from the Coniacian of Zululand in South Africa and suggested that the genus *Marshallites* may also be present in New Zealand, citing some specimens from Henderson's collection (Henderson, 1970). This means that members of this genus could potentially have reached the Atlantic–Indian Province during the Turonian–Coniacian, and possibly New Zealand during the Santonian–Campanian, migrating from the PPR to other regions of the world. This statement is still only a hypothesis. In the studied region, the maximum flourishing of this subfamily occurred during the Cenomanian age, and later finds have not been discovered.

Plate II. (1–4, 6, 7, 10) *Neogastroplites* sp. cf. *N. americanus* (Ress. and Weym.): (1) no. 175/13088, (a) lateral view, (b) ventral view, (c) apertural view, outcrop 1378, (2) no. 141/13088, (a) lateral view, (b) ventral view, (3) no. 140/13088, (a) right lateral view, (b) left lateral view; north-eastern coast of Penzhina Bay, outcrop 2083, collections of V.P. Pokhialainen, 1962; (4) no. 107/13088 (impression), (6) no. 144/13088, (a) lateral view, (b) ventral view; Penzhinsky Ridge, right tributary of the Chikhangi-Akat River, outcrop 26, collections of G.A. Zakrzhevsky, 1958; Upper Albian–Cenomanian; (7) no. 133/13088, Pekulney Mountains, outcrop 81/4, collection of G.A. Kibanov, 1953; Upper Albian–Cenomanian; (10) no. 106/13088, (a) lateral view, (b) ventral view; northeastern coast of Penzhina Bay, outcrop 45, collection of A.I. Tikhomirov, 1960; Lower Cenomanian, Parajaubertella kawakitana Zone; (5) *Stoliczkaia* (*Lamnayella*) cf. *japonica* (Matsumoto, Kiwuka et Katto), no. 105/13088, north-eastern coast of Penzhina Bay, outcrop 45, collection of A.I. Tikhomirov, 1960; Lower Cenomanian, Parajaubertella kawakitana zone; (8) *Sonneratia* sp., no. 135/13088, (a) right lateral view, (b) left lateral view; Pekulney Mountains, upper reaches of the Kriovoy stream, outcrop 280, collection of V.A. Kitaev, 1955; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (9) *Neophylloceras seresitense* (Pervinquière), no. 113/13088, (a) right lateral view, (b) ventral view, (c) left lateral view, Penzhina River basin, Golodny Klyuch River, outcrop 106, collections of T.D. Zonova, 1972; Upper Cenomanian, Marshallites olcostephanoides Zone; (11, 12) *Eogunnarites vereshagini* Terekhova: (11) no. 43/13088, NE coast of Penzhina Bay, Cape Mamet between the Pervyi Klyuch and Vtoroi Klyuch rivers, outcrop 043, collection of Yu.G. Mirolyubov, 1973; (12) no. 166/13088, (a) lateral view, (b) ventral view; Pontonean Mountains, outcrop 30/3, collection of Yu.G. Mirolyubov, 1971; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone.

Plate II



The next species found in our collection is *Eogunnarites vereshagini* Terekhova (Terekhova, 1980; this work, Plate II, figs. 11, 12; Plate IV, figs. 3–5; Plate V, figs. 1–4). This species is considered to be endemic to the Pacific region and has not been found anywhere else in the world. Terekhova (1980) identified this species as *Brahmaites* (B.) *brahma* (Forbes), based on one specimen from her own collection and another one described in an atlas for the North-East of Russia (Vereshchagin et al., 1965). However, this is a Maastrichtian species, and the age of the deposits has been determined to be Cenomanian (Turrilites costatus Zone) (Terekhova, 1980). The present authors do not revise the species, but the three specimens shown in Plate II (figs. 11, 12) do fit its description. This species is similar to *Eogunnarites matsumotoi* Murphy et Rodda and *E. alaskaensis* Matsumoto, mentioned in the description *Eogunnarites* sp. by G.P. Terekhova (1980). The authors decided to classify the studied specimens as *Eogunnarites vereshagini* Terekhova, since they differ in sculpture and size from the two species mentioned above. The stratigraphic distribution of this species most likely covers Upper Albian Cleoniceras sp.–Beudanticeras sp. Zone and Middle Cenomanian Turrilites costatus Zone (Fig. 2). Previously, it was also mentioned by T.D. Zonova (2004) when describing the reference section of the Albian–Cenomanian deposits of the Penzhina Depression. The related species included Albian zonal index species, such as *Pseudobelioceras carlottense* (Whiteaves) and *Inoceramus anglicus* Woods. However, the ammonites found by G.P. Terekhova (1980) come from the Middle Cenomanian Turrilites costatus Zone. Alabushev (1995) described one specimen as *Eogunnarites unicus* (Yabe) from the lowest Cenomanian. Thus, the genus *Eogunnarites* was most likely widespread during the late Albian–middle Cenomanian stratigraphic interval and was an endemic to the Paleo-Pacific region.

The Lyelliceratidae family is represented in the collection by the subfamily Stoliczkaiellinae, which includes only the early Cenomanian species *Stoliczkaia* (*Lamnayella*) cf. *japonica* (Matsumoto, Kiwuka et Katto) (Plate II, fig. 5). This allows us to clarify the age of one location on the north-eastern coast of Penzhina Bay (outcrop 45), which was previously defined as Albian–early Cenomanian. In the work of T. Matsumoto et al. (2004), the Early Cenomanian age of the complex Stoliczkaia (Lamnayella) japonica Zone established on Hokkaido Island has been convincingly identified, as it contains zonal cosmopolitan species that allow for global correlation. Matsumoto also provided radiometric data confirming the age of the complex Stoliczkaia (Lamnayella) japonica Zone. It lies below the well-defined Mantelliceras saxbii Zone and above the basal Cenomanian Graysonites wooldridgei Zone (Fig. 3). The specimen presented in this paper is poorly preserved, so the definition is provided in open nomenclature. Due to the small number of specimens, the Stoliczkaia (Lamnayella) japonica Zone is not yet been distinguished in the North-East of Russia. However, this discovery is extremely important, as it clarifies the age of the deposits. In general, the Lyelliceratidae family is not well represented in the sections of the northwestern Paleo-Pacific. So far, only a few representatives of the above family have been found in Japan and North-East Russia.

The Hoplitidae family in the described collection is represented by three subfamilies: Cleoniceratinae, Gastroplitinae, and Sonneratiinae, but its taxonomic diversity is low. Only five taxa have been identified: *Cleoniceras* (*Crycia*) *perezianum* (Whiteaves) (Plate VI, fig. 1), *Cleoniceras* (*Crycia*) *dubium* Michailova et Terechova (Plate VI, fig. 3), and *Cleoniceras* sp. (Plate IV, figs. 1, 2; Plate VI, fig. 2) (Cleoniceratinae); *Neogastroplites americanus* (Reeside et Weymouth) (Plate V, figs. 7, 8) and *Neogastroplites* sp. cf. *Neogastroplites americanus* (Reeside and Weymouth) (Gastroplitinae) (Plate II, figs. 1–4, 6, 7, 10); *Sonneratia* sp. (Sonneratiinae) (Plate II, fig. 8). Most taxa are from the North Pacific region, which makes them well suited for regional correlation studies. Only the genus *Sonneratia* is not included in this list as it has also been found in Europe (Bayle, 1878; Kennedy et al., 1981), tas well as in he Upper Albian of Arctic Canada (Jeletzky, 1964), California and Oregon in the USA (Anderson, 1938; Jones et al., 1965). Several *Sonneratia* species have been found in sections of North-East Russia. This late Albian genus can be further used for interregional correlation.

Cleoniceras (*Crycia*) *perezianum* (Whiteaves) and *Cleoniceras* (*Crycia*) *dubium* Michailova et Terechova are late Albian North Pacific species (Alabushev, 1995; Jaht-Yazykova and Zonova, 2012). The genus *Cleoniceras* can be considered to be cosmopolitan.

The situation with the taxonomic definitions of gastroplitines is quite complex, as they are classified as *Neogastroplites americanus* (Reeside et Weymouth) and *N.* sp. cf. *N. americanus* (Reeside et Weymouth). It is possible that *N. kamchatkensis* Alabushev et Wiedmann, 1994, previously described from the North-East of Russia, is a twin species of *N. americanus* (Reeside et

Plate III. (1, 2) *Anagaudryceras buddha* (Forbes): (1) No. 120/13088, (a) lateral view, (b) apertural view; Penzhina River basin, outcrop 98/3, collection of T.V. Tarasenko, 1957; (2) no. 30/10693, (a) lateral view, (b) ventral view; Sakhalin, Naiba River, oucrop 86 (see Poyarkova, 1987, Plate XXIII, fig. 8a); Upper Albian–Cenomanian, Desmoceras (Pseudouhligella) japonicum Zone; (5, 6) *Anagaudryceras* cf. *buddha* (Forbes): (5) no. 84/13088, (6) no. 83/13088, north-eastern coast of Penzhina Bay, Cape Mamet, mouth of the Vtoroi Klyuch River, outcrop 047, collection of Yu.G. Mirolyubov, 1973; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (3, 4) Beudanticeras sp.: (3) no. 173/13088, (4) no. 174/13088, north-eastern coast of Penzhina Bay, outcrop 50, collection of M.A. Pergament, 1954; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone.

Plate III



Weymouth) (Jagt-Yazykova and Zonova, 2012). The genus *Neogastroplites* is known from the Albian and Cenomanian and is widespread in the PPR. Alabushev (1995) believed that the species *N. kamchatkensis* replaced *N. americanus* in the sections of North-East Russia. W. A. Cobban wrote in a private letter to E. A. Yazykova (2000) that, in his opinion, all *Neogastroplites* in the North-East of Russia belong to *N. kamchatkensis*, since *N. americanus* is endemic to the Mowry Inland Sea of North America. There is no doubt that *Neogastroplites* has a high degree of adaptability to changing conditions and a wide range of variability in its ontogenesis (Kennedy and Cobban, 1976; De Baets et al., 2015), and some authors even call it extreme (Yacobucci, 2004). A.I. Alabushev and J. Wiedmann (1994, p. 72, 73) described *N. kamchatkensis* as being similar to *N. americanus* and distinguished it from different morphotypes found in various regions of the PPR based on their morphological features. The authors of this article are not yet ready to draw a final conclusion, as a detailed comparison of these two species and all known morphotypes is necessary, taking into account their geographical and stratigraphic distributions. For now, we will assume that both species are present in the North East of Russia, but can be found in both the upper Albian and Cenomanian deposits (Fig. 2).

Based on the number of finds, the family Gaudryceratidae, one of the most widespread in the Cretaceous deposits of various regions of the PPR, is represented in the collection by two genera: *Gaudryceras* with the endemic species *Gaudryceras penjiensis* Vereschagin (Plate V, fig. 3) and *Anagaudryceras* with the species *Anagaudryceras buddha* (Forbes) (Plate III, figs. 1, 2) and *Anagaudryceras* cf. *buddha* (Forbes) (Plate III, figs. 5, 6). Additionally, there are two disputed specimens, which are identified as *Anagaudryceras* sp. (Plate V, figs. 2, 5). The genus *Anagaudryceras* is considered to be cosmopolitan. The species *A. buddha* (Forbes) also has a wide geographic distribution and can be considered an oceanic cosmopolitan. The stratigraphic range of the species is limited to the Cenomanian, but there are some finds that may extend this range to the Turonian (Madagascar) and Coniacian (Japan) (Kennedy and Klinger, 1979). Based on these data, it can be assumed that there has been further migration of this species, or that there have been errors in its identification in the territory of Madagascar and Japan, since there were only a few reports of the presence of *A. buddha* (Forbes) (Kennedy and Klinger, 1979).

Another species, *Neophylloceras seresitense* (Pervinquière), which can be considered cosmopolitan and is also known from the upper Albian of Japan and Cenomanian of the Pacific regions of Russia, belongs to the family Phylloceratidae (Plate II, fig. 9). This species also needs revision. *Phylloceras velledae seresitense* was described by L. Pervinquière (1907) as a Cenomanian cosmopolitan species. Later it was assigned by Matsumoto (Matsumoto, 1959) to the genus *Neophylloceras*. Other researchers (Förster, 1975) classified this species as *Phylloceras* (*Hypophylloceras*), *Phylloceras* (Szives, 2007) or *Hyporbulites* (Collignon, 1956; Oudni et al., 2025). The authors of this work classify this taxon into the genus *Neophylloceras*. The stratigraphic distribution of the species is most likely limited to the terminal Albian–Cenomanian (Fig. 2). T.D. Zonova (2004) noted its first occurrence precisely at the Albian–Cenomanian boundary or in Middle Cenomanian deposits in many sections of the Penzhina Depression.

The family Desmoceratidae is represented only by a genus *Beudanticeras* (Beudanticeratinae), which is usually considered to be Albian (Wright et al., 1996). The species *Beudanticeras sutherlandbrowni* (McLearn) identified by the authors (Plate VI, figs. 4–6; Plate VII, figs. 1–6) was originally described as the member of the genus *Proplacenticeras*. For the first time in the North-East of Russia, Vereshchagin et al. (1965, p. 61, Plate 74, figs. 3a, 3b, 4) described as *Proplacenticeras* ? sp. found in the Penzhina River basin. Later, this specimen was identified along with other samples by A.I. Alabushev (1988) as the species *sutherlandbrowni*. However, it was assigned to the new genus *Rapidoplacenticeras* (Alabushev, 1988; Alabushev, 1995; Alabushev and Wiedmann, 1997). Later, the genus *Rapidoplacenticeras* was included in the synonymy of *Beudanticeras* as a synonym of the juvenile form (Riccardi and Medina, 2002; Latil et al., 2023). The authors of this article agree with this decision. *B. sutherlandbrowni* (McLearn) is known only in the northern Pacific region (north-east Russia and Canada, British Columbia (McLearn, 1972)), that is, apparently, it is a typical endemic species of the northern Paleo-Pacific. Since *B. sutherlandbrowni* was found in the Cretaceous deposits of the Maly Upupkin River basin (outcrop 1345), a tributary of the Penzhina River, then the age of these deposits is also considered to be Late Albian. Previously, these deposits had been attributed to the Albian–Cenomanian and were dated by A.I. Alabushev (1988) to the Albian–Cenomanian

Plate IV. (1, 2) *Cleoniceras* sp.: (1) то. 176/13088, (a) lateral view, (b) apertural view, (c) lobe line; north-eastern coast of Penzhina Bay, outcrop 2277, collection of V.P. Pokhialainen, 1962; (2) no. 186/13088, Anadyr River basin, outcrop 619/6b, collection of V.F. Belyi, 1959; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (3–5) *Eogunnarites vereshagini* Terekhova, (3) no. 43/13088, (a) lateral view, (b) ventral view, (c) apertural view; northeastern coast of Penzhina Bay, Cape Mamet, mouth of the Vtoroi Klyuch River, outcrop 047, collection of Yu.G. Mirolyubov, 1973; (4) no. 23/13088, (a) lateral view, (b) apertural view; Penzhina River basin, upper reaches of the Izvilistaya River, tributary of the Niklekuyul River, outcrop 2163, collection of V.P. Pokhialainen, 1962; (5) no. 21/13088, (a) left lateral view, (b) ventral view, (c) right lateral view; Pontonean Mountains, Amytgin River, outcrop 159b, collections of A.F. Mikhailov, 1955; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone.

Plate IV



or Cenomanian. The same correction applies to the deposits on the Amytgin River, Pontoneus Mountains (outcrop 159), from where *B.* cf. *sutherlandbrowni* (McLearn) was identified (Plate VII, figs. 7–9). Another specimen of this genus, described in 1965 (Vereshchagin et al., 1965, pl. 19, fig. 1), was found in the Anadyr River basin, a tributary of the Orlovka River. It was identified as *Beudanticeras* sp. cf. *B. beudanti* Brongniart (Plate VIII). *B. beudanti* is also classified as an Albian species (Kennedy, 1993). Previously, *Beudanticeras* aff. *glabrum* (Whiteaves) was identified in the Albian of the North-East of Russia (Terekhova and Basov, 1972), and *Beudanticeras* (*Grantziceras*) *affine* (Whiteaves), found on the Mamet River, was mentioned without an image (Shigeta et al., 1999). The authors of this paper consider this level to be quite reliable for biostratigraphic correlations. In this study, the Cleoniceras sp.–Beudanticeras sp. zone is distinguished in the regional zonal scheme, since both genera are cosmopolitan.

RESULTS AND DISCUSSION

In total, 20 taxa of Albian–Cenomanian monomorphic ammonoids collected in the Pacific regions of Russia were identified in the studied collection, including taxa in open nomenclature. The collection under consideration includes six families of ammonoids (Desmoceratidae, Kossmaticeratidae, Hoplitidae, Lyelliceratidae, Gaudryceratidae, Phylloceratidae). In total, to date, in this vast region (North-East of Russia–Sakhalin–Primorye), 14 families of Albian ammonoids have been identified, as well as eight Cenomanian families. As a result, some age adjustments were made to several locations. Additionally, the stratigraphic distribution of the studied taxa (Fig. 2) and the age of zonal divisions (Fig. 3) have been clarified, allowing for a more accurate regional biostratigraphic scheme. Some taxa can be used to make global correlations, including *Neophylloceras seresitense* (Pervinquière), *Anagaudryceras buddha* (Forbes), *Beudanticeras* sp. cf. *B. beudanti* Brongniart, and *Sonneratia* sp.

Despite the fact that the studied collection is mainly represented by taxa that are likely to be of North Pacific origin based on their distribution, it can be concluded that there was a relatively high level of biodiversity in the Albian–Cenomanian period. The first occurrence of cosmopolitan ammonoid species in the PPR was associated with transgression and comfortable temperatures in early Albian (12.5°–21.6°C) (Zakharov et al., 2006). At the Albian–Cenomanian

Plate V. (1, 4) *Eogunnarites vereshagini* Terekhova: (1) no. 44/13088, (a) ventral view, (b) lateral view; (4) no. 41/13088, (a) ventral view, (b) right lateral view, (c) left lateral view, (d) apertural view; Penzhina River basin, upper reaches of the Izvilistaya River, tributary of the Niklekuyul River, outcrop 81, collection of Yu.G. Mirolyubov, 1973; outcrop 2163, collection of V.P. Pokhialainen, 1962; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (2, 5) *Anagaudryceras* sp.: (2) no. 206/13088, Maly Upupkin River, tributary of the Belaya River, Penzhina River valley, North-East of Russia, collection of T.D. Zonova, 1972, outcrop 401/1774; (5) no. 161/13088, Lesnaya River area, Western Kamchatka, collection of N.M. Markin, 1961; upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (6) *Marshallites* sp., no. 163/13088, Klyuch Golodny River, Penzhina River valley, North-East of Russia; upper Albian–Cenomanian, Marshallites cumshewaensis Zone; (3) *Gaudryceras penjiensis* Vereschagin, no. 45/13088, (a) lateral view, (b) apertural view; Penzhina River basin, upper reaches of the Izvilistaya River, tributary of the Niklekuyul River, outcrop 81, collection of Yu.G. Mirolyubov, 1973; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (7, 8) *Neogastroplites americanus* (Reside et Weymouth): (7) no. 130/13088, (8) no. 129/13088, (a) right lateral view, (b) ventral view, (c) left lateral view; the coast of Penzhina Bay, Cape Mamet, between the Pervyi Klyuch and Vtoroi Klyuch rivers, North-East of Russia, collections of Yu.G. Mirolyubov, 1973, outcrop 047v; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone.

Plate VI. (1) *Cleoniceras* (*Crycia*) *perezianum* (Whiteaves), No. 145/13088, (a) lateral view, (b) ventral view; Koryak Upland, North-East, collection of E.V. Ankudinov, 1964, outcrop 259; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (2) *Cleoniceras* sp., no. 177/13088, (a) lateral view, (b) apertural view; coast of Penzhina Bay, North-East of Russia, collection of M.A. Pergament, 1953, outcrop 336; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (3) *Cleoniceras* (*Crycia*) *dubium* Michailova et Terechova, no. 185/13088, (a) lateral view, (b) apertural view; Anadyr River basin, North-East of Russia, collection of B.F. Belyi, 1955, outcrop 619/2b; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (4–6) *Beudanticeras sutherlandbrowni* (McLearn): (4) no. 62/13088; (5) no. 60/13088, (a) lateral view, (b) apertural view; Tikhlyavayam River, Penzhina Bay, North-East of Russia, collection of A.F. Mikhaylov, 1955, outcrop 4; (6) no. 66/13088, (a) lateral view, (b) apertural view; Maly Upupkin River, a tributary of the Belaya River, right bank of the left ravine 2 km upstream from the mouth, Penzhina River valley, North-East of Russia, collection of T.D. Zonova, 1972, outcrop 1; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone.

Plate VII. (1–6) *Beudanticeras sutherlandbrowni* (McLearn): (1) no. 52/13088, (a) left lateral view, (b) apertural view, (c) right lateral view, (2) no. 49/13088; (4) no. 61/13088, (a) lateral view, (b) apertural view; (5) no. 50/13088, (a) right lateral view, (b) ventral view, (c) left lateral view, (d) view from the mouth; (6) no. 73/13088, (a) lateral view, (b) ventral view; Tikhlyavayam River, Penzhina Bay, North-East of Russia, collection of I.M. Migovich, outcrop 1261a; collection of Yu.G. Mirolyubov, 1971 outcrop 030/10; collection of A.F. Mikhailov, 1955, outcrop 4; collection of M.A. Pergament, 1959, outcrop 338; (3) no. 77/13088, (a) left lateral view, (b) view from the mouth, (c) right lateral view; the Maly Upupkin River, a tributary of the Belaya River, the Penzhina River valley, North-East of Russia, collection of T.D. Zonova, 1972, outcrop 1345; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone; (7–9) *Beudanticeras* cf. *sutherlandbrowni* (McLearn): (7) no. 59/13088, (8) no. 58/13088, (a) lateral view, (b) ventral view; (9) no. 57/13088, (a) lateral view, (b) ventral view; Amytgin River, Penzhina River valley, North-East of Russia, collection of A.F. Mikhailov, 1955, outcrop 159; Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone.

Plate V



Plate VI

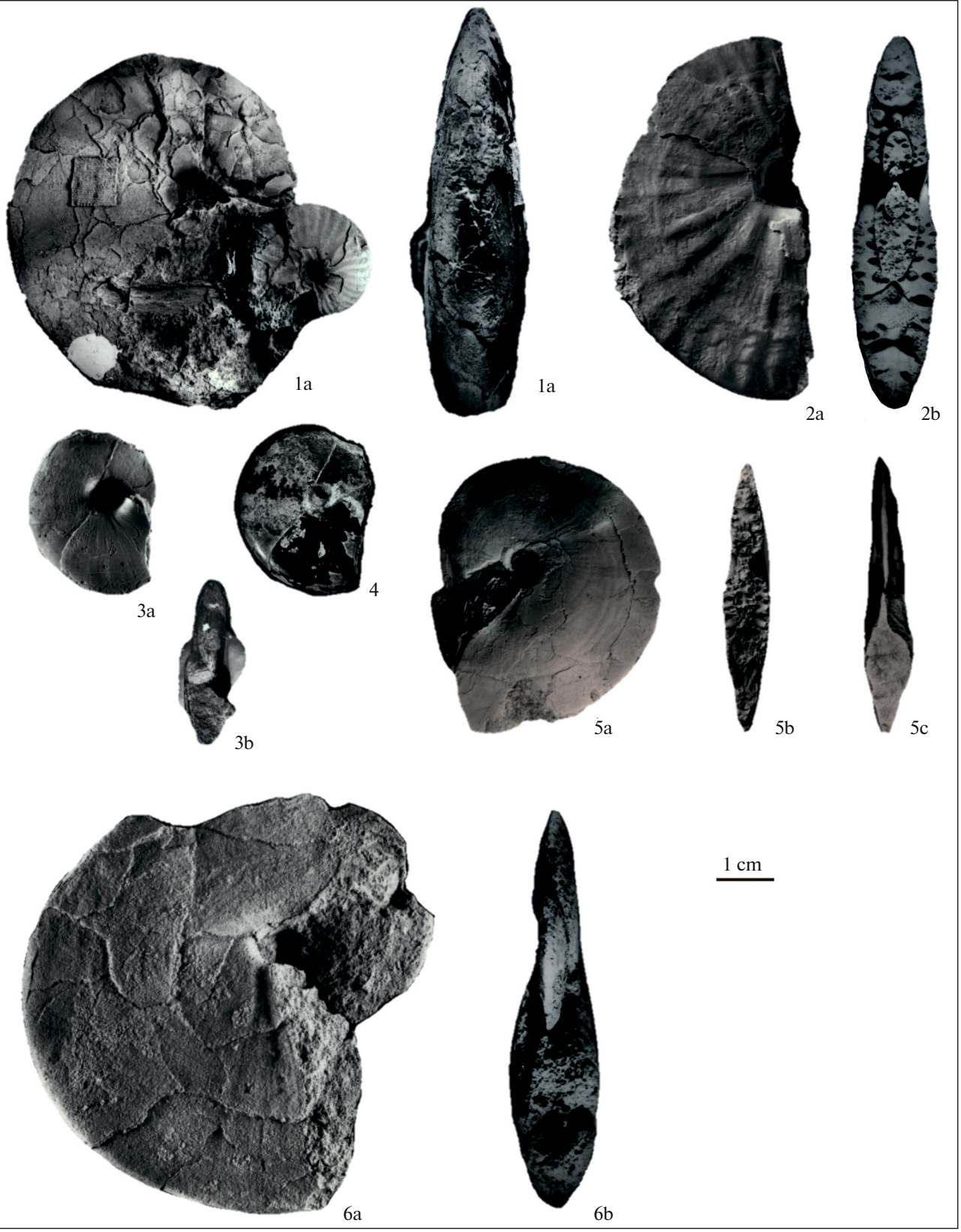


Plate VII



Plate VIII



Plate VIII. *Beudanticeras* sp. cf. *B. beudanti* Brongniart (×0.5), no. 13/11799, Anadyr River basin, Orlovka River, North-East of Russia, collection of V.F. Belyi, 1959 (see Vereshchagin et al., 1965, Plate 19, fig. 1); Upper Albian, Cleoniceras sp.–Beudanticeras sp. Zone.

boundary, a change in the ammonoid assemblages occurred (Jagt-Yazykova, 2011), as well as the last occurrence of the subfamilies Beudanticeratinae and Cleoniceratinae. However, the rest of the families and genera crossed this milestone. Representatives of the genera *Marshallites*, *Neophylloceras*, *Neogastroplites*, *Gaudryceras* and *Eogunnarites* are also found in the Cenomanian. During this period, migratory links between the Paleo-Pacific and Tethys were maintained, which is confirmed by the presence of cosmopolitan forms such as *Neophylloceras seresitense* (Pervinquière), *Anagaudryceras buddha* (Forbes), *Parapuzosia* (*Austiniceras*) *austeni* (Sharpe), genera *Mantelliceras* and *Acanthoceras* (Jagt-Yazykova and Zonova, 2012). Beginning in the late Cenomanian, as a result of a relatively short-term regression and active tectonic rearrangement, these links were broken (Kirillova, 2000). As a result, new migrants did not appear. In addition, differences in late Cenomanian ammonite complexes of Sakhalin, Primorye and Sikhote-Alin from the corresponding complexes of the north-eastern regions of the Pacific coast of Russia (Penzhina Bay, Koryakia) in terms of the taxonomic composition become more noticeable (Jagt-Yazykova and Zonova, 2012). The late Cenomanian is characterized by an increase in the degree of endemism and gradual isolation of the Pacific paleobiogeographic realm. All representatives of the Cenomanian fauna, including the dominant marshallitine and gastroplitine groups, disappeared at this level, which is consistent with a global mass extinction event at the Cenomanian–Turonian boundary.

CONCLUSION

According to Bengtson and Kakabadze (2018), the most significant event in the evolution of ammonites at the families and generic levels occurred at the end of the Aptian–beginning of the Albian (boundary interval), which provides grounds for placing the lower boundary of the "Middle Cretaceous" series at the base of the Albian Stage. In the Late Cretaceous, no such significant event was identified, except for the Cenomanian–Turonian boundary interval, which could be used as the upper boundary of the "Middle Cretaceous". This may be a strong argument for recognizing a Middle Cretaceous period but as stated above, comprehensive research is needed to fully understand this issue.

The studied Albian–Cenomanian fauna of the region represents a unique combination of endemic and cosmopolitan taxa, reflecting complex migration processes. This makes the studied interval important for understanding the evolution of the Pacific paleobiogeographic realm and its connections with other paleobiogeographic provinces.

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AUTHOR CONTRIBUTION

E.A. Yazykova wrote the main text, created figures 2 and 3, and compiled the table. V.A. Shamakov created Figure 1 and technically processed the table. He also participated in the taxonomic identification of the studied material and editing the text.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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