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New Data on Fauna and Biostratigraphy of Norian Deposits in the Kotel'nyi Island (New Siberian Islands)

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Abstract—A section of lower and middle Norian deposits in the Tikhaya River lower courses of (the central part of Kotel'nyi Island, New Siberian Islands) is described. After revision, the taxonomic composition of fauna from the sequence is verified, and formerly unknown taxa are identified. Stratigraphic range of ammonoids, nautiloids, coleoids, and conodonts in the section are analyzed, and the local biostratigraphic scheme, which includes zones, subzones, and beds with fauna, is suggested for the lower-middle Norian interval. Distinguished for the first time are beds with nautiloids, the *Striatosirenites kinasovi* Zone, and *Cyrtopleurites* ex gr. *altissimus* Beds with ammonoids. The local biostratigraphic scheme of Norian deposits is correlated with the ammonoid zonation in Canada and with the standard scale. Ammonoids of the genus *Cyrtopleurites*, which have been found for the first time in deposits of the Kotel'nyi Island and are characteristic of the *Cyrtopleurites bicrenatus* Zone, the lower one in the middle Norian of the standard scale, enabled the direct Boreal-Tethyan correlation of their host rocks and positioning of the lower-middle Norian boundary in Boreal regions. Geographic ranges of ammonoid, nautiloid, coleoid, and conodont taxa from Norian deposits of the Kotel'nyi Island are considered. Based on peculiar features of the studied fauna (coexistence of Boreal and Tethyan elements, a significant proportion of cosmopolitan taxa, and presence of species known from North America), the Kotel'nyi island region is defined as a separate subprovince in the Siberian Province of the Boreal Realm.

Key words: Triassic, cephalopods, conodonts, biostratigraphy, correlation, biogeography, Siberia.

INTRODUCTION

The taxonomic diversity of most invertebrate groups gradually increased during the Triassic and enhanced biogeographic distinctions between faunas of lower- and high-latitude areas (Dagys, 1974, 1976; Dagys *et al.*, 1979; Dagys and Shevyrev, 1981). In the Late Triassic, when geographic differentiation between marine invertebrates became obvious, the distinction of Tethyan fauna from those of the Boreal and Notal regions enhanced further.

Clear biogeographic distinctions between the Boreal and Tethyan faunas of the Late Triassic resulted in elaboration of autonomous Upper Triassic zonal schemes for these regions, on the one hand, and brought about a series of debatable problems concerning significant biostratigraphic boundaries and interregional correlation, on the other. Still debatable are the position of Middle-Upper Triassic boundary and ranges of Carnian and Norian stages in the Boreal Realm, and the problem of the Rhaetian calls for further investigations. The lower-upper Carnian and lower-middle Norian boundaries are also conventional to a considerable extent in distribution areas of Boreal deposits.

The direct correlation of Triassic deposits in the Boreal and Tethyan regions seems to be possible only for some intervals corresponding to episodes of eustatic sea-level rise, which resulted in a greater taxonomic similarity of faunas in different biochores. For instance, the lower boundary of the upper Norian is reliably traceable in all the regions at the appearance level of the cosmopolitan bivalve genus *Monotis* (Dagys and Tozer, 1989; *Obshchaya shkala…*, 1984). Ammonoids of the genus *Neoprotrachyceras* enable correlation between the lower Carnian *Neoprotrachyceras seimkanense* Zone of Siberia and the standard *Austrotrachyceras austriacum* Zone (Krystyn, 1978; *Obshchaya shkala…*, 1984). Some stratigraphic intervals of the Carnian and of the lower and middle Norian in Boreal regions are correlated with coeval deposits of the Tethys based on transitional sections of British Columbia and Arctic Canada. As is well known, the abundant and diverse ammonoid fauna of British Columbia includes taxa (genera *Stolleyites, Pterosirenites, Wangoceras, Norosirenites, Pleurodistichites, Neohimavatites)* widespread in Boreal sections and are associated here with numerous Tethyan ammonoids.

In addition to recognition and tracing of reference levels and to the analysis of ecotones, the comprehensive study of different fossil groups and geographic differentiation of faunas within the Boreal region are also of interest for the Boreal–Tethyan correlation of the

Upper Triassic. The complete marine sequences of the Upper Triassic well characterized by fauna are known in the Boreal Realm of northeastern Asia. The corresponding sea basin represented a system of shelf marginal seas bounded by the Siberian paleoland on the west and by the pre-Pacific ocean on the southeast (Bychkov, 1992). The geographic differentiation of Late Triassic ammonoid, nautiloid, bivalve, and brachiopod faunas was insignificant in the vast territory of northeastern Asia, although some distinctions between non-orthostratigraphic groups of faunas from Yakutia and Kolyma–Okhotsk region have been reported (Dagys *et al.*, 1996). In some regions, however, e.g., in upper courses of the Bol'shoi Anyui River and in the Anadyr River basin, representatives of Tethyan bivalves and ammonoids appeared in Boreal fauna assemblages during the late Norian (Kiparisova *et al.*, 1966; Afitskii, 1970; Dagys *et al*., 1979; Bychkov, 1992). Some Tethyan ammonoid genera are also known from Norian deposits of the Kotel'nyi Island (Diener, 1916; 1924). Investigation of these mixed faunas from northeastern Asia, which include Tethyan and Boreal taxa, are of a great interest for paleobiogeography and detailed stratigraphy. Unfortunately, we should mention a different standard of knowledge on the Upper Triassic fauna and stratigraphy in separate regions of northeastern Asia.

The purpose of this work is to fill partially the gap by means of comprehensive biostratigraphic and biogeographic analyses of the Norian ammonoids, nautiloids, bivalves, and conodonts from the New Siberian Islands, the insufficiently studied and hard-to-reach region of northeastern Asia.

INVESTIGATION HISTORY OF UPPER TRIASSIC DEPOSITS IN THE KOTEL'NYI ISLAND

Triassic deposits of New Siberian Islands are poorly studied, as the region is rather remote and not easily accessible. Few publications are devoted to these deposits. Presence of Triassic deposits in the Kotel'nyi Island was established for the first time in 1801, when M.M. Hedenstrom found the *Hedenstroemia hedenstroemi* Keyserling ammonite species of the Early Triassic. His collection was comprehensively described by Keyserling (1845). Later geological expeditions to carried out on New Siberian Islands, with E.V. Toll and K.A. Vollosovich as participants, were organized by the Russian Academy of Sciences in 1886, 1893, and 1900, and afterward Diener (1916; 1924) described collection of the Upper Triassic fauna from the Kotel'nyi Island. In 1955–1956, geologists from the Research Institute of Arctic Geology (NIIGA) performed the geological survey at the scale of 1 : 1000000 in New Siberian Islands. D.A. Vol'nov, D.S. Sorokov, and S.V. Cherkesov studied the northern part of the Kotel'nyi Island. They established that the Triassic System of the Kotel'nyi Island includes three series with all stages except for the Induan and Rhaetian (Vol'nov *et al.*, 1970).

New data on the Triassic stratigraphy were obtained by geologists from NIIGA (D.A. Vol'nov, E.N. Preobrazhenskaya, M.K. Kos'ko, V.G. Trufanov, N.S. Bondarenko, B.P. Gavrilov, and V.F. Nepomiluev) in the course of thematic studies and geological survey in the Kotel'nyi Island in 1972–1974. Identification of numerous paleontological materials made it possible to verify the Triassic stratigraphy and to suggest a scheme of biostratigraphic subdivisions in Triassic deposits, which included stages and beds with fauna (Preobrazhenskaya *et al.*, 1975; Korchinskaya, 1977). The *Discophyllites taimyrensis*, *Sirenites hayesi*, and *Halobia* beds were distinguished within the Carnian. No ammonoids were found in overlying beds, although many *Halobia* species were found to occur in Norian deposits as well. In the Norian sequence (250 m thick), Korchinskaya distinguished the lower mudstone member with foraminifers, spores, and pollen of the Triassic habit, which have been attributed previously to the Carnian fossils. She divided the overlying deposits into the *Otapiria ussuriensis, Monotis scutiformis*, and *Monotis ochotica* beds were singled out. The mudstone sequence about 100 m thick that overlies the *Monotis ochotica* Beds was arbitrarily attributed to the Norian-Rhaetian based on foraminifers and palynological data.

In 1984, Triassic deposits in the central part of the Kotel'nyi Island and along its northwestern coast were studied by A.Yu. Egorov, Ya.A. Bogomolov, and Yu.M. Baranov, the researchers of the Cosmoaerogeological Expedition No. 3 (Moscow), and by A.G. Konstantinov from the Institute of Geology and Geophysics (Novosibirsk). Based on the results of field work and paleontological materials collected in abundance, they verified thickness, nomenclature, paleontological characteristics, and biozonation of some Lower and Middle Triassic subdivisions and significantly corrected the detailed stratigraphy of the Upper Triassic, especially of the Norian (Egorov *et al.*, 1987). In particular, they proved presence, using paleontological data, of the lower Norian *obručevi* Zone previously distinguished by convention (Dagys *et al.*, 1979). In addition, they subdivided the middle and upper Norian in detail and distinguished subzones of the *scutiformis* and *ochotica* zones. At the same time, in distinction from predecessors, bivalves *Otapiria dubia* (Ichikawa) and *O. korkodonensis* Polubotko were considered as characteristic of the *Eomonotis* Beds in the *daonellaeformis* Subzone of the *scutiformis* Zone.

The ammonoids and nautiloids collected in 1984 from lower and middle Norian deposits of the Balyktakh River basin, Kotel'nyi Island, were revised and identified anew in the course of works aimed to revise the Boreal Triassic fauna, to verify further the Triassic biostratigraphic schemes for northeastern Asia, and to perfect their paleontological substantiation. Recently, conodonts have been found for the first time at some levels in Upper Triassic deposits of the Kotel'nyi Island (Klets, 1996, 1998). The results of fauna revision allow us to refine substantially the paleontological character-

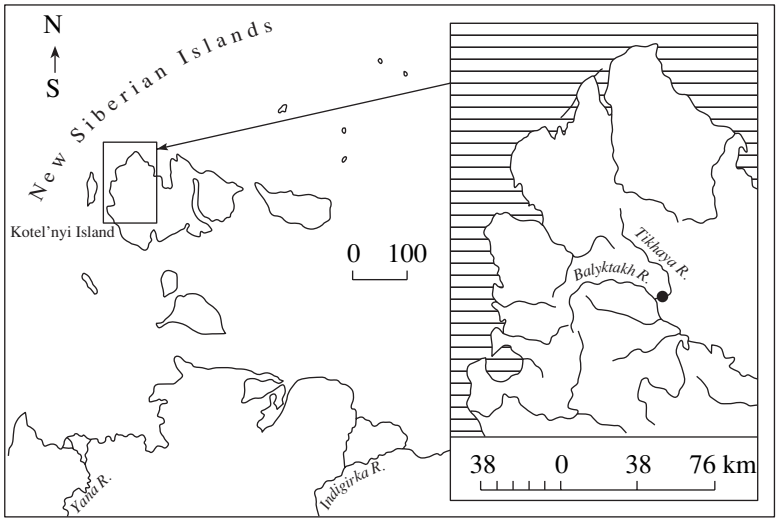


Fig. 1. The Tikhaya River locality of the studied Norian sequence (the Balyktakh River upper courses in central part of the Kotel'nyi Island).

istics and biostratigraphy of Norian deposits, and to distinguish for the first time some subdivisions, which were formerly missed from the local stratigraphic scheme of lower and middle Norian deposits of the Kotel'nyi Island. New data are also used to establish a more justified position of the lower-middle Norian boundary in the region. The refined taxonomy of the regional Norian fauna is undoubtedly of interest for the Boreal-Tethyan correlation of the Upper Triassic and for the comparative biogeographic analysis of the Late Triassic faunas of the Boreal realm.

The lower-middle Norian sequence studied in lower courses of the Tikhaya River, the most complete one among others known in the Kotel'nyi Island (Fig. 1), is description below. Ammonoids were identified by Konstantinov, nautiloids and coleoids by Sobolev, conodonts by Klets. Data by Egorov *et al.* (1987) are used to determine bivalves and to subdivide deposits based on this fossil group. In addition, Konstantinov and Sobolev identified *Halobia* forms in samples stored in the Central Siberian Geological Museum (CSGM), United Institute of Geology, Geophysics, and Mineralogy, Siberian Division, Russian Academy of Sciences (Novosibirsk).

The studied collection of ammonoids, nautiloids, and conodonts is stored in the CSGM under nos. 635, 759, and 792.

STRATIGRAPHY OF THE STUDIED SECTION

Lower and middle Norian deposits were studied in exposures along the right bank of Tikhaya River (a left tributary of Balyktakh River in its upper courses), 2–3 km upstream of the mouth. In this region, Norian deposits are faulted against the underlying clay sequence with lenses of bituminous limestone (Exp. 189).[1] The latter yield ammonoids *Neosirenites irregularis* (Kiparisova), *Yakutosirenites* aff. *pentastichus* (Vozin), *Proarcestes* sp.) of the upper Carnian *Yakutosirenites pentastichus* Zone (Fig. 2). Above the fault, the following succession of beds is observable:

Exposure 190

1. Dark gray, mudstone-like clay with rare interlayers of clayey limestone concretions (15 m).

Paleontological characteristics: (1–2 m)[2] bivalves *Halobia kawadai* Yehara, *Zittelihalobia fallax* (Mojsisovics), *Z.* aff. *obručevi* (Kiparisova) and conodonts *Norigondolella navicula* (Huckriede); (9 m) bivalves *Zittelihalobia fallax* (Mojs.).

2. Dark gray, mudstone-like clay with frequent lenticular horizons of siderite concretions (20 m).

Paleontological characteristics: (1 m) ammonoids *Striatosirenites* ex gr. *kinasovi* Bytschkov, *Arctophyllites popovi* (Archipov), *Cladiscites tolli* Diener; nautiloids *Germanonautilus* cf. *popowi* Sobolev; bivalves *Zittelihalobia indigirensis* (Popow), *Z.* aff. *obručevi* (Kiparisova); (5 m) ammonoids *Striatosirenites kinasovi* Bytschkov (Fig. 3a; Plate, no. 1), *Arcestes* sp. juv.; nautiloids *Proclydonautilus* cf. *spirolobus* (Dittmar) (Figs. 3b, 3c); phragmocone remains of coleoids; bivalves *Zittelihalobia fallax* (Mojs.); brachiopods *Sinuplicorhynchia wollosowitschi* (Diener); (9–13 m) ammonoids *Arctophyllites* cf. *popovi* (Arch.); bivalves *Zittelihalobia fallax* (Mojs.); (17–18 m) bivalves *Halobia* ex gr. *austriaca* Mojs., *Zittelihalobia indigirensis* (Popow), *Z. fallax* (Mojs.), *Z.* aff. *obručevi* (Kipar.).

[1] Numbers of exposures and brief lithological description of rocks are given after Egorov *et al.* (1987).

[2] By paleontological characterization, levels of fossils above the bed base are given in parentheses.

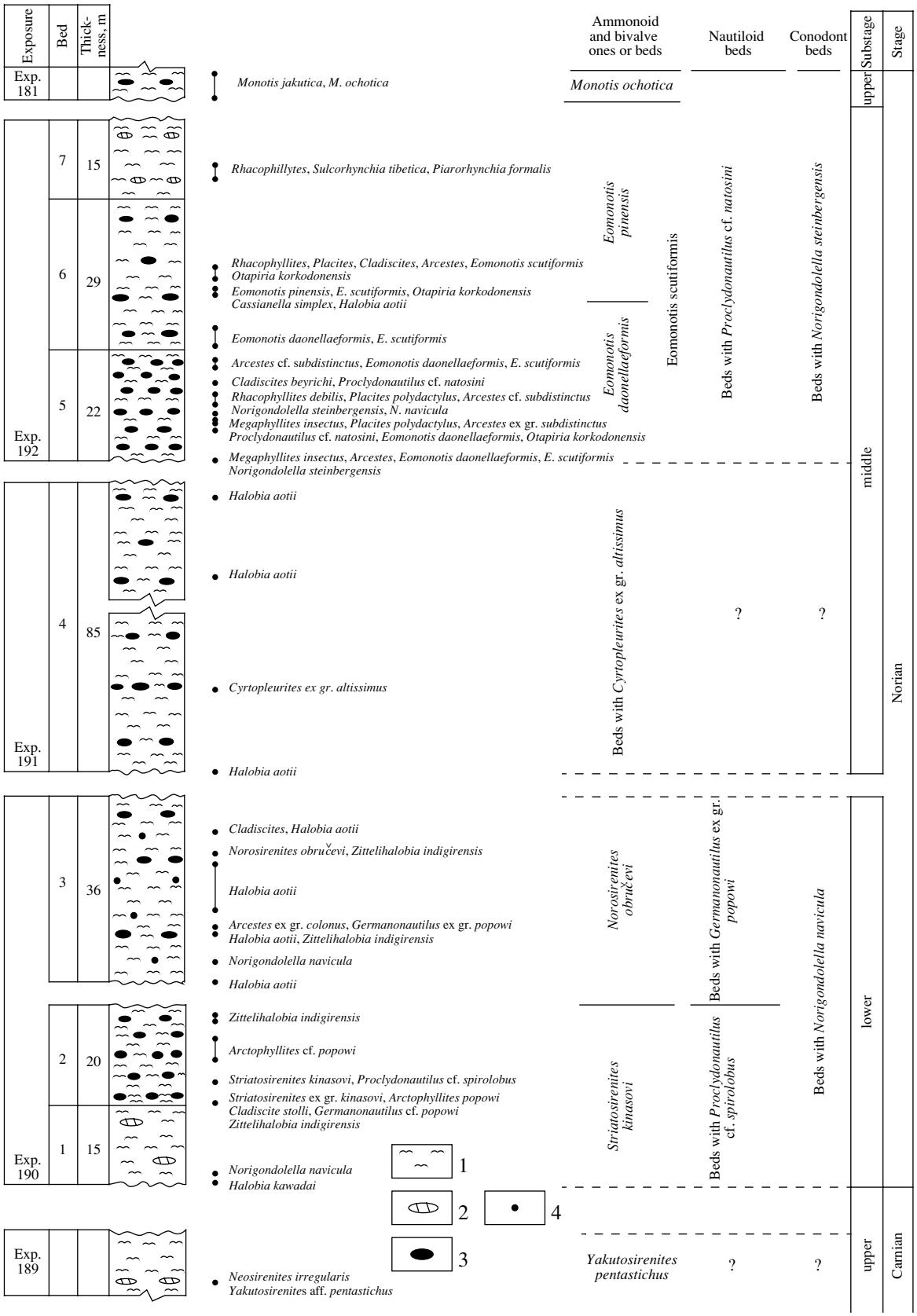


Fig. 2. Biostratigraphy of lower and middle Norian deposits, the Tikhaya River locality (the Balyktakh River upper courses in central part of the Kotel'nyi Island): (1) clay; (2–4) concretions: (2) clayey limestone, (3) siderite, and (4) phosphate.

Ammonoids *Anatomites* sp. indet., *Pinacoceras regiforme* Diener and *Cladiscites tolli* Diener, described long ago (Diener, 1916, 1924) from the Balyktakh River right bank, were probably derived from the stratigraphic interval corresponding to Bed 2. The boundary with overlying bed is faulted.

3. Black, mudstone-like clay with rare, large, scattered, bun-shaped siderite concretions. Small phosphate concretions are scattered throughout the bed (36 m).

Paleontological characteristics: (0–1 m) bivalves *Halobia aotii* Kobayashi et Ichikawa; (4 m) conodonts *Norigondolella navicula* (Huckriede) (Plate, no. 5); (10 m) ammonoids *Arcestes* sp. indet.; nautiloids *Germanonautilus* ex gr. *popowi* Sob.; bivalves *Halobia aotii* Kob. et Ichik., *Zittelihalobia indigirensis* (Popow), *Z. fallax* (Mojs.), *Z.* aff. *obručevi* (Kipar.); (11 m) ammonoids *Arcestes* ex gr. *colonus* Mojsisovics; nautiloids *Germanonautilus* ex gr. *popowi* Sob. (Plate, no. 3); brachiopods *Sulcorhynchia tibetica* (Bittner), *Costispiriferina* sp.; gastropods; (14–23 m) bivalves *Halobia aotii* Kob. et Ichik., *H.* ex gr. *hoernesi* Mojs.; brachiopods *Sulcorhynchia tibetica* (Bittn.); (25 m) ammonoids *Norosirenites obručevi* (Bajarunas) (Plate, no. 2); bivalves *Halobia aotii* Kob. et Ichik., *Zittelihalobia indigirensis* (Popow); brachiopods *Sulcorhynchia tibetica* (Bittn.); gastropods; (29 m) ammonoids *Cladiscites* sp. indet.; bivalves *Halobia aotii* Kob. et Ichik. The contact with the overlying bed is faulty.

Exposure 191

4. Black, mudstone-like clay with horizons of siderite concretions (85 m).

Paleontological characteristics: (16 m) ammonoids *Cyrtopleurites* ex gr. *altissimus* Mojsisovics (Plate, no. 6).

Rare bivalves *Halobia aotii* Kob. et Ichik., *H.* ex gr. *plicosa* Mojs., *Zittelihalobia fallax* (Mojs.), *Z.* aff. *obručevi* (Kipar.); brachiopods *Orbiculoidea* sp. are dispersed throughout the bed.

Further downstream of Tikhaya River, there is an unexposed interval in the section.

Exposure 192

5. Black, dense clay with lenticular horizons of siderite concretions (22 m).

Paleontological characteristics: (the base) ammonoids *Megaphyllites insectus* (Mojs.), *Arcestes* sp. indet.; conodonts *Norigondolella steinbergensis* (Mosher) (Plate, no. 7); (6 m) ammonoids *Arcestes* sp. indet.; nautiloids *Proclydonautilus* cf. *natosini* McLearn (Fig. 3d, e; Plate, no. 8); gastropods; (7–8.5 m) ammonoids *Megaphyllites insectus* (Mojs.), *Placites polydactylus* (Mojs.), *Arcestes* ex gr. *subdistinctus* Mojs, *A.* sp. indet.; fragments of coleoid phragmocones; (9 m) conodonts *Norigondolella steinbergensis* (Mosher), *N. navicula* (Huckriede); (11–13 m) ammonoids *Rhacophyllites debilis* (Hauser), *Placites polydactylus* (Mojs.), *Arcestes* cf. *subdistinctus* Mojs., *A.* sp. indet.; fragments of coleoid phragmocones; (15 m) ammonoids *Cladiscites beyrichi* Welter, *C.* sp. indet., *Placites polydactylus* (Mojs.), *Arcestes* sp. indet.; nautiloids *Proclydonautilus* cf. *natosini* McLearn; (18–20 m) ammonoids *Arcestes* cf. *subdistinctus* Mojs., *A.* sp. indet.; fragments of coleoid phragmocones.

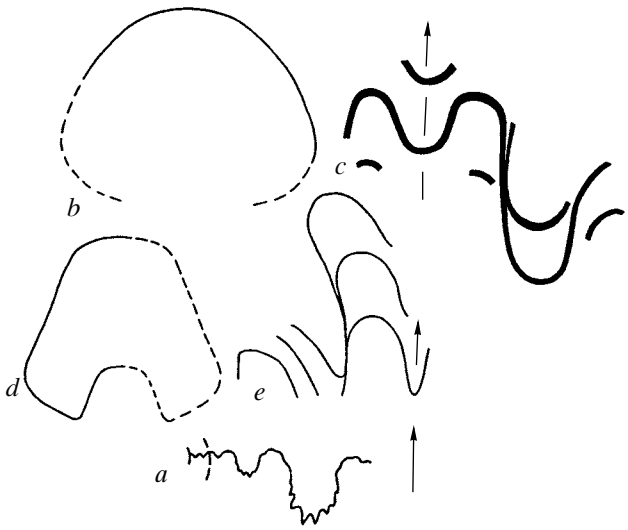
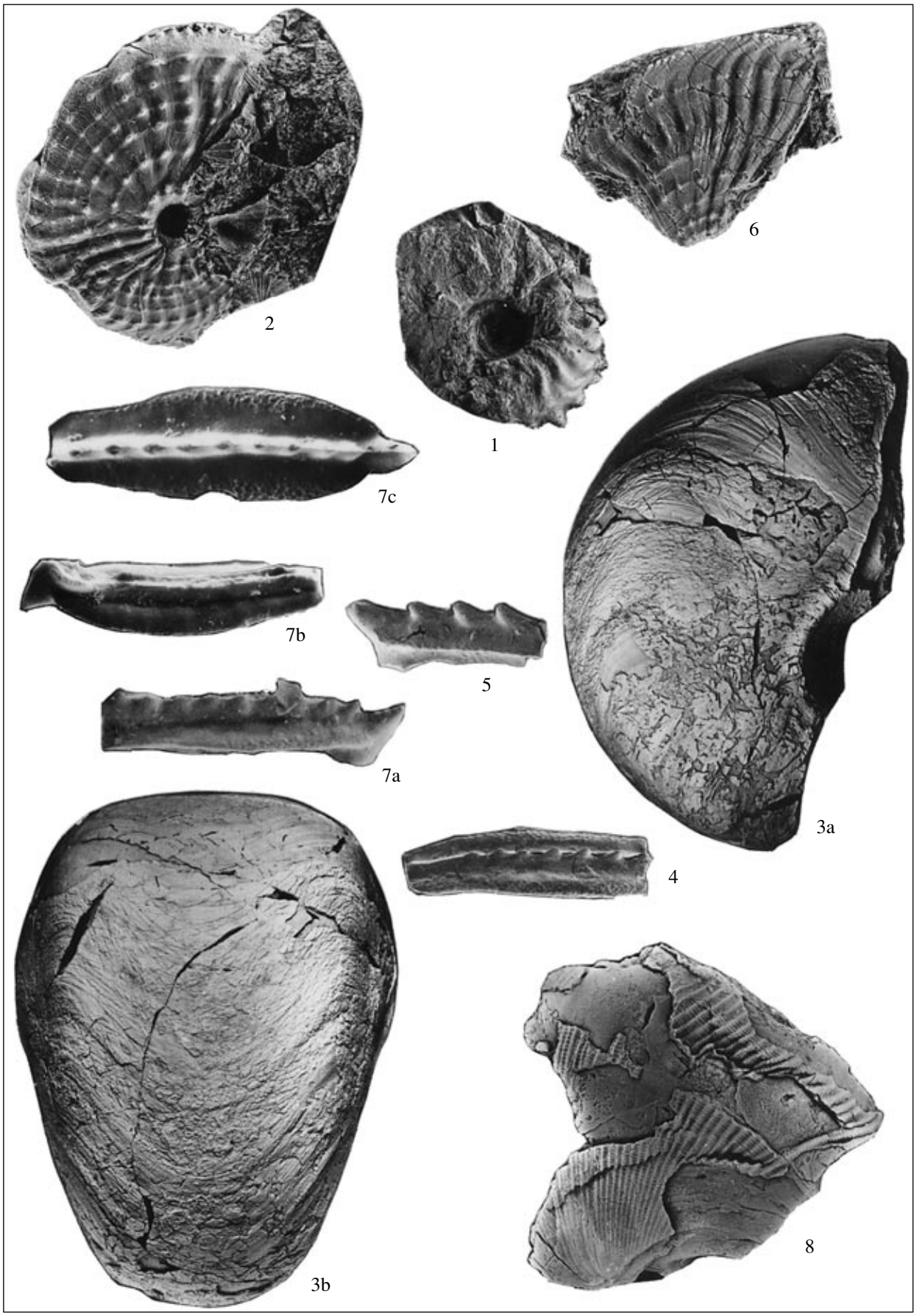


Fig. 3. Suture lines and cross sections of whorls characteristic of *Proclydonautilus* and *Striatosirenites* genera from Norian deposits of the Kotel'nyi Island (Tikhaya River locality, the Balyktakh River upper courses): (*a*) *Striatosirenites kinasovi* Bytschkov, Specimen 759/97a, CSGM, lobe line at H = 4.2 mm (×6), Exp. 190, Sample 190-2-5p, the lower Norian, the *Striatosirenites kinasovi* Zone; (*b*) whorl cross section and (*c*) suture line at H = 92 mm of *Proclydonautilus* cf. *P. spirolobus* (Dittmar), Specimen 759/97, (×0.33), CSGM, the same exposure, sample number, and age; (*d*) whorl cross section and (*e*) suture line at H = 90 mm of *Proclydonautilus* cf. *P. natosini* McLearn, Specimen 759/99, (×0.33), CSGM; Exp. 192, Sample 192-1-6p; the middle Norian, the *Eomonotis scutiformis* Zone, the *Eomonotis daonellaeformis* Subzone.

In addition, bivalves *Eomonotis daonellaeformis* Kipar., *E. scutiformis* (Teller), *Otapiria korkodonensis* Polubotko, *O. dubia* (Ichik.) are numerous throughout the bed. It is likely that ammonoids *Dittmaritoides* sp. described earlier (Korchinskaya, 1977; Preobrazhenskaya and Korchinskaya, 1979) are derived from this part of the section.

6. Gray, mudstone-like, shaly clay with horizons of siderite concretions (29 m).

Paleontological characteristics: (0–5 m) bivalves *Eomonotis daonellaeformis* Kipar., *E. scutiformis* (Teller), *Halobia* sp.; (11–12 m) bivalves *Eomonotis pinensis* Westermann, *E. scutiformis* (Teller), *Otapiria korkodonensis* Polub., *Halobia aotii* Kob. et Ichik., *Cassianella simplex* Kipar.; (14–16 m) ammonoids *Placites polydactylus* (Mojs.), *Rhacophyllites* cf. *debilis* (Hauer), *Cladiscites* ex gr. *beyrichi* Welter, *Arcestes*


2
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ex gr. *subdistinctus* Mojs., *A.* sp., orthoceratids *Trematoceras* sp.; fragments of very large (up to 80 mm in diameter) coleoid phragmocones; bivalves *Eomonotis scutiformis* (Teller), *Otapiria korkodonensis* Polub.; brachiopods *Sulcorhynchia* cf. *tibetica* (Bittn.).

7. Dark gray clay with rare thin horizons of clayey limestone concretions (15 m).

Paleontological characteristics: (1 m) fragments of very large coleoid phragmocones; (4–7 m) ammonoids *Rhacophyllites* sp.; brachiopods *Sulcorhynchia tibetica* (Bittn.), *Piarorhynchia formalis* Dagys, *Orbiculoidea* sp.

Greenish gray clays with numerous late Norian bivalves *Monotis* are exposed at some distance downstream.

BIOSTRATIGRAPHIC SUBDIVISIONS AND CORRELATION

The analyzed stratigraphic ranges of ammonoids, nautiloids, and conodonts in the Tikhaya River section are used to distinguish the successive fauna assemblages and corresponding zones and beds with fauna of the lower–middle Norian sequence of the Kotel'nyi Island.

Bed 2 from Exposure 190 yields ammonoids *Cladiscites tolli* Diener and *Arctophyllites popovi* (Archipov). In addition, treating and revising the collection, we found two specimens of *Striatosirenites kinasovi* Bytschkov. This form found for the first time in the Kotel'nyi Island is the index species of the lowermost *kinasovi* Zone of the Norian, which had been recently distinguished in northeastern Russia (Konstantinov and Sobolev, 1999a, 1999b). The *Arctophyllites popovi* (Arch.) is also typical of that zone. The *Striatosirenites kinasovi* Zone was first established in the Omolon Massif, in the northern coast of the Sea of Okhotsk, and in the Adycha River basin. Age equivalents of the zone were formerly assumed for the Kotel'nyi Island. The assumption was based on the fact that *Pinacoceras regiforme* Diener, which has been described for the first time from Upper Triassic deposits of the Balyktakh River right bank in the Kotel'nyi Island (Diener, 1924), is known from the ammonoid assemblage of the *kinasovi* Zone distinguished in the Omolon Massif and in the northern coast of the Sea of Okhotsk (Konstantinov and Sobolev, 1999a, b). The refined taxonomic composition of ammonoids and found index species imply for the first time that the described section begins with the *Striatosirenites kinasovi* Zone that includes Bed 2 and arbitrarily Bed 1, in the lower part of which conodonts *Norigondolella navicula* (Huckriede) and early Norian *Halobia kawadai* Kob et Ichik. were found.

Based on the nautiloid assemblage of *Germanonautilus* cf. *popowi* Sobolev and *Proclydonautilus* cf. *spirolobus* (Dittmar), the section interval under discussion can be distinguished as *Proclydonautilus* cf. *spirolobus* Beds corresponding in range to the lower *Proclydonautilus spirolobus* Subzone of the nautiloid *Proclydonautilus seimkanensis* Zone (Konstantinov and Sobolev, 1999b).

In the overlying Bed 3, Exposure 190, ammonoids *Arcestes* ex gr. *colonus* Mojs were found in the lower part, whereas *Norosirenites obručevi* (Bajar.) is confined to the upper one. Both species are typical of the lower Norian *Pinacoceras verchojanicum* Zone (Dagys *et al.*, 1979) that was renamed at the last stratigraphic conference (Dagys, 1986), being known now as the *Pterosirenites (= Norosirenites) obručevi* Zone. Accordingly, the Bed 3 of Exp. 190 is referred to the *Norosirenites obručevi* Zone. Nautiloids *Germanonautilus* ex gr. *popowi* Sob. found in the same stratigraphic interval allow us term this interval as *Germanonautilus* ex gr. *popowi* Beds. As the species *Proclydonautilus spirolobus* (Dittmar) of clydonautilids has not been found in these beds, they are likely to correspond in range to the upper *Proclydonautilus seimkanensis* Subzone of the lower Norian nautiloid zone of the same name (Konstantinov and Sobolev, 1999b).

Conodonts found at two stratigraphic levels in Bed 1 and Bed 3 imply that the corresponding interval in Exposure 190 can be termed as the *Norigondolella navicula* Beds. The lower boundary of the beds is established based on the appearance of index species. The overlying 85-m-thick member of mudstone-like clay with horizons of siderite concretion (Exp. 190, Bed 4), which was arbitrarily referred before to the *Otapiria ussuriensis* Zone (Egorov *et al.*, 1987), yields individual fragments of ammonoids *Cyrtopleurites* ex gr.

PLATE

Cephalopods and conodonts from Norian deposits of the Kotel'nyi Island (Tikhaya River locality, the Balyktakh River upper courses).

(1) *Striatosirenites kinasovi* Bytschkov, Specimen 759/97a (×3), lateral view; Exp. 190, Sample 190-2-5p; the lower Norian, the *Striatosirenites kinasovi* Zone. (2) *Norosirenites obručevi* (Bajarunas), Specimen. 792/1 (natural size), lateral view; Exp. 190, Sample 190-3-25p; the lower Norian, the *Norosirenites obručevi* Zone. (3) *Germanonautilus* ex gr. *G. popowi* Sobolev, Specimen 759/157 (×0.66): (3a) lateral view, (3b) ventral view; Exp. 190, Sample 190-3-11p, the same age. (4) *Norigondolella navicula* (Huckriede), Specimen 635/2 (×100), top view; Exp. 190, Sample 190-3-4p, the same age. (5) *Norigondolella navicula* (Huckriede), Specimen 635/4 (×150), lateral view; the same locality and age. (6) *Cyrtopleurites* ex gr. *C. altissimus* Mojsisovics, Specimen 792/2 (natural size), lateral view; Exp. 191, Sample 190-1-16p; the middle Norian, *Cyrtopleurites* ex gr. *C. altissimus* Beds. (7) *Norigondolella steinbergensis* (Mosher), Specimen 635/9: (7a) lateral view (×200), (7b) bottom view (×200), (7c) top view (×232); Exp. 192, Sample 192-1-osn.; the middle Norian, the *Eomonotis scutiformis* Zone, the *Eomonotis daonellaeformis* Subzone. (8) *Proclydonautilus* cf. *P. natosini* McLearn, Specimen 759/99 (×0.66), lateral view; Exp. 192, Sample 192-1-6p; the same age.

altissimus Mojs. at the level of 16 m above the base. Halobians, the dominant *Halobia aotii* Kob. et Ichik. included, are dispersed throughout the member. This part of the sequence is distinguished as the *Cyrtopleurites* ex gr. *altissimus* Beds. Since ammonoids are rare in the beds, their lower and upper boundaries are conventional, assumed to be coincident with those of Bed 4.

Numerous bivalves, ammonoids, and more rare nautiloids, fragments of coleoid phragmocones, and brachiopods were found in overlying deposits represented by black and gray, pelitomorphic massive clays with lenticular horizons of siderite concretions and with thin interlayers of clayey limestone (Exp. 192, Beds 5, 6, and 7). This interval was previously subdivided into zones based on stratigraphic ranges of bivalves of the genus *Eomonotis* (Egorov *et al.*, 1987). Bed 5 coupled with the lower part of Bed 6 represent the *Eomonotis daonellaeformis* Subzone of the *Eomonotis scutiformis* Zone, whereas the rest of Bed 6 and Bed 7 correspond to the *Eomonotis pinensis* Subzone. Lower boundaries of both subzones are established based on the appearance of their index species. At some levels of the stratigraphic interval under discussion, there were found numerous well-preserved ammonoids representing cosmopolitan long-lived forms with smooth shells. These are *Megaphyllites insectus* (Mojs.), *Arcestes* ex gr. *subdistinctus* Mojs., *Placites polydactylus* (Mojs.), *Cladiscites beyrichi* Welter, and *Rhacophyllites debilis* (Hauer).

Nautiloids *Proclydonautilus* cf. *natosini* McLearn and conodonts *Norigondolella steinbergensis* (Mosher) were found at two stratigraphic levels in Bed 5 of Exposure 192. Nautiloids similar to *Proclydonautilus natosini* were also encountered in association with *Monotis jakutica* (Teller) and *M. zabaikalica* (Kiparisova) at the base of the upper Norian deposits of the described section. Consequently, the *Proclydonautilus* cf. *natosini* Beds of the Kotel'nyi Island correspond to the *Eomonotis scutiformis* Zone and probably to the lower part of the *Monotis ochotica* Zone. Large (up to 80 mm in diameter) coleoid phragmocones present in deposits of the *Eomonotis pinensis* Subzone are of interest. Coleoids of such a large size have not been known so far from Norian deposits in other regions of northeastern Russia. In addition to the middle Norian, the biozone of *Norigondolella steinbergensis* (Mosher) spans the upper Norian substage as well, and the *Norigondolella steinbergensis* Beds correspond therefore to the *Eomonotis scutiformis* and *Monotis ochotica* zones.

Hence, the biostratigraphic scheme for the lower and middle Norian that is established in this work based on distribution of ammonoids and bivalves includes five biostratigraphic units in the rank of zones and beds. From the base upward, these are the *Striatosirenites kinasovi* and *Norosirenites obručevi* zones of the lower Norian and the *Cyrtopleurites* ex gr. *altissimus* Beds and the *Eomonotis daonellaeformis* and *Eomonotis pinensis* subzones of the middle Norian. The lower Norian includes the *Proclydonautilus* cf. *spirolobus* and *Germanonautilus* ex gr. *popowi* beds with nautiloids, and also the *Norigondolella navicula* Beds with conodonts. In middle-upper Norian interval, there are distinguishable the *Proclydonautilus* cf. *natosini* Beds with nautiloids and the *Norigondolella steinbergensis* Beds with conodonts.

Let us consider now the correlation of local stratigraphic scheme proposed for the lower-middle Norian deposits of the Kotel'nyi island with the standard scale. Links necessary for the Boreal-Tethyan correlation of the Upper Triassic, in particular, of the Norian deposits can be found in sections of North America (Tozer, 1967; Silberling and Tozer, 1968; Tozer, 1994), the Pacific coast of which represented an ecotone of the Triassic time, where the ammonoid community consisted of mixed Tethyan and Boreal taxa.

The *Striatosirenites kinasovi* Zone was previously correlated with the lower subzone of the *Stikinoceras kerri* Zone of British Columbia (Konstantinov and Sobolev, 1999b) based on ammonoid species common for both zones, such as *Pterosirenites auritus* Tozer and *Pinacoceras regiforme* Diener (Table). At the same time, the *Stikinoceras kerri* Zone is correlated with the lower Norian *Guembelites jandianus* Zone of the standard ammonoid zonation, although Krystyn (1980) believes that only the upper subzone of the *jandianus* Zone has equivalents in the *kerri* Zone of North America. Nautiloids *Proclydonautilus spirolobus* (Dittmar) occurring in the *kinasovi* Zone and in the *jandianus* Zone of the Alps suggest their synchronism, at least partial. Conodonts *Norigondolella navicula* (Huckriede) and bivalves *Halobia kawadai* Yehara were encountered in the lower part of the *kinasovi* Zone on the Kotel'nyi Island. According to data reported by Krystyn (1980), *Norigondolella navicula* coexists in Austria (Hallstatt) with *Epigondolella abneptis* and *E. primitia* in the lower (*jandianus, paulckei*, and *magnus* zones) and middle (*bicrenatus* and *columbianus* zones) Norian deposits. In Canada (Orchard, 1991; Orchard and Tozer, 1997), *Norigondolella navicula* appears at the base of the *kerri* Zone and marks the base of Norian deposits and an upper part of the *Metapolygnathus primitius* Zone of the conodont scale. Suggesting the conodont standard for the Austrian-Alpine Province, Kozur (1980) who established the *navicula* Subzone of the lower Norian based on the appearance of its index species regarded it as the age analog of the *Stikinoceras kerri* and *Malayites paulckei* zones of the ammonoid scale. According to his data, that index species is frequent in the *Juvavites magnus* and *Cyrtopleurites bicrenatus* Zones and rare in the *Sirenites argonautae* and *Sagenites giebeli* Zones. As to halobians, species *Halobia kawadai* Yehara represented, according to I.V. Polubotko *(Obshchaya shkala..., 1984; Polubotko,* 1984), a vicarious form of the early Norian *Halobia styriaca* Mojsisovics. All the data confirm therefore a synchronism of the lower Norian boundary in the Boreal and Tethyan realms.

Correlation scheme for Norian deposits of the Kotel'nyi Island

<table>
<tr><td rowspan="2">Stage</td><td rowspan="2">Substage</td><td colspan="4">the Kotel'nyi Island, Tikhaya River lower courses</td><td colspan="2">British Columbia</td><td>Alps</td></tr>
<tr><td>Conodont Beds</td><td>Nautiloid beds</td><td colspan="2">Zones, subzones, and beds in ammonoid and bivalve successions</td><td colspan="2">Ammonoid zonation</td><td>Ammonoid zonation</td></tr>
<tr><td rowspan="9">Norian</td><td>upper</td><td rowspan="4">Beds with Norigondolella steinbergensis</td><td rowspan="4">Beds with Proclydonautilus cf. P. natosini</td><td colspan="2">Monotis ochotica</td><td>Gnomohalorites cordilleranus</td><td>Lissonites pecki</td><td rowspan="2">Rhabdoceras suessi</td></tr>
<tr><td>middle</td><td rowspan="3">Eomonotis scutiformis</td><td>Eomonotis pinensis</td><td rowspan="3">Mesohimavatites columbianus</td><td>Paraquembelites ludingtoni</td></tr>
<tr><td rowspan="3">Eomonotis daonellaeformis</td><td>Alloclionites welteri</td><td rowspan="3">Mesohimavatites columbianus</td></tr>
<tr><td>Neohimavatites canadensis</td></tr>
<tr><td>lower</td><td rowspan="3">conodonts not found</td><td rowspan="3">nautiloids not found</td><td colspan="2">Beds with Cyrtopleurites ex gr. altissimus</td><td colspan="2">Drepanites rutherfordi</td><td>Cyrtopleurites bicrenatus</td></tr>
<tr><td rowspan="3">?
presumable hiatus</td><td rowspan="2">Juvavites magnus</td><td>Dimorphotoceras caurinum</td><td rowspan="2">Juvavites magnus</td></tr>
<tr><td>Indojuvavites brunneus</td></tr>
<tr><td rowspan="3">Malayites dawsoni</td><td>Discomalayites carinatus</td><td rowspan="3">Malayites paulckei</td></tr>
<tr><td rowspan="2">Beds with Norigondolella navicula</td><td>Beds with Germanonautilus ex gr. popowi</td><td>Norosirenites obručevi</td><td>Pseudocardioceras idunae</td></tr>
<tr><td>Beds with Proclydonautilus cf. spirolobus</td><td>Striatosirenites kinasovi</td><td>Stikinoceras kerri</td><td>Wangoceras pax</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>Gonionotites rarus</td><td rowspan="2">Guembelites jandianus</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>Discostyrites ireneanus</td></tr>
</table>

Hence, the *Striatosirenites kinasovi* Zone of the Kotel'nyi Island is undoubtedly of the early Norian age and can be correlated, based on ammonoids, nautiloids, bivalves, and conodonts, with the *Stikinoceras kerri* Zone of British Columbia and with the standard *Guembelites jandianus* Zone.

An upper part of the *Norosirenites obručevi* Zone of Kotel'nyi Island, in which the index species was found, is correlative with the lower subzone of the *Malayites dawsoni* Zone of British Columbia. The arguments in favor are the presence of *Norosirenites* forms in both zones and similarity or even identity of the Canadian *Norosirenites krystyni* Tozer and Siberian *N. obručevi* (Bajarunas). The *Malayites dawsoni* Zone is an equivalent of the standard *Malayites paulckei* Zone *(Obshchaya shkala…*, 1984). The lower part of the *obručevi* Zone, which yields ammonoids *Arcestes* ex gr. *colonus* Mojs., is likely corresponding in stratigraphic range to the upper subzone of the *kerri* Zone and, accordingly, to the upper part of the *jandianus* Zone.

Ammonoids of the genus *Cyrtopleurites* found in overlying deposits of the Kotel'nyi Island have not been previously known in northeastern Asia and Boreal Realm. Up to the present, representatives of the genus have been reported to occur in the Eastern Alps, on the Sicily Island, in the Himalayas, on the Timor Island, in southeastern Asia, and in British Columbia. The *Cyrtopleurites* aff. *strabonis* described by Popov from the Cape Hansa, the Wilczek Land Island of Franz Josef Land (Popov, 1958, p. 18, Plate, no. 1) has sculpture different from that typical of the genus *Cyrtopleurites* and represents most likely a species of the *Norosirenites* genus, which is not described yet. Ammonoids of the genus *Cyrtopleurites* are confined everywhere to the lowermost middle Norian. They are characteristic components of the ammonoid fauna from the *Cyr-*

topleurites bicrenatus Zone of the lowermost middle Norian in the Eastern Alps and in correlative zones of other regions of the Tethyan realm.

Thus, the *Cyrtopleurites* ex gr. *altissimus* Beds of the Kotel'nyi Island can be directly correlated with the *Drepanites rutherfordi* Zone of British Columbia and with the *Cyrtopleurites bicrenatus* Zone of the eastern Alps, both bearing *Cyrtopleurites* forms. Units correlative with the *Juvavites magnus* Zone and with upper parts of the *Malayites dawsoni* and *Malayites paulckei* Zones cannot be established in the described section.

Ammonoids of the genus *Cyrtopleurites* found for the first time in Norian deposits of the Kotel'nyi Island specify the taxonomic composition of Late Triassic ammonoids of Boreal Realm and are important for recognition of reliable equivalents of the lower *Cyrtopleurites bicrenatus* Zone of the middle Norian and for determination of the lower-middle Norian boundary position in Boreal sections. The *Cyrtopleurites* ex gr. *altissimus* Beds of the Kotel'nyi Island span stratigraphic range (above the *Norosirenites obručevi* Zone and below the *Eomonotis scutiformis* Zone) that corresponds to the *Otapiria ussuriensis* Zone in the Norian zonal scale of northeastern Asia (Dagys, 1986). The lower boundary of the *Otapiria ussuriensis* Zone was arbitrarily placed at the base of the middle Norian Substage *Obshchaya shkala…*, 1984). Equivalents of the *bicrenatus* Zone, which are now established in the Kotel'nyi Island and occupy stratigraphic range of the *ussuriensis* Zone, indicate that the lower-middle Norian boundary should be placed in northeastern Asia somewhere inside the latter. This is evident from composition of ammonoids *(Norosirenites tenuistriatus* (Popow), *Malayites* ex gr. *parcus* McLearn, *Dittmaritoides guembeli* Vavilov et Archipov) found in the *ussuriensis* Zone and from interregional correlations (Dagys *et al.*, 1979; Bychkov, 1995; Konstantinov and Sobolev, 1999b; Konstantinov, 2000).

The *Eomonotis pinensis* Subzone of the *Eomonotis scutiformis* Zone is equivalent to the upper subzone of the *Mesohimavatites columbianus* Zone of British Columbia, where it yields *Eomonotis pinensis* (Westermann) (Tozer, 1994). Ammonoids *Neohimavatites canadiensis* McLearn found in the third (from the base) subzone of the *columbianus* Zone substantiate its correlation with the *Eomonotis daonellaeformis* Subzone, because *Neohimavatites* forms similar to Canadian species are typical of the latter (Bychkov and Polubotko, 1970). However, the *daonellaeformis* Subzone can be alternatively correlated with the second and lower (partially) subzones of the *columbianus* Zone, because Vavilov (1982) reported data on ammonoids *Dittmaritoides (= Pleurodistichites guembeli* Archipov et Vavilov) and *Eomonotis daonellaeformis* (Kiparisova) found associated in deposits of the Karadan Formation of the Kharaulakh Ridge and also known from the lower subzone of the *columbianus* Zone.

Such a correlation of the *daonellaeformis* Zone is consistent with data on distribution of nautiloids and conodonts in deposits of the Kotel'nyi Island. In particular, *Proclydonautilus natosini* McLearn was found in beds of British Columbia, which correspond to the second and third subzones of the *columbianus* Zone (McLearn, 1946, 1960; Tozer, 1994). Conodonts *Norigondolella steinbergensis* (Mosher) and *N. navicula* (Huckriede) found at two levels of the *daonellaeformis* Subzone (Exp. 192, Bed 5) are known to occur in association with *Epigondolella abneptis* (Huckriede) and *Mockina postera* (Mosher) in the middle Norian *bicrenatus* and *columbianus* zones of Austria (Krystyn, 1980). In British Columbia, the *Norigondolella steinbergensis* (Mosher) is a common component of the conodont assemblage from the *Epigondolella postera* Zone, a close age analog of the second (from the base) subzone of the *columbianus* Zone (Orchard, 1991; Orchard and Tozer, 1997).

BIOGEOGRAPHIC ANALYSIS OF FAUNA

The study region is a part the New Siberian structural-facies zone that was at the subplatform stage of evolution in the Triassic (Dagys *et al.*, 1979). The uniform carbonate-clayey composition of deposits with fossils, which mainly represent pelagic groups of fauna, indicate that sedimentation settings of an open and warm sea were situated rather far away from the coast (Egorov *et al.*, 1987). The Late Triassic, particularly Norian biota of the region was also peculiar. It was of a mixed type and consisted of Boreal and Tethyan taxa.

Norian ammonoids from the Kotel'nyi island represent 13 genera of 11 families: Megaphyllitidae (*Magaphyllites*), Gymnitidae (*Placites*), Pinacoceratidae (*Pinacoceras*), Cladiscitidae (*Cladiscites, Paracladiscites*), Arcestidae (*Arcestes*), Sirenitidae (*Striatosirenites, Norosirenites*), Cyrtopleuritidae (*Cyrtopleurites*), Distichitidae (*Dittmaritoides* = *Pleurodistichites*), Haloritidae (*Anatomites*), Ussuritidae (*Arctophyllites*), and Discophyllitidae (*Rhacophyllites*). Among genera, one (*Arctophyllites*) is characteristic of the Boreal Realm (Konstantinov, 1995). The other two, *Anatomites* described by Diener in 1924 and *Cyrtopleurites* established for the first time in the study region, are typical of the Tethyan Realm. All the others are cosmopolitan. Most of them represent long-lived ammonoids with smooth shells. Genera *Norosirenites* and *Dittmaritoides* are known from mixed ammonoid assemblages of British Columbia, where they are represented by forms similar, if not identical, to Siberian species. A characteristic feature of ammonoid fauna from the Kotel'nyi Island, other than presence of southern taxa, consists in abundance and taxonomic diversity of ammonoids at several levels, especially in the middle and upper Norian. This feature is untypical of synchronous fauna known in other regions of northeastern Asia. The fauna in question is most similar to that known

from upper reaches of the Bol'shoi Anyui River, where representatives of Tethyan haloritids (*Catenohalorites* and *Halorites*) and horistoceratids (*Rhabdoceras*) coexist with dominating cosmopolitan families and genera of ammonoids (Afitskii, 1970).

Norian coiled nautiloids are represented in the study region by two cosmopolitan genera *Germanonautilus* (Tainoceratidae) and *Proclydonautilus* (Clydonautilidae). The genus *Proclydonautilus* includes two species *P. spirolobus* (Dittmar) and *P. natosini* McLearn. The first one is of the almost global distribution, while the second is known from lower and middle Norian deposits of northeastern British Columbia and Yukon (Tozer, 1982). In the Late Triassic, the indicated regions were located in middle latitudes, being populated by the mixed Boreal-Tethyan invertebrate fauna. The genus *Germanonautilus* is represented by Siberian endemics *G. popowi* Sobolev.

Unusually large phragmocones of coleoids present in the Norian cephalopod fauna of the Kotel'nyi Island emphasize its peculiarity. Such forms formerly unknown in the Upper Triassic deposits of northeastern Asia are common in the Alpine region (Mojsisovics, 1871).

Conodonts have been found recently in Norian deposits of the Kotel'nyi Island and in other areas of Upper Triassic deposits of northeastern Asia (Klets, 1996, 1998). They are of a uniform morphology in distinction from conodonts of the Tethyan Realm. Southern conodont faunas (Burii, 1989; Klets, 1995; Igo and Koike, 1983; Koike *et al.*, 1991; Kozur, 1980; Krystyn, 1980; Zhao and Zhang, 1991; and others) considerably differ from those of northern latitudes. The genus *Epigondolella* possessing tuberculate platforms was most prosperous in the Tethys during the early and middle Norian. The genus *Mockina*, the ancestor of the late Norian-Rhaetian genus *Parvigondolella*, appeared in the terminal early Norian and became widespread in southern seas. The genus *Metapolygnatus* died out at the beginning of the Norian, and *Norigondolella* forms, presumable descendants of the genus *Paragondolella*, appeared in the same latitudes in the earliest Norian. Only representatives of the genus *Norigondolella*, which had a smooth upper surface of the platform, penetrated into northern Siberia during the Norian.

Kurushin (Egorov *et al.*, 1987; Kurushin, 1998) previously pointed out that Norian bivalve assemblages of the Kotel'nyi Island include the North American species *Monotis (Pacifimonotis) subcircularis* Gabb, *M. (Entomonotis) posteroplana* Westermann, the genus *Cassianella.* According to Bychkov (1992), the last genus is a typical Tethyan taxon.

Thus, typical Tethyan taxa indicative of warm (tropical) habitats coexist with Boreal elements nearly in all Norian fauna groups of the Kotel'nyi Island. Being not confined to a particular stratigraphic datum, they occur throughout the whole Norian sequence. This indicates the peculiarity of regional biota that likely characterizes an independent paleobiochore of the Boreal realm, i.e., the New Siberian subprovince of the Siberian province, rather than a short-term invasions of southern elements. Another characteristic feature of the regional Norian biota is a considerable proportion of cosmopolitan taxa in its composition and presence of forms identical or similar to North American fossils. This is likely indicative of free connections and fauna exchange between East Pacific paleobasins of the Norian time.

CONCLUSIONS

1. The lower-middle Norian sedimentary sequence exposed in lower reaches of the Tikhaya River (central part of the Kotel'nyi Island) has been studied and described. After revision, the taxonomic composition of Norian ammonoids, nautiloids, coleoids, and conodonts characteristic of the study region has been refined and elucidated further.

2. Based on the analysis of stratigraphic ranges of ammonoids, nautiloids, and conodonts, the regional stratigraphy has been refined and the local biostratigraphic scheme including zones, subzones, and beds with fauna is proposed for the lower-middle Norian sequence of the Kotel'nyi Island. Three biostratigraphic units of the ammonoid succession are distinguished: the *Striatosirenites kinasovi* (initially recognized) and *Norosirenites obručevi* zones in the lower Norian and the *Cyrtopleurites* ex gr. *altissimus* Beds (initially recognized) in the middle Norian. The lower-middle Norian biostratigraphic zonation of nautiloids is outlined the first time. It corresponds to the succession of *Proclydonautilus* cf. *P. spirolobus* and *Germanonautilus* ex gr. *G. popowi* beds of the lower Norian underlying the *Proclydonautilus* cf. *P. natosini* Beds of the middle and lower upper Norian. The *Norigondolella navicula* Beds of the lower Norian and the *Norigondolella steinbergensis* Beds of the middle-upper Norian are established in the conodont succession.

3. The local biostratigraphic scheme of the lower-middle Norian sequence of the Kotel'nyi Island is correlated with the Canadian and standard ammonoid scales. Ammonoids of the genus *Cyrtopleurites*, which are characteristic of the lower *Cyrtopleurites bicrenatus* Zone in the standard middle Norian zonation and of correlative zones, have been found for the first time in the Kotel'nyi Island. They enabled the direct Boreal-Tethyan correlation and substantiated positioning of the lower-middle Norian boundary in Boreal regions of northeastern Russia.

4. Biogeography of Norian ammonoids, nautiloids, coleoids, and conodonts from the Kotel'nyi Island is comprehensively analyzed. Characteristic features of the studied fauna are its mixed composition exemplifying coexistence of Boreal and Tethyan fossils, a substantial proportion of cosmopolitan taxa, and presence of forms identical or similar to North American taxa. This suggests that the peculiar Norian fauna of the

study region characterizes the independent New Siberian subprovince within the Siberian province of the Boreal Realm, on the one hand, and free connections between East Pacific paleobasins of the Norian time, on the other.

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