ISSN 1342-9574
National Museum of Nature and Science Monographs No. 38

THE LOWER TRIASSIC SYSTEM IN THE ABREK BAY AREA, SOUTH PRIMORYE, RUSSIA

Edited by
Yasunari Shigeta
Yuri D. Zakharov
Haruyoshi Maeda
Alexander M. Popov

National Museum of Nature and Science
Tokyo, March 2009

The Lower Triassic System in the Abrek Bay area, South Primorye, Russia

Edited by
Yasunari Shigeta
Yuri D. Zakharov
Haruyoshi Maeda
Alexander M. Popov

National Museum of Nature and Science
Tokyo, March 2009

Contents

Contributors

Hisayoshi Igo Institute of Natural History, 3–14–24 Takada, Toshima-ku, Tokyo 171–0033, Japan
(E-mail: igohisa@mac.com)

Andrzej Kaim Institute of Paleobiology, Polish Academy of Sciences, PL-00-818 Warszawa, Poland
(E-mail: kaim@twarda.pan.pl)

Taro Kumagae Department of Geology and Mineralogy, Graduate School of Science, Kyoto University, Kitashirakawa-Oiwake-cho, Sakyo-ku, Kyoto 606–8502, Japan
(E-mail: kumagae-t@kueps.kyoto-u.ac.jp)

Haruyoshi Maeda Department of Geology and Mineralogy, Graduate School of Science, Kyoto University, Kitashirakawa-Oiwake-cho, Sakyo-ku, Kyoto 606–8502, Japan
(E-mail: maeda@kueps.kyoto-u.ac.jp)

Keiji Nakazawa 28-2, Koyama-shimouchikawara-cho, Kita-ku, Kyoto 603–8132, Japan
(E-mail: keiji10310@maia.eonet.ne.jp)

Tatsuo Oji Department of Earth and Planetary Science, University of Tokyo, 7–3–1 Hongo, Bunkyo-ku, Tokyo 113–0033, Japan
(E-mail: oji@eps.s.u-tokyo.ac.jp)

Alexander M. Popov Far Eastern Geological Institute, Russian Academy of Sciences, Far Eastern Branch, Stoletija Prospect 159, Vladivostok 690022, Russia
(E-mail: popov_alexander@list.ru)

Yasunari Shigeta Department of Geology and Paleontology, National Museum of Nature and Science, 3–23–1 Hyakunin-cho, Shinjuku-ku, Tokyo 169–0073, Japan
(E-mail: shigeta@kahaku.go.jp)

Yasuyuki Tsujino Tokushima Prefectural Museum, Hachiman-cho, Tokushima 770–8070
(E-mail: tsujino-yasuyuki-1@mt.tokushima-ec.ed.jp)

Yukiyasu Tsutsumi Department of Geology and Paleontology, National Museum of Nature and Science, 3–23–1 Hyakunin-cho, Shinjuku-ku, Tokyo 169–0073, Japan
(E-mail: ytsutsu@kahaku.go.jp)

Haruka Yamagishi University Museum, University of Tokyo, 7–3–1 Hongo, Bunkyo-ku, Tokyo 113–0033, Japan
(E-mail: haruka@df7.so-net.ne.jp)

Kazumi Yokoyama Department of Geology and Paleontology, National Museum of Nature and Science, 3–23–1 Hyakunin-cho, Shinjuku-ku, Tokyo 169–0073, Japan
(E-mail: yokoyama@kahaku.go.jp)

Yuri D. Zakharov Far Eastern Geological Institute, Russian Academy of Sciences, Far Eastern Branch, Stoletija Prospect 159, Vladivostok 690022, Russia
(E-mail: yurizakh@mail.ru)

Abstract

The stratigraphy and paleontology of a Lower Triassic section exposed within a quarry along the northeastern coast of Abrek Bay, South Primorye has been the subject of an intense investigation. This 165 meter thick section is divided lithostratigraphically into the Lazurnaya Bay and Zhitkov formations in ascending order. The Lazurnaya Bay Formation, which unconformably overlies the Permian Abrek Formation, consists mainly of sandstone exhibiting an upward-fining sequence, whereas the overlying Zhitkov Formation consists of dark gray, laminated mudstone intercalated with thin, turbiditic fine sandstone beds.

The Lazurnaya Bay Formation consists of the following three facies types in ascending order: a distal deltaic facies deposited during a transgressive event; a shelf environment above storm wave base; and a transitional facies from a shelf to a slope environment. A lower slope environment represents the lower part of the Zhitkov Formation, while the main part consists of a proximal basin-floor facies. This thick monotonous succession of barely bioturbated, laminated mudstone suggests deposition in a stable anoxic basin-floor setting.

Aside from the lower part of the Lazurnaya Bay Formation, the remaining Lower Triassic strata are very fossilferous. Ammonoids, nautiloids, gastropods, bivalves, brachiopods, conodonts and shark fossils are abundant throughout the sequence, while crinoids and scaphopods are present only in the upper part. Nine ammonoid zones (taxon-rang zones) and beds, *Lytophiceras* sp. Zone, *Gyronites subdharmus* Zone, *Ambitoides fuliginatus* Zone, *Clypeoceras spitiense* "bed", *Paranorites varians* Zone, *Clypeoceras timorense* Zone, *Radioprionites abrekensis* "bed", *Balhaeceras balhaense* "bed", and *Arctoceras subhydaspis* "bed", as well as three conodont zones, *Neogondolella carinata* Zone, *Neospathodus dieneri*-*N. pakistanensis* Zone, and *Neospathodus* ex gr. *waageni-N. novaeholladiae* Zone are recognized in ascending order. Based on these ammonoids and conodonts, the sequence ranges in age from Early Induan (Griesbachian) to middle Early Olenekian (middle Smithian). Even though the ammonoid faunas contain a few species that are common to other realms, the majority of ammonoids are essentially endemic. In contrast, the bivalve fauna appears to be more related to the Maizuru fauna of Southwest Japan. While the grypoceratid nautiloids exhibit diverse shell forms and siphuncle positions, evidence suggests that they diversified primarily in the western Panthalassa area during the Early Triassic. The existence of *Holocrinus* in beds of early Smithian age, which represents the oldest known occurrence in the world, suggests that crinoids experienced an earlier recovery in South Primorye following the Permian-Triassic (P/Tr) mass extinction.

The transition from the Lazurnaya Bay Formation to the Zhitkov Formation occurred during the early Late Induan (early Dienerian). Sedimentation appears to be continuous from the Late Induan to the Early Olenekian, and faunal successions during this interval are relatively complete and exceptionally well preserved. This phenomenon likely resulted from deposition under much deeper and quieter environmental conditions than other areas in the western part of the "Ussuri Basin". Although this fining-upward sequence is for the most part typical throughout South Primorye, the datum planes of fossil zones obviously extend across lithostratigraphic boundaries. In the Abrek Bay area, the Induan/Olenekian boundary exists within the Zhitkov Formation, whereas in other western areas of the region, it occurs in the Lazurnaya Bay Formation. These facts support an eastward-deepening setting of the Triassic System in the basin.

Ammonoids are rare in the laminated mudstone of the Zhitkov Formation, but they are common in the very fine sandstone beds that are intercalated within the mudstone. These occurrences suggest that these ammonoids were not indigenous to the slope-basin environment, but rather were of allochthonous origin. Most of the ammonoids likely lived in shallower facies, and after death their empty shells were transported from their biotope to the anoxic basin-floor by low-density turbidite gravity flows.

Sandstones exhibit a strong monazite age peak at 500 Ma and a subordinate peak at 270 Ma. These age patterns indicate that Triassic sediments in the Abrek Bay area were derived from the Khanka Block and/or the adjacent Jiamusi Block, with no contribution from the nearby Sino-Korea Craton. Similar age patterns have been recognized in Permian and Lower to Middle Triassic sandstones in the Maizuru Belt of southwest Japan, which suggests that both areas belonged to either the Khanka Block or the Jiamusi Block during the Early Triassic. This assumption is also supported by the faunal similarity of bivalves between South Primorye and the Maizuru belt.

Eight new genera (ammonoids: *Shamaraites*, *Ussuridiscus*, *Ambitoides*, *Abrekites*, *Radioprionites*, *Ussuriflemingites*, and *Balhaeceras*; gastropoda: *Abrekopsis*) and sixteen new species (nautiloids: *Gyronautilus popovi*, *Xiaohenautilus abrekensis*, and *Menuthionautilus evolutus*; ammonoids: *Ambitoides orientalis*, *Abrekites editus*, *A. planus*, *Radioprionites abrekensis*, *Ussuriflemingites abrekensis*, *U. primoriensis*, *Balhaeceras balhaense*, *Rohillites laevis*, and *Parahedenstroemia kiparisovae*; gastropods: *Warthia zakharovi*, *Bellerophon abrekensis*, *Chartronella maedai*, and *Strobeus shigetai*) are described.

Key words: Abrek, ammonoids, conodonts, Induan/Olenekian, Lower Triassic, recovery, South Primorye, stratigraphy.

ロシア・南部プリモーリエ・アベレック湾地域の下部三畳系（重田康成・ Yuri D. Zakharov ・前田晴良・ Alexander M. Popov 編）：

アベレック湾北東岸の採石場に露出する下部三畳系について、層序学的研究と古生物学的研究を行った．下部三畳系はインドゥアン前期（グリンスバキアン期）からオレネキアン前期の中頃（スミシアン中期）に及び，層厚は 165 m に達する．下位からラズルナヤ・ベイ層とジトコフ層に区分される．ラズルナヤ・ベイ層はペルム系アベレック層を不整合で覆い，主に上方細粒化を示す砂岩より成る．一方，ジトコフ層は葉理の発達した暗灰色泥岩と細粒砂岩の薄いタービダイト層より成る．

ラズルナヤ・ベイ層は下位から海進期に堆積したデルタ末端相，暴風時波浪限界より浅海の陸棚相，陸棚から陸棚斜面への漸移相を示す．一方，ジトコフ層下部は陸棚斜面下部相，主部は堆積盆の中で陸に近い領域 (proximal basin) を示す．ジトコフ層主部の厚い単調な泥岩層は葉理が発達し生物擾乱をほとんど欠く．これは泥岩層が貧酸素環境下の安定した堆積盆内で堆積したことを示す．

化石は，ラズルナヤ・ベイ層下部を除き，豊富に産出する．特にジトコフ層には異地性の化石密集層がしばしば挟まれる一方，周囲の泥岩中には化石は希である．化石はアンモノイド類，オウムガイ類，巻貝類，二枚貝類，腕足類，コノドント類，サメ類を中心とし，ウミユリ類やツノガイ類も産出する．アンモノイド区間帯（タクソン区間帯）および化石層は下位から *Lytophiceras* sp. 帯，*Gyronites subdharmus* 帯，*Ambitoides fuliginatus* 帯，*Clypeoceras spitiense* 層，*Paranorites varians* 帯，*Clypeoceras timorense* 帯，*Radioprionites abrekensis* 層，*Balhaeceras balhaense* 層，*Arctoceras subhydaspis* 層が認められた．また，コノドント化石帯は下位から *Neogondolella carinata* 帯，*Neospathodus dieneri*-*N. pakistanensis* 帯，*Neospathodus* ex gr. *waageni*-*N. novaehollandiae* 帯が認められた．産出したアンモノイドのうち，他域と共通するのは数種にすぎず，大部分は固有種である．一方，二枚貝化石群は西南日本の舞鶴化石群に類似する．産出したグリポセラス科オウムガイ類は多様な殻形態と連室細管位置をもち，オウムガイ類が三畳紀前期にパンサラッサ海西部地域で多様化したことを示す．スミシアン前期から産出した *Holocrinus* は本属の最古の記録であり，プリモーリエ南部地域ではペルム紀／三畳紀 (P/T) 境界後のウミユリ類の回復が早かったことを示す．

ラズルナヤ・ベイ層からジトコフ層への遷移はインドゥアン後期の前期（ディーネリアン前期）頃に起きた．インドゥアン後期からオレネキアン前期にわたる連続的な堆積作用のため，例外的に保存が良い化石群がジトコフ層中に保存された．下部三畳系の上方細粒化はプリモーリエ南部地域では顕著であり，化石帯は岩相層序境界と斜交する．アベレック湾地域ではインドゥアン期／オレネキアン期境界はジトコフ層中に位置するが，より西側の地域ではラズルナヤ・ベイ層中に位置する．アベレック湾地域の下部三畳系は「ウスリー堆積盆」の西部地域よりも水深が深い環境下で堆積したと思われる．

アンモノイド類はジトコフ層の葉理が発達した泥岩中では稀であるが，泥岩に挟まれる細粒砂岩層中からは多産する．これらの産状はアンモノイド類が陸棚斜面－陸棚環境よりも浅海に生息し，死後その殻が低密度重力流により貧酸素環境の堆積盆に運搬されたことを示す．

砂岩に含まれるモナズ石の形成年代には 5 億年前と 2.7 億年前が認められた．同様の年代パターンは西南日本の舞鶴帯のペルム系と下部~中部三畳系砂岩にも認められている．これらは両地域の三畳紀前期の堆積物がハンカ地塊あるいは隣接するジャムシ地塊に由来し，中朝地塊には関係しないことを示す．

本論文では，8 新属（アンモノイド類： *Shamaraites, Ussuridiscus, Ambitoides, Abrekites, Radioprionites, Ussuriflemingites, Balhaeceras*，巻貝類： *Abrekopsis*）と 16 新種（オウムガイ類： *Gyronautilus popovi, Xiaohenautilus abrekensis, Menuthionautilus evolutus*, アンモノイド類： *Ambitoides orientalis*，*Abrekites editus, A. planus, Radioprionites abrekensis, Ussuriflemingites abrekensis, U. primoriensis, Balhaeceras balhaense, Rohillites laevis, Parahedenstroemia kiparisovae*，巻貝類： *Warthia zakharovi, Bellerophon abrekensis, Chartronella maedai, Strobeus shigetai*）を記載した．

猪郷久義・ Andrzej Kaim ・熊谷太朗・前田晴良・中澤圭二・大路樹生・
Alexander M. Popov ・重田康成・辻野泰之・堤　之恭・山岸　悠・横山一己・ Yuri D. Zakharov

Introduction

(by. Y. Shigeta, Y. D. Zakharov, H. Maeda, A. M. Popov, K. Yokoyama and H. Igo)

Marine Lower Triassic deposits are widely distributed in South Primorye, Russian Far East and have attracted the attention of many scientists since pioneer workers D. L. Ivanov, C. Diener, and A. Bittner described ammonoids, bivalves and other fossils from the area in the 1890s. During the 20th century, numerous fossils of various kinds of taxa have been described, and subsequently, it is now recognized that South Primorye may provide an important key to the establishment of a precise biostratigraphic framework for the Lower Triassic (Markevich & Zakharov, 2004).

The Lower Triassic in South Primorye yields numerous well-preserved fossils from various horizons within a relatively complete biostratigraphic sequence, including some biozones with species common to the Boreal, Tethyan and Eastern Panthalassa realms (Kiparisova, 1938, 1961, 1972; Burij, 1959; Burij & Zharnikova, 1962, 1981; Zakharov, 1968, 1996, 1997a, 1997b; Buryi, 1979, 1997; Zakharov *et al.*, 2002, 2004a, 2004b, 2005a, 2005b). Consequently, Y. D. Zakharov proposed the Tri Kamnya Cape and Abrek Bay sections as candidates for the Global Stratotype Section and Point (GSSP) for the Induan-Olenekian (I/O) boundary (Zakharov, 1994, 1996; Zakharov & Popov, 1999; Zakharov *et al.*, 2000, 2002). Although the two sections were later withdrawn as GSSP candidates due to magnetostratigraphy problems (Zakharov, 2004, 2006), future paleontological and geological studies of both sections will surely contribute to a better understanding of the dynamics of the biotic recovery following the Permian-Triassic (P/Tr) mass extinction, as well as to the establishment of a biostratigraphic framework. Moreover, its mid-paleolatitudinal setting in western Panthalassa makes it a key biogeographical reference, since the majority of recent works dealing with Early Triassic faunas are from low-paleolatitudinal regions in the Tethys and eastern Panthalassic basins (e.g., Schubert & Bottjer, 1995; Krystyn *et al.*, 2003; Twitchett *et al.*, 2004; Pruss & Bottjer, 2004a, 2004b; Fraiser & Bottjer, 2004; Twitchett & Barras, 2004; Mu *et al.*, 2007; Brayard & Bucher, 2008; Komatsu *et al.*, 2008).

The Abrek Bay section is worthy of consideration as one of the reference sections for Triassic stratigraphy in South Primorye (Markevich & Zakharov, 2004). Zakharov *et al.*, (2000) have already outlined the regional geology of the area, and a number of Triassic mega-fossils have been described by previous authors (Diener, 1895; Bittner, 1899b; Kiparisova, 1938, 1960, 1961, 1972; Dagys, 1974; Zakharov & Shigeta, 2000). However, most fossils as well as microfossils have not yet been described and many fossil assemblages are still unknown.

In order to better understand the fossil assemblages and establish the area's biostratigraphy, a Japanese-Russian Joint Research Program was started in 1998, and scientific expeditions to Abrek Bay and other areas were successfully carried out for ten years. This paper includes the results of the field survey and laboratory investigations as well as pertinent discussions regarding the Abrek Bay section.

Research methods

During field work, we investigated most distinctive sedimentary features of the Triassic sequence, carefully observed the mode of fossil occurrence and followed bedrock-controlled collection techniques in order to establish the biostratigraphy of ammonoids and conodonts. Most megafossil samples were carefully recovered from the strata with special attention to detailed taphonomic considerations.

In an effort to investigate conodonts and other microfossils, we have examined a total of twenty-seven rock samples. Microfossils were removed from the rocks by applying 5% acetic acid to approximately 0.5 kg of sample material, then sieving (2 mm, 0.42 mm, and

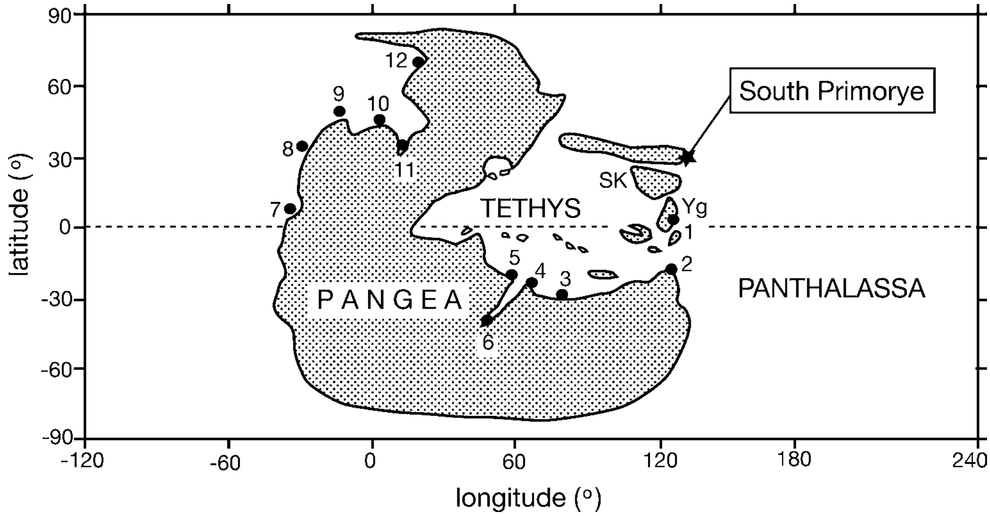


Fig. 1. Paleogeographical map of the Early Triassic period showing the paleoposition of South Primorye and other areas (modified after Péron *et al.*, 2005; Brayaed *et al.*, 2006). SK: Sino-Korea (North China) Craton, Yg: Yangtze (South China) Craton, 1: South China, 2: Timor, 3: Spiti, 4: Salt Range, 5: Oman, 6: Madagascar, 7: Nevada, 8: British Columbia, 9: Ellesmere Island, 10, Spitbergen, 11: Greenland, 12: Olenek River area.

0.1 mm screens) and washing. Laboratory residues were hand-picked using a binocular microscope, and microfossils were mounted onto cardboard microslides with water soluble glue (gum tragacanth).

Most of the conodonts are discrete segminate elements. Fragile ramiform elements are also present, but they are fragmented and difficult to identify. The orientation of elements is now largely modified by intensive analyses of multielement reconstruction of conodont animals (e.g., Purnell *et. al.*, 2000). The specimens treated herein are mostly P elements, thus we apply traditional usage of orientation terms such as defined by Sweet (1988).

The conventional approach to provenance studies of sandstones is based on the determination of palaeo-current trends, the nature and modal proportion of the constituent rock and mineral clasts, and chemical analyses of the heavy minerals in the sandstones. The development of analytical techniques that allow age determination to be made for individual mineral grains has provided powerful tools for use in provenance studies. Many age dating methods have been applied to the provenance studies of zircon e.g., SHRIMP (Ireland, 1991; Tsutsumi *et al.* 2003), fission-track (Garver *et al.* 1999), and ICPMS (Wyck & Norman, 2004; Evans *et al.* 2001), and of monazite by EPMA (Suzuki, *et al.* 1991; Yokoyama *et al.*, 2007). In order to discuss the provenance of various Lower Triassic sandstone detritus in the Abrek Bay area, we analyzed a total of seven sandstone samples, and calculated the age of 188 grains of monazite.

Repository of specimens

All fossils and rock samples investigated herein were collected during field work and transported from Russia to Japan with permission from the Russian Government and other concerned authorities. Specimens of cephalopods, gastropods, bivalves, scaphopods, and conodonts are kept at the National Museum of Nature and Science, Tokyo. Shark teeth and scales, and crinoid columnals and cirrals are kept at the University Museum, University of Tokyo. Specimens of brachiopods are kept at the Far Eastern Geological Institute, Vladivostok.

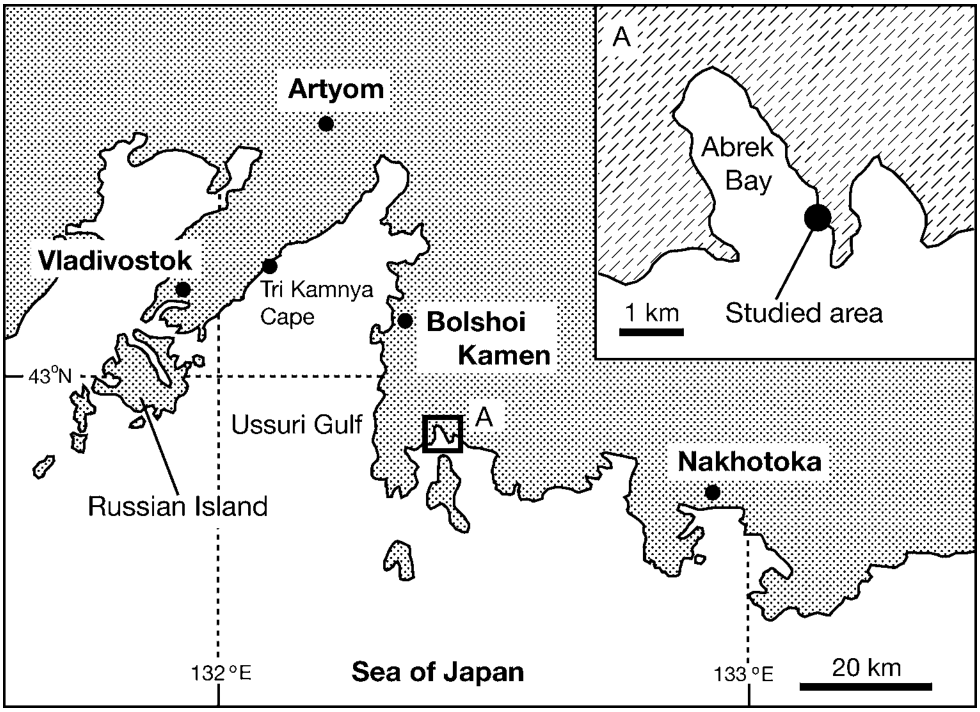


Fig. 2. Map showing location of Abrek Bay area, South Primorye, Far East Russia. Area is located about 45 km southeast of Vladivostok.

Paleogeographical and geological setting
(by Y. Shigeta, H. Maeda, K. Yokoyama and Y. D. Zakharov)

Collision and amalgamation of continental or microcontinental blocks are recognized as one of the major tectonic processes responsible for the formation of East Asia during the Permian to Triassic period. Lower Triassic marine deposits in South Primorye belong to the Khanka Block, which is composed of Precambraian metamorphic rocks covered by thick Paleozoic-Mesozoic volcanic-sedimentary deposits (Khanchuk, 2001). The Khanka Block was part of the continent that was amalgamated with the Northeast China Block, including the Jiamusi and Shongliao-Zhangguangcai blocks during the Early Permian (Jia *et al.*, 2004). Collision of the Khanka Block and the Sino-Korea Craton began during the Late Permian-Early Triassic and was completed by the Late Triassic. The Yangtze Craton also collided with the Sino-Korea Craton during the Triassic to form a huge continent that essentially is the present-day Eurasian continent.

The Lower Triassic System in South Primorye, consisting mainly of clastic rocks deposited in various environments, was probably deposited along the eastern continental margin of the Khanka block, which was probably situated in the middle northern latitudes (Fig. 1, Péron *et al.*, 2005; Zakharov *et al.*, 2008). These outcrops are distributed in two areas, 1) the Russian Island-Vladivostok-Artyom area and the western coast of the Amur Gulf, and 2) the eastern coast of the Ussuri Gulf and Abrek Bay area. The former belongs to “the Voznesenka Block” and the latter to “the Sergeevka Block”, both of which are subblocks of the Khanka Block (Khanchuk *et al.*, 1996). In the Russian Island-Vladivostok-Artyom area, shallow marine facies predominate in the southwestern part (Russian Island), while offshore facies dominate in the north-

Fig. 3. Satellite photograph of Abrek Bay area, South Primorye. Well exposed Lower Triassic section is located in quarry along northeastern coast of Abrek Bay. Quarry is visible just southeast of southernmost ships.

eastern part (Artyom). As indicated by Zakharov (1968, 1997a), an eastward-deepening setting is inferred. In the other area, thick basal conglomerate is characteristic of the western part (eastern coast of Ussuri Gulf). The Lower Triassic Abrek section represents the typical eastern offshore facies as described below.

Stratigraphy

(by H. Maeda, Y. Shigeta, Y. Tsujino and T. Kumagae)

Located about 45 km southeast of Vladivostok, the Abrek Bay Lower Triassic section is well exposed in a quarry on the northeastern coast of Abrek Bay (Figs. 2–5), in which a 165 m thick continuous succession of Lower Triassic strata is visible. These sediments unconformably overlie the Permian Abrek Formation, dip 15–50° westward, and strike N40–70°E. Lithostratigraphically, they are divided into the Lazurnaya Bay and Zhitkov formations in ascending order.

Lazurnaya Bay Formation

Stratotype: Lazurnaya (=Shamara) Bay on the western coast of Ussuri Gulf, South Primorye (Zakharov, 1996).

Thickness: 84.8 m in total. Detailed stratigraphic level and interval are shown as height from the base, e.g., 15 m level and 25–30 m interval (see Figs. 6–8, 11–13).

Fig. 4. Triassic outcrop in Abrek Bay area. Upper: Distant view of northern part of quarry. In addition to the Lower Triassic section, overlying sediments of Middle Triassic age are partially exposed in distance. Ammonoids and radiolarians of Anisian age occur in calcareous concretions in dark gray, laminated mudstone (Zakhrov *et al.*, 2000). Middle: View of studied outcrop from the north. Lower: View of studied outcrop from the south. A 165 m thick continuous succession of Lower Triassic strata is observable in the quarry. Lithostratigraphically, the section is divided into the Lazurnaya Bay and Zhitkov formations in ascending order. The Lazurnaya Bay Formation, which unconformably overlies the Permian Abrek Formation, consists mainly of sandstone exhibiting an upward-fining sequence. In contrast, the overlying Zhitkov Formation consists of dark gray, laminated mudstone intercalated with thin, fine sandstone beds of turbidic origin, some of which are fossiliferous.

Lithology: The formation consists mainly of sandstone and exhibits a fining-upward sequence. Sandstone and conglomerate comprise the lower part (0–26.5 m level), while the middle part (32–59.2 m) consists of bedded sandstone intercalated with wavy-mudstone layers. Alternating beds of fine-grained sandstone and mudstone intercalated with slump breccia dominate the upper part (62–84.8 m).

Although covered by soil and vegetation, the basal part above the unconformity consists of greenish gray, medium to fine-grained thickly bedded sandstone exhibiting a coarsening-upward sequence (0–6 m). It is succeeded by alternating beds of coarse-grained sandstone and granule conglomerate (6.0–8.9 m), and pebble conglomerate composed mainly of rounded to subrounded volcanic rock and chert pebbles and cobbles ranging from 30–100 mm in diameter in a greenish gray, medium-grained sandstone matrix (8.9–14.4 m; Fig. 11). The top of the lower part of the formation consists of greenish gray, medium-grained thickly bedded sandstone containing mudstone patches and shell patches (14.4–26.5 m). Each sandstone bed grades upward into bioturbated muddy sandstone via laminated fine-grained sandstone.

The middle part (32–59.2 m) consists mainly of ill-sorted, greenish gray, fine-grained sandstone intercalated with wavy-mudstone layers. The sandstone beds are 5–20 cm thick, and sometimes contain thin lenticular shellbeds, while the intercalated wavy mudstone layers are 1–5 cm thick, intensely mottled (Fig. 12), and contain *Phycosiphon* tubes (Figs. 6, 7).

Yellowish gray, 20–100 cm thick, fine to medium-grained sandstone beds are also occasionally intercalated in the middle part (37–38.2 m, 38.2–38.8 m, 43.4–43.8 m, 47.2–48 m; Figs. 6, 7). These sandstone beds, which sometimes contain mudstone patches, are, in turn, intercalated with thin shellbeds containing poorly preserved bivalve shells (AB1005, 1006). Current ripples exhibiting a NW to SW direction are clearly visible in the basal plane of some sandstone beds (37 m at AB1006). A greenish gray, medium to fine-grained sandstone at the 54–57 m level is also intercalated with wavy-mudstone layers, but fewer than the middle part in general, and it also contains calcareous concretions in the lower part (Fig. 7). A wavy-layer at 56.8 m displays climbing ripples, suggesting a NW direction.

The upper part (62–84.8 m), beginning immediately above an unexposed interval (59.2–62 m), consists of alternating beds of bluish-gray to greenish-gray, fine-grained sandstone (2–20 cm thick) and dark gray wavy-laminated mudstone (1–10 cm thick). These sandstone beds, which sometimes become thicker, 30–80 cm (77–79 m, 81–82 m, 82–84.6 m), are ill-sorted and slightly mottled, and grade upward into wavy-mudstone layers. Bioturbation has usually obscured the top surface of the sandstone. Current ripples suggesting a direction of S74°W to N74°E are observable on the top surface of the sandstone bed (84.6 m; Fig. 8).

Slump breccia, consisting of angular mudstone blocks and subangular or subrounded fine-grained sandstone blocks, and yellowish gray, fine-grained muddy sandstone matrix, is intercalated in the upper part (79–81 m, Fig. 13).

Fossils: Megafossils are rare in the lower part of the Lazurnaya Bay Formation. Shell patches in the bedded sandstone contain the following taxa: ammonoid—*Lytophiceras*? sp. indet.; bivalve—*Promyalina putiatinensis* (Kiparisova); and brachipods—*Orbiculoidea* sp. indet. at AB1004 (23–24.5 m).

The middle part of the Lazurnaya Bay Formation is more fossiliferous. Lenticular shellbeds contain brachiopods—*Lingula borealis* Bittner and *Orbiculoidea* sp. indet. at AB1005 (33.1 m) and AB1006 (37.2 m). Poorly preserved ammonoids—*Lytophiceras* sp. indet. and *Tompophiceras* sp. indet.; bivalve—*Claraia stachei* Bittner; and brachiopod—*Orbiculoidea* sp. indet. were collected at AB1007 (39.2 m). Various brachiopod taxa were found along with *Lingula borealis* and *Abrekia sulcata* Dagys in the sandstone bed at AB1008

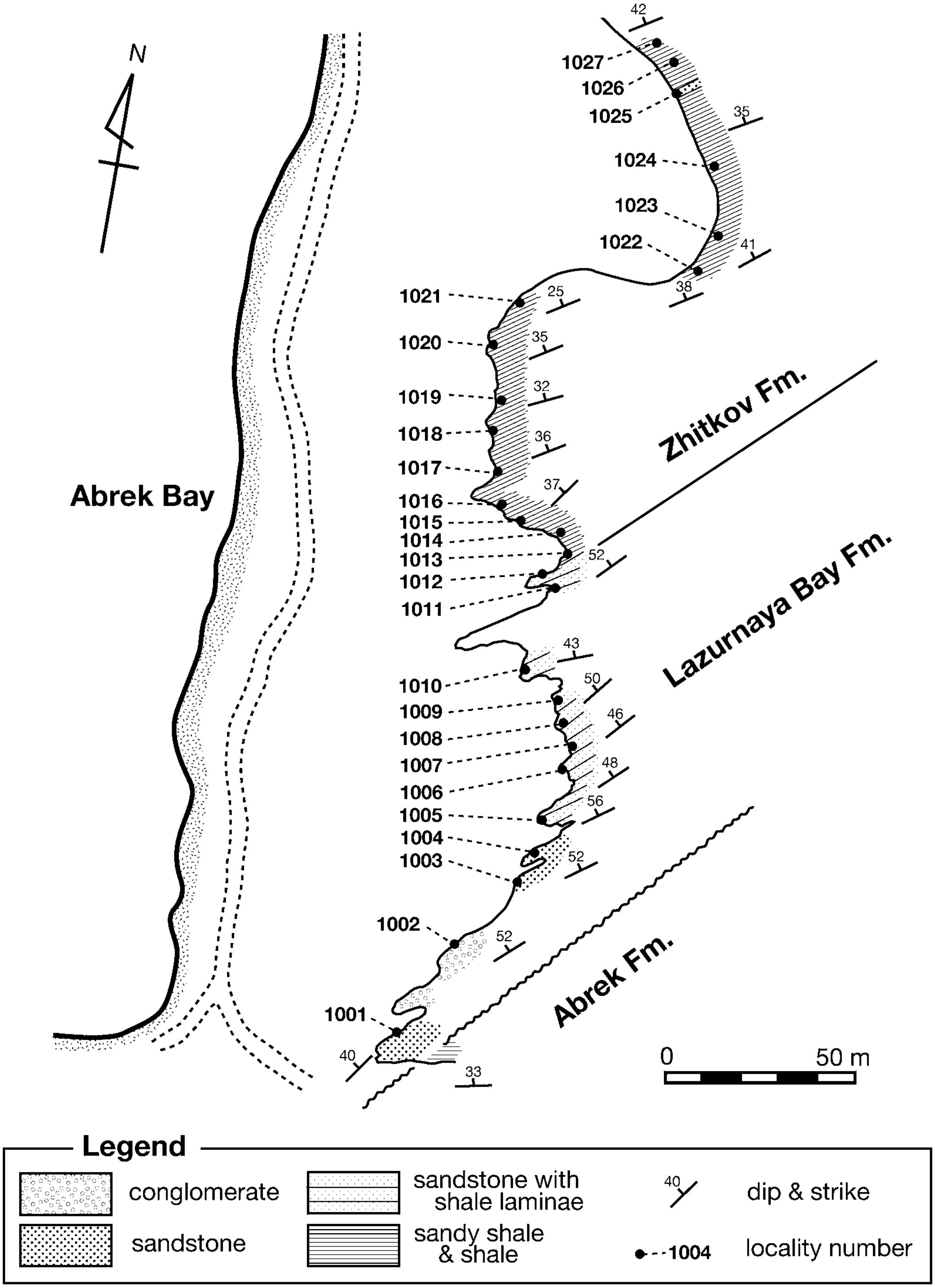


Fig. 5. Plan view of Abrek Bay section showing rock types and structural attitude of beds as well as locality numbers. In text, locality numbers are preceded by prefix “AB”.

(43.5 m). This bed also contains the following taxa: ammonoid—*Bukkenites*? sp. indet.; nautiloid—*Gyronautilus popovi* Shigeta and Zakharov sp. nov.; gastropod—*Warthia zakharovi* Kaim sp. nov.; and conodont—*Neogondolella carinata* (Clark, 1959). Ammonoids collected from calcareous concretions at AB1009 (53.8–54.6 m) include *Lytophiceras*? sp. indet., *Pseudoproptychites hiemalis* (Diener) and *Ussuridiscus varaha* (Diener) gen. nov.

Megafossils are very common in the upper part of the Lazurnaya Bay Formation. The following fossils along with many microgastropods were collected from calcareous concretions at AB1010 (64.8–67 m): ammonoids—*Pseudoproptychites hiemalis*, *Ussuridiscus varaha*, *Wordieoceras* cf. *wordiei* (Spath), *Dunedinites magnumbilicatus* (Kiparisova), and *Gyronites subdharmus* Kiparisova; nautiloid—*Gyronautilus praevolutus* (Kiparisova); bivalves—*Claraia stachei*, *Leptochondria minima* (Kiparisova), "*Modiolus*" sp. indet., *Neoschizodus* cf. *laevigatus* (Ziethen), *Promyalina schamarae* (Bittner), *Pteria ussurica* (Kiparisova), *Myoconcha* sp. indet., *Triaphorus* aff. *multiformis* Kiparisova, *Ochotomya*? sp. indet., *Unionites canalensis* (Catullo), and *Unionites fassaensis* (Wissmann); gastropods—*Bellerophon abrekensis* Kaim sp. nov., *Worthenia* sp. indet., *Abrekopsis depressispirus* (Batten and Stokes) gen. nov., *Coelostylina* sp. indet.; and conodont—*Neogondolella carinata*.

The following fossils are abundant in the sandstone bed at AB1011 (81–82 m): ammonoids—*Ussuridiscus varaha*, *Gyronites subdharmus* and *Pachyproptychites otoceratoides* (Diener); and nautiloid—*Xiaohenautilus abrekensis* Shigeta and Zakharov sp. nov. A large sized specimen of the gastropod—*Omphaloptycha hormolira* Batten and Stokes was also obtained.

The following megafossils along with the conodont—*Neogondolella carinata* were collected from calcareous concretions at AB1012 (82–84.6 m): Nautiloid—*Menuthionautilus evolutus* Shigeta and Zakharov sp. nov.; ammonoid—*Ambitoides fuliginatus* (Tozer) gen. nov.; bivalves—*Claraia stachei*, *Promyalina schamarae*, and *Unionites fassaensis*; gastropod—*Bellerophon abrekensis* Kaim sp. nov.

Depositional environment: The lower part of the Lazurnaya Bay Formation mainly represents a distal deltaic facies deposited during a transgression. Fluvial facies and tidal facies sensu stricto seem to be absent in the Abrek Bay section although coarse-grained deposits are predominant in a transgressive succession (Bhattacharya, 2006). The occurrence of marine fossils supports this view.

The middle part of the Lazurnaya Bay Formation represents a shelf environment above the storm wave base (Sutter, 2006). Various benthic activities indicate that the facies were not deposited under the oxygen-minimum zone, but in the aerobic surface-water column. Wave dominated sedimentary structures are not preserved because of bioturbation.

The upper part of the Lazurnaya Bay Formation represents a transitional facies from a shelf to a slope environment. The intercalation of slump deposits supports this view (Sutter, 2006; Posamentier & Walker, 2006).

Zhitkov Formation

Stratotype: Zhitkov Cape on the eastern coast of Russian Island, South Primorye (Zakharov, 1997a).

Thickness: Greater than 81 m (84.6–165.6 m interval above the base of the Lazurnaya Bay Formation; Figs. 8–10, 13, 14).

Lithology: The Zhitkov Formation consists mainly of dark gray, laminated mudstone intercalated with thin (1–20 cm thick), turbiditic fine sandstone beds, some of which are fossiliferous. It conformably overlies the Lazurnaya Bay Formation and is subdivided into the lower part (84.6–95.8 m) and the main part (95.8–165.6 m).

The lower part (84.6–95.8 m) consists of alternating beds of dark bluish-gray, laminated mudstone and fine sandstone, many of which

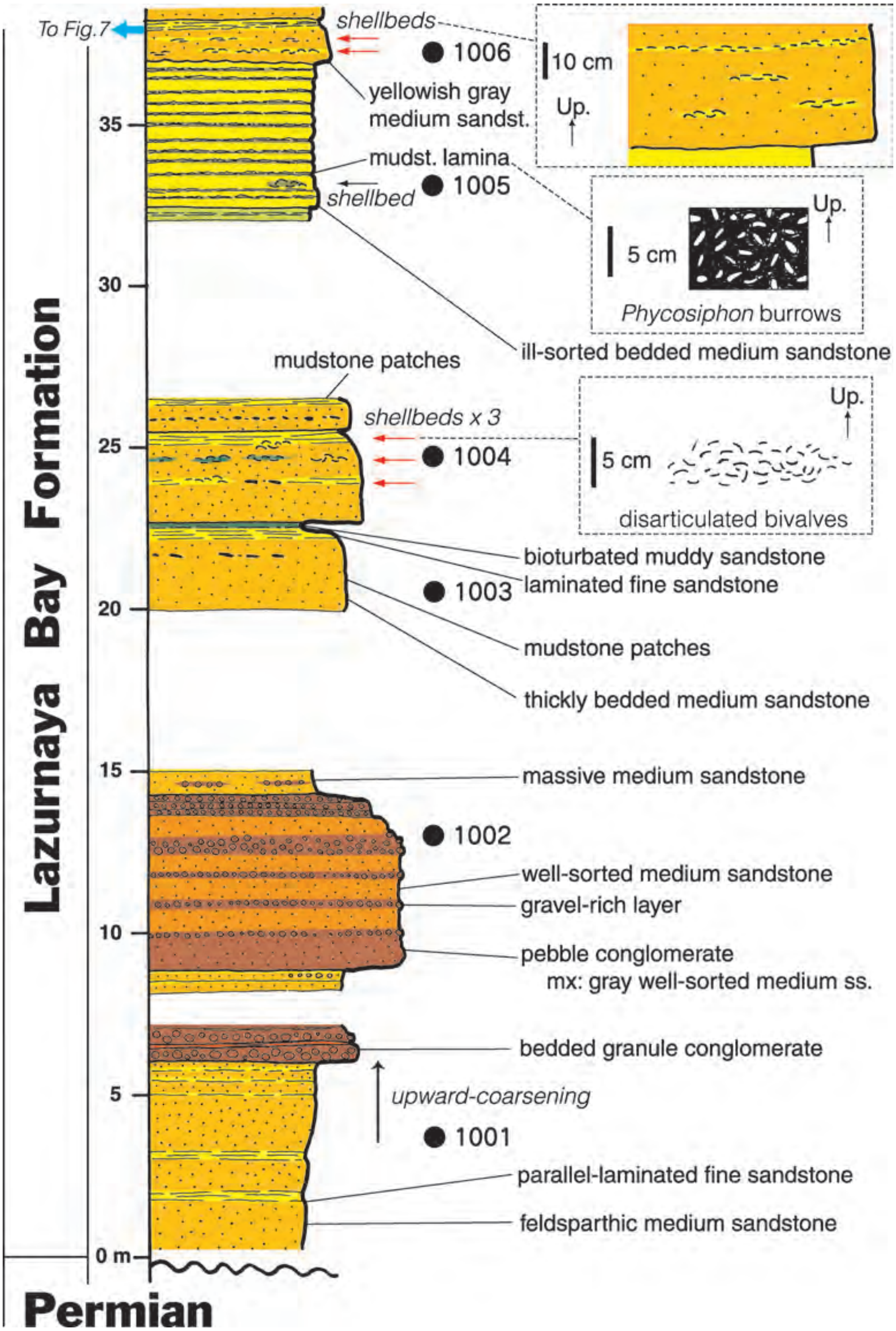


Fig. 6. Columnar section of the Lower Triassic System in the Abrek Bay area (part 1). Top of the figure connects to the bottom of the next Fig. 7. Legend is in Fig. 10. Metric figures by the column indicate the stratigraphic levels above the base of the Triassic System.

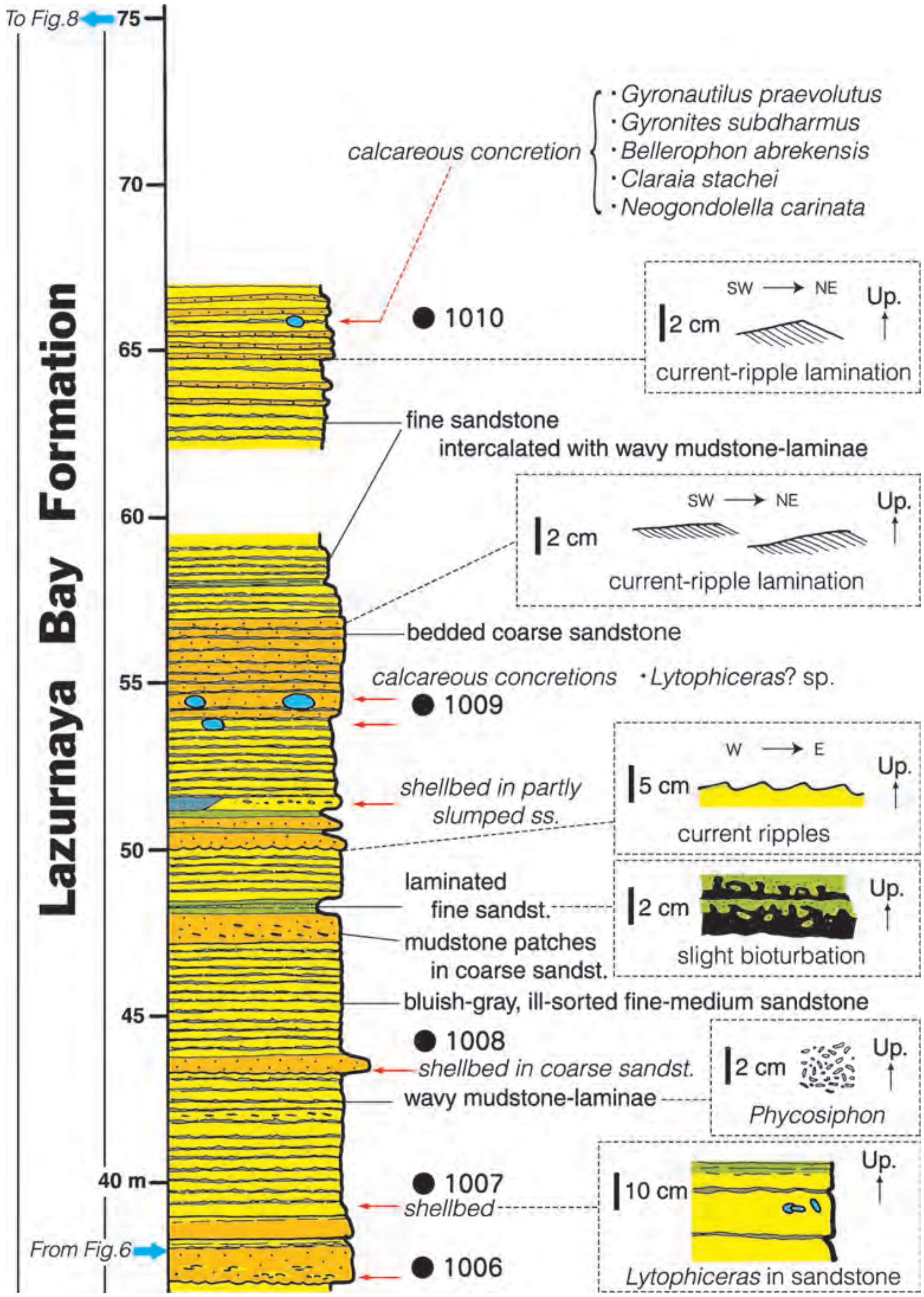


Fig. 7. Columnar section of the Lower Triassic System in the Abrek Bay area (part 2). Bottom of the figure continues from Fig. 6, and the top connects to the bottom of the next Fig. 8. Legend is in Fig. 10. Metric figures by the column indicate the stratigraphic levels above the base of the Triassic System.

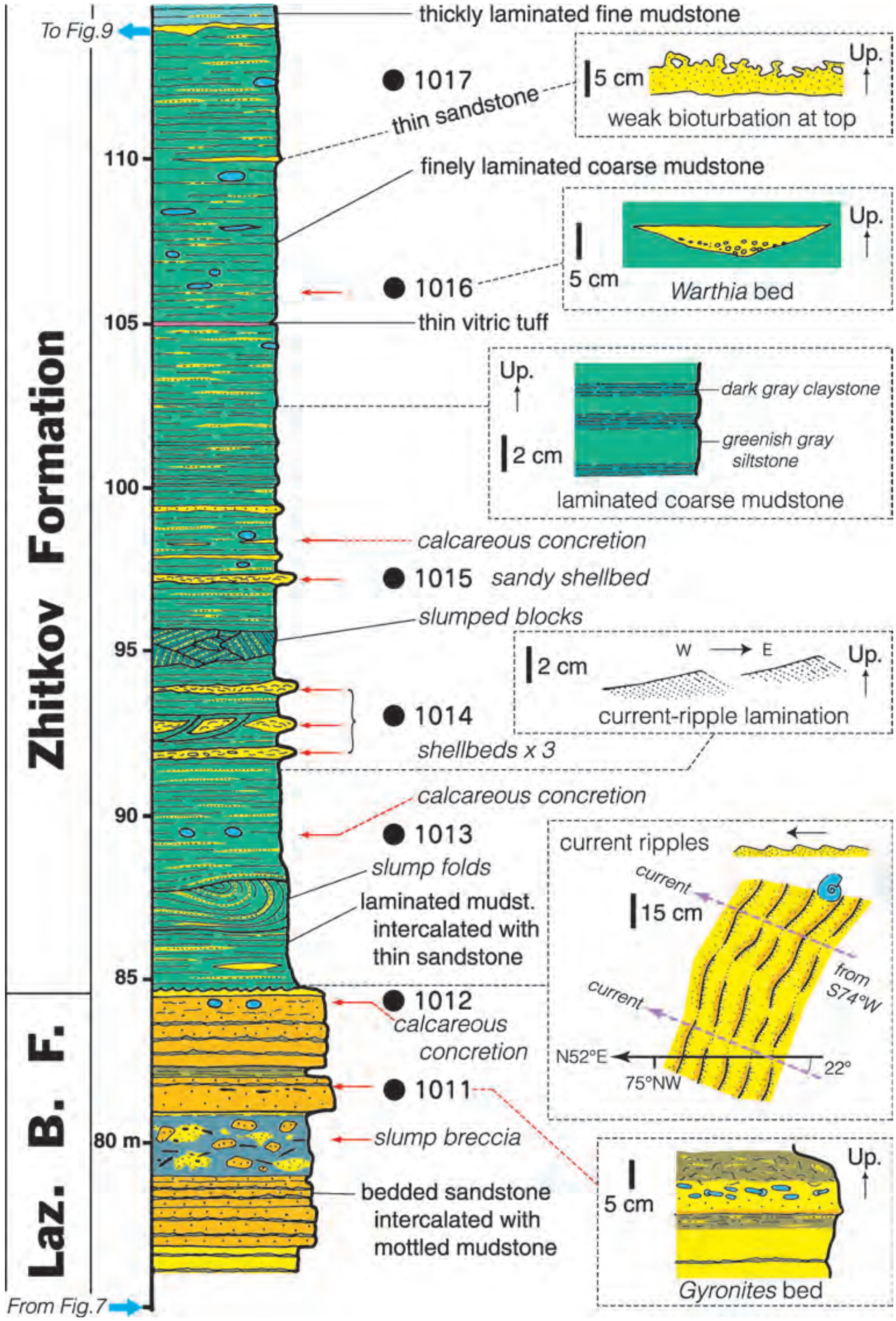


Fig. 8. Columnar section of the Lower Triassic System in the Abrek Bay area (part 3). Bottom of the figure continues from Fig. 7, and the top connects to the bottom of the next Fig. 9. Legend is in Fig. 10. Metric figures by the column indicate the stratigraphic levels above the base of the Triassic System.

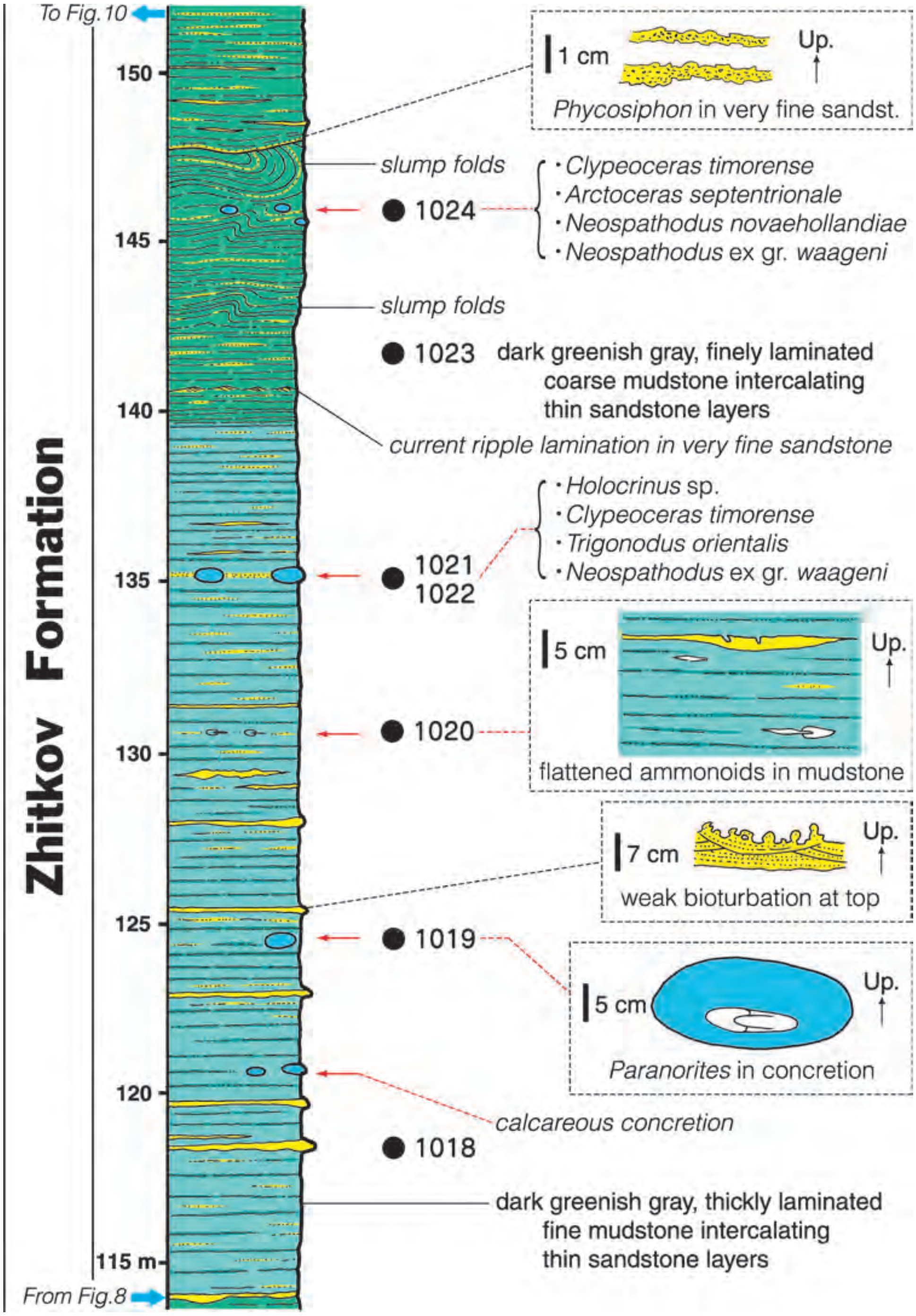


Fig. 9. Columnar section of the Lower Triassic System in the Abrek Bay area (part 4). Bottom of the figure continues from Fig. 8, and the top connects to the bottom of the next Fig. 10. Legend is in Fig. 10. Metric figures by the column indicate the stratigraphic levels above the base of the Triassic System.

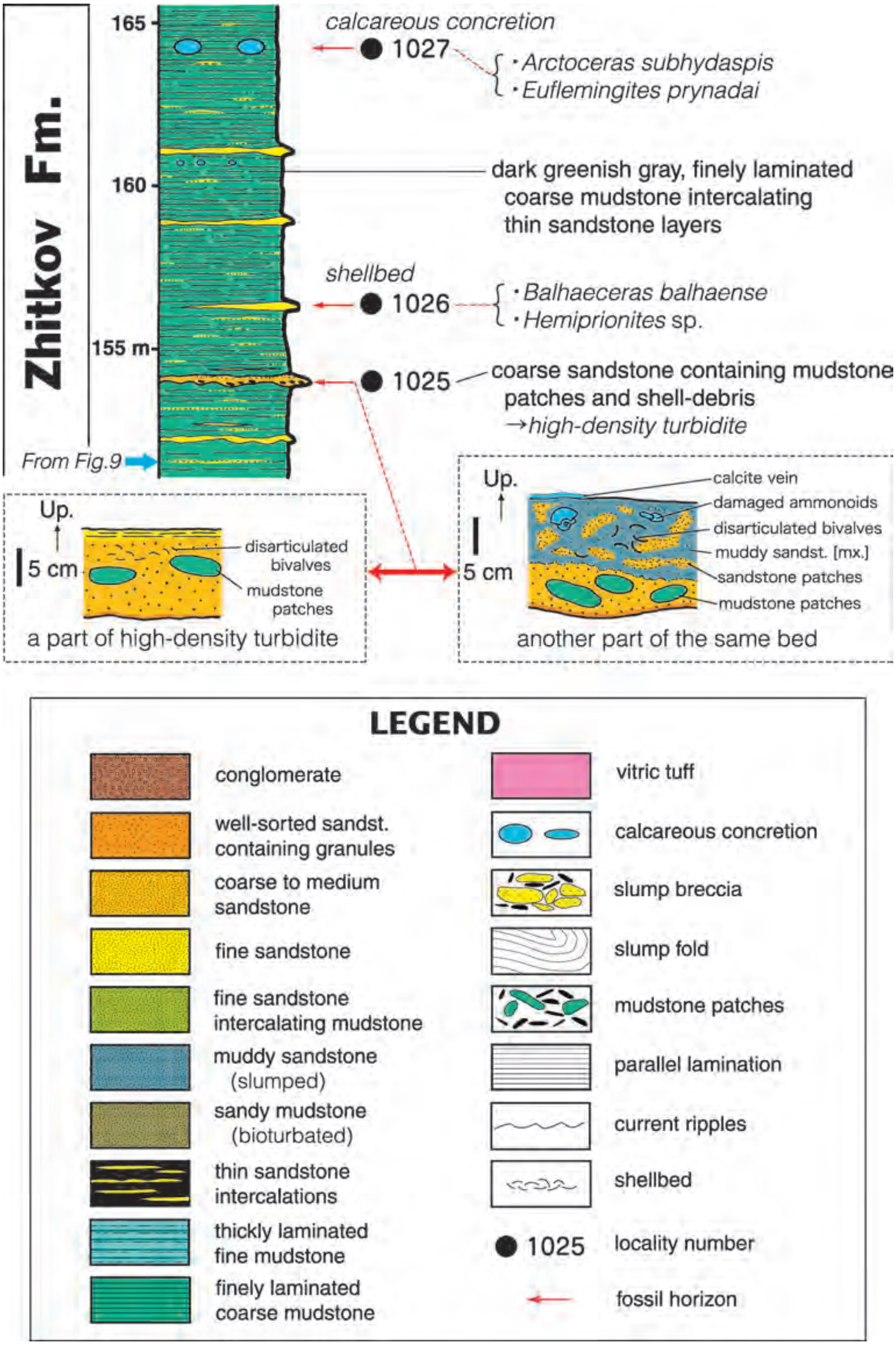


Fig. 10. Columnar section of the Lower Triassic System in the Abrek Bay area (part 5). Bottom of the figure continues from Fig. 9. Metric figures by the column indicate the stratigraphic levels above the base of the Triassic System.

Fig. 11. Conglomerate in lower part of Lazurnaya Bay Formation at AB1002. Upper: Alternating beds of coarse-grained sandstone and granule conglomerate. Lower: Pebble conglomerate composed mainly of rounded to sub-rounded volcanic rock, chert pebbles and cobbles ranging from 30–100 mm in diameter in matrix of greenish gray, medium-grained sandstone.

Fig. 12. Upper: Bedded sandstone intercalated with wavy-mudstone layers in middle part of Lazurnaya Bay Formation. Lower: Ill-sorted, greenish gray, fine-grained sandstone intercalated with wavy-mudstone layers at AB1005.

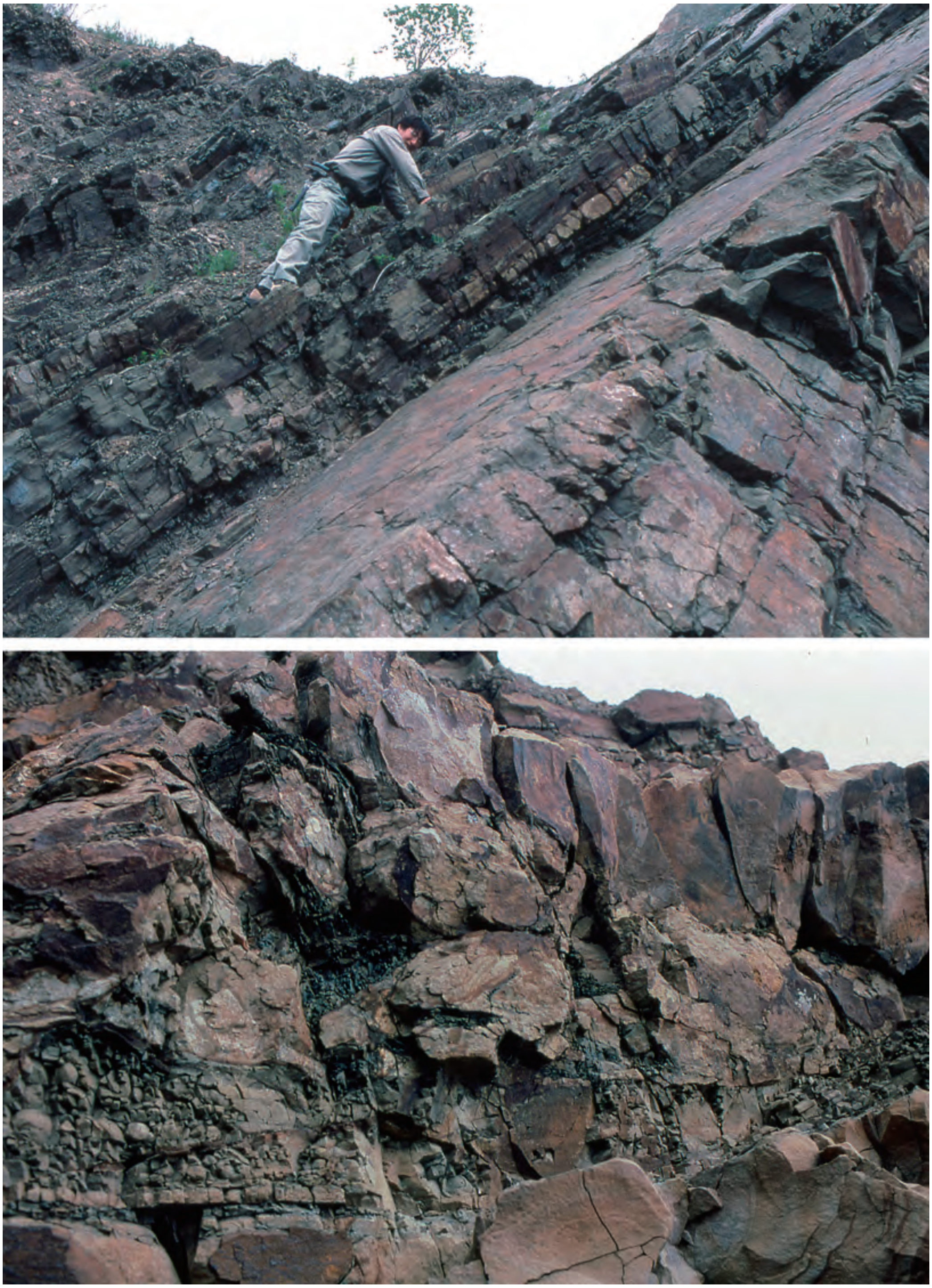


Fig. 13. Upper: Man is standing on approximate contact between Lazurnaya Bay Formation and Zhitkov Formation. Lower: Slump breccia consisting of angular mudstone blocks and subangular or subrounded fine-grained sandstone blocks in matrix of yellowish gray, fine-grained muddy sandstone in upper part of Lazurnaya Bay Formation.

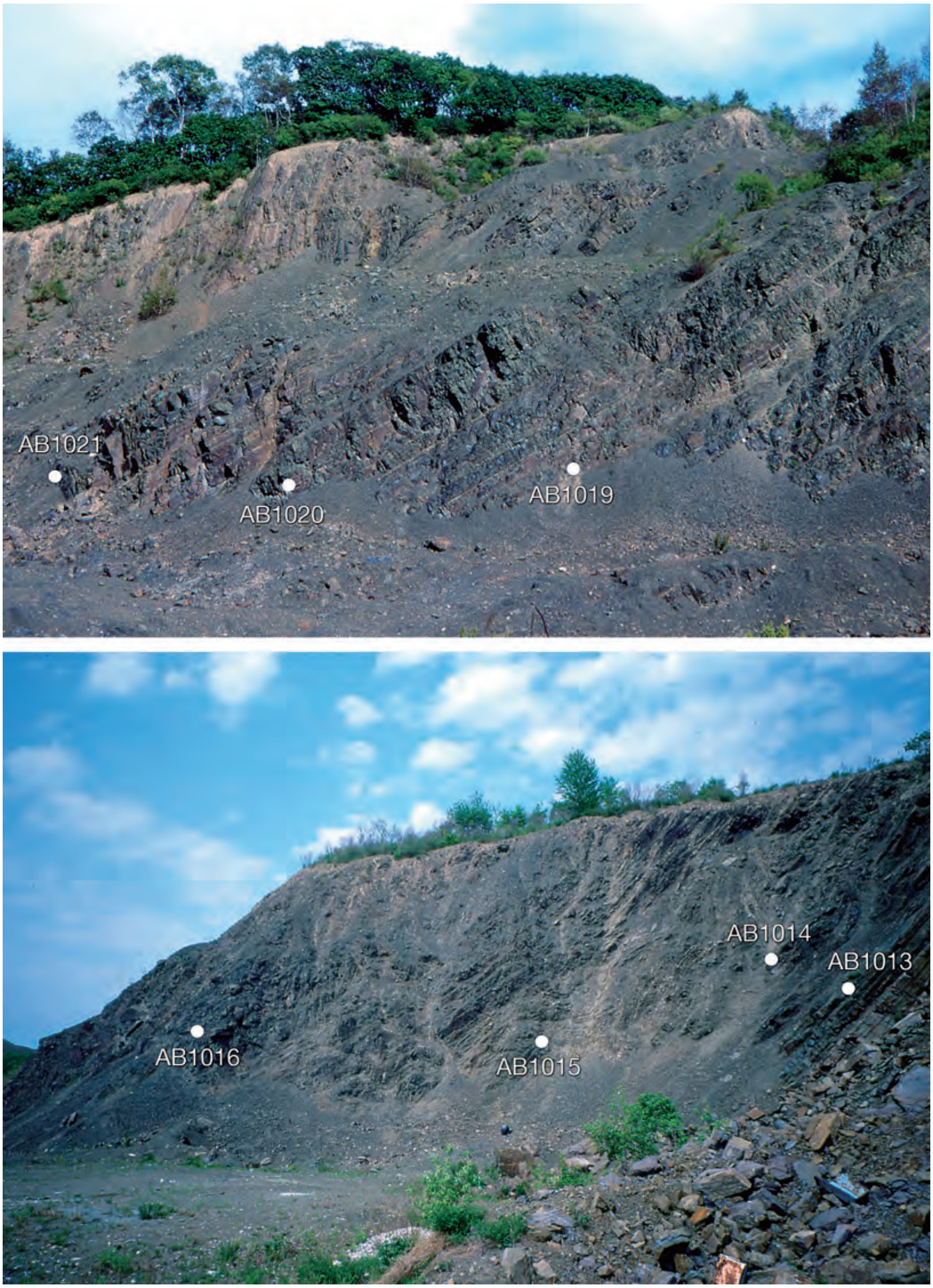


Fig. 14. Dark gray, laminated mudstone intercalated with thin turbiditic fine sandstone beds in Zhitkov Formation. Megafossils are very rare in mudstone in which very little bioturbation is present. In contrast, some sandstone beds are very fossiliferous. Upper: Main part of formation. Induan/Olenekian boundary occurs between AB1021 and AB1019. Lower: Lowermost part and lower main part of formation.

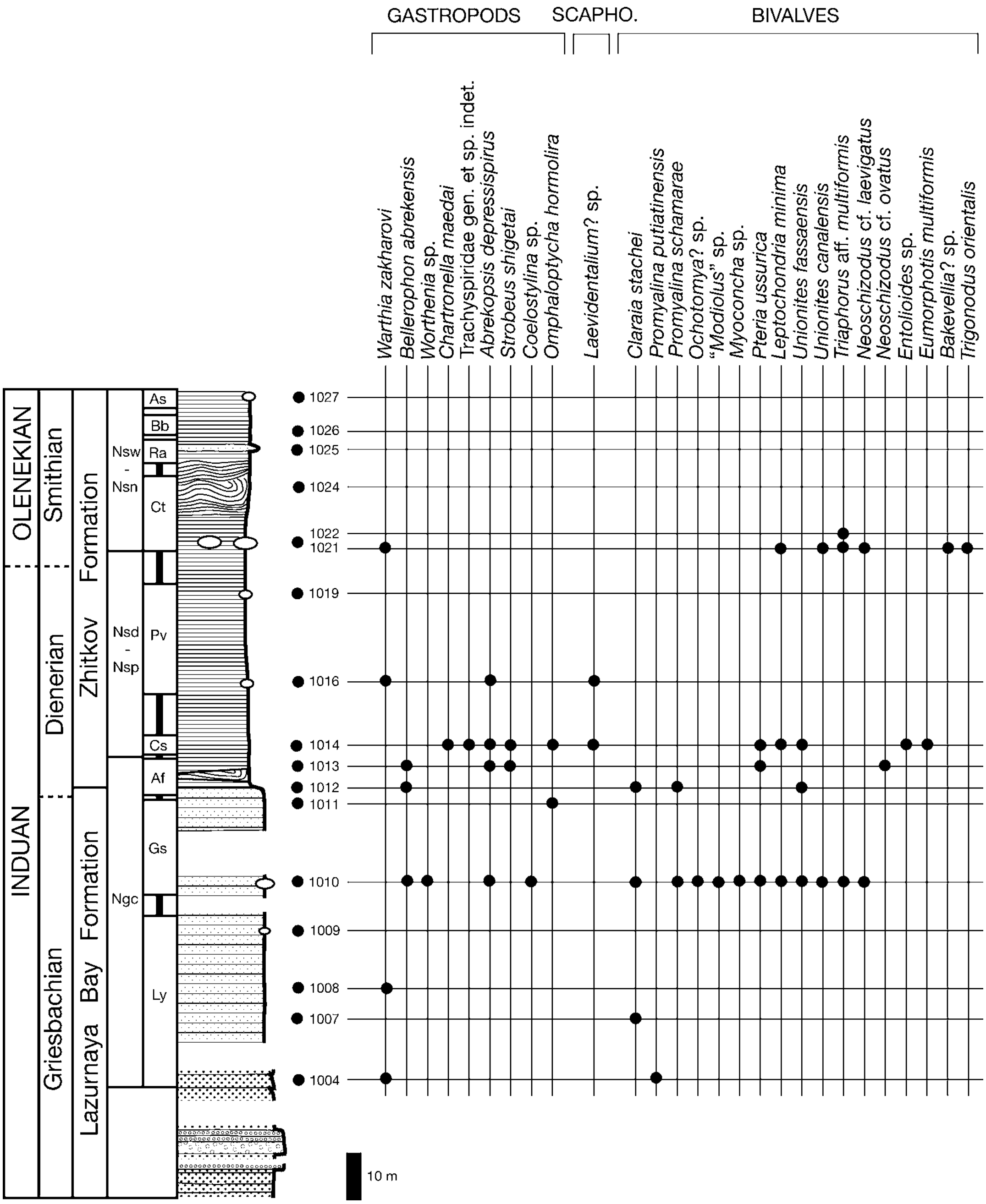
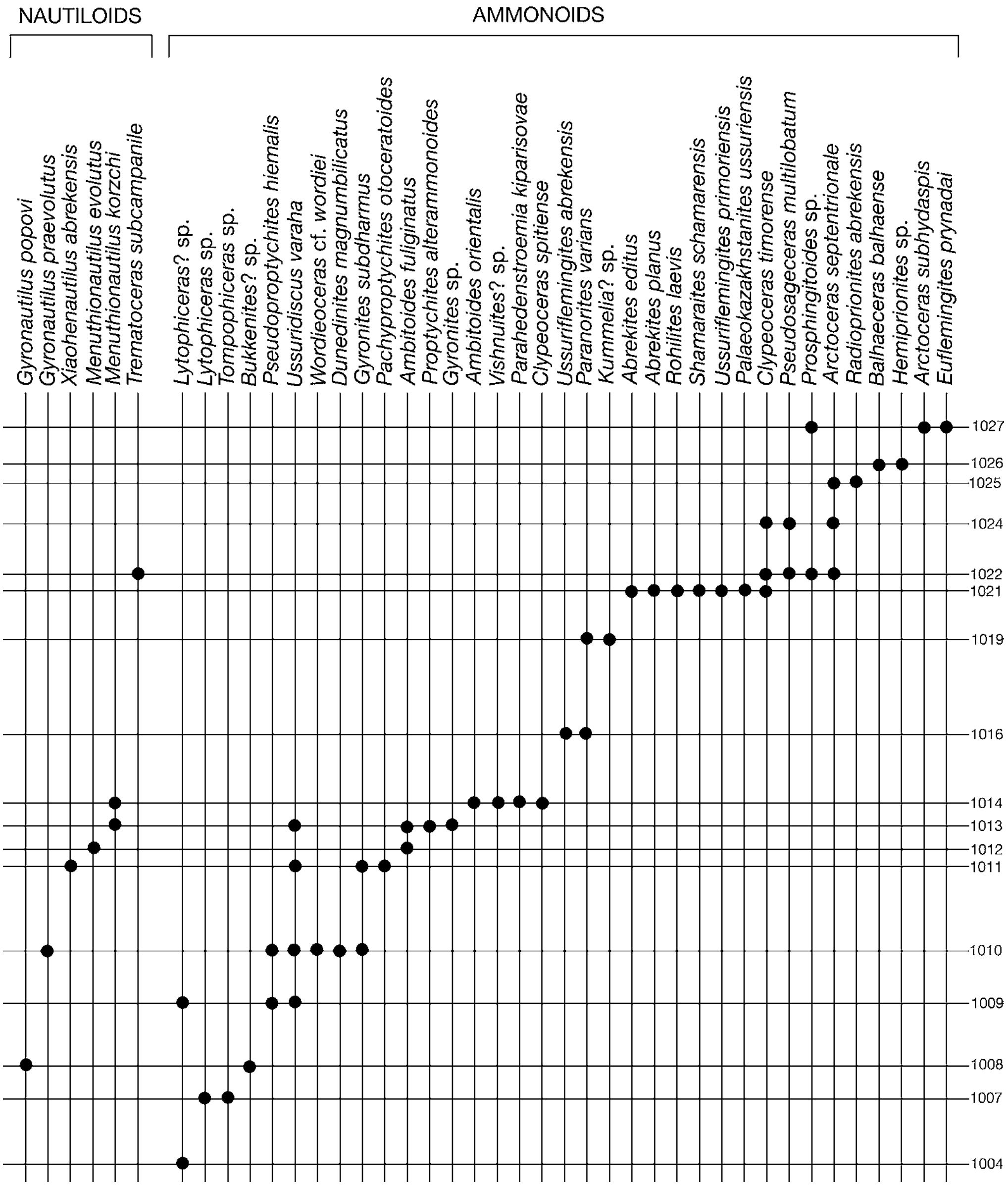


Fig. 15. Distribution of gastropod, scaphopod, bivalve, nautiloid, and ammonoid taxa in Abrek Bay section. Ly: *Lytophiceras* sp. Zone, Gs: *Gyronites subdharmus* Zone, Af: *Ambitoides fuliginatus* Zone, Cs: *Clypeoceras spitiense* "bed", Pv: *Paranorites varians* Zone, Ct: *Clypeoceras timorense* Zone, Ra: *Radioprionites abrekensis* "bed", Bb: *Balhaeceras balhaense* "bed", As: *Arctoceras subhydaspis* "bed", Ngc: *Neogondolella carinata* Zone, Nsd-Nsp: *Neospathodus dieneri-N. pakistanensis* Zone, Nsw-Nsn: *Neospathodus* ex gr. *waageni-N. novaehollandiae* Zone.


NAUTILOIDS
AMMONOIDS
Gyronautilus popovi
Gyronautilus praevolutus
Xiaohenautilus abrekensis
Menuthionautilus evolutus
Menuthionautilus korzchi
Trematoceras subcampanile
Lytophiceras? sp.
Lytophiceras sp.
Tompophiceras sp.
Bukkenites? sp.
Pseudoproptychites hiemalis
Ussuridiscus varaha
Wordieoceras cf. wordiei
Dunedinites magnumbilicatus
Gyronites subdharmus
Pachyproptychites otoceratoides
Ambitoides fuliginatus
Proptychites alterammonoides
Gyronites sp.
Ambitoides orientalis
Vishnuites? sp.
Parahedenstroemia kiparisovae
Clypeoceras spitiense
Ussuriflemingites abrekensis
Paranorites varians
Kummelia? sp.
Abrekites editus
Abrekites planus
Rohillites laevis
Shamaraites schamarensis
Ussuriflemingites primoriensis
Palaeokazakhstanites ussuriensis
Clypeoceras timorense
Pseudosageceras multilobatum
Prosphingitoides sp.
Arctoceras septentrionale
Radioprionites abrekensis
Balhaeceras balhaense
Hemiprionites sp.
Arctoceras subhydaspis
Euflemingites prynadai
1027
1026
1025
1024
1022
1021
1019
1016
1014
1013
1012
1011
1010
1009
1008
1007
1004

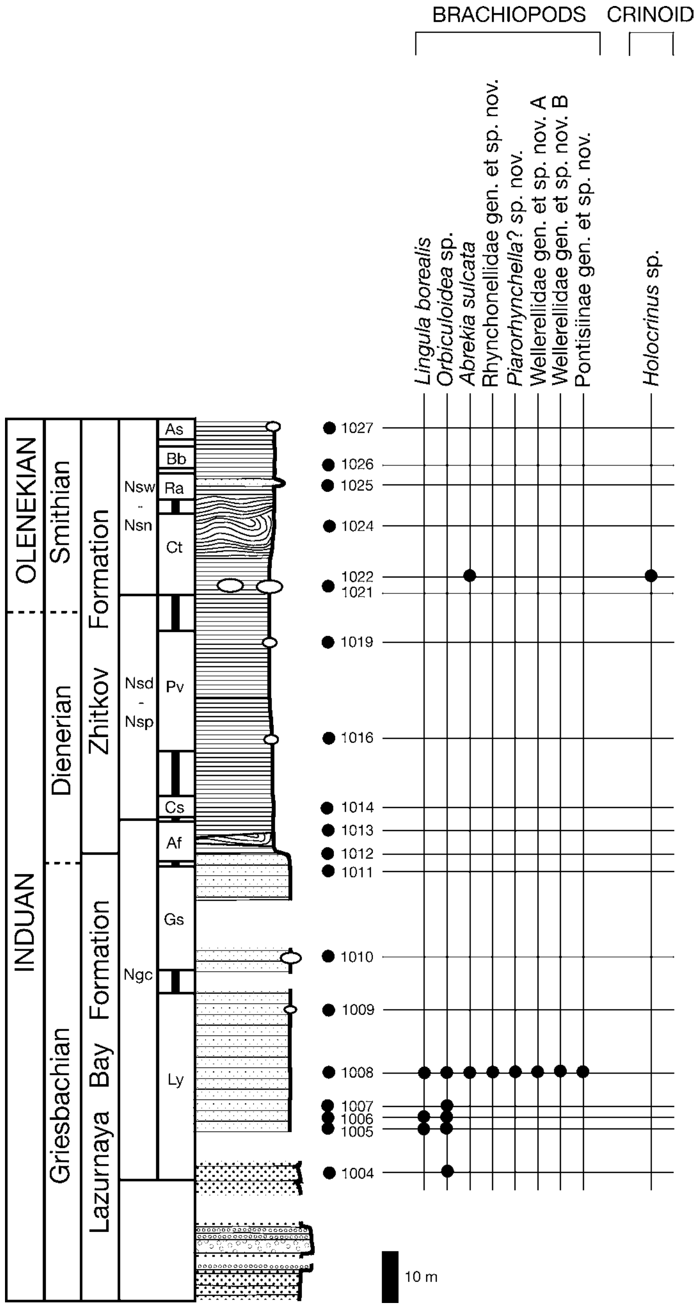


Fig. 16. Distribution of brachiopod and crinoid taxa in Abrek Bay section. Ly: *Lytophiceras* sp. Zone, Gs: *Gyronites subdharmus* Zone, Af: *Ambitoides fuliginatus* Zone, Cs: *Clypeoceras spitiense* "bed", Pv: *Paranorites varians* Zone, Ct: *Clypeoceras timorense* Zone, Ra: *Radioprionites abrekensis* "bed", Bb: *Balhaeceras balhaense* "bed", As: *Arctoceras subhydaspis* "bed", Ngc: *Neogondolella carinata* Zone, Nsd-Nsp: *Neospathodus dieneri-N. pakistanensis* Zone, Nsw-Nsn: *Neospathodus* ex gr. *waageni-N. novaehollandiae* Zone.

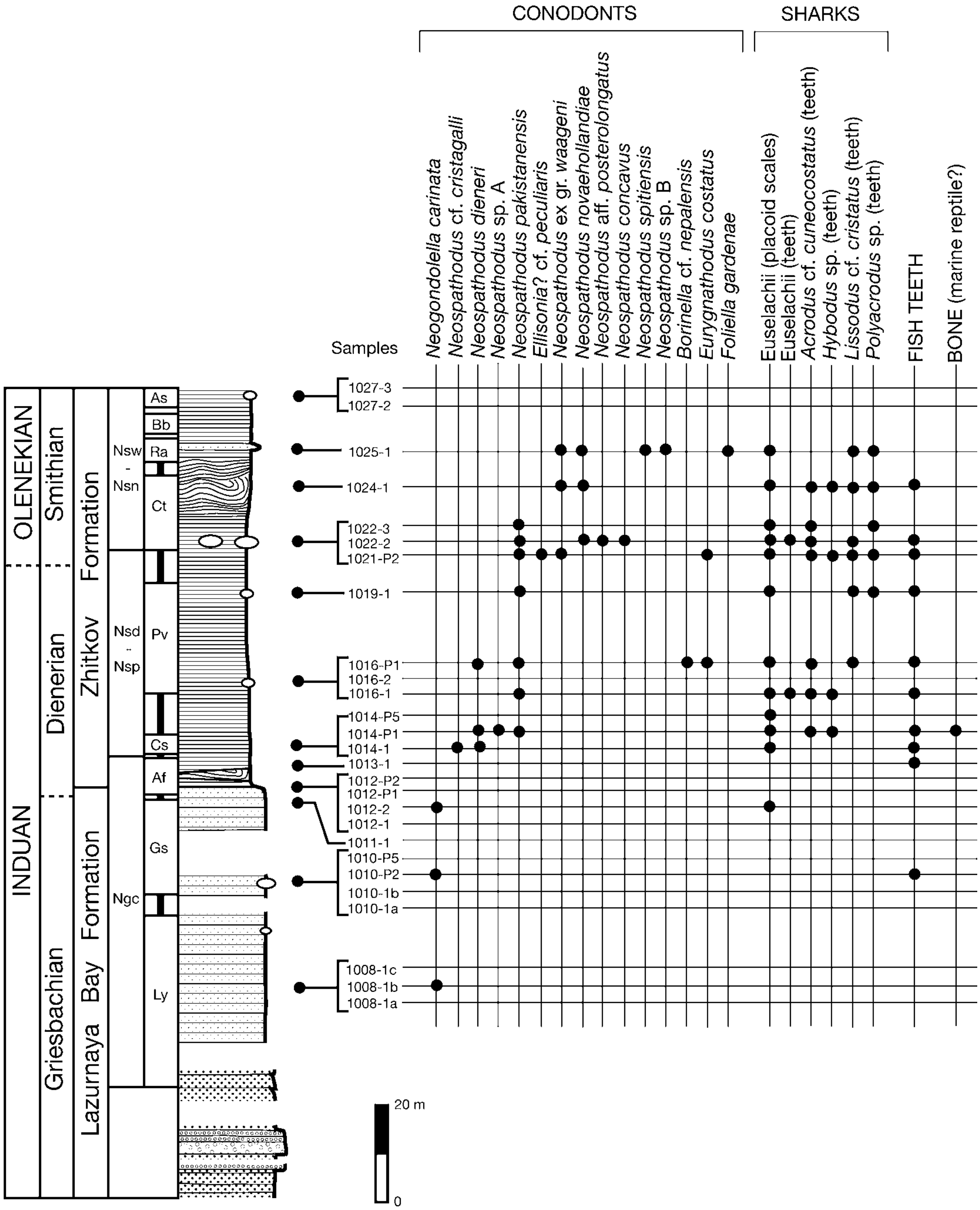


Fig. 17. Distribution of conodonts and shark fossils in Abrek Bay section. Ly: *Lytophiceras* sp. Zone, Gs: *Gyronites subdharmus* Zone, Af: *Ambitoides fuliginatus* Zone, Cs: *Clypeoceras spitiense* "bed", Pv: *Paranorites varians* Zone, Ct: *Clypeoceras timorense* Zone, Ra: *Radioprionites abrekensis* "bed", Bb: *Balhaeceras balhaense* "bed", As: *Arctoceras subhydaspis* "bed", Ngc: *Neogondolella carinata* Zone, Nsd-Nsp: *Neospathodus dieneri-N. pakistanensis* Zone, Nsw-Nsn: *Neospathodus* ex gr. *waageni-N. novaehollandiae* Zone.

form slumped sheets and blocks (Figs. 8, 13, 14). The 30–200 cm thick slump sheets are piled on each other and bounded by low-angle synsedimentay faults, and a few of them exhibit slump folds. The slump blocks are 30–120 cm in diameter and angular shaped (Fig. 8). Several fossiliferous, 10–20 cm thick, fine sandstone beds exhibiting turbiditic features are also intercalated in the basal part.

The main part of the Zhitkov Formation (95.8–165.6 m) consists mainly of dark bluish gray or greenish gray, laminated mudstone intercalated with a few thin (0.5–3 cm), fine-grained sandstone layers (Fig. 14). Very little bioturbation is present in the mudstone, and it occasionally contains spherical or ellipsoidal calcareous concretions ranging in size from 10 to 40 cm. The sandstone layers exhibit parallel and/or current-ripple laminations that resemble the sedimentary features of the upper part of a Bouma sequence, which is suggestive of their distal-turbidite origin. Also intercalated in the main part is a 15 cm thick feldspathic, coarse-grained sandstone bed (99.5 m) as well as a thin bentonitic tuff bed (105 m). A burrowed upper surface is present on a 7 cm thick intercalated sandstone bed at the 110 m and 125.5 m levels (Figs. 8, 9).

Slump deposits (142.5–148 m), characterized by folds and consisting of dark greenish gray, laminated sandy mudstone with intercalations of fine-grained sandstone, are intercalated in the upper part of the main part of the Zhitkov Formation. Ellipsoidal calcareous concretions occur in the mudstone. All of the intercalated sandstones are weakly bioturbated and contain *Phycosiphon*-type burrows, some of which are calcified and fossiliferous (Fig. 9). Also intercalated in the upper part of the main part of the Zhitkov Formation is a 60 cm thick feldspathic, coarse-grained sandstone bed, which exhibits features of a high-density turbidite (154.2–154.4 m; Fig. 10). The lower half consists of coarse-grained sandstone containing sub-rounded to elongated mud patches attaining a diameter of 8 cm, while the upper half consists of ill-sorted muddy sandstone containing abraded shells of ammonoids and bivalves.

Fossils: Calcareous concretions at AB1013 (89.5 m) contain the following taxa: ammonoids—*Ussuridiscus varaha* (Diener) gen. nov., *Ambitoides fuliginatus* (Tozer) gen. nov., *Proptychites alterammonoides* (Krafft) and *Gyronites* sp. indet.; nautiloid—*Menuthionautilus korzchi* (Kiparisova); bivalves—*Neoschizodus* cf. *ovatus* (Goldfuss) and *Pteria ussurica* (Kiparisova); and gastropods—*Bellerophon abrekensis* Kaim sp. nov., *Abrekopsis depressispirus* Kaim gen. nov., and *Strobeus shigetai* Kaim sp. nov.

The calcareous portions of the sandstone beds as well as the calcareous concretions from the 91.8–94.2 m interval at AB1014 are quite fossiliferous. The following fossils along with many microgastropods and a bone fragment, possibly from a marine reptile, were collected: ammonoids—*Ambitoides orientalis* Shigeta and Zakharov gen. nov. sp. nov., *Vishnuites*? sp. indet., *Parahedenstroemia kiparisovae* Shigeta and Zakharov sp. nov., and *Clypeoceras spitiense* (Krafft); nautiloid—*Menuthionautilus korzchi*; gastropods—*Chartronella maedai* Kaim sp. nov., Trachyspiridae gen. et sp. indet., *Abrekopsis depressispirus*, *Strobeus shigetai*, and *Omphaloptycha hormolira* Batten and Stokes; bivalves—*Entolioides* sp. indet., *Eumorphotis multiformis* (Bittner), *Leptochondria minima* (Kiparisova), *Pteria ussurica*, and *Unionites fassaensis* (Wissmann); scaphopod—*Laevidentalium*? sp. indet.; conodonts—*Neospathodus* cf. *cristagalli* (Huckriede), *Neospathodus dieneri* Sweet, *Neospathodus pakistanensi*s Sweet, and *Neospathodus* sp. A; placoid scales, and shark teeth—*Acrodus* cf. *cuneocostatus* Cuny, Rieppel and Sander and *Hybodus* sp. indet. Microgastropod preservation is remarkably good, and the protoconch can be observed in most specimens.

In the main part, the following assemblages were collected from calcareous concretions at

AB1016 (106.2 m): Ammonoids—*Ussuriflemingites abrekensis* Shigeta and Zakharov gen. nov. sp. nov. and *Paranorites varians* (Waagen); gastropods—*Warthia zakharovi* Kaim sp. nov. and *Abrekopsis depressispirus*; scaphopod—*Laevidentalium*? sp. indet.; conodonts—*Neospathodus dieneri*, *Neospathodus pakistanensis*, *Eurygnathodus costatus* Staesche, and *Borinella* cf. *nepalensis* (Kozur and Mostler); placoid scales, and shark teeth—*Acrodus* cf. *cuneocostatus*, *Hybodus* sp. indet., and *Lissodus* cf. *cristatus* Delsate and Duffin. Specimens of *Warthia zakharovi* are usually found in a clusters in the calcareous concretions. (Fig. 8)

The following fossils were collected from calcareous concretions at AB1019 (124.6 m): Large ammonoid, *Kummelia*? sp. indet. and *Paranorites varians*, conodont—*Neospathodus pakistanensis*; placoid scales and shark teeth—*Polyacrodus* sp. indet. and *Lissodus* cf. *cristatus*. The calcified fine-grained sandstone at AB1021 and AB1022 (135.2 m) is very fossiliferous, and the following well-preserved fossils along with many microbivalves were collected: ammonoids—*Abrekites editus* Shigeta and Zakharov gen. nov. sp. nov., *Abrekites planus* Shigeta and Zakharov gen. nov. sp. nov., *Rohillites laevis* Shigeta and Zakharov sp. nov., *Shamaraites schamarensis* (Zakharov) gen. nov., *Ussuriflemingites primoriensis* Shigeta and Zakharov gen. nov. sp. nov., *Palaeokazakhstanites ussuriensis* (Zakharov), *Clypeoceras timorense* (Wanner), *Pseudosageceras multilobatum* Noetling, *Prosphingitoides* sp. indet., and *Arctoceras septentrionale* (Diener); nautiloid—*Trematoceras subcampanile* (Kiparisova); bivalves—*Bakevellia*? sp., *Leptochondria minima*, *Neoschizodus* cf. *laevigatus* (Ziethen), *Triaphorus* aff. *multiformis* Kiparisova, *Trigonodus orientalis* Bittner, and *Unionites canalensis*; gastropod—*Warthia zakharovi*; brachiopod—*Abrekia sulcata* Dagys; crinoid columnals and cirrals—*Holocrinus* sp. indet.; conodonts—*Ellisonia*? *peculiaris* (Sweet), *Neospathodus pakistanensis*, *Neospathodus* ex. gr. *waageni* Sweet, *Neospathodus novaehollandiae* McTavish, *Neospathodus* aff. *posterolongatus* Zhao and Ochard, *Neospathodus concavus* Zhao and Orchard, and *Eurygnathodus costatus* Staesche; placoid scales and shark teeth—*Acrodus* cf. *cuneocostatus*, *Hybodus* sp. indet., *Lissodus* cf. *cristatus*, and *Polyacrodus* sp. indet.

In the upper part of the main part of the Zhitkov Formation, calcareous concretions from the slump deposits at AB1024 (146 m) contain the following fossils: ammonoids—*Clypeoceras timorense*, *Pseudosageceras multilobatum* and *Arctoceras septentrionale*; conodonts—*Neospathodus* ex. gr. *waageni* and *Neospathodus novaehollandiae*; placoid scales and shark teeth—*Acrodus* cf. *cuneocostatus*, *Hybodus* sp. indet., *Lissodus* cf. *cristatus*, and *Polyacrodus* sp. indet.

At AB 1025 (154.2–154.4 m), the high-density turbidite, consisting of feldspathic coarse-grained sandstone and ill-sorted muddy sandstone, is fossiliferous, and the following fossils were collected: ammonoids—*Arctoceras septentrionale* and *Radioprionites abrekensis* Shigeta and Zakharov gen. nov. sp. nov.; conodonts—*Neospathodus* ex. gr. *waageni*, *Neospathodus novaehollandiae*, *Neospathodus spitiensis* Goel, *Neospathodus* sp. B, and *Foliella gardenae* (Staesche); placoid scales, and shark teeth—*Lissodus* cf. *cristatus*, and *Polyacrodus* sp. indete.

In addition, the calcified sandstone beds intercalated with mudstone at AB1026 (156.5 m) yielded: ammonoids—*Balhaeceras balhaense* Shigeta and Zakharov gen. nov. sp. nov. and *Hemiprionites* sp. indet. Calcareous concretions at AB1027 (161.4–166 m) contain the large ammonoids *Arctoceras subhydaspis* (Kiparisova) and *Euflemingites prynadai* (Kiparisova).

Depositional environment: The lower part of the Zhitkov Formation represents a lower slope environment, which is suggested by the predominance of a slump-deposit intercalations

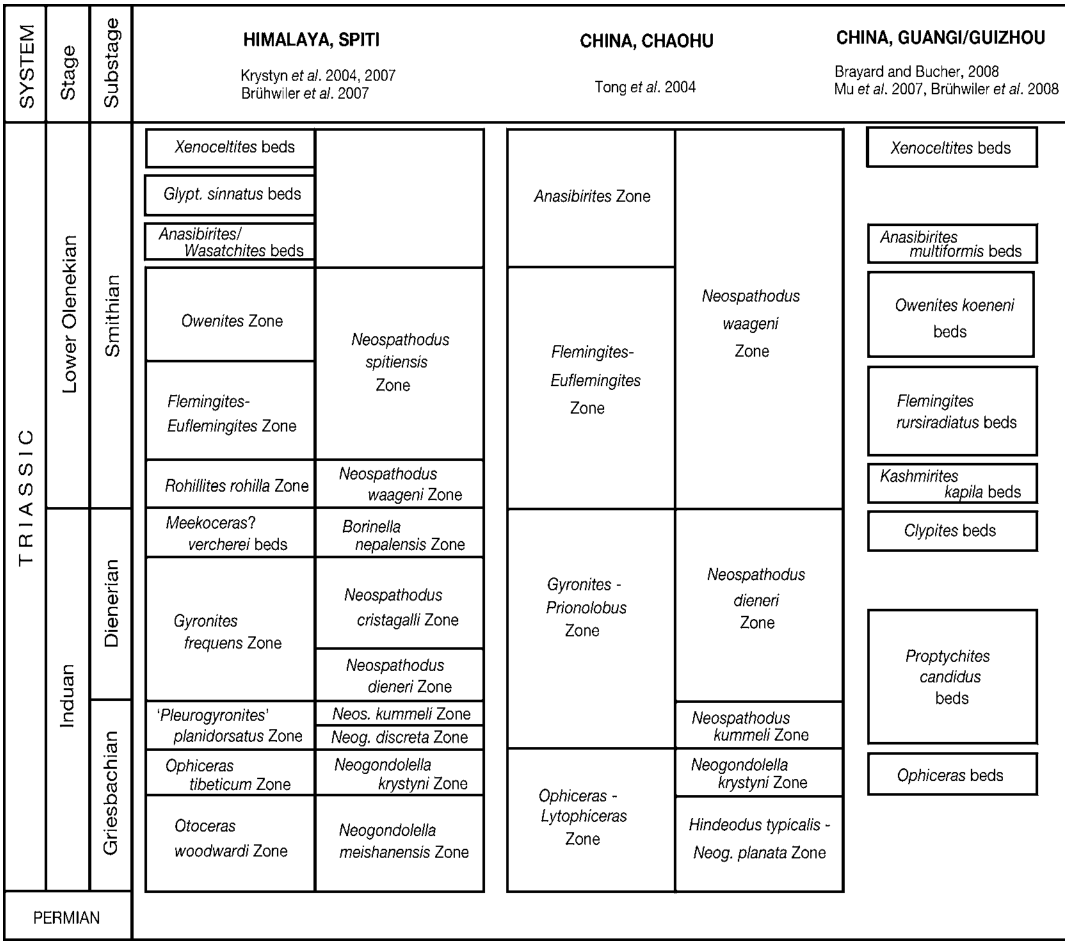


Fig. 18. Ammonoid and conodont biostratigraphic subdivisions of the Early Triassic of South Primorye and correlation with other regions.

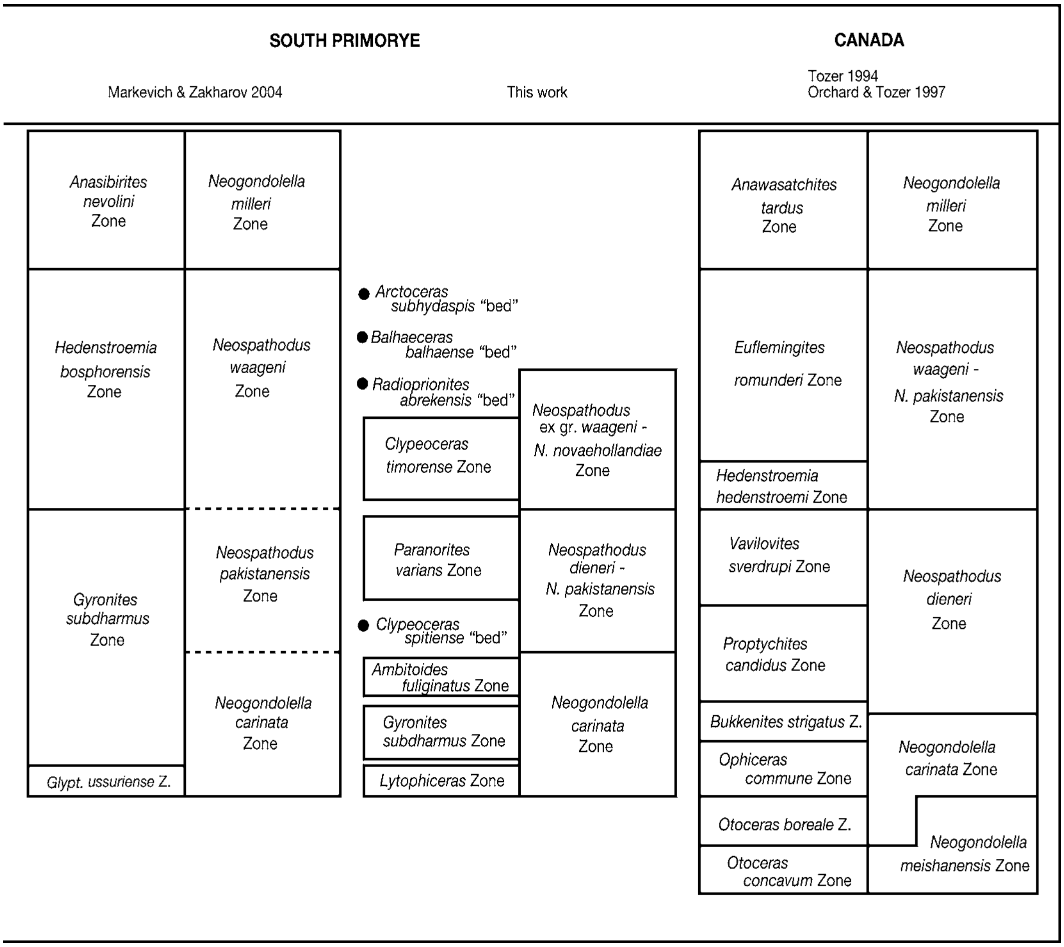
(Sutter, 2006; Posamentier & Walker, 2006), while the main part of the Zhitkov Formation represents a proximal basin-floor facies (Sutter, 2006; Posamentier & Walker, 2006). The thick monotonous succession of barely bioturbated, laminated mudstone suggests deposition in a stable anoxic basin-floor setting.

Biostratigraphy

Ammonoid succession (by Y. Shigeta, H. Maeda and Y. D. Zakharov)

Markevich and Zakharov (2004) established an early Triassic ammonoid biostratigraphic scheme for South Primorye, in which they recognized the following four ammonoid zones, ranging from the Griesbachian to the Smithian: *Glyptophiceras ussuriense* Zone, *Gyronites subdharmus* Zone, *Hedenstroemia bosphorensis* Zone, and *Anasibirites nevolini* Zone. However, none of the zonal index taxa were found in the Abrek Bay section other than *Gyronites subdharmus* Kiparisova.

Our carefully controlled bed-by-bed sampling program has produced abundant material, which significantly adds to the knowledge



of these biostratigraphic subdivisions (Fig. 18). However, at this point it would be premature to introduce formal zones because fossil occurrence is not stratigraphically continuous but confined mostly to a few fossils beds. Our knowledge of Early Triassic ammonoid faunas in South Primorye is still somewhat inadequate. Hence, we provisionally utilize the "bed" or zone (taxon-range zone) approach as documented below. Here, the "bed" means the case that the index taxon occurs only from a fossil-bed. The zone means a taxon-range zone of the index species, and consists of two or much more fossil beds. Boundary between such zones remains obscure because of intermittent fossil-occurrence.

Lytophiceras *sp. Zone*: This zone, which are partly correlative with the *Glyptophiceras ussuriense* Zone of Markevich and Zakharov (2004), is characterized by the occurrence of the typical Early Induan (Griesbachian) ammonoid genus *Lytophiceras*. At AB1007, this genus is associated with *Tompophiceras* sp. indet. and at AB1009, it is found with *Pseudoproptychites hiemalis* (Diener) and *Ussuridiscus varaha* (Diener) gen. nov.

Gyronites subdharmus *Zone*: Zone is mainly characterized by *Gyronites subdharmus*, but other taxa are also found at various levels as follows: *Dunedinites magnumbilicatus* (Kiparisova) and *Wordieoceras* cf. *wordiei* (Spath) in the lower part, *Pachyproptychites otoceratoides* (Diener) in the upper part, and *Ussuridiscus varaha* in the zone. The genus *Wordieoceras* is typical of the late Griesbachian, and *W. wordiei* is known from late Griesbachian beds in Greenland (Spath, 1930, 1935) and Arctic Canada (Tozer, 1994). Zone in the lower part are partly correlative with the *Ophiceras commune* Zone (early late Griesbachian) of Arctic Canada (Tozer, 1994).

Age diagnostic ammonoid taxa have not been found in the upper part, which probably is of late Early Induan (late Griesbachian) age, but the nautiloid *Xiahenautilus abrekensis* sp. nov. occurs at AB1011. In South China, the stratigraphic range of *Xiaohenautilus* is restricted to the upper Griesbachian (Mu *et al.*, 2007). Markevich and Zakharov (2004) assigned a Late Induan (Dienerian) age to the *G. subdharmus* Zone. However, the local range biozone of *G. subdharmus* should be correlated with the late Early Induan (late Griesbachian).

Ambitoides fuliginatus *Zone*: Index ammonoid, *Ambitoides fuliginatus* (Tozer) gen. nov., occurs with the following taxa: *Proptychites alterammonoides* (Krafft), *Ussuridiscus varaha* and *Gyronites* sp. indet. *Proptychites alterammonoides* is known to occur in the "*Meekoceras*" beds (Dienerian) of the Northwest Himalayan region (Krafft, 1909; Waterhouse, 2002), while *Ambitoides fuliginatus* occurs in the *Proptychites candidus* Zone (early Dienerian) of northeastern British Columbia (Tozer, 1994). These ammonoids strongly suggest that the *A. fuliginatus* Zone is of early Late Induan (early Dienerian) age.

Clypeoceras spitiense "*bed*": Bed contains index species *Clypeoceras spitiense* (Krafft) as well as *Ambitoides orientalis* Shigeta and Zakharov gen. nov. sp. nov., *Parahedenstroemia kiparisovae* Shigeta and Zakharov sp. nov. and *Vishnuites*? sp. indet. *Clypeoceras spitiense* is a well known Himalayan Dienerian ammonoid, and the bed is correlative with the "*Meekoceras*" beds (Dienerian) of the Northwest Himalayan region (Krafft, 1909; Waterhouse, 2002).

Paranorites varians *Zone*: Zone contains index species *Paranorites varians* (Waagen) as well as *Ussuriflemingites abrekensis* Shigeta and Zakharov gen. nov. sp. nov. in the lower part and *Kummellia*? sp. indet. in the upper part. *P. varians* is known from the Lower Ceratite Limestone of the Salt Range (Waagen, 1895), and *Kummellia* is known from the *Paranorites-Vishnuites* Zone (Dienerian) of Kashmir (Bando, 1981; Waterhouse, 1996a). Zone is probably Late Induan (Dienerian) in age.

Clypeoceras timorense *Zone*: Zone contains a very abundant, diverse fauna, which include the following genera: *Clypeoceras*, *Abrekites* gen. nov., *Rohillites*, *Shamaraites* gen. nov., *Ussuriflemingites* gen. nov., *Palaeokazakhstanites*, *Pseudosageceras*, *Prosphingitoides*, and *Arctoceras*. *Clypeoceras timorense* (Wanner), the most common ammonoid, is known from the Lower Olenekian (lower Smithian) of Timor, and *Rohillites* is also a typical early Smithian genus. Therefore, this subdivision is of early Early Olenekian (early Smithian) age.

Radioprionites abrekensis "*bed*": Bed is characterized by the occurrence of the newly described index ammonoid *Radioprionites abrekensis* Shigeta and Zakharov gen. nov. sp. nov. as well as *Arctoceras septentrionale* (Diener). Neither species is age diagnostic, but *Arctoceras* is a typical Smithian genus. According to Markevich and Zakharov (2004), the upper part of the *Arctoceras septentrionale* bearing beds in South Primorye contains *Owenites koeneni* Hyatt & Smith and *Balhaeceras balhaense* Shigeta and Zakharov gen. nov. sp. nov. Hence, this subdivision is correlative with the bed under the *O. koeneni* beds (middle Smithian) of the Tethyan and Eastern Panthalassic realms (Kummel & Steele, 1962;

Brühwiler *et al.*, 2007; Brayard & Bucher, 2008).

Balhaeceras balhaense *"bed"*: Newly described index ammonoid *Balhaeceras balhaense* also occurs in the *Owenites koeneni* beds in other sections in South Primorye (Zakharov, 1968), and hence, this subdivision is correlated with the middle Early Olenekian (middle Smithian).

Arctoceras subhydaspis "*bed*": Bed is characterized by the occurrence of the index species and *Euflemingites prynadai* (Kiparisova). *A. subhydaspis* (Kiparisova) is always found immediately below the *Anasibirites nevolini* Zone (upper Smithian) in other sections in South Primorye (Markevich & Zakharov, 2004). Therefore, the subdivision is of middle Early Olenekian (middle Smithian) age.

Conodont succession (by H. Igo)

The Lower Triassic section in the Abrek Bay area can be divided into three conodont zones in ascending order as follows: *Neogondolella carinata* Zone, *Neospathodus dieneri-N. pakistanensis* Zone, and *Neospathodus* ex gr. *waageni-N. novaehollandiae* Zone (Fig. 18).

Neogondolella carinata *Zone*: Zone is not well defined because specimens of the index species, which occur sporadically in the middle to upper part of the Lazurnaya Bay Formation, are mostly fragmental or attrited. *Neogondolella carinata* (Clark) is a worldwide species and ranges from the Greisbachian to the Smithian (Orchard, 2007a). Zone encompasses the following ammonoid zones: *Lytophiceras* sp. Zone and *Gyronites subdharmus* Zone of the Lazurnaya Bay Formation, and the *Ambitoides fuliginatus* Zone of the lowermost Zhitkov Formation.

Neospathodus dieneri-N. pakistanensis *Zone*: Zone begins with the first appearance of *Neospathodus dieneri* Sweet and *N. pakistanensis* Sweet and ends with the first occurrence of *N.* ex gr. *waageni* Sweet. *N. pakistanensis* occurs frequently throughout the zone, but *N. dieneri* appears mainly in the lower part. The following other taxa rarely co-occur: *N.* cf. *cristagalli* (Huckriede), *Eurygnathodus costatus* Staesche, *Borinella* cf. *nepalensis* (Kozur and Mostler), and *Neospathodus* sp. A. Zone encompasses the *Clypeoceras spitiense* ammonoid bed and *Paranorites varians* ammonoid Zone in the Zhitkov Formation.

N. dieneri is a well-known species and ranges from the Dienerian to the Smithian (Orchard, 2007a). Zhao *et al.* (2007) summarized the Lower Triassic conodont sequence in the Pingdingshan section in Chaohu, Anhui, China. They defined the *N. dieneri* Zone in the upper part of the Yinkeng Formation (Upper Induan, Dienerian) and further subdivided it into three subzones as defined by the successive occurrence of *N. dieneri* Morphotypes 1, 2, and 3, which also range upward into higher subzones. In the Abrek Bay section, a form of *N. dieneri* similar to the above-mentioned Morphotypes 1 and 2 occurs in the lower part of the zone, and Morphotype 3, characterized by a posterior cusp that is broader and shorter than other denticles, occurs in the middle part of the zone.

N. pakistanensis, the other characteristic species of the zone, ranges upward into the lowest part of the next higher zone. As pointed out by several authors (e.g., Matsuda, 1983), *N. pakistanensis* exhibits considerable morphological variation in terms of size, general lateral profile, shape of basal cavity, and number of denticles. Specimens from the lower and middle parts of the zone have slightly shorter elements and fewer denticles compared with those from the next higher zone.

These conodonts strongly suggest that the zone, which is mainly of Upper Induan (Dienerian) age, is correlative with the *N. dieneri* Zone of China, India and other regions.

Neospathodus ex gr. waageni-N. novaehollandiae *Zone*: Zone is defined by the first occurrence of *Neospathodus* ex gr. *waageni* and *N. novaehollandiae* McTavish, both of which occur frequently throughout the zone. *N.* ex gr. *waageni* is a well-known index species of the Early Olenekian (Smithian) throughout the world (Orchard, 2007a). Consequently, the zone is correlated with the Early Olenekian (Smithian). Zone encompasses at least the *Clypeoceras timorense* ammonoid Zone and *Radioprionites abrekensis* ammonoid "bed" of the Zhitkov Formation.

N. waageni, originally described from the Salt Range (Sweet, 1970), has been described several times by subsequent authors from Lower Triassic rocks elsewhere in the world. These authors all report morphological variation mainly in the profile of the basal margin, length of the posterior process, and shape of the basal cavity (e.g., Matsuda, 1983). Zhao *et al.* (2004) reported the occurrence of abundant specimens in the Pingdingshan Section of China and recognized three distinct subspecies that clearly occur in succession. Consequently, they subdivided the zone into three subzones, to which Zhao and Orchard (in Zhao *et al.*, 2007) applied the following names: *N. waageni eowaageni*, *N. waageni waageni*, and *N. posterolongatus*.

N. waageni (s.l.) is also abundant in the Muth Section in Spiti. According to Orchard and Krystyn (2007) and Orchard (2007a), *N. waageni* (s.l.) occurs in Smithian strata and consists of six morphotypes including two subspecies, *N. waageni waageni* and *N. waageni eowaageni*. Their Morphotype 1 is characterized by the development of platform flanges at the posterior end. Morphotype 2 corresponds to *N. waageni waageni* and Morphotype 3 has a length to height ratio of about 1 : 1 and upturned denticles identical to those of *N. waageni eowaageni*. Morphotype 4 is characterized by the presence of a posteriormost small denticle. Morphotype 5 has an unusually large triangular cusp. Morphotype 6 exhibits denticles that tend to radiate in a fan-like fashion from the base. It is difficult to determine the morphological variation of these morphotypes, given that the authors illustrated each of their types with only one lateral and basal view. In the present study, the author treats the species in a broad sense as *N.* ex gr. *waageni* and detailed identification is reserved for future research. However, the following comments are intended to discuss similarities of the present *N. waageni* (s.l.) with the above-mentioned six morphotypes from Spiti. *N.* ex gr. *waageni* from the Abrek Bay section exhibits variation in the profile of the basal margin, basal cavity, and denticulation, which have already been pointed out by their authors. Specimens obtained from the basal part of the zone (AB1021) have a similar profile as observed in *N. waageni waageni*. Most specimens from the lower part of the zone (AB1024) have the same configuration that is characteristic of *N. waageni eowaageni*.

N. aff. *posterolongatus* Zhao and Orchard from the basal part of the zone is represented by a single specimen that exhibits close similarity in general profile to *N. posterolongatus*, a proposed species based on *N. waageni* subsp. nov. B by Zhao *et al.* (2004). Several other specimens identified as *N.* ex gr. *waageni* were obtained from the middle part of the zone in association with *N. spitiensis* and *Foliella gardenae* (Staesche).

The basal part of the zone yields abundant, well-preserved elements of *N. novaehollandiae*, which is the other characteristic species in the zone. Although a few specimens were recovered, *N. pakistanensis* is associated with *N. novahollandiae* in this part of the zone. Both species are similar and previous authors, such as Matsuda (1983) and Nicora (1991), considered them to be conspecific. Recently, Orchard (2007a) discussed the validity of both species and pointed out that the shape of the basal cavity is an important criterion for distinguishing between species, rather than the lateral profile of the underside or the degree of platform flange growth. The characteristic morphology observable in both species exhibits considerable variation in the present material. However, the occurrence of *N. novaehollandiae* in the

Abrek Bay section is more common at higher levels than *N. pakistanensis*. Furthermore, in our collection, *N. novaehollandiae* includes many large-sized individuals and some exhibit pathological or aberrant features in the basal cavity and lateral process. The present author concluded that *N. pakistanensis* and *N. novaehollandiae* are independent species, and the former is a precursor of the latter species within the same species lineage.

Several specimens identified as *N. spitiensis* occur in the middle part of the zone. According to Orchard (2007a) this species is a direct descendant of *N. posterolongatus*, and the stratigraphic level of *N. spitiensis* in the Abrek Bay section supports this view, but *N. posterolongatus* apparently is missing in the section.

Only one specimen identifiable as *Foliella gardenae* was recovered from the middle part of the zone in association with *N. spitiensis*. This interesting Smithian aged conodont, originally described from the upper Campiller Formation of South Tirol, Austria (Staesche, 1964), also occurs in Smithian aged equivalent rock units in Slovenia (Kolar-Jurkovsek & Jurkovsek, 1996), Primoryie, Far East Russia (Buryi, 1979), Sichuan, Southwest China (Dai & Tian, 1983), and other Chinese localities.

The lower to middle part of the zone yields other conodont elements identified as *Neospathodus concavus* Zhao and Orchard, *Neospathodus* sp. B, and *Ellisonia*? cf. *peculiaris* (Sweet), but these occurrences are rare and the specimens are fragmentary. A single specimen of *N. concavus* recovered from the basal part of the zone is characterized by an arched, large and long element, and it has a short cusp compared with that of the original Chinese specimen (Zhao & Orchard, in Zhao *et al.*, 2007). Orchard & Krystyn (2007) illustrated the other type of this species from Spiti that bears 13 denticles on its strongly arched blade. The general configuration of the present element agrees with the Spiti specimen, except for a large cusp and the size of the sixth denticle.

Correlation (by Y. Shigeta and H. Igo)

The geological age of the basal part of the Lazurnaya Bay Formation remains uncertain because no direct, age diagnostic evidence has been found. In contrast, the overlying lower and middle parts of the formation, containing the *Lytophiceras* sp. Zone and the lower part of the *Neogondolella carinata* Zone, is supposedly of Early Induan (Griesbachian) age. Furthermore, the upper part of the formation, characterized by the *Gyronites subdharmus* Zone and the middle part of the *Neogondolella carinata* Zone, is correlatable with the late Early Induan (late Griesbachian).

A change in the ammonoid assemblage in the uppermost part of the Lazurnaya Bay Formation and the overlying lowest part of the Zhitkov Formation, in which *Ambitoides fuliginatus* is common, suggests that these parts are early Late Induan (early Dienerian) in age. The lower part of the Zhitkov Formation yields *Clypeoceras spitiense* and is of Late Induan (Dienerian) age. This correlation is also supported by the occurrence of *Neospathodus dieneri* and *N. pakistanensis*.

The First Appearance Datum (FAD) of *N. waageni* (s.l.) has been basically accepted as the primary marker for the definition of the Induan-Olenekian (I/O) boundary (Tong *et al.*, 2003; Krystyn *et al.*, 2007; Zhao *et al.*, 2007). *N.* ex gr. *waageni* first appears at AB1021 (and AB1022) in the main part of the Zhitkov Formation. Therefore, the I/O boundary should be placed at a horizon between AB1019 and AB1021 (or AB1022), given that Late Induan (Dienerian) ammonoids occur at AB1019.

The uppermost part of the main part of the Zhitkov Formation yields the middle Early Olenekian (middle Smithian) ammonoid *Arctoceras subhydaspis*, which is characteristic member of the horizon immediately underlying the upper Smithian *Anasibirites nevolini* Zone in South Primorye.

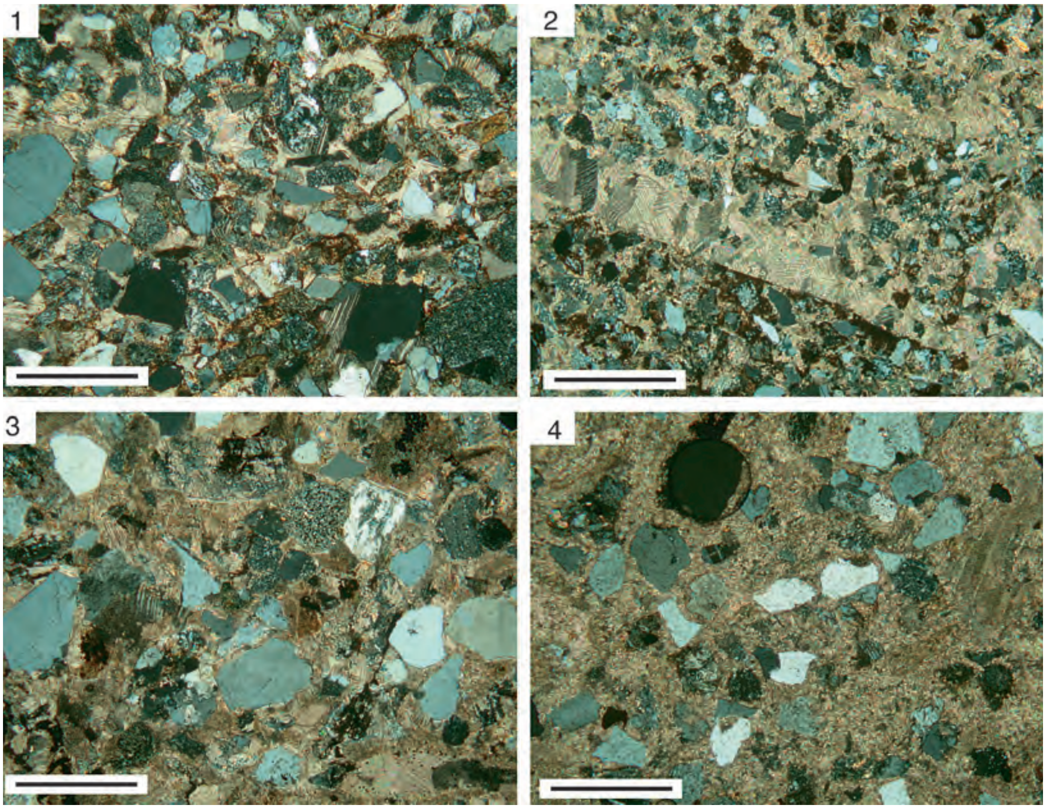


Fig. 19. Photomicrographs, under cross polarized light, of calcareous sandstones and limestone from the Abrek Bay area. 1, Calcareous sandstone from AB1004. 2, Calcareous sandstone from AB1011. 3, Calcareous sandstone from AB1014. 4, Limestone with detrital minerals from AB1025. Scale bar=0.5 mm.

Age distribution of detrital monazites in the sandstone

(by K. Yokoyama, Y. Shigeta and Y. Tsutsumi)

Seven sandstone samples, three from the Lazurnaya Bay Formation at AB1004, AB1007 and AB1011 and four from the Zhitkov Formation at AB1014, AB1016, AB1019 and AB1025, were investigated for age analyses of monazite (Figs. 5–10). All sandstones are fossiliferous sandstones, consisting mainly of calcite with subordinate amounts of detrital mineral and lithic fragment (Fig. 19). Technically, these rocks should be identified as limestone or calcareous sandstone, but they are tentatively denoted as sandstone in this paper. Sandstones of Permian to Triassic age from the Japanese Islands and a sample of sand from Khabarovsk, along the Amur River, were analyzed to compare with those from the Abrek Bay area.

Analytical procedure

Procedures for the separation of heavy minerals and their subsequent analysis for monazite are the same as described by Yokoyama *et al.* (1990). The theoretical basis for monazite age calculation is essentially the same as that developed by Suzuku *et al.* (1991).

Monazites were analyzed with an electron probe micro-analyzer (EPMA) fitted with a Wavelength Dispersive Spectrometer (WDS), JXA-8800 situated in the National Museum of Nature and Science, Tokyo. Analytical condi-

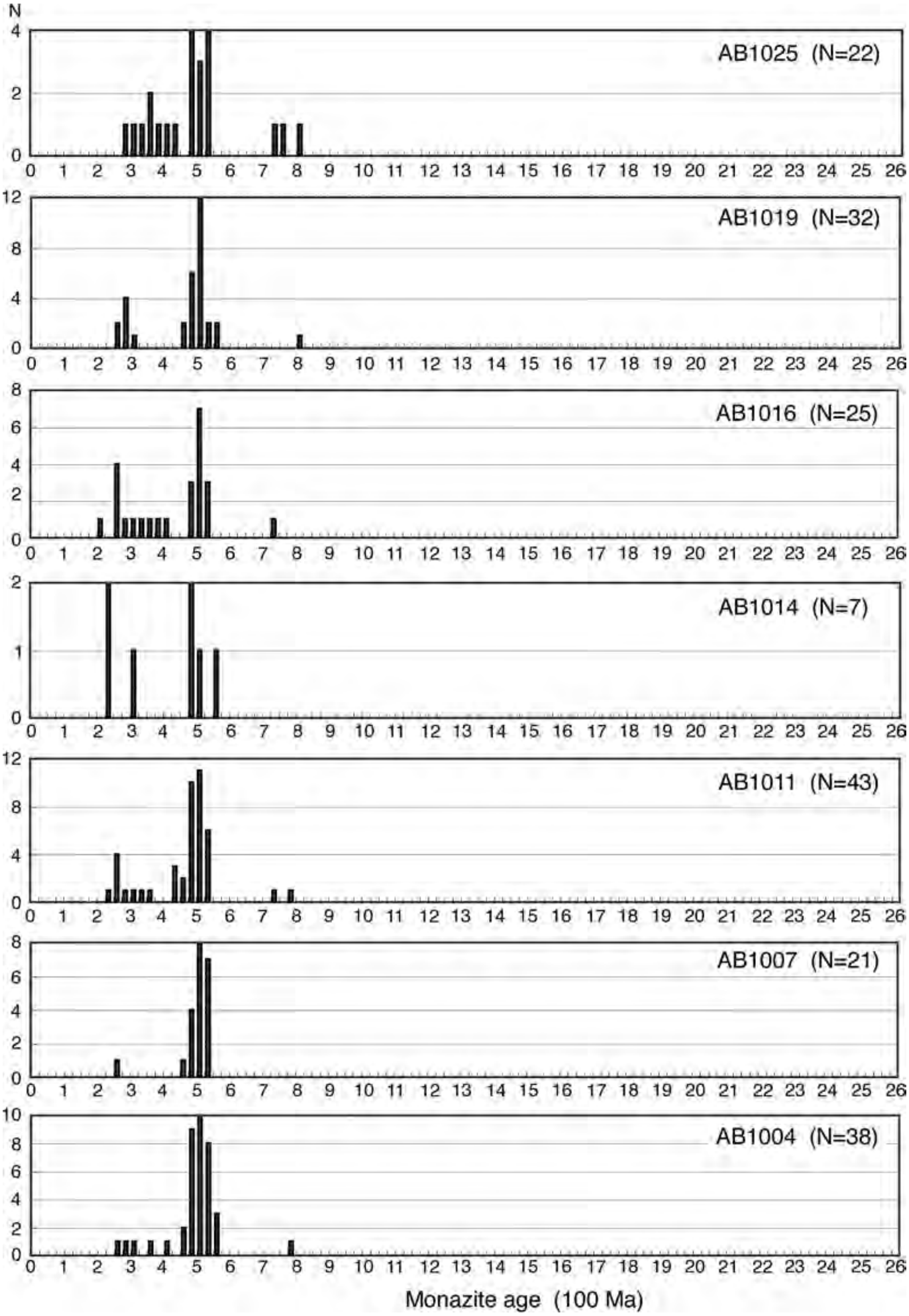
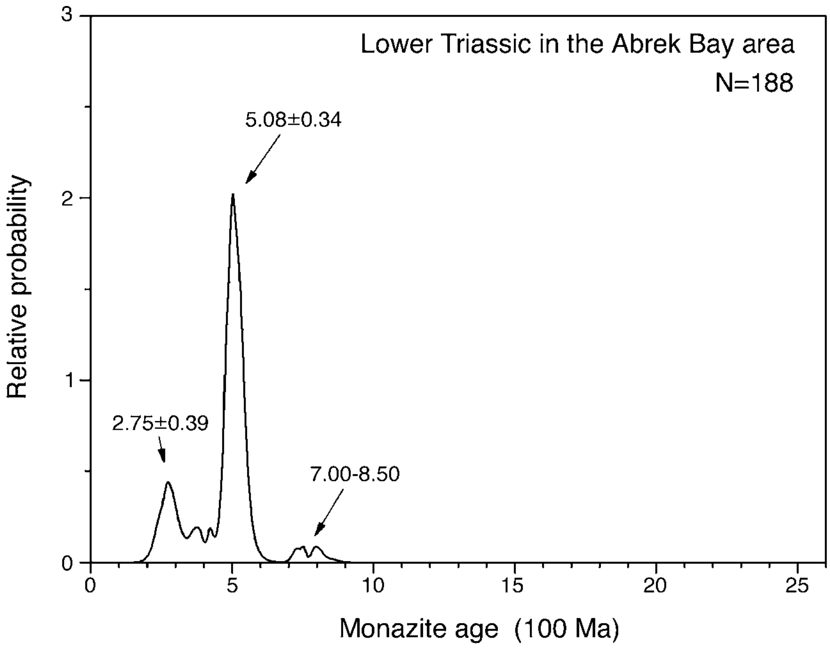


Fig. 20. Age histograms of detrital monazites from sandstones in the Abrek Bay area. Vertical axis represents number of analyzed monazite grains.



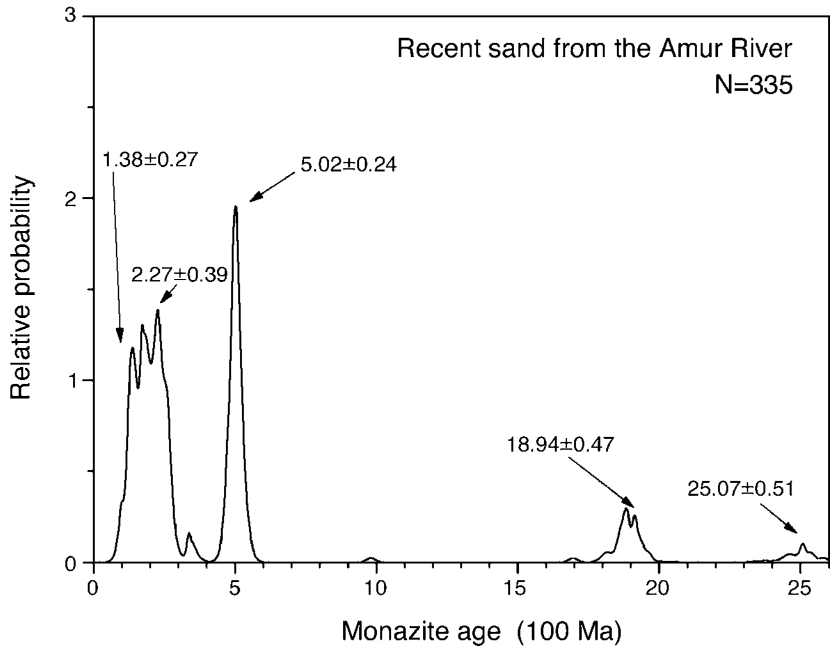


Fig. 21. Probability distribution diagrams of monazite ages of sandstones from the Abrek Bay area (upper) and the sand sample from the Amur River (lower). Numerical value (N) denotes the number of analyzed monazite grains.

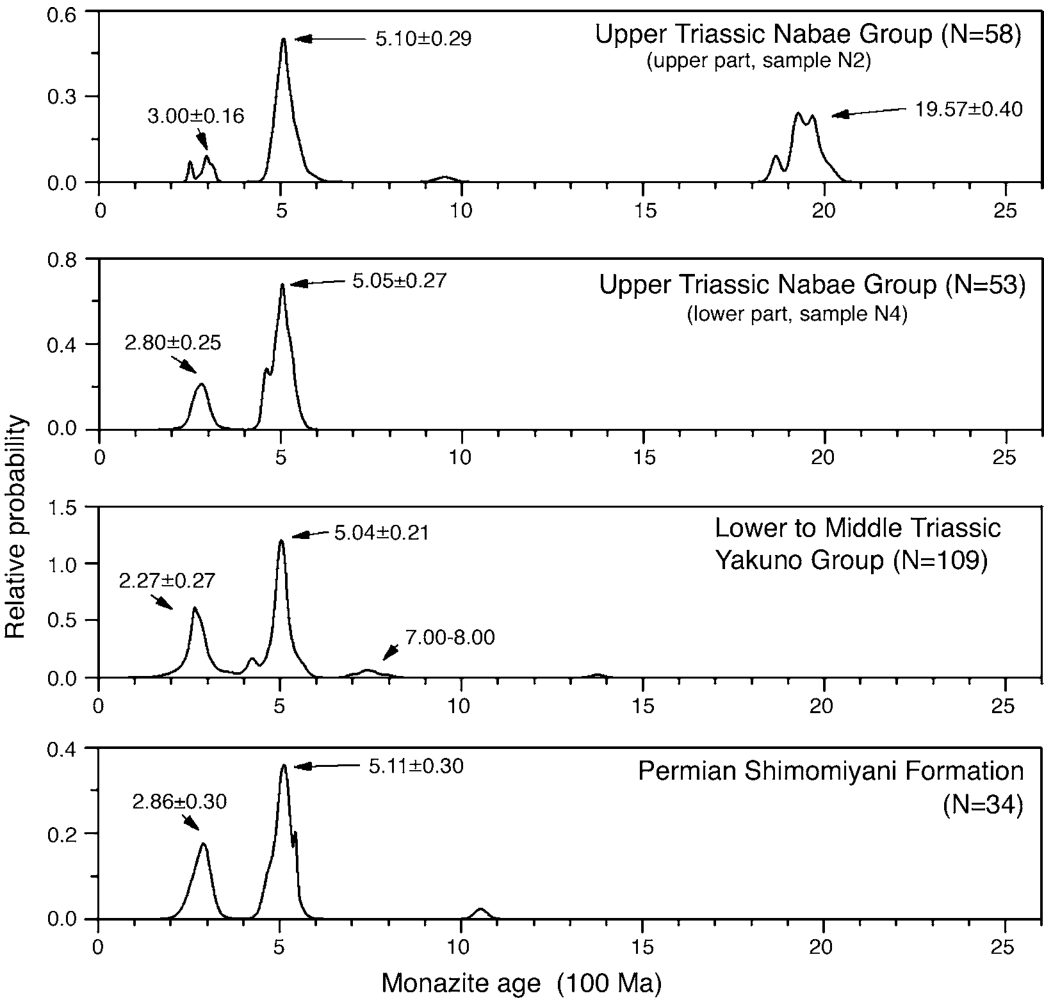


Fig. 22. Probability distribution diagrams of monazite ages of sandstones from the Maizuru Belt. Numerical value (N) denotes the number of analyzed monazite grains.

tions are the same as those described by Santosh *et al.* (2006). Age calibrations were carefully performed by comparing data obtained by EPMA dating with those acquired by the SHRIMP technique (Santosh *et al.*, 2006). Apart from minor shifts due to machine drift and variations in standard conditions, the ages obtained from both techniques were found to have good consistency. Monazites with ages of 3020 Ma and 64 Ma, obtained from SHRIMP and K-Ar methods, respectively, were used as internal standards for age calibrations. The standard deviation of the obtained ages depends mostly on the PbO content of the monazite, and age errors are within a few percent for most of the analyzed monazites that were rich in ThO_2.

Results

Although monazite grains are not common in the samples, due probably to their calcareous nature, about 200 grains were recovered and analyzed. Monazite ages are presented as frequency diagrams in Fig. 20.

Monazite ages range from ca. 240 Ma to 1000 Ma with a strong peak at around 500 Ma and a subordinate peak at around 270 Ma. Although there is no drastic change in monazite age throughout the sequence, and a notably different age distribution pattern is not observed in the sandstones, it is noteworthy that younger monazites are not common in the lower sequence, and weak peaks at 300–400 Ma and 700–800 Ma are observed in sample AB1025. Each age datum has a more or less moderate standard deviation. Then, all data were represented in Fig. 21 by a probability distribution diagram calculated with a multipeak Gauss fitting method (Williams, 1998). Peak positions are 508 Ma and 275 Ma. Several data are plotted in 700–850 Ma, but no clear peak has been recognized in the range older than 600 Ma.

Monazite ages in the recent sand sample from the Amur River are shown in Fig. 21 together with that from the Abrek Bay area. The river mainly cuts through the Northeast China Block (Jiamusi and Songliao-Zhangguangcao blocks), which formed a continent with the Khanka Block during the Early Permian. The drainage basin of the river also includes a part of the Sino-Korea and Siberian cratons. A major peak much older than 300 Ma occurs at 500 Ma, similar to the sandstones in question. Weak peaks appear at 1900 and 2500 Ma, due probably to the Sino-Korea Craton (Yokoyama *et al.*, 2007). The southern part of the Siberian Craton has undergone granulite facies metamorphism between 488 and 478 Ma (Salnikova *et al.*, 1998). The contribution from the Siberian Craton to age data for the Amur River is represented by the huge peak at 500 Ma.

Most sandstones in the Japanese Islands have a strong peak at 1900 Ma, but no peak around 500 Ma (Yokoyama & Saito, 1996, 2001),which is similar to those from the Korean Peninsula (Yokoyama *et al.*, 2007). Permian to Upper Triassic sandstones in the Maizuru belt have different peaks than other sandstones in the Japanese Islands, but they are similar to those from sandstones in the Abrek Bay area. The Permian sandstones in the Maizuru belt are associated with chert (Ishiga & Suzuki, 1984), and belong to part of a subduction complex, thus indicating a deep sea origin, whereas the Lower to Middle Cretaceous Yakuno Group and the Upper Triassic Nabae Group are composed mostly of shallow marine sediment with a trace amount of fresh or brackish water sediment (Nakazawa, 1958), and overlie Permian rocks, either by unconformity or fault contact. Probability diagrams of sandstones from the Maizuru Belt are presented in Fig. 22. While a major peak appears at 500–510 Ma in all samples, an age near 700–800 Ma is recognized in Lower to Middle Triassic sandstones of the Yakuno Group, but only the Upper Triassic sandstone from the upper part of the Nabae Group shows a moderate peak at 1900 Ma, similar to the other sandstones in the Japanese Islands.

Discussion

The significance of the Lower Triassic section in the Abrek Bay area can be summarized as follow.

1) A newly discovered fossiliferous succession in South Primorye ranging in age from Induan (Griesbachian, Dienerian) to Early Olenekian (Smithian) is described.

2) The mode of occurrence of ammonoids is documented.

3) The age of detrital monazites in the sandstone is determined.

Age data of monazites (by K. Yokoyama, Y. Shigeta and Y. Tsutsumi)

Age analysis of detrital monazite provides us with prehistorical information about river drainage systems. These age data are especially important in the area and time frame encompassing the collision and amalgamation of continental or microcontinental blocks. In Far East Asia, the Khanka Block collided with the Jiamusi and Songliao-Zhangguangcao blocks during the Early Permian (Jia *et al.*, 2004). The collision of the Khanka Block and the Sino-Korea Craton started during Late Permian-Early Triassic time and was completed by the Late Triassic to form the huge continent that is essentially the Eurasian continent of today.

Age data for the Khanka Block are restricted. As far as recent data are concerned, approximately 500 Ma was reported from granite and gneiss samples (Khanchuk *et al.*, 1996), which is similar to those from the Jiamusi Block (Wilde *et al.*, 2000, 2003). A Precambrian age was recognized as a discordant age for zircon: 1179±80 Ma (Jia *et al.*, 2004). Monazite with a Precambrian age of 700–800 Ma is rarely observed in Lower Triassic sandstones from the Abrek Bay area (Fig. 21). These data show the presence of a Precambrian terrane in the Khanka or Jiamusi blocks. Even if Precambrian rock occurs widely as a basement rock, it is hard to elucidate through monazite age determination because monazite age is easily reset by later stage high-grade metamorphism, which occurred commonly in these blocks.

River drainage systems in the East Asia region have changed with geological time as evidenced by collision events during Permian to Triassic time. Age data, revealing a strong concentration at 500 Ma and an absence of 1900 Ma in the sandstones from the Abrek area, demonstrate that their provenance was within the Khanka Block and a portion of the Jiamusi Block, and that there is no contribution from the Sino-Korea Craton. If detrital minerals were supplied by a huge river such as the Amur, their age distribution would present a peak at 1900 Ma. An absence of the 1900 Ma peak is due to local supply or an incomplete amalgamation of the Sino-Korea Craton and Khanka Block during the Early Triassic.

The sandstones in the Abrek Bay area have the same age pattern as those of the Lower to Middle Triassic shallow marine sandstones of the Yakuno Group in the Maizuru belt, i.e., a major peak at 500–519 Ma, a subordinate peak at 270–280 Ma and sporadic data at 700–850 Ma (Figs. 21, 22). They are essentially similar to other sandstones in the Maizuru belt. A clear difference is found in the sandstone of the Upper Triassic Nabae Group. The lower sandstone of the Nabae Group is similar to the sandstones mentioned above, whereas the upper sandstone has a clear peak at 1900 Ma in addition to a major peak at 500 Ma (Fig. 22). This signifies that the provenance of the detritus includes not only the Khanka-Jiamusi Block, but also the Sino-Korea Craton, thus indicating an almost complete amalgamation of the craton and block.

The Samarka Belt at the eastern side of the Khanka Block is a Jurassic accretionary complex. It is now understood to be a northern extension of the Mino-Tamba Belt of the Inner Zone of southwest Japan, based on similarities of lithology, age and geologic structure (Kojima, 1989). These complexes were originally constructed through a series of accretionary processes as continuous belts, which were later separated into several remnants following tectonic movements. Other small belts including the Maizuru belt are not yet well understood. Sandstones in the Maizuru belt have a different age pattern than Jurassic and Triassic sandstones in other areas of the Japanese Islands (Yokoyama & Saito, 1996, 2001). The coincidence in monazite data from sandstones in the Maizuru Belt and the Abrek Bay area, South Primorye, suggests that the Maizuru Belt belongs to the Khanka Block or Jiamusi Block, and that the belt should be located near South Primorye. Tectonic reconstruction in the region of the Sea of Japan is still enigmatic because collisions, opening of back-arc basins and rotation of small blocks were common even after deposition of Triassic sediments. Furthermore, many faults with lateral displacement have been described along the continental margin. At present, monazite age data of the sandstones will more or less place a constraint on any tectonic model for the Far

East Asia region. Wilde *et al.* (2003) discussed that the Jiamusi Block was located along the northern margin of the Australian block, based on the presence of the late Pan-African magmatic event at ∼500 Ma. It is possible that the Khanka Block, with a major peak at 500 Ma, will be closely associated with the Jiamusi Block, and that both were once located near the northern part of the Australian Block. Some data with a 700–800 Ma peak corresponds to the Mozambique event, which is also common in the areas affected by the Pan-African magmatic event. However, it is premature to discuss tectonic reconstruction due to a lack of substantial age data for the Khanka and Jiamusi blocks.

This analysis is a reconnaissance study of the sandstones in Far East Asia. Further monazite age data, including that derived from Upper Triassic sandstones in both, the Khanka Block and the Sino-Korean Craton, will more clearly reveal the timing of the amalgamation. Furthermore, this type of study regarding both the block and the craton will clarify their boundaries and will provide a more realistic history of the collision and amalgamation that formed the continent.

The position of the Abrek Bay section in the "Ussuri Basin" (by Y. Shigeta and H. Maeda)

Lower Triassic deposits unconformably overlie Permian rocks with basal conglomerate throughout the South Primorye region. The lower portion, consisting mainly of sandstone and conglomerate of the Lazurnaya Bay Formation, represents a shallow marine facies above the storm wave-base. This sequence is overlain by the Zhitkov Formation, consisting of laminated sandy mudstone and mudstone with intercalations of sandstone, which suggests an offshore facies deposited in a deep anoxic basin. Such a fining-upward sequence is characteristic of deposits in the Triassic sedimentary "Ussuri Basin".

Regardless of lithological uniformity, datum planes of fossil zones obviously extend across lithostratigraphic boundaries. For example, in the Seryj and Tri Kamnya Capes areas, the Induan/Olenekian boundary occurs in the upper part of the Lazurnaya Bay Formation (Zakharov, 1996; Markevich & Zakharov, 2004). In contrast, in the Abrek Bay area the boundary occurs within the Zhitkov Formation.

Shallow marine facies appear in the Induan and Olenekian (Smithian, Spathian) at Atlasov Cape and Russian Island in the western part of the "Ussuri Basin" (Markevich & Zakharov, 2004). Certain fossil zones are not recorded in these localities since strong wave and current action frequently interrupted sedimentation.

Conversely, shallow marine facies change to offshore facies within the lower Upper Induan (lower Dienerian) in the Abrek Bay area in the eastern part of the basin. In this area, sedimentation appears to be continuous during the Late Induan and Early Olenekian, and stratigraphic and faunal successions are exceptionally well preserved. This setting most likely resulted from deposition under the much deeper and quieter environmental conditions that were prevalent in the Abrek Bay area as compared to the western part of the basin, and it supports an eastward-deepening setting of the Triassic System in the "Ussuri Basin" (Zakharov, 1968, 1997a).

Ammonoid mode of occurrence (by H. Maeda and Y. Shigeta)

In the upper part of the Lazurnaya Bay Formation and the overlying Zhitkov Formation, ammonoids are mainly preserved in gravity-flow deposits such as turbidites and slump deposits. In contrast, background deposits represented by laminated mudstone are almost barren of megafossils.

Ammonoids in particular are abundant in the fine-grained muddy sandstone beds, which are sporadically intercalated in the laminated mudstone (Figs. 8–10). These sandstone beds lack a coarse-grained portion, and their sedimentary features resemble the upper half of a Bouma sequence. They are interpreted as dis-

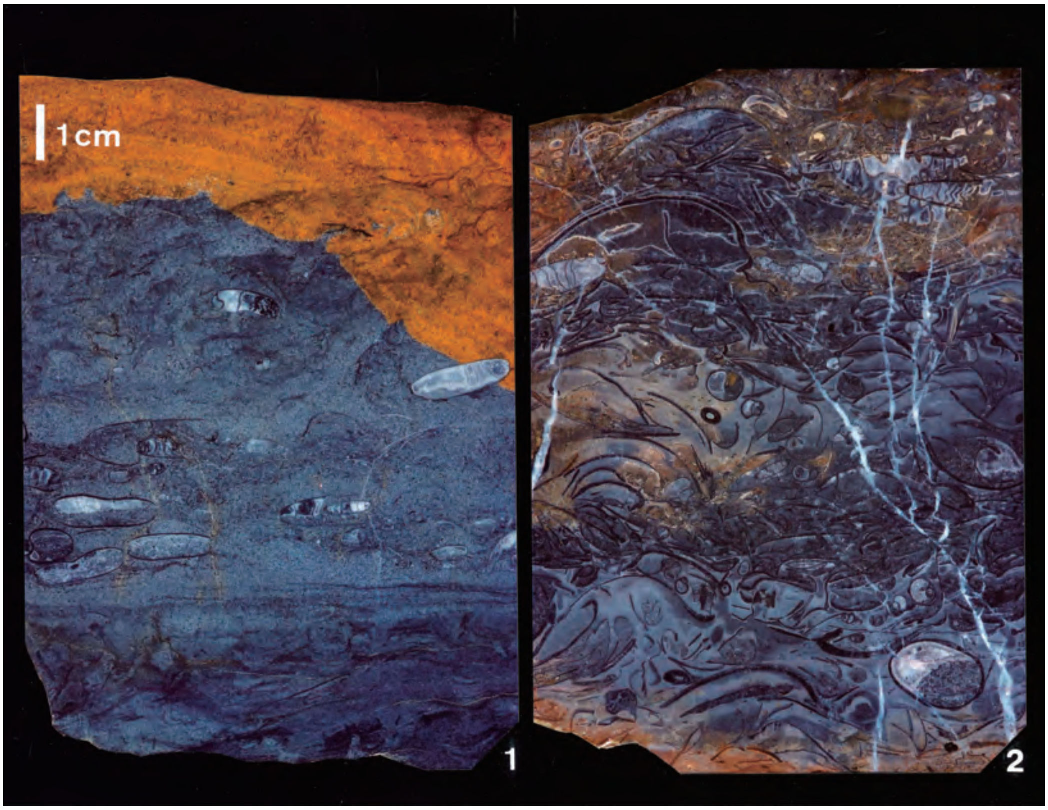


Fig. 23. 1, Vertical profile exhibiting ammonoid mode of occurrence in fossiliferous turbidic fine sandstone bed (AB1011) in upper part of Lazurunaya Bay Formation. Light-colored elliptical sections represent sparry calcite-filled septate portions of *Gyronites subdharmus* Kiparisova shells. Note that shells are aligned parallel to bedding plane and are mainly accumulated in middle part of sandstone. Some shells exhibit geopetal strucuture. 2, Vertical profile exhibiting bivalve mode of occurrence in fossiliferous turbidic fine sandstone bed (AB1014) in lower part of Zhitkov Formation. Dark colored platy material represents bivalve shell tests. In contrast with ammonoids, bivalve shells are accumulated in all orientations throughout the fine-grained turbiditic sandstone bed.

tal turbidites, whose density is much lower than that of coarser-grained proximal turbidites (Reineck & Singh, 1973).

Fig. 23 illustrate a vertical profile of the fossiliferous turbidite beds that at AB1011 and AB1014. Ammonoid shells are well-preserved, aligned parallel to the bedding plane, and are mainly accumulated in the middle part of a low-density turbidite (Fig. 23.1). Some even exhibit a geopetal strucuture.

On the other hand, bivalve shells, which are also abundant in the fine-grained sandstone beds, exhibit different taphonomic features. Compared with ammonoids, bivalve shells are accumulated in a jumbled mass, one on top of the other within the fine-grained turbiditic sandstone bed from the bottom to the top (Fig. 23.2). This occurrence is attributable to hydrodynamic sorting, which occurs during deposition of the turbidites, and is caused by differences in shell density (Maeda & Seilacher, 1996). Thickly-shelled bivalves have a shell density of 2.0 g/cm^3 or higher. In contrast, the density of empty ammonoid shells remains around 1.1–1.2 g/cm^3, even though they are fully waterlogged (Maeda, 1987, 1999; Maeda & Seilacher, 1996).

The scarcity of ammonoids in the surrounding mudstone (back ground) suggests that they were not indigenous to the slope-basin envi-

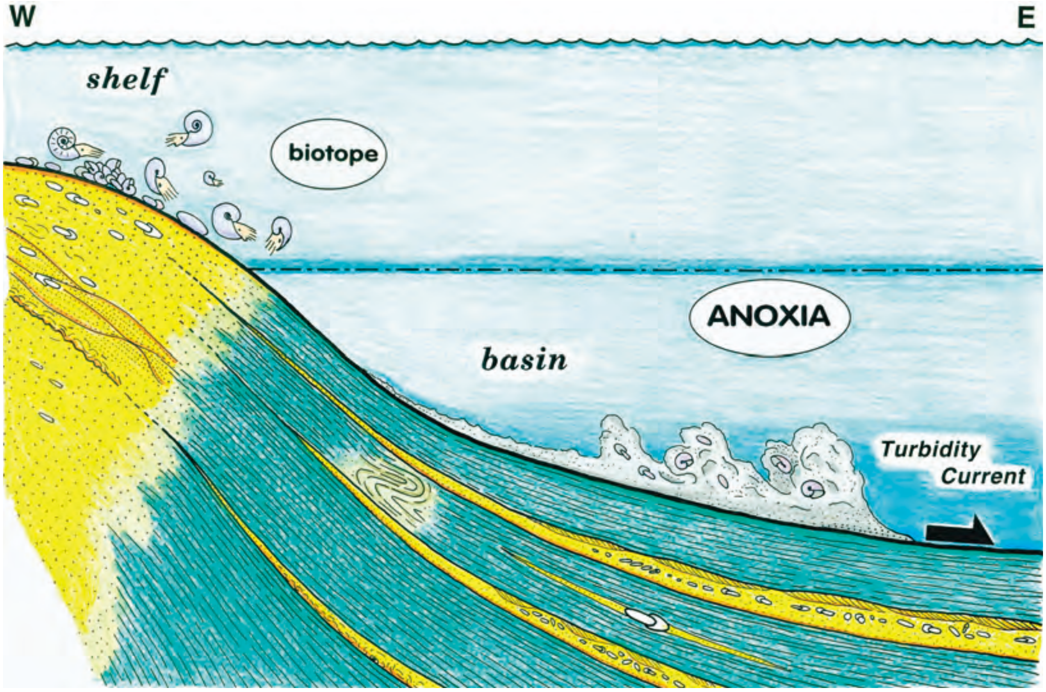


Fig. 24. Schematic paleoenvironmental profile during Early Triassic period in South Primorye, Russia. In the western area, shallow marine sandstone facies was predominated; e.g., Russian Island. Many ammonoids show indigenous mode of occurrence, and their biotope seemed in such shelf environment. On the other hand, laminated mudstone facies deposited under anoxia is widespread in the eastern area, e.g., Abrek Bay area. Paleo-current directions also suggest development of deep basinal environment eastward. Ammonoids are scarce in surrounding mudstone but occur restrictedly from intercalated very fine sandstone beds. These features may suggest that those ammonoids were allochthonous and that they were transported from their biotope to deep anoxic basin by low-density turbidite after death.

ronment, but rather, were of allochthonous origin. The majority of ammonoids from these formations probably lived at shallower depths, and after death, their empty shells were transported from their biotope to the anoxic basin-floor by gravity flows, most likely low-density turbidites (Fig. 24). Unlike the resultant severe damage expected from high-density gravity flows such as slump deposits, turbulence within low-density turubidites caused minimal damage to ammonoid shells during transport. Therefore, their shells were well preserved even though they were of allochthonous origin.

Aspects of ammonoid faunas (by Y. Shigeta)

Even though most members of the Griesbachian, Dienerian and early Smithian ammonoid faunas from the Abrek Bay area are clearly endemic, these faunal groups do contain a few species that are common to other realms. For instance, the occurrence of the late Griesbachian ammonoid *Wordieoceras* cf. *wordiei* (Spath) certainly indicates a relationship with the Boreal realm, given that this taxon is common in Greenland and Arctic Canada. Likewise, the early Dienerian fauna includes *Ambitoides fuliginatus* (Tozer) gen. nov., which also occurs in northeastern British Columbia, as well as *Proptychites alterammonoides* (Krafft) and *Clypeoceras spitiense* (Krafft), both of which are known from the Northwest Himalayan area. These ammonoids suggest relationships with the Eastern Panthalassic and Tethyan realms, respectively.

Brayard *et al.* (2008) recently discussed the paleobiogeography of Smithian ammonoids from South Primorye and concluded that the fauna exhibits strong affinities at the generic level with South China. However, early Smithian faunas in South Primorye and South China contain many endemic genera and species and they actually share very few common species (Kiparisova, 1961; Zakharov, 1968; Brayard & Bucher, 2008; Brühwiler *et al.*, 2008). This fact suggests that the ammonoid fauna of South Primorye exhibits only a very weak relationship with South China during the early Smithian.

Present-day East Asia was formed by the collision and amalgamation of several microcontinental blocks, which were located at the interface between the Panthalassic and Tethyan Oceans during the Early Triassic period. South China, which is part of the Yangtze (South China) Craton, was located at the paleoequator, and South Primorye was probably situated in the middle northern paleolatitudes of the Northeast China Block (Fig. 1).

As discussed earlier, ammonoids lived only in the shallower environment above the storm wave base due to the anoxic conditions thought to be so prevalent in deeper waters during the Early Triassic period (Fig. 24). Ammonoids had a nektobenthic mode of life similar to recent *Nautilus* (e.g., Scott, 1940; Tanabe, 1979; Cecca, 1992; Westermann, 1996), but their migration between microcontinents may have been severely restricted by the surrounding oxygen-poor deeper waters (Wignall & Twitchett, 2002).

For many benthic gastropods and bivalves, the duration of the planktonic stage is a very important factor controlling the extent of their geographical distribution (Jablonski & Lutz, 1980, 1983; Scheltema, 1971). Most ammonoids had a planktic life after hatching, but its duration is still obscure (Landman *et al.*, 1996). In contrast with ammonoids, conodonts from the Abrek Bay area include many pandemic species. They had a nektonic mode of life and may have swum the oceans between the microcontinents. If Lower Triassic ammonoids had a long interval of planktic life after hatching, they likely would have shown a pandemic distribution much like the conodonts. Their restricted habitat along with a relatively short planktonic stage may have combined to cause endemism in Early Triassic ammonoids.

Holocrinus **species from the early Smithian**
(by T. Oji)

Assuming the ammonoid based age assignment is correct, the existence of *Holocrinus* within the early Smithian *Clypeoceras timorense* beds represents the oldest known occurrence of this taxon in the world. Prior to this discovery, the oldest occurrence of *Holocrinus* sp. was in the late Smithian *Glyptophiceras aequicostatus* Zone of the Hiraiso Formation in northeast Japan (Nakazawa *et al.*, 1994; Kashiyama & Oji, 2004; Brühwiler *et al.*, 2007). Spathian aged *Holocrinus* columnals and other skeletal fragments are common in the upper Thaynes Formation and the Virgin Limestone Member of the Moenkopi Formation of the western United States (Shubert & Bottjer, 1995; Shubert *et al.*, 1992; Baumiller & Hagdorn, 1995). *Holocrinus* also has been reported from the Spathian member of the Werfen Formation in the Dolomites of northern Italy (Baumiller & Hagdorn, 1995; Twitchett, 1999).

Holocrinus is regarded as the first post-Paleozoic articulate crinoid (Twitchett & Oji, 2005) and its biogeographic distribution apparently indicates that the recovery of crinoids following the Permian-Triassic (P/Tr) mass extinction was earlier in the western Panthalassa represented by sections in Japan and South Primorye, than in the eastern Panthalass (western USA) and western Tethys (southern Europe). This difference in recovery patterns with respect to biogeographic areas is similar for certain other benthic animals, such as ichnofossils (Twitchett, 2006).

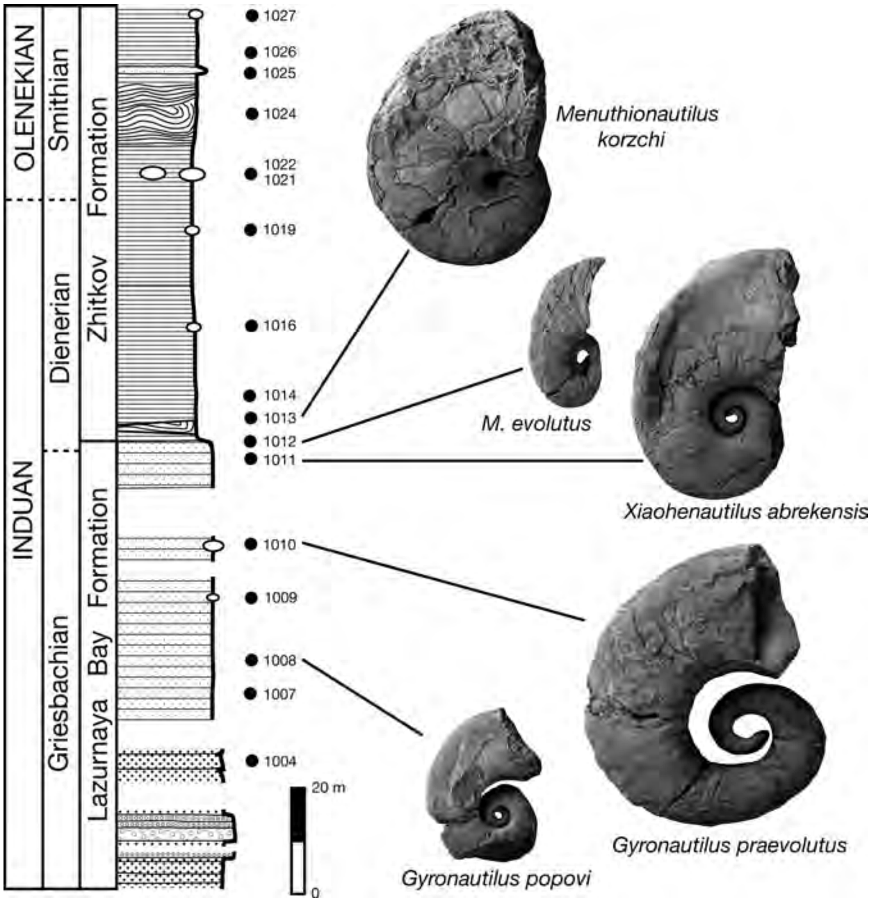


Fig. 25. Columnar section showing detailed occurrence of grypoceratid nautiloids in the Abrek Bay section.

Recovery of nautiloids in the Early Triassic (by Y. Shigeta)

As with most other organisms, the nautiloids underwent a major biotic crisis during the Permian-Triassic (P/Tr) transition. Unfortunately, the fossil record for this interval is far from complete and has been poorly understood. However, recent discoveries in the Abrek Bay area provide an important key for understanding their recovery during the Early Triassic.

The following five species, belonging to three genera of nautilids, have been found in succession in Induan (Greiesbachain and Dienerian) deposits in the Abrek Bay area: 1) *Gyronautilus popovi* Shigeta and Zakharov sp. nov., with evolute inner whorls, gyroconic outer whorls, and sub-central siphunle position; 2) *Gy. praevolutus* (Kiparisova), distinguished by a gyroconic shell throughout ontogeny and near-ventral siphuncle position; 3) *Xiaohenautilus abrekensis* Shigeta and Zakharov sp. nov., characterized by a moderately evolute shell and near-ventral siphuncle position; 4) *Menuthionautilus evolutus* sp. nov., with a moderately evolute shell and siphuncle located next to venter; and 5) *M. korzchi* Kiparisova, with a very involute shell and siphuncle located next to venter (Fig. 25).

Gy. popovi more closely resembles early Induan members of *Grypoceras* from the Himalayan area (Griesbach, 1880; Diener, 1897), and it seems best to consider *Gy. popovi* to be an offshoot of an early Induan species of

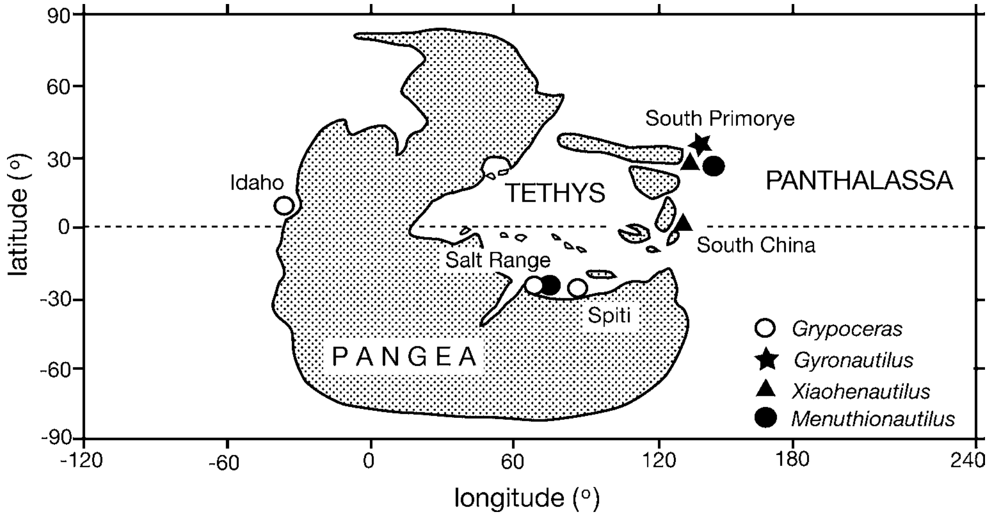


Fig. 26. Paleogeographical distribution of Induan aged grypoceratid nautiloids (Griesbach, 1880; Diener, 1897; Kummel, 1953a, b; Nakazawa & Dickins, 1985; Xu, 1988; Mu *et al.*, 2007). Map base after Fig. 1.

Grypoceras. *Gy. popovi* differs from *Gy. praevolutus* by its evolute inner whorls, but both species probably belong to the same evolutionary lineage. *Gy. praevolutus* and *X. abrekensis* both have a near-ventral siphuncle position, and if this morphological variable is considered as diagnostic in regard to phylogenetic relationships, then *X. abrekensis* would likely be an offshoot of *Gy. praevolutus*. The shell form of *M. evolutus* is very similar to *X. abrekensis*, but its siphuncle position is the same as that of *M. korzchi*. *M. korzch* likely evolved from *X. abrekensis* via *M. evolutus* Thus, the five species from the Abrek Bay section may belong to the same evolutionary lineage within the Grypoceratidae.

The Grypoceratidae, long recognized as one of the more successful nautiloid families, flourished during the Permian and developed diverse shell forms and siphuncle positions (Kummel, 1953a). However, most family members became extinct during the P/Tr transition, and only one genus, an ancestor of *Grypoceras*, survived (Kummel, 1953a). *Grypoceras* is characterized by a moderately involute shell and a central siphuncle, and Grypoceratid nautiloids from the Abrek Bay area suggest that this survivor again developed diverse shell forms and siphuncle positions after the P/Tr mass extinction. Induan aged Grypoceratids have been described from Idaho, the Salt Range, Spiti and South China (Fig. 26), and their biogeographic distribution shows that they diversified in the western Panthalassa and Tethys areas. In contrast, the nautilid families Tainoceratidae and Liroceratidae also crossed the P/Tr boundary, but they developed in the Boreal realm during the Early Triassic (Sobolev, 1989, 1994).

Gyronautilus is the only known uncoiled nautilid genus that lived during the Mesozoic and Cenozoic eras. During extinction periods, it has been shown that many ammonoids, under intense environmental stress, were affected by a drastic simplification of their shell geometory. Guex (2006) observed that a process termed "proteromorphosis" can result in relatively tightly coiled ammonoids giving rise to highly evolute forms or uncoiled heteromorphs. The appearance of *Gyronautilus* just after the P/Tr mass extinction seems to agree with this hypothesis, and its evolutionary clock may have been reinitialized by extreme environmental stress (Guex, 2006).

Table 1. Early Triassic bivalves of South Primorye and the occurrence of common or closely related species in other areas. 1: Maizuru Zone, Japan (Nakazawa, 1961), 2: Kamura Limestone, Japan (Kambe, 1963), 3: Northwest China (Yang *et al.*, 1983; Lu & Chen, 1986), 4: Southwest China (Editorial Group on Fossil Lamellibranchiata of China, 1976; Gan & Yin, 1978), 5: Siberia (Kurushin, 1992; Dagys *et al.*, 1996), 6: Greenland (Spath, 1930, 1935), and South Primorye (Bittner, 1899b; Kiparisova, 1938; added species in this paper *).

Species	Area					
	1	2	3	4	5	6
Palaeonucula goldfussi (Alberti)	—	—	○	—	—	—
Palaeonucula oviformis (Eck)	○	—	—	—	—	—
Palaeoneilo? *prinadae* Kiparisova	—	—	—		—	—
Palaeoneilo elliptica praecursor (Frech)	○	—	○	—	—	—
Palaeoneilo ledaeformis Kiparisova	—	—	—	—	—	—
Nuculana sp. nov. (Kiparisova)	○	—	—	—	—	—
Nuculana skorochodi (Kiparisova)	—	—	—	—	○	—
Nuculana aff. *becki* (Philippi)	—	—	—	—	—	—
"*Modiolus*" sp. indet.*	—	—	—	—	—	—
Promyalina schamarae (Bittner)	—	—	—	—	○	—
Promyalina putiatinensis (Kiparisova)	—	—	○	○	—	—
Promyalina aff. *blasingeri* (Philippi)	—	—	—	—	—	—
Pteria ussurica (Kiparisova)	—	○	—	—○	—	—
Bakevellia (*Neobakevellia*?) *exporrecta* (Lepsius)	—	○	○	—	—	—
Bakevellia (*Neobakevellia*?) *exporrecta linearis* (Gordon)	—	—	—	—	—	—
Bakevellia (*Neobakevellia*?) *mytiloides* (Schlotheim)	—	—	—	—	—	—
Bakevellia? sp. indet.*	—	—	—	—	—	—
Eumorphotis iwanowi Bittner	—	—	○	○	—	—
Eumorphotis maritima Kiparisova	○	—	—	—	—	—
Eumorphotis multiformis (s.l.) Bittner	○	○	○	○	—	○
Clarai aurita (Hauer)	—	—	○	○	—	—
Claraia stachei Bittner*	—	—	—	○	○	○
Claraia cf. *tridentina* Bittner	—	—	—	—	—	—
Crittendenia australaisatica (Krumbeck)	—	—	—	—	—	—
Crittendenia aff. *decidens* (Bittner)	○	—	—	○	—	—
Leptochondria bittneri (Kiparisova)	○	—	○	○	—	—
Leptochondria minima (s.l.) (Kiparisova)	○	○	○	○	○	—
Entolium microtis Wittenburg	○	—	○	—	—	—
Entolioides sp. indet.*	○	—	—	—	—	—
Scythentolium ussuricus (Bittner)	○	—	—	—	—	—
"*Pecten*" aff. *sojalis* Wittenburg	○	—	—	—	—	—
"*Etheripecten*" *amuricus* (Bittner)	—	—	—	—	—	—
Chlamys? *cryshtofowichi* Kiparisova	—	○	—	—	—	—
Chlamys? aff. *duronicus* Wittenburg	—	—	—	—	—	—
Chlamys sp. indet. Kiparisova	—	—	—	—	—	—
Camptonectes? *wittenbergi* Kiparisova	—	—	—	—	—	—
Unionites fassaensis (Wissmann)	—	—	○	○	○	—
Unionites fassaensis brevis (Bittner)	—	○	—	—	—	○
Unionites canalensis (Catullo)	—	○	○	○	—	—
Unionites aff. *borealis* Spath	—	—	—	—	—	○
Neoschizodus cf. *laevigatus* (Ziethen)	○	—	○	○	○	—
Neoschizodus laevigatus ovalis (Philippi) ?	—	—	○	—	—	—
Neoschizodus cf. *ovatus* (Goldfuss)	—	—	—	—	—	—
Neoschizodus ex. gr. *orbicularis* (Bronn)	—	—	—	—	—	—
Trigonodus orientalis Bittner	—	—	—	—	—	—
Myoconcha aff. *goldfussi* Dunker	—	—	—	—	—	—
Myoconcha plana Kiparisova	—	—	—	—	—	—
Myoconcha sp. indet.*	—	—	—	—	—	—

Table 1. Continued.

Species	Area					
	1	2	3	4	5	6
Triaphorus aff. *multiformis* Kiparisova	—	—	—	—	—	—
Ochotomya? sp. indet.*	—	—	—	—	—	—
Peribositria abrekensis (Kiparisova)	—	—	—	—	—	—
Peribositria mimer (Orberg)	—	—	—	—	○	—
Peribositria aff. *tenuissima* (Böhm)	—	—	—	—	○	—
Peribositria sp. indet.	—	—	—	—	—	—
Nos. of common or closely allied species to South Primorye fauna	13	7	14	12	8	4

Brief note on the bivalve fauna of South Primorye (by K. Nakazawa)

Bittner (1899b) and Kiparisova (1938) described nearly fifty species of bivalves from the Lower Triassic of South Primorye, and our study has resulted in an additional six species. Table 1 exhibits a list of bivalve species from South Primorye as well as common or closely related species from other areas.

Two Triassic bivalve faunas are recognized in Japan. Both are in southwest Japan and include the Maizuru fauna of the Maizuru Zone (Nakazawa, 1961) and the accreted limestone fauna from the Kamura Limestone (Kambe, 1963). The former occurs in a clastic rock facies, which probably was deposited near shore, whereas the Kamura Limestone, of oceanic origin, was primarily formed in a low latitudinal warm sea and then migrated northward and accreted in its present position. During the Early Triassic, there is not much difference between the two faunas, but by Late Triassic time, the Upper Triassic oceanic limestone fauna is more characteristic of a low latitudinal Tethyan setting, while the Maizuru fauna is more similar to faunas of South Primorye and Siberia (Nakazawa, 1991). The fauna of southwest China belongs to the Yangtze Craton, whereas the Quinghai fauna of northwest China belongs to the Sino-Korea Craton (Yang *et al.*, 1983; Lu & Chen, 1986). There is not much difference between these faunas due to the preponderance of cosmopolitan species during the Early Triassic.

All evidence indicates that the South Primorye fauna is more similar to those of Japan and China than to the Boreal faunas of Siberia and Greenland. Many Boreal taxa that are either common or related to those of South Primorye include rather widely distributed species belonging to *Eumorphotis*, *Claraia*, *Unionites*, *Neoschizodus* and *Leptochondria*. *Peribositria* from South Primorye exhibits a Boreal affinity, but the typical Boreal genus *Atomodesma* has not been found in South Primorye.

Based on the number of South Primorye species that are either common or intimately related, the Maizuru fauna contains nearly the same number as that of China. Furthermore, when considering the fact that the Maizuru Zone is far narrower and smaller in areal extent and contains a somewhat lesser number of species than China, one must conclude that the South Primorye fauna is more intimately related to the Maizura fauna than to the Chinese fauna. This conclusion is supported by the structural-geological continuity between the Inner Side of southwest Japan, which includes the Maizuru Zone and that of South Primorye (Kojima *et al.*, 2000; Ishiwatari & Tsujimori, 2003).

Systematic Paleontology

Cephalopods (by Y. Shigeta and Y. D. Zakharov)

Systematic descriptions basically follow the classification established by Sweet (1964) for orthocerids, Kummel (1964) for nautilids, and Tozer (1981, 1994) for ceratitids. Morphological terms are those used in the Treatise on Invertebrate Paleontology (Moore, 1957, 1964). Quantifiers used to describe the size and shape of ammonoid shells replicate that proposed by Matsumoto (1954, p. 246) and modified by Haggart (1989, Table 8.1).

Abbreviations for shell dimensions: D=shell diameter; U=umbilical diameter; H=whorl height; W=whorl width.

Institution abbreviations: NSM=National Museum of Nature and Science, Tokyo; CGM=Central Research Geological Prospecting Museum (CNIGR Museum), St. Petersburg; DVGI=Far Eastern Geological Institute, Vladivostok; GSC=Geological Survey of Canada, Ottawa; GSI=Geological Survey of India, Kolkata.

Class Cephalopoda Leach, 1817
Order Orthocerida Kuhn, 1940
Superfamily Orthoceratoidea M'Coy, 1844
Family Orthoceratidae M'Coy, 1844
Genus ***Trematoceras*** Eichwald, 1851

Type species: *Orthoceras elegans* Münster, 1841.

Trematoceras subcampanile
(Kiparisova, 1954)
Fig. 27

Orthoceras sp. indet. ex aff. *campanile* Mojsisovics. Diener, 1895, p. 10, pl. 4, fig. 5.
Orthoceras subcampabile Kiparisova, 1954, p. 20, pl. 11, figs. 1, 2.
Trematoceras subcampanile (Kiparisova). Kiparisova, 1961, p. 14, pl. 1, figs. 1, 2.

Holotype: CGM 596, figured by Diener (1895, p. 10, pl. 4, fig. 5), from the Lower Triassic (Olenekian) of Paris Bay, Russian Island, in South Primorye, Russia.

Material examined: Three specimens, NSM PM23100–23102, from AB1022.

Description: Moderately expanding orthoconic shell with 4–5 degree adoral angle of expansion and circular whorl cross-section. Juvenile shell ornamented with network lirae consisting of fine longitudinal ridges and fine transverse lirae, while larger shells exhibit fine transverse lirae. Centrally located siphuncle with cylindrical connecting ring, and short, orthochoanitic septal neck. Suture simple and straight. Cameral deposits not observed.

Occurrence: Described specimens from AB1022 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species occurs abundantly in Olenekian deposits at many localities in South Primorye (Kiparisova, 1961)

Discussion: *Trematoceras subcampanile* (Kiparisova, 1954) is morphologically very close to *T. campanile* (Mojsisovics, 1882, p. 291), *T. vulgare* Schastlivtceva, (1981, p. 77), *T. ciarum* Schastlivtceva, (1986, p. 125) and *T. boreale* Schastlivtceva, (1986, p. 125), but differs in that its juvenile shell is ornamented with network lirae. It differs from *T. mangishlakense* Schastlivtceva, (1981, p. 79) and *T. insperatum* Schastlivtceva, (1988, p. 67) by its smaller angle of shell expansion.

Order Nautilida Agassiz, 1847
Superfamily Trigonoceratoidea Hyatt, 1884
Family Grypoceratidae Hyatt, 1900
Genus ***Gyronautilus*** Zakharov and Shigeta, 2000

Type species: *Syringoceras praevolutum* Kiparisova, 1961.

Discussion: *Gyronautilus* was placed within the family Grypoceratidae because of its flattened venter and its suture, which displays distinct ventral and lateral lobes (Zakharov &

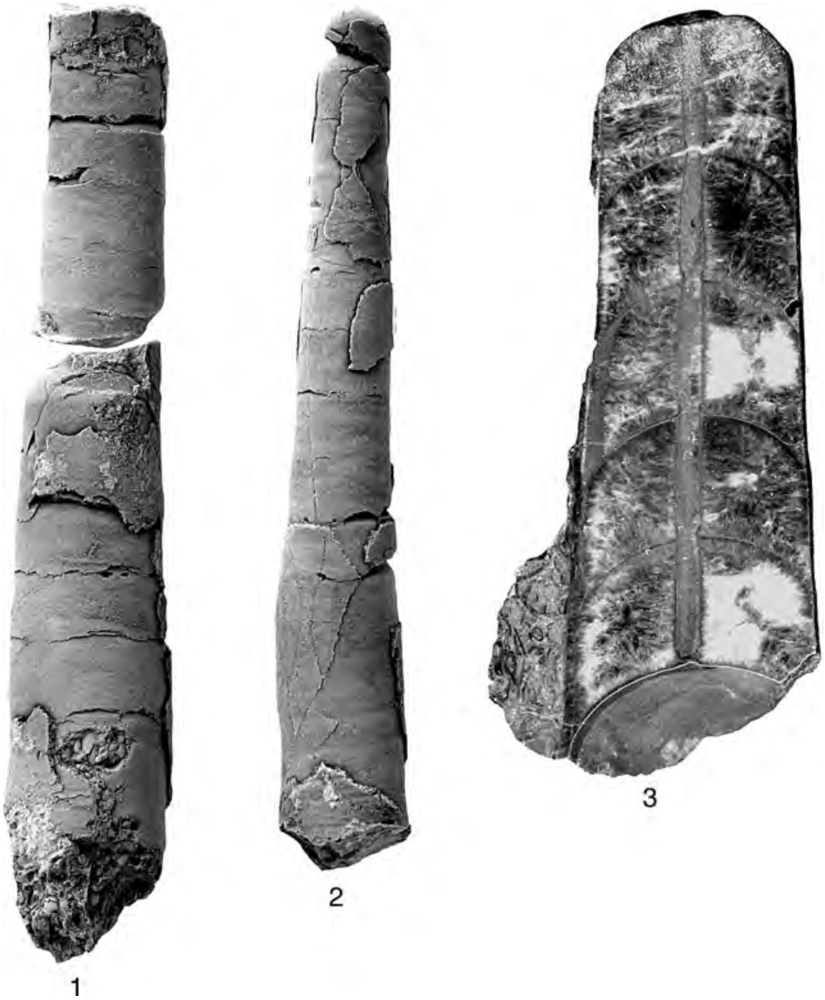


Fig. 27. *Trematoceras subcampanile* Kiparisova, 1954 from AB1022. 1, NSM PM23100, ×1.0. 2, NSM PM23101, ×1.0. 3, NSM PM23102, ×2.0.

Shigeta, 2000). Shimansky (1962) recognized four subfamilies within the family Grypoceratidae: Domatoceratinae, Grypoceratinae, Syringonautilinae and Clymenonautilinae. Zakharov and Shigeta (2000) proposed an additional subfamily Gyronautilinae, and placed *Gyronautilus* in it.

Gyronautilus popovi Shigeta and Zakharov sp. nov.

Figs. 28, 29

Type specimens: Holotype, NSM PM23104, from AB1008; paratype, NSM PM23103, from AB1008.

Diagnosis: *Gyronautilus* with evolute inner whorls and gyroconic outer whorls.

Etymology: Named for Alexander M. Popov, who collected the specimens.

Description: Gyroconic shell characterized by evolute inner whorls, subquadratic to subtrapezoidal whorl section, broadly rounded to subtabulate venter, rounded ventral shoulders, fairly concave dorsum and nearly parallel to slightly convex flanks with maximum whorl width just above umbilical shoulder. Umbili-

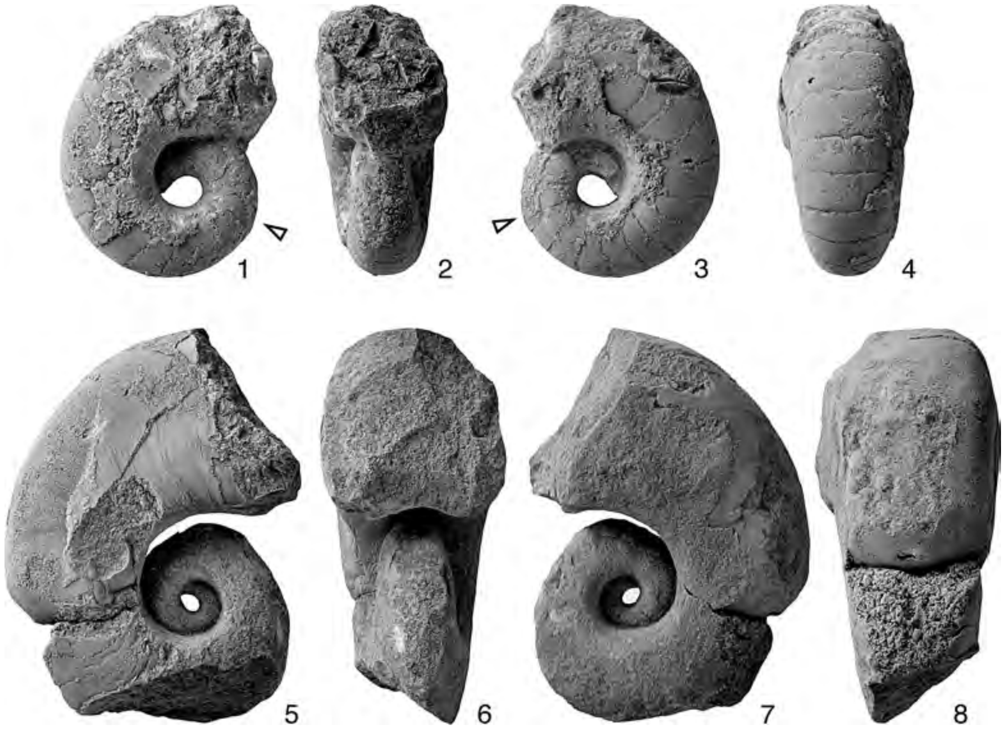


Fig. 28. *Gyronautilus popovi* Shigeta and Zakharov sp. nov. from AB1008. 1–4, NSM PM23103, paratype, ×2.0. 5–8, NSM PM23104, holotype, ×1.0. White arrows indicate position of the embryonic constriction.

cus exhibits moderately high, vertical wall with rounded shoulders and fairly small (2–3 mm) umbilical perforation. Embryonic shell 7.5 mm in length and consists of one half whorl. Body chamber length unknown. Siphuncle located at two thirds of whorl height. Ornamentation consists of sinuous growth lines with deep, U-shaped hyponomic sinus on venter. Suture simple with shallow ventral lobe and shallow, wide lateral lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23104	52.0	14.7	23.3	23.3	0.28	1.00
NSM PM23103	17.4	4.8	8.4	8.0	0.28	0.95

Occurrence: Described specimens from AB1008 within the *Lytophiceras* sp. Zone (Early Induan=Griesbachian) in the middle part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: *Gyronautilus popovi* sp. nov. differs from *Gy. praevolutus* (Kiparisova, 1961, p. 25) by its evolute inner whorls, but both species probably belong to the same evolutionary lineage.

Among the previously described Early Induan (Griesbachian) species, *Gy. popovi* sp. nov. more closely resembles *Nautilus quadrangulus* var. *brahmanicus* Griesbach (1880, p. 104) (assigned to *Grypoceras* Hyatt, 1883 by Kummel in 1953a) from the Himalayan area, in terms of whorl cross-section, siphuncle position, ornamentation and suture line. *Gy. popovi* sp. nov. is somewhat similar to *Nautilus brahmanicus* var. *hexagonalis* Diener (1897, p. 11) from the Early Induan (Griesbachian) of the Himalayan area, but differs in whorl cross-section. It seems best to consider *Gy. popovi* sp. nov. to be an offshoot of a species of the early Induan genus *Grypoceras*, such as *Gr. brahmanicum*.

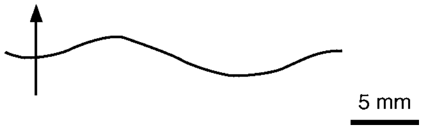


Fig. 29. Suture line of *Gyronautilus popovi* Shigeta and Zakharov sp. nov., NSM PM23104, holotype, from AB1008, at H=17 mm.

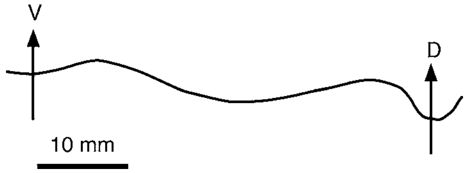


Fig. 30. Suture line of *Gyronautilus praevolutus* (Kiparisova, 1961), NSM PM23105, from AB1010, at H=33 mm. V: venter, D: dorsum.

Gyronautilus praevolutus (Kiparisova, 1961)

Figs. 30–35

Syringoceras praevolutum Kiparisova, 1961, p. 25, pl. 4, fig. 2, text-fig. 26.

Gyronautilus praevolutus (Kiparisova). Zakharov and Shigeta, 2000, p. 232, figs. 2–4.

Holotype: CGM 12/5504, figured by Kiparisova (1961, p. 25, pl. 4, fig. 2), from the Lower Triassic (Olenekian?) in the Abrek Bay area in South Primorye, Russia.

Material examined: Three specimens, NSM PM16132, 23105, 23106, from AB1010.

Description: Gyroconic shell distinguished by subquadratic whorl section, broadly rounded to subtabulate venter, rounded ventral shoulders, slightly concave dorsum and nearly parallel to slightly convex flanks. Umbilicus characterized by moderately high, subvertical wall with rounded shoulders and small (4–6 mm) umbilical perforation. Embryonic shell 11.3 mm in length, exogastrically curved and consists of one half whorl. Body chamber represents about 130° in spiral length. Ornamentation consists of sinuous growth lines with deep, U-shaped hyponomic sinus on venter. Siphuncle located near venter at one fifth of whorl height. Suture simple with shallow ventral lobe, shallow, wide lateral lobe and deep dorsal lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM16132	92.6	31.5	41.5	37.1	0.34	0.89
NSM PM23106	135.0	48.0	54.0	55.0	0.36	1.02
NSM PM23105	–	30.0	35.5	30.3	–	0.85

Occurrence: Described specimens from AB1010 within the *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: *Gyronautilus praevolutus* (Kiparisova, 1961) differs from *Gy. popovi* sp. nov. in that its shell is gyroconic throughout ontogeny.

Kiparisova (1961) proposed *Syringoceras praevolutum* on the basis of a single small specimen (Fig. 31.1–31.3) collected in 1948 by N. K. Trifonov from the Lower Triassic (Olenekian?) in the Abrek Bay area. Although the exact locality and horizon of the specimen were not documented, Zakharov and Shigeta (2000) later found a large specimen, NSM PM16132 (Fig. 35), at the type locality, which they identified as *S. praevolutum*. They carefully described its shell features throughout ontogeny, and proposed *Gyronautilus* as a new genus of Grypoceratidae. They collected the specimen from a horizon represented by AB1010 in the Lazurnaya Bay Formation, and interpreted its occurrence as Early Olenekian, based on previous biostratigraphical work by Zakharov and Popov (1999). However, the horizon of AB1010 is now correlated with the late Early Induan (late Griesbachian).

Genus ***Xiaohenautilus*** Xu, 1988

Type species: *Xiaohenautilus sinensis* Xu, 1988.

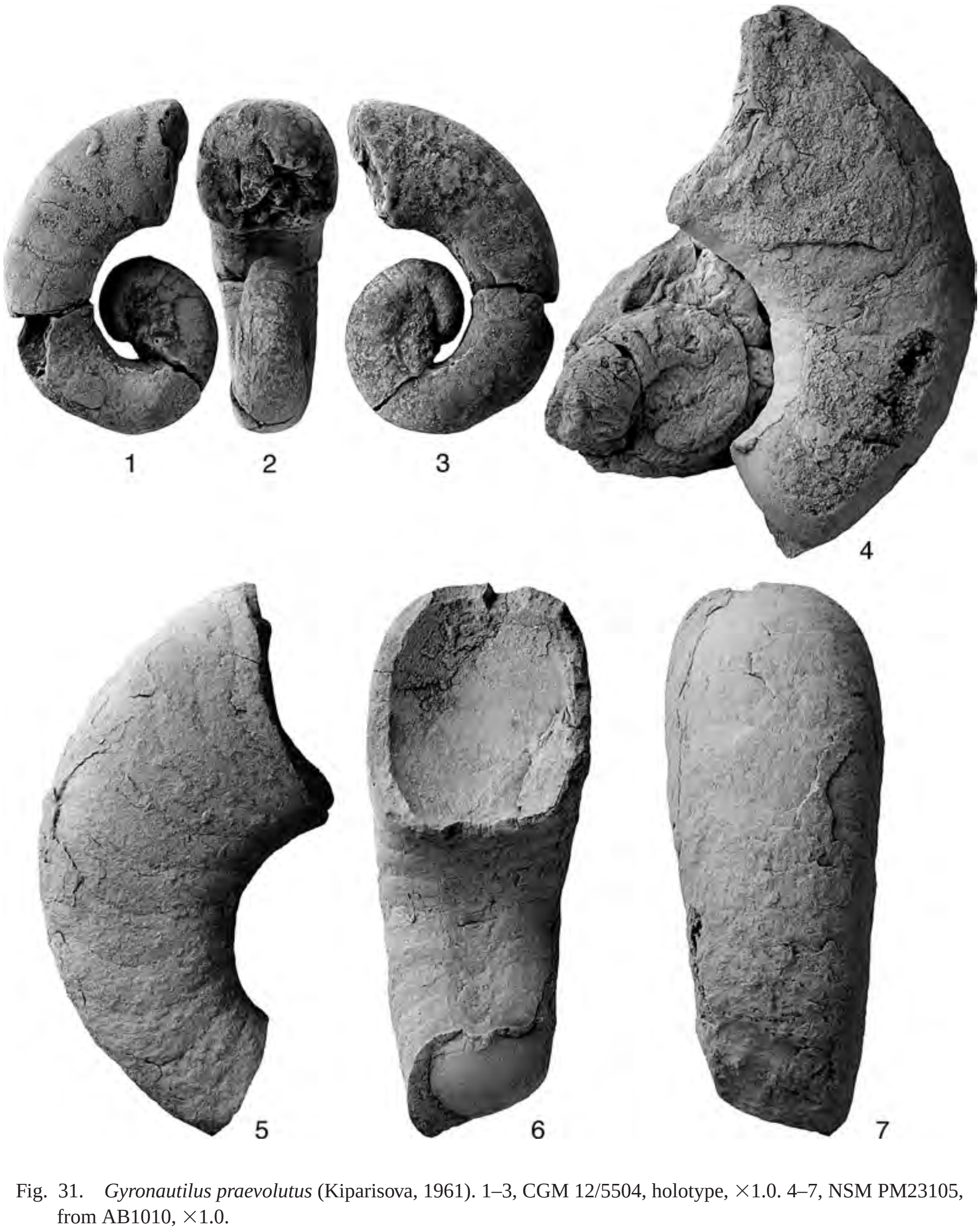


Fig. 31. *Gyronautilus praevolutus* (Kiparisova, 1961). 1–3, CGM 12/5504, holotype, ×1.0. 4–7, NSM PM23105, from AB1010, ×1.0.

→

Fig. 32. *Gyronautilus praevolutus* (Kiparisova, 1961), NSM PM23106, from AB1010. 1–9, ×2.0. 10–12, ×1.0. White arrows indicate position of the embryonic constriction.


1
2
3
4
5
6
7
8
9
10
11
12

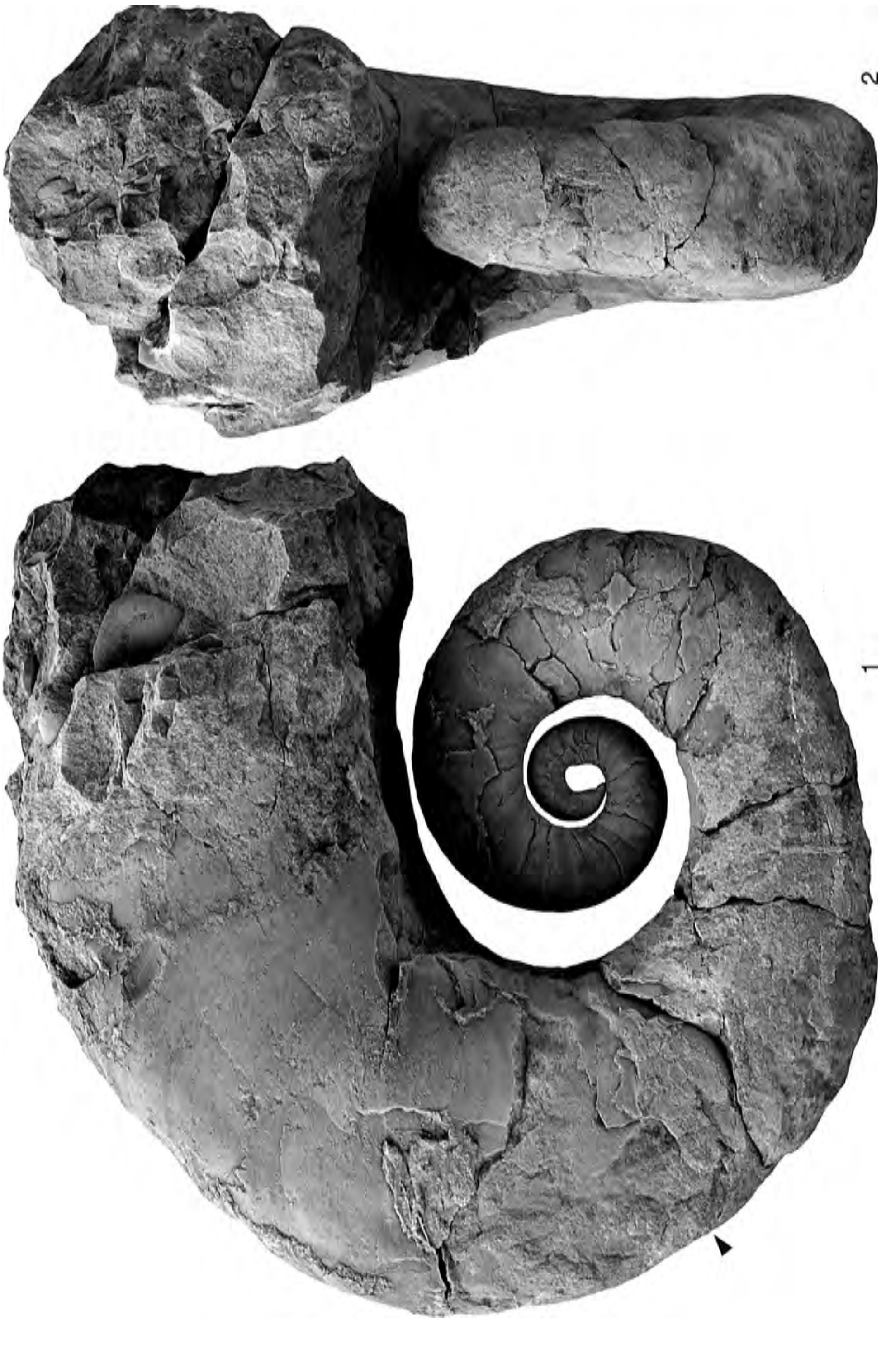


Fig. 33. *Gyronautilus praevolutus* (Kiparisova, 1961). 1–2, NSM PM23106, from AB1010, ×1.0. Black arrow indicates position of last preserved septum.

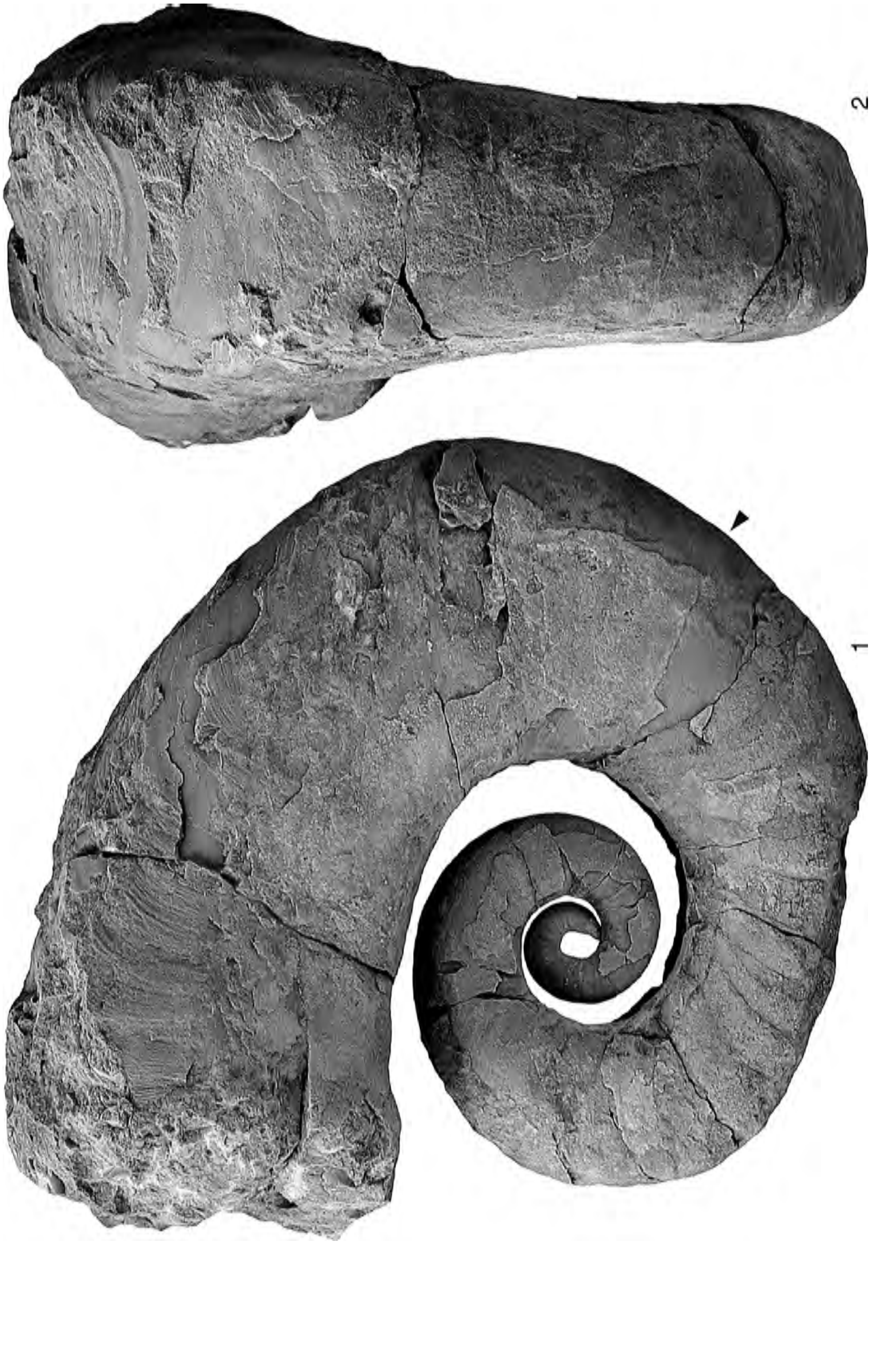


Fig. 34. *Gyronautilus praevolutus* (Kiparisova, 1961). 1–2, NSM PM23106, from AB1010, ×1.0. Black arrow indicates position of last preserved septum.

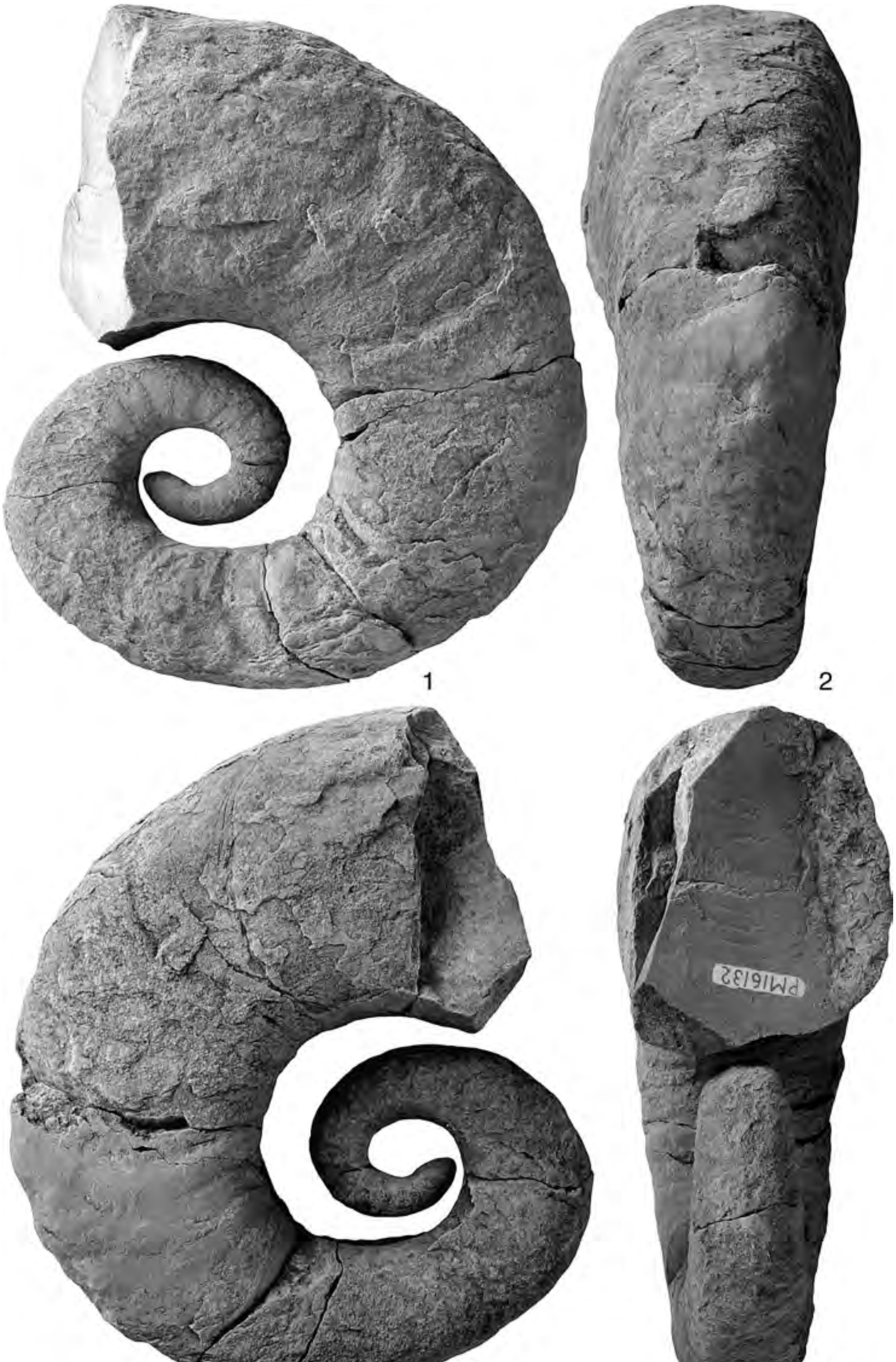


Fig. 35. *Gyronautilus praevolutus* (Kiparisova, 1961). 1–4, NSM PM16132, from AB1010, ×1.0.

Xiaohenautilus abrekensis Shigeta and Zakharov sp. nov.

Figs. 36–42

Type specimens: Holotype, NSM PM23110, from AB1011; paratypes, thirteen specimens, NSM PM23107–23109, 23111–23120, from AB1011.

Diagnosis: Moderately evolute *Xiaohenautilus* with a subquadratic to subtrapezoidal whorl section and delicate network lirae.

Etymology: Named after Abrek Bay (Strelok Strait) in South Primorye.

Description: Moderately evolute, thickly discoidal shell with subquadratic to subtrapezoidal whorl section, broadly rounded venter, rounded ventral shoulders and nearly parallel flanks with maximum whorl width just above umbilical shoulder. Umbilicus characterized by moderately high, vertical wall with rounded shoulders and fairly small (2–4 mm) umbilical perforation. Embryonic shell about 8 mm in length and consists of one half whorl. Body chamber represents about 130° in spiral length. Shell ornamented with delicate network lirae consisting of very fine spiral lirae as well as fine, sinuous growth lines with deep, U-shaped hyponomic sinus on venter. Siphuncle located near venter at one fifth of whorl height. Suture simple with shallow ventral lobe and shallow, wide lateral lobe. Attachment scars, visible on flanks in front of last septum, exhibit a tongue-shaped outline (Fig. 37.5).

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23110*	47.0	11.4	24.3	19.8	0.24	0.81
NSM PM23107	61.7	16.8	30.7	25.4	0.27	0.83
NSM PM23108	8.3	–	4.4	4.3	–	0.98
NSM PM23109	49.7	13.0	23.6	18.1	0.26	0.82
NSM PM23111	60.8	14.7	30.6	25.8	0.24	0.84
NSM PM23112	65.4	17.7	29.8	25.0	0.27	0.84
NSM PM23113	50.7	13.0	25.6	–	0.26	–
NSM PM23114	54.2	13.1	26.4	23.8	0.24	0.90
NSM PM23115	61.2	15.0	29.5	24.0	0.25	0.81
NSM PM23116	66.5	16.8	32.0	27.2	0.25	0.85
NSM PM23117	77.6	17.9	40.0	33.5	0.23	0.84
NSM PM23118	65.0	15.8	32.2	26.5	0.24	0.82

* Measurements taken at last septum.

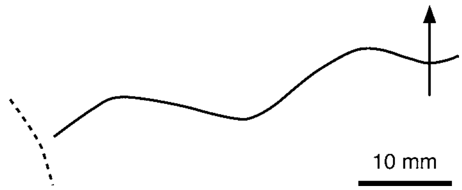


Fig. 36. Suture line of *Xiaohenautilus abrekensis* Shigeta and Zakharov sp. nov., NSM PM23111, paratype, from AB1011, at H=26 mm.

Occurrence: Described specimens from AB1011, within the *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: *Xiaohenautilus abrekensis* sp. nov can be easily distinguished from *X. sinensis* Xu (1988, p. 439) by its more evolute coiling, and from *X. huananensis* Xu (1988, p. 439) by its subquadratic to subtrapezoidal whorl section.

This species bears some resemblance to *Gyronautilus praevolutus* (Kiparisova, 1961) in its near-ventral siphuncle position and whorl cross-section. Other early Induan Grypoceratids, such as *Grypoceras brahmanicum* (Griesbach, 1880) and *Gy. popovi* sp. nov., have a sub-central siphuncle position. If siphuncle position is considered to be diagnostic in regard to phylogenetic relationships, then *X. abrekensis* sp. nov. would likely be an offshoot of *Gy. praevolutus*.

An attachment scar observed on a specimen of *X. abrekensis* sp. nov. (NSM PM23107, Fig. 37.5) is equivalent to the mantle myoadhesive band, which is the anterior edge of the bean-shaped attachment area of the cephalic retractor muscle in recent *Nautilus* Linné, 1758 (Mutvei *et al.*, 1993; Doguzhaeva & Mutvei, 1996; Mutvei & Doguzhaeva, 1997; Isaji *et al.*, 2002). The cephalic retractor muscles, representing the most massive muscles in *Nautilus*, serve to retract the body and assist in locomotion. Because the tongue-shaped outline of the attachment scar closely resembles that

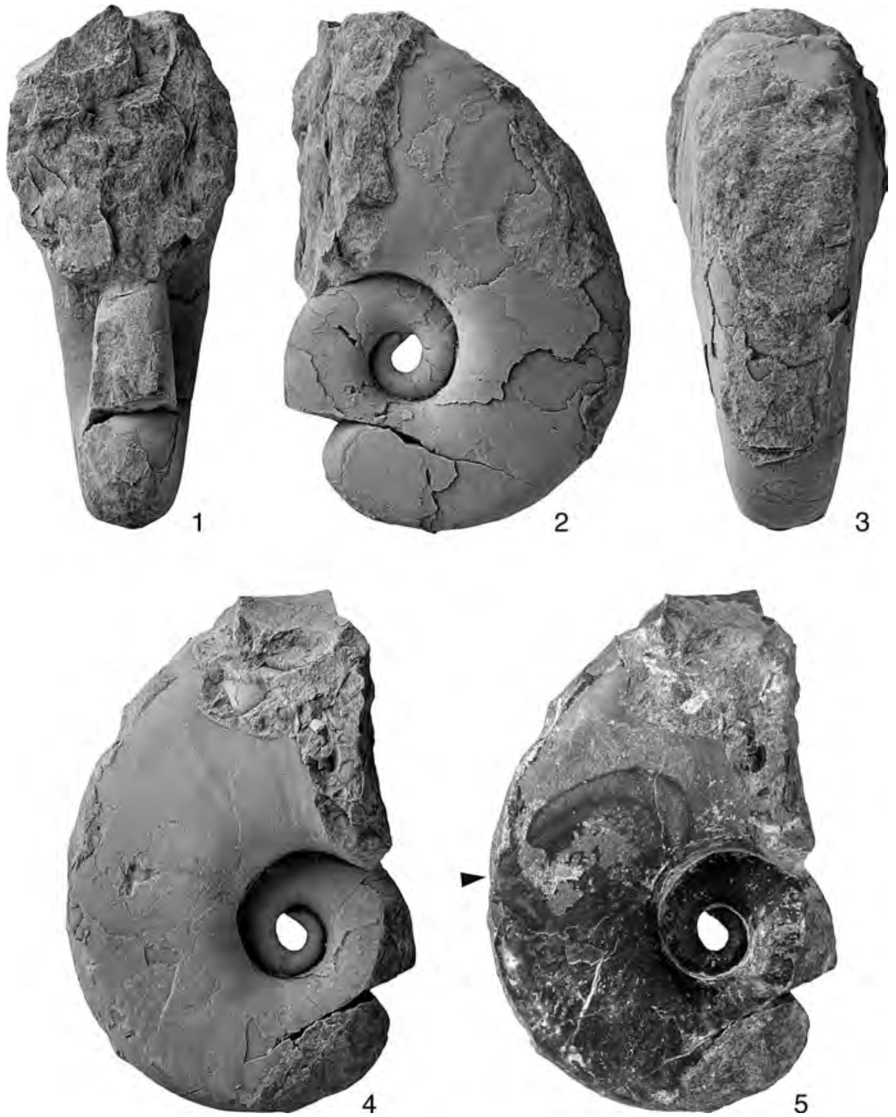
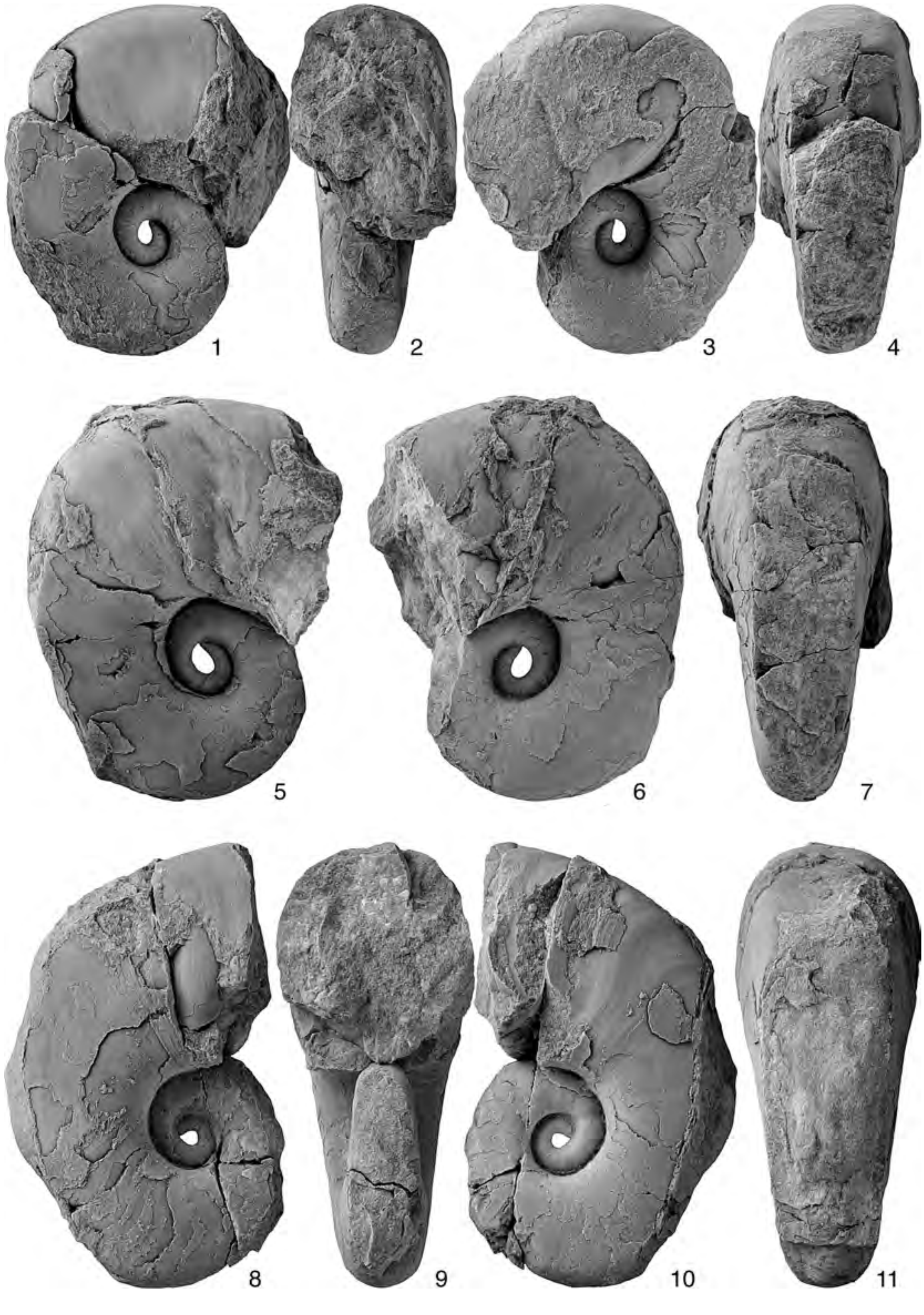


Fig. 37. *Xiaohenautilus abrekensis* Shigeta and Zakharov sp. nov. 1–5, NSM PM23107, paratype, from AB1011, ×1.0. Black arrow indicates position of last preserved septum.

→

Fig. 38. *Xiaohenautilus abrekensis* Shigeta and Zakharov sp. nov. from AB1011. 1–4, NSM PM23114, paratype, ×1.0. 5–7, NSM PM23115, paratype, ×1.0. 8–11, NSM PM23116, paratype, ×1.0.


1
2
3
4
5
6
7
8
9
10
11

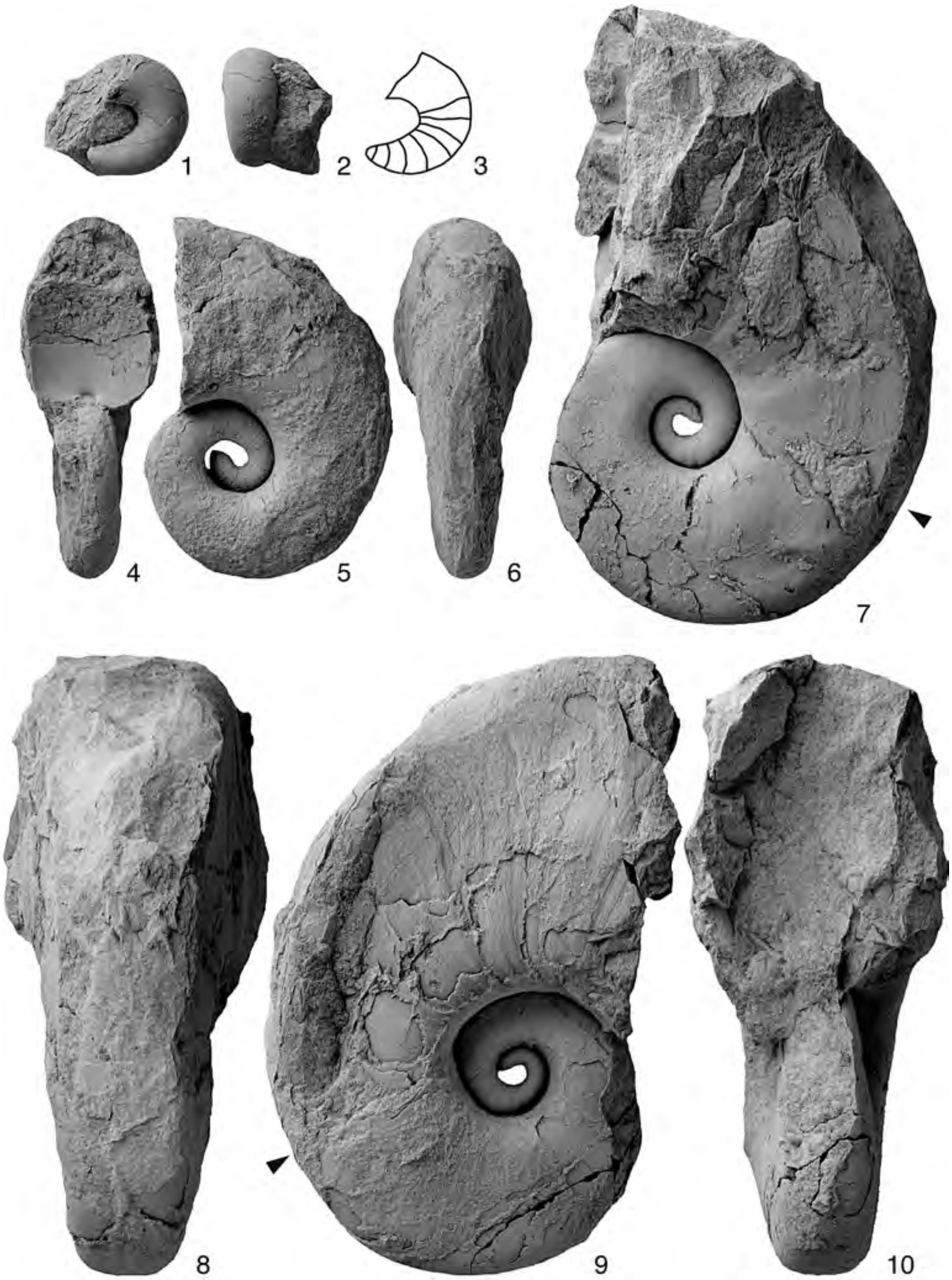


Fig. 39. *Xiaohenautilus abrekensis* Shigeta and Zakharov sp. nov. from AB1011. 1–3, NSM PM23108, paratype, ×2.0. 4–6, NSM PM23109, paratype, ×1.0. 7–10, NSM PM23110, holotype, ×1.0. Black arrows indicate position of last preserved septum.

Fig. 40. *Xiaohenautilus abrekensis* Shigeta and Zakharov sp. nov. from AB1011. 1–4, NSM PM23117, paratype, ×1.0. 5–6, NSM PM23118, paratype, ×1.0. Black arrows indicate position of last preserved septum.

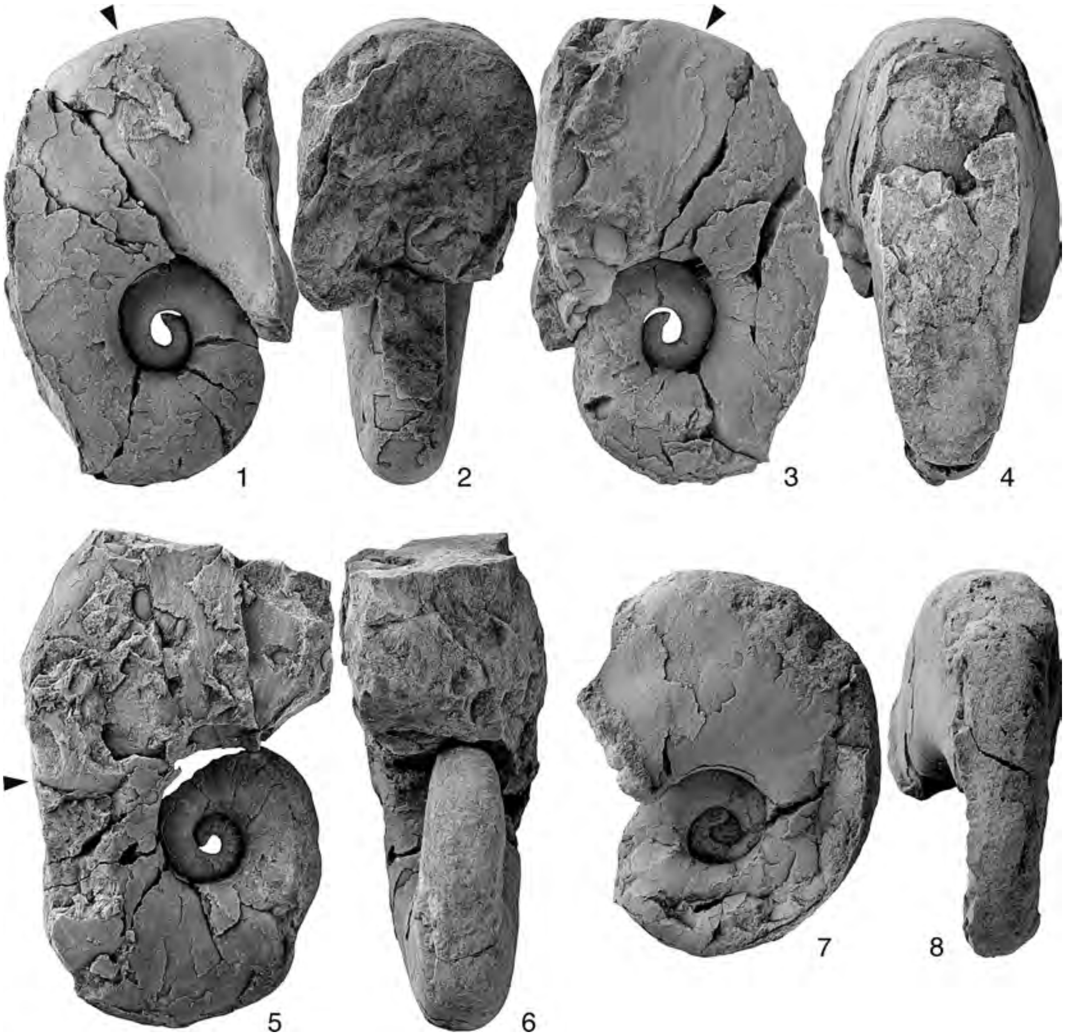


Fig. 41. *Xiaohenautilus abrekensis* Shigeta and Zakharov sp. nov. from AB1011. 1–4, NSM PM23111, paratype, ×1.0. 5–6, NSM PM23112, paratype, ×1.0. 7–8, NSM PM23113, paratype, ×1.0. Black arrows indicate position of last preserved septum.

of *Nautilus*, the soft part morphology of *X. abrekensis* sp. nov. was probably similar. Similar attachment scars have also been reported on the Middle Triassic nautiloid *Germanonautilus* Mojsisovics, 1902 (Klug & Lehmkuhl, 2004).

Genus ***Menuthionautilus*** Collignon, 1933

Type species: *Nautilus* (*Menuthionautilus*) *keislingeri* Collignon, 1933.

Discussion: Kummel (1953a, b) pointed out that the shell shape and suture of *Menuthionautilus* clearly place it in the Grypoceratidae, and that it displays close affinities with the Late Paleozoic *Domatoceras* Hyatt, 1891 and Triassic *Grypoceras* Hyatt, 1883. Shimansky (1962) included the genus in the subfamily Domatoceratinae. However, its delicate network lirae ornamentation and marginal siphuncle position indicate affinities with *Xiaohenautilus* Xu, 1988, *Syringoceras* Hyatt, 1894 and *Syringonautilus* Mojsisovics, 1902. Although it is unclear to which subfamily

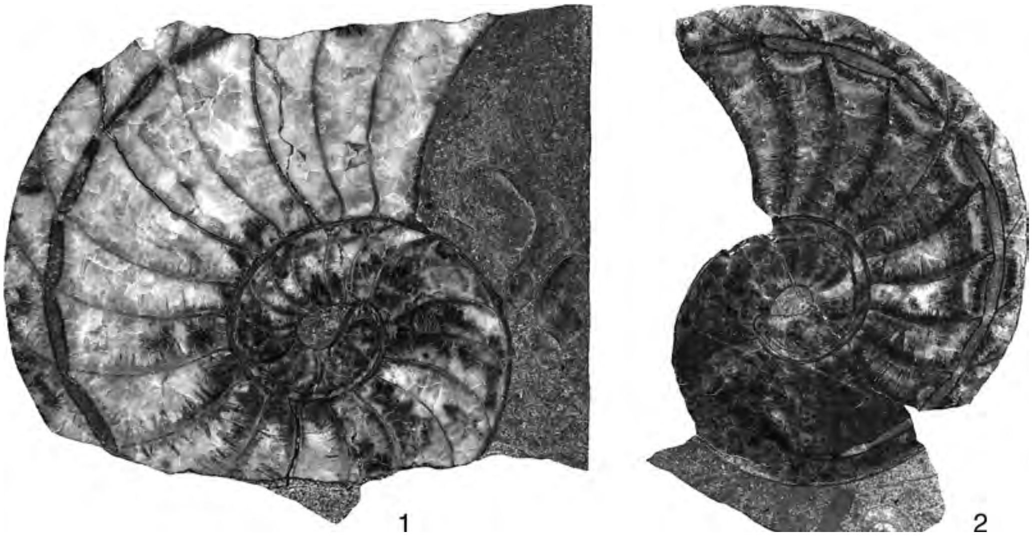


Fig. 42. Median sections of *Xiaohenautilus abrekensis* Shigeta and Zakharov sp. nov. from AB1011. 1, NSM PM23119, paratype, ×2.0. 2, NSM PM23120, paratype, ×2.0.

Xiaohenautilus should be assigned, Shimansky (1962) placed the latter two genera within the subfamily Syringonautilinae. *Menuthionautilus* most likely developed from the *Xiaohenautilus* - Syringonautilinae lineage.

Menuthionautilus korzchi Kiparisova, 1960

Figs. 43–46, 48

Menuthionautilus korzchi Kiparisova, 1960, p. 136, pl. 33, fig. 1; Kiparisova, 1961, p. 18, pl. 2, fig. 2.

Holotype: CGM 6/5504, figured by Kiparisova (1960, p. 136, pl. 33, fig. 1), from the Lower Triassic (Induan, *Flemingites*? beds) in the Abrek Bay area in South Primorye, Russia.

Material examined: Six specimens, NSM PM23121, 23123–23127, from AB1013, and one specimen, NSM PM23122, from AB1014.

Description: Very involute shell characterized by rapidly expanding whorl height, broadly rounded venter, rounded ventral shoulders and broadly convex flanks forming a subquadratic whorl section with maximum whorl width occurring at one third of distance across flank from umbilicus. Umbilicus narrow and deep with well rounded shoulders, and fairly small (2–3 mm) umbilical perforation. Embryonic shell about 8 mm in length and consists of one half whorl. Body chamber equivalent to about 110° in spiral length. Ornamentation includes delicate network lirae consisting of fine, dense spiral lirae and fine, sinuous growth lines as well as a deep, U-shaped hyponomic sinus on venter. Siphuncle located next to venter. Suture simple with shallow ventral lobe and shallow, wide lateral lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23121	12.3	2.6	6.5	6.2	0.21	0.95
NSM PM23122	23.9	5.2	12.8	12.2	0.22	0.95
NSM PM23123*	39.5	3.1	22.6	18.6	0.08	0.82
NSM PM23124*	46.2	3.1	28.9	25.2	0.07	0.87
NSM PM23125*	56.5	3.0	37.2	–	0.05	–
NSM PM23126*	59.1	2.0	34.0	31.2	0.03	0.91
NSM PM23127	69.8	4.0	40.1	37.2	0.06	0.93

* Measurements taken at last septum.

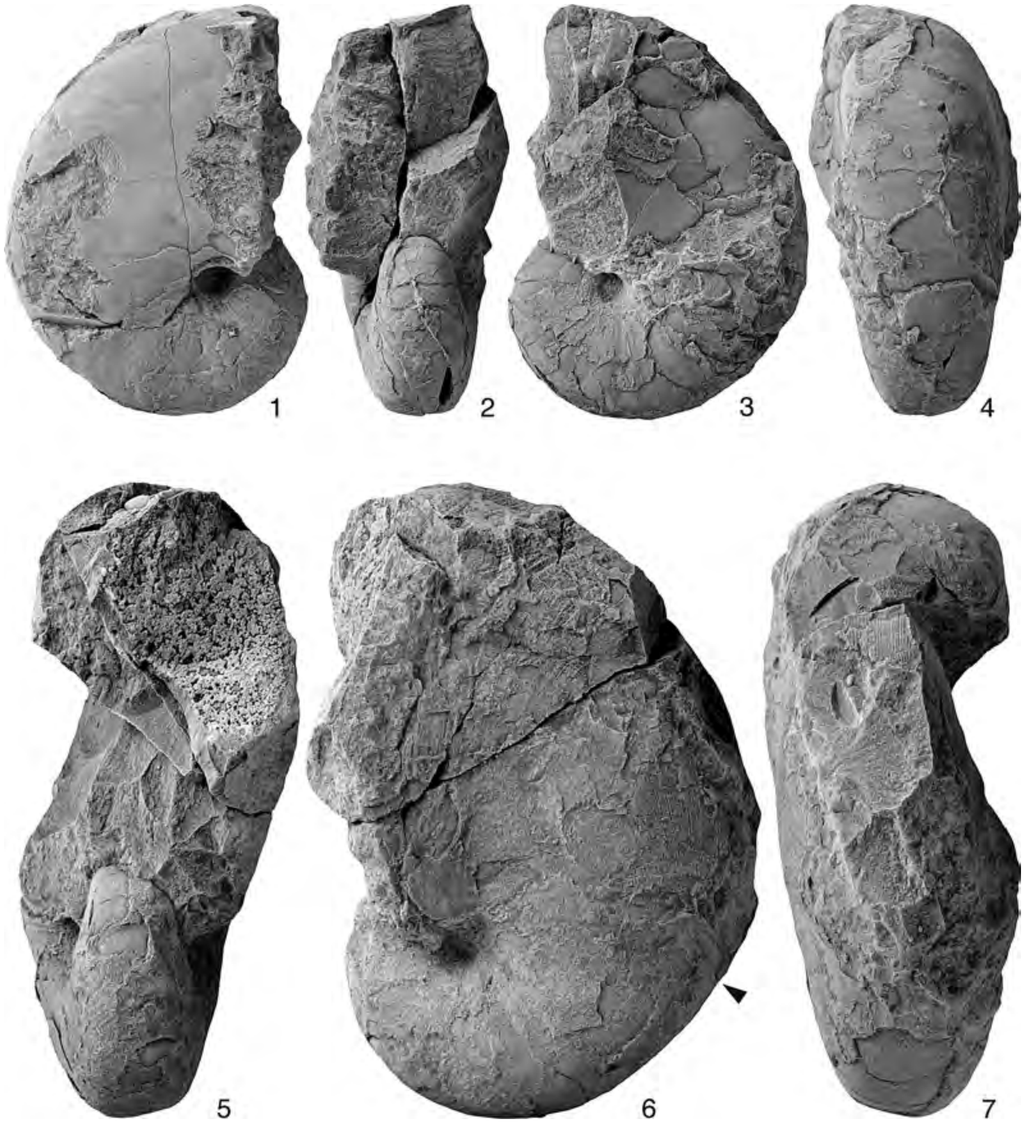
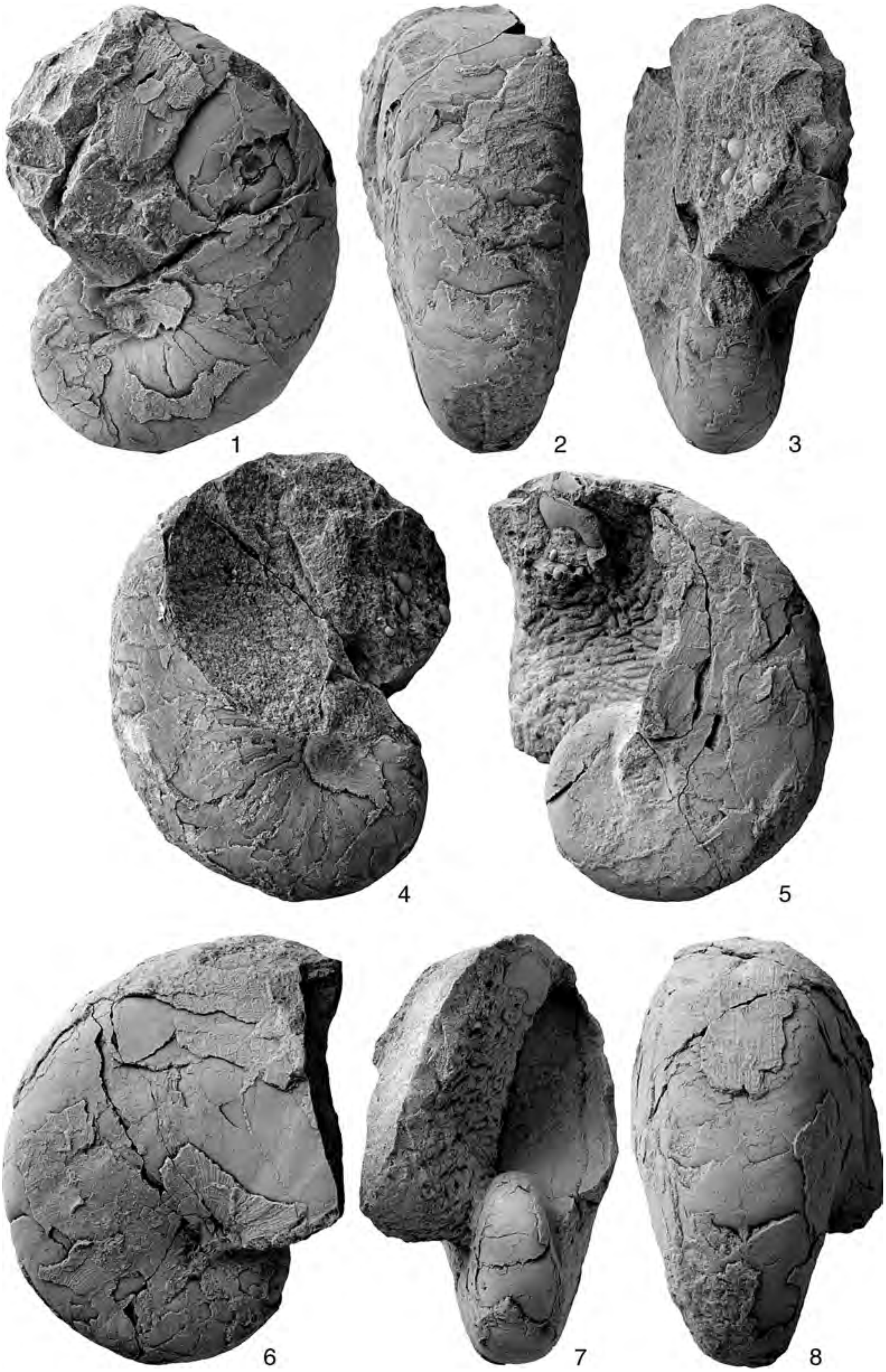


Fig. 43. *Menuthionautilus korzchi* Kiparisova, 1960 from AB1013. 1–4, NSM PM23123, ×1.0. 5–7, NSM PM23124, ×1.0. Black arrow indicates position of last preserved septum.

→

Fig. 44. *Menuthionautilus korzchi* Kiparisova, 1960 from AB1013. 1–4, NSM PM23125, ×1.0. 5–8, NSM PM23126, ×1.0.


1
2
3
4
5
6
7
8

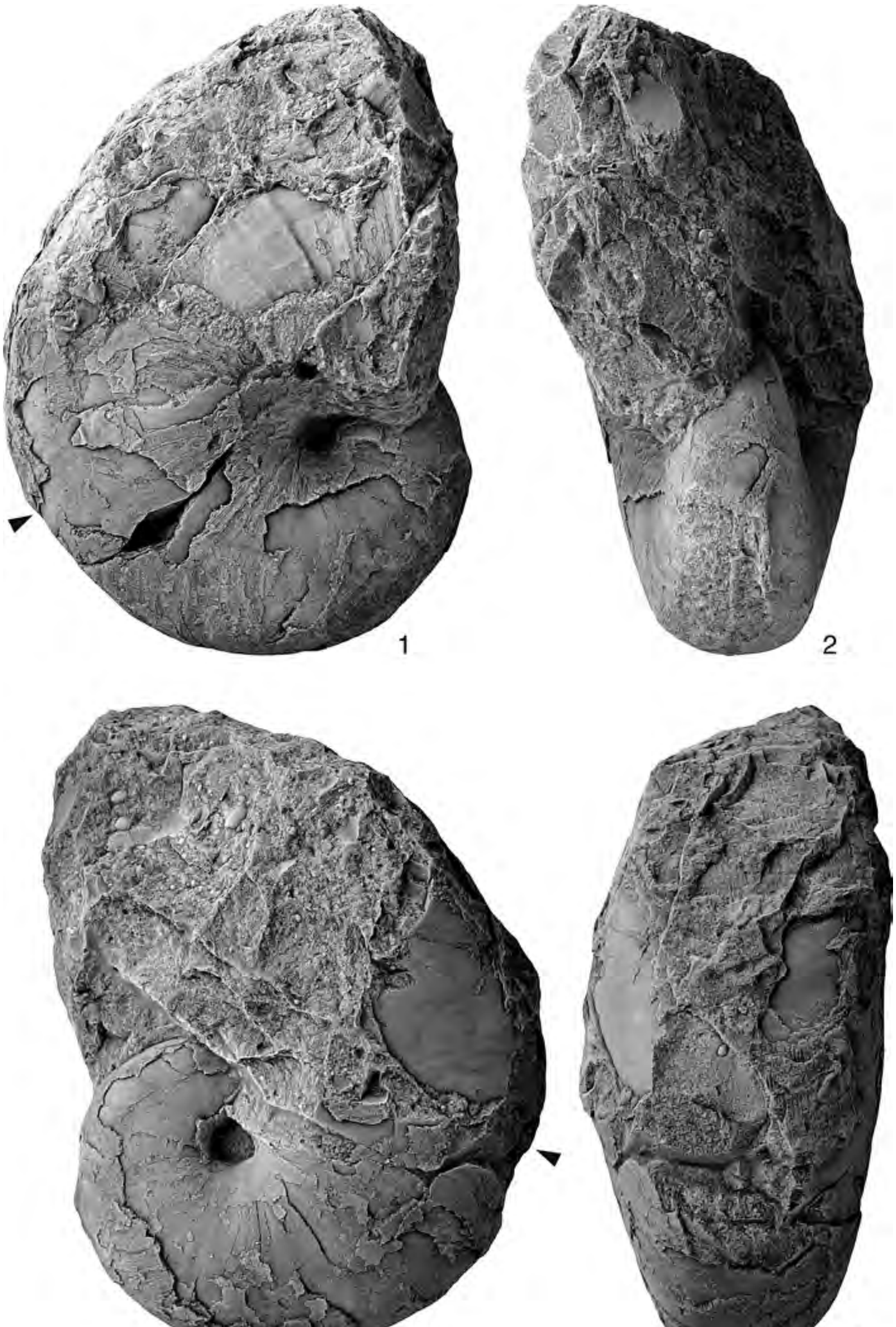


Fig. 45. *Menuthionautilus korzchi* Kiparisova, 1960. 1–4, NSM PM23127, from AB1013, ×1.0. Black arrows indicate position of last preserved septum.

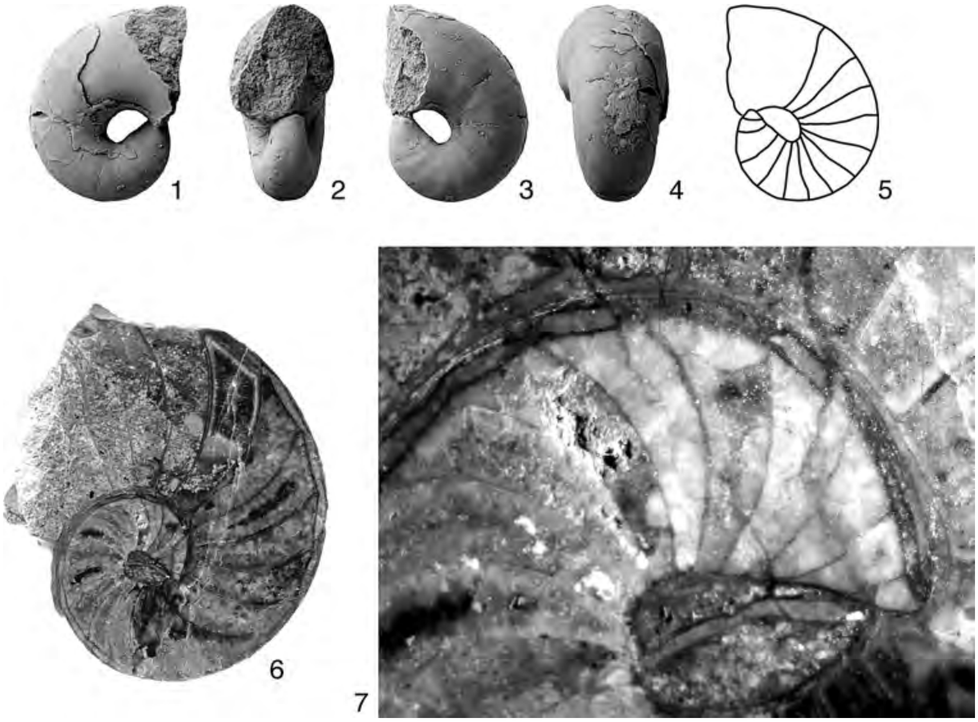


Fig. 46. *Menuthionautilus korzchi* Kiparisova, 1960. 1–5, NSM PM23121, from AB1013, ×2.0. 6, Median section, NSM PM23122, from AB1014, ×2.0. 7, Apical part of NSM PM23122, ×10.0.

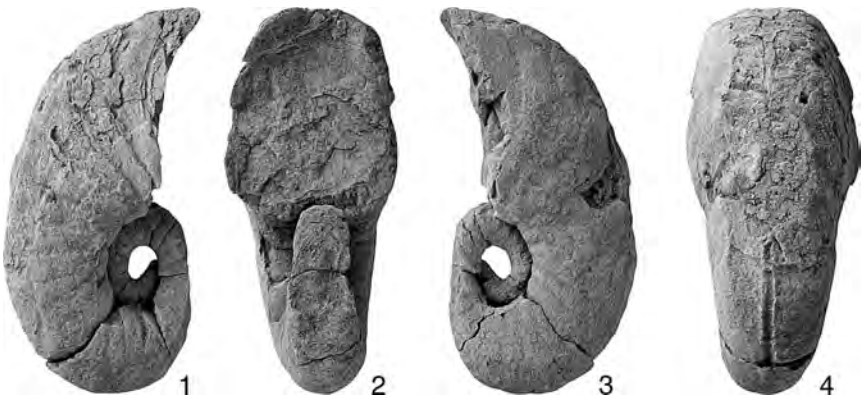


Fig. 47. *Menuthionautilus evolutus* Shigeta and Zakharov sp. nov. 1–4, NSM PM23128, holotype, from AB1012, ×1.0.

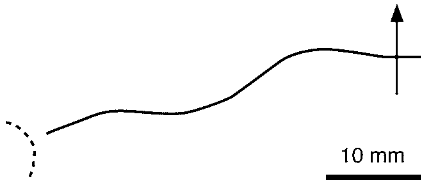


Fig. 48. Suture line of *Menuthionautilus korzchi* Kiparisova, 1960, NSM PM23127, from AB1013, at H=31 mm.

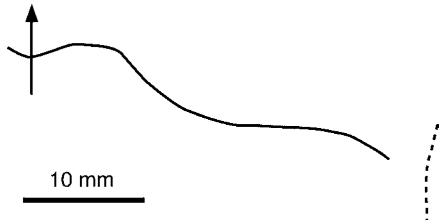


Fig. 49. Suture line of *Menuthionautilus evolutus* Shigeta and Zakharov sp. nov., NSM PM23128, holotype, from AB1012, at H=26 mm.

Occurrence: Described specimens from AB1013 within the *Ambitoides fuliginatus* Zone and from AB1014 within the *Clypeoceras spitiense* "bed", both early Late Induan (early Dienerian) in the basal part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: *Menuthionautilus korzchi Kiparisova*, 1960 differs from *M. kieslineri* Collignon (1933, p. 164) by its more inflated shell, and bears some resemblance to *Xiaohenautilus abrekensis* sp. nov. with regard to its delicate network lirae ornamentation and marginal siphuncle position. Although Kummel (1953a, b) believed that it descended from *Domatoceras* Hyatt, 1891 or *Grypoceras* Hyatt, 1883, we now consider *Menuthionautilus* to be an offshoot of *Xiaohenautilus* Xu, 1988.

Menuthionautilus evolutus Shigeta and Zakharov sp. nov.

Figs. 47, 49

Holotype: NSM PM23128, from AB1012.

Diagnosis: Moderately evolute *Menuthionautilus* with subquadratic whorl section.

Etymology: Species name refers to its evolute coiling.

Description: Moderately evolute shell characterized by broadly rounded venter, rounded ventral shoulders and broadly convex flanks forming a subquadratic whorl section. Umbilicus with moderately high, vertical wall with rounded shoulders, and small (3–5 mm) umbilical perforation. Embryonic shell about 7 mm in length and consists of one half whorl. Body chamber not preserved. Shell ornamentation not preserved. Siphuncle located next to venter. Suture simple with shallow ventral lobe, and shallow, wide lateral lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23128	51.0	11.6	26.0	23.3	0.23	0.90

Occurrence: Described specimen from AB1012 within the *Ambitoides fuliginatus* Zone (early Late Induan=early Dienerian) in the uppermost part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: *Menuthionautilus evolutus* sp. nov. is easily distinguished from *M. korzchi* Kiparisova (1960, p. 136) and *M. kieslineri* Collignon (1933, p. 164) by its evolute coiling. The moderately evolute shell is very similar to *Xiaohenautilus abrekensis* sp. nov., *X. sinensis* Xu (1988, p. 439) and *X. huananensis* Xu (1988, p. 439) of late Early Induan (late Griesbachian) age. We consider *Menuthionautilus* to be an offshoot of *Xiaohenautilus* Xu, 1988.

Order Ceratitida, Hyatt, 1884

Superfamily Xenodiscoidea Frech, 1902

Family Xenodiscidae Frech, 1902

Genus ***Tompophiceras*** Popov, 1961

Type species: *Tompophiceras fastigatum* Popov, 1961.

Tompophiceras sp. indet.

Fig. 50.7–50.8

Material examined: NSM PM23129 from AB1007.

Description: Very evolute serpenticone with sub-elliptical whorl section, broadly rounded venter, rounded ventral shoulders and convex flanks with maximum whorl width at mid-flank. Umbilicus wide with moderately high, oblique wall and rounded shoulders. Ornamentation consists of distinct, convex ribs arising on umbilical shoulder, becoming more prominent on mid-flank and fading on ventral shoulder. Suture not visible.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23129	34.0	17.7	8.6	–	0.52	–

Occurrence: Described specimen from AB1007 within the *Lytophiceras* sp. Zone (Early Induan=Griesbachian) in the middle part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: Even though the present specimen is fragmental, its distinctive features enable us to assign it with reasonable confidence to the genus *Tompophiceras*. However, a definitive species assignment cannot be made.

Zakharov (Zakharov & Rybalka, 1987, p. 33) described *Glyptophiceras* (*Glyptophiceras*) *ussuriense* from the early Induan of South Primorye, but upon re-examination, its ornamentation and shell shape justify its assignment to the genus *Hypophiceras* Trumpy, 1969 or *Tompophiceras*. This species differs from our specimen by its prominent ribs.

Family Xenoceltitidae Spath, 1930
Genus ***Shamaraites*** Shigeta and Zakharov gen. nov.

Type species: *Anakashmirites schamarensis* Zakharov, 1968.

Composition of the genus: Two species, *Dinarites latiplicatus* Diener (1895, p. 11) and *Anakashmirites schamarensis* Zakharov (1968, p. 104).

Diagnosis: Moderately evolute shell with subquadratic whorl section, subtabulate to low, arched venter, nearly parallel to slightly convex flanks, variable constrictions and ceratitic suture line.

Etymology: Named after Shamara Bay, Ussury Gulf, in South Primorye.

Occurrence: Lower part of the Lower Olenekian (lower Smithian) in South Primorye, Russia.

Discusion: *Shamaraites* gen. nov. differs from other representatives of Xenoceltitidae such as *Pseudoceltites* Hyatt, 1900, *Kashmirites* Diener, 1913, *Anakashmirites* Spath, 1930, and *Eukashmirites* Kummel, 1969, by the presence of distinct constrictions and the absence of distant, radial ribs. This new genus is close in shape and ornamentation to *Kashmirites varianus* Chao (1959, p. 279), the type species of *Hebeisenites* Brayard and Bucher, 2008, and *Jinyaceras bellum* Brayard and Bucher (2008, p. 31), but it has a well-developed ceratitic suture with a large first lateral saddle and reduced second lateral lobe (Zakharov, 1968, fig. 26).

Shamaraites schamarensis (Zakharov, 1968)

Figs. 50.1–50.4, 51

Anakashmirites schamarensis Zakharov, 1968, p. 104, pl. 20, fig. 3, text-fig. 26b, c.

Holotype: DVGI 211/801, figured by Zakharov (1968, p. 104, pl. 20, fig. 3), from the lower part of the Lower Olenekian (*Hedenstroemia bosphorensis* Zone) on the western coast of Ussuri Gulf, near Tri Kamnya Cape, in South Primorye, Russia.

Material examined: NSM PM23130, from AB1021.

Description: Moderately evolute shell with subquadratic whorl section, subtabulate venter, angular ventral shoulders and nearly parallel to slightly convex flanks. Umbilicus moderately wide, with moderately high, subvertical wall

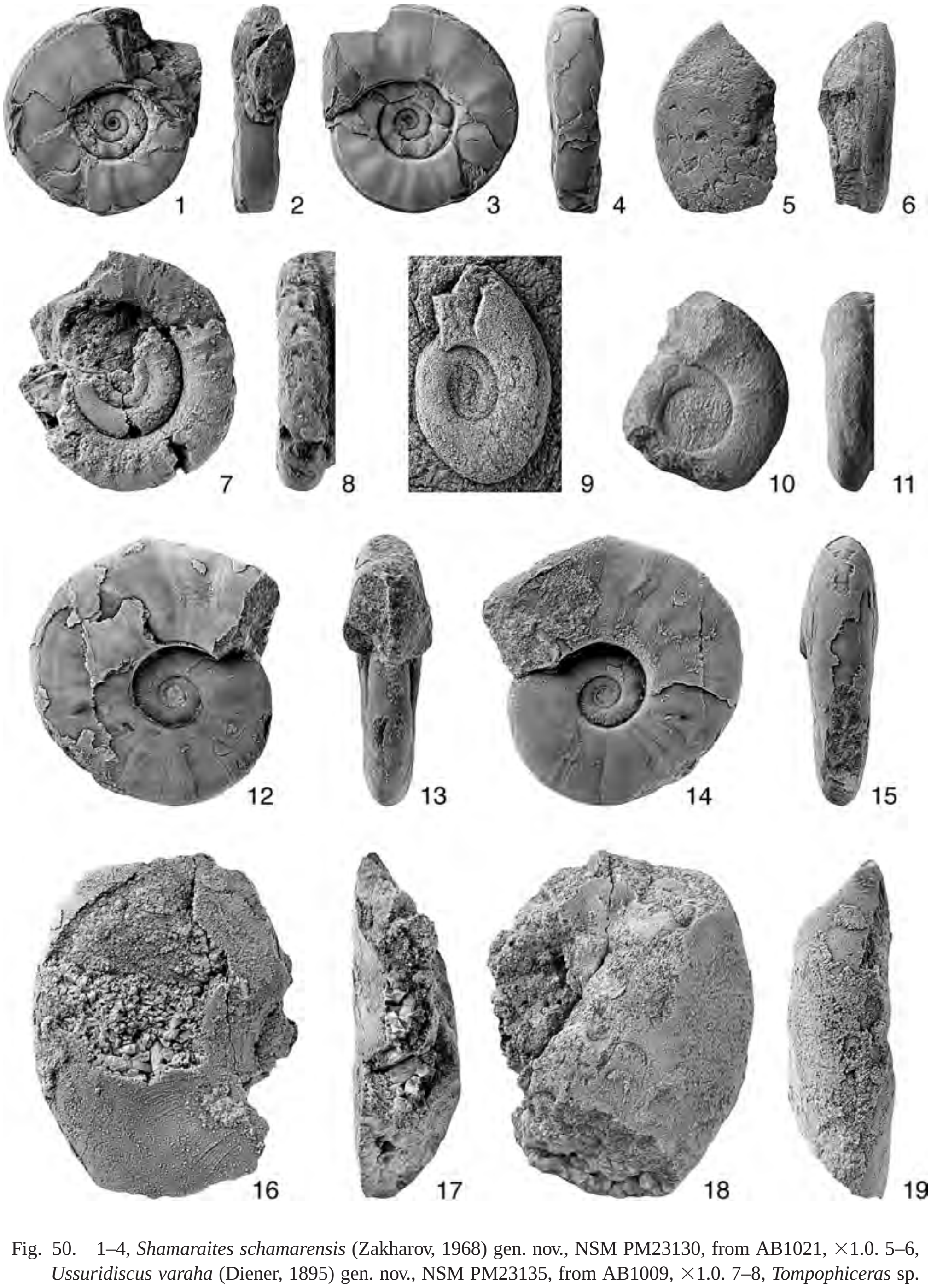


Fig. 50. 1–4, *Shamaraites schamarensis* (Zakharov, 1968) gen. nov., NSM PM23130, from AB1021, ×1.0. 5–6, *Ussuridiscus varaha* (Diener, 1895) gen. nov., NSM PM23135, from AB1009, ×1.0. 7–8, *Tompophiceras* sp. indet., NSM PM23129, from AB1007, ×1.0. 9–11, *Lytophiceras* (?) sp. indet. 9, NSM PM23132, from AB1004, ×1.0. 10–11, NSM PM23133, from AB1009, ×1.0. 12–15, *Wordieoceras* cf. *wordiei* (Spath, 1930), NSM PM23134, from AB1010, ×1.0. 16–19, *Lytophiceras* sp. indet., NSM PM23131, from AB1007, ×1.0.

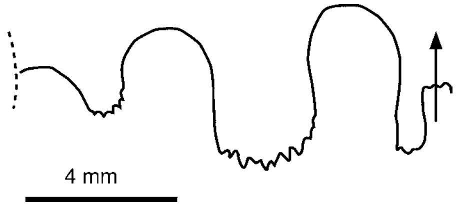


Fig. 51. Suture line *Shamaraites schamarensis* (Zakharov, 1968) gen. nov., NSM PM23130, from AB1021, at H=8 mm.

and rounded shoulders. Ornamentation consists of distinct, prorsiradiate constrictions, which form small plications on body chamber and nearly disappear on venter. Suture ceratitic with wide ventral lobe, divided by a median saddle into two short branches with a few denticulations at each base. First lateral saddle higher than second saddle and third saddle lower. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe about one-half depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23130	29.8	11.4	10.1	8.3	0.38	0.82

Occurrence: Described specimen from AB1021 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species also occurs in the *Hedenstroemia bosphorensis* Zone along the western coast of Ussuri Gulf, near Tri Kamnya Cape, South Primorye (Zakharov, 1968; Markevich & Zakharov, 2004).

Discussion: *Shamaraites schamarensis* (Zakharov, 1968) differs from *S. latiplicata* (Diener, 1895, p. 12) by its subtabulate venter and angular ventral shoulders.

Superfamily Meekoceratoidea Waagen, 1895
Family Ophiceratidae Arthaber, 1911
Genus ***Lytophyceras*** Spath, 1930

Type species: *Ophiceras chamunda* Diener, 1897.

Lytophiceras sp. indet.

Fig. 50.16–50.19

Material examined: NSM PM23131, part of an outer whorl, from AB1007.

Description: Moderately involute, discoidal shell with rounded venter, nearly parallel flanks and umbilicus with low, oblique wall and rounded shoulders. Shell surface either smooth or ornamentated with fine growth lines. Suture ceratitic with deep, weakly indented lateral lobes.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23131*	–	–	28.1	14.0	–	0.50

* Measurements at last septum.

Occurrence: Described specimen from AB1007 within the *Lytophiceras* sp. Zone (Early Induan=Griesbachian) in the middle part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: The described specimen possibly represents a portion of an outer whorl of *Lytophiceras eusakuntala* (Zakharov, 1987, p. 35), which displays the same shell shape. However, the fragmental nature of the specimen precludes a definitive assignment.

Waterhouse (1994) assigned *Lytophiceras eusakuntala* to *Himophiceras* Waterhouse, 1994, but we reject this synonymy because *L. eusakuntala* differs from all species of *Himophiceras* by its gently rounded umbilical wall, which is one of the diagnostic features of *Lytophiceras*.

Lytophicerasku? sp. indet.

Fig. 50.9–50.11

Material examined: NSM PM23132 from AB1004, and NSM PM23133 from AB1009. Specimens poorly preserved.

Description: Moderately evolute shell with rounded venter, rounded ventral shoulders, gently convex flanks and moderately wide umbilicus with low, oblique wall and rounded shoulders. Shell surface smooth. Suture not visible.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23132	20.6	7.7	8.0	–	0.37	–
NSM PM23133	21.1	8.6	7.2	6.6	0.41	0.92

Occurrence: Described specimens from AB1004, AB1009 within the *Lytophiceras* sp. Z0ne (Early Induan=Griesbachian) in the lower and middle parts of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: The uncertain assignment of these specimens to *Lytophiceras* is based only on their similar morphology to Ophiceratidae.

Genus ***Wordieoceras*** Spath, 1930

Type species: *Vishnuites wordiei* Spath, 1930.

Wordieoceras cf. ***wordiei*** (Spath, 1930)

Figs. 50.12–50.15, 52

cf. *Vishnuites wordiei* Spath, 1930, p. 31, pl. 2, fig. 11; Spath, 1935, p. 41, pl. 4, fig. 5, pl. 12, fig. 2.

cf. *Wordieoceras wordiei* (Spath). Tozer, 1994, p. 58, pl. 5, figs. 1–3, pl. 6, figs. 1–3, pl. 7, figs. 1–4, text-fig. 8.

Material examined: NSM PM23134, from AB1010.

Description: Moderately evolute, fairly compressed shell with subrectangular whorl section, subacute venter, rounded ventral shoulders and nearly parallel to slightly convex flanks with maximum whorl width just above umbilical shoulders. Umbilicus moderately wide with low, subvertical wall, and rounded shoulders. Ornamentation consists of conspicuous, rectiradiate, slightly sinuous constrictions as well as fine, sinuous growth lines. Suture ceratitic with wide ventral lobe divided by a median saddle into two short branches. First lateral saddle lower than second saddle, and third saddle even lower. First lateral lobe deep and narrow with many denticulations at base. Depth of second lateral lobe about one-half of first lobe.

Measurements (*mm*):

Fig. 52. Suture line of *Wordieoceras* cf. *wordiei* (Spath, 1930), NSM PM23134, from AB1010, at H=9.5 mm.

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23134	35.5	10.9	15.0	9.3	0.31	0.62

Occurrence: Described specimen from AB1010 within the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye. *Wordieoceras wordiei* is also known from beds of late Griesbachian age in Greenland (Spath, 1931, 1935) and Arctic Canada (Tozer, 1994).

Discussion: Although the present specimen is ornamented with conspicuous constrictions, its shell morphology enables us to identify it with reasonable confidence as *Wordieoceras wordiei* (Spath, 1930, p. 31). It is close to *W.* aff. *wordiei* and *W. guizhouensis*, (both described by Zakharov & Mu in Mu *et al.*, 2007, p. 862), which are characterized by a narrowly rounded venter and rounded venter, respectively, but differs from them by its subacute venter and more involute shell.

Genus ***Vishnuites*** Diener, 1897

Type species: *Xenaspis* (*Vishnuites*) *pralambha* Diener, 1897.

Vishnuites? sp. indet.

Figs. 53, 54

Material examined: NSM PM23136 from AB1014.

Description: Moderately evolute, fairly compressed shell with acutely keeled venter

Fig. 53. *Vishnuites*? sp. indet. 1–4, NSM PM23136, from AB1014, ×3.0.

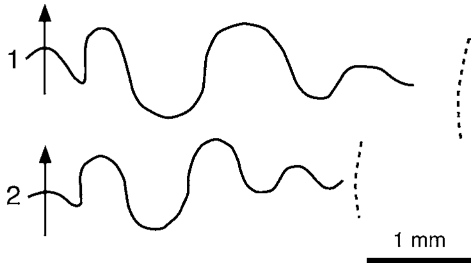


Fig. 54. Suture lines of *Vishnuites*? sp. indet., NSM PM23136, from AB1014. 1, at H=4 mm. 2, at H=3 mm.

and convex flanks with maximum whorl width at mid-flank. Moderately wide umbilicus with low, near vertical wall and rounded shoulders. Ornamentation consists only of weak, radial folds. Suture goniatitic with first lateral saddle lower, narrower than second saddle, and third saddle lower than first and second. First lateral lobe deep, wide, and second lateral lobe about two third depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23136	10.9	3.5	4.6	3.2	0.32	0.70

Occurrence: Described specimen from *Clypeoceras spitiense* "bed" (AB1014, Late Induan=Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: The assignment of the specimen to *Vishnuites* is uncertain, and is based only on the similarity of its morphology with *Vishnuites*.

Family Meekoceratidae Waagen, 1895
Genus ***Ussuridiscus*** Shigeta and Zakharuv gen. nov.

Type species: *Meekoceras* (*Kingites*) *varaha* Diener, 1895.

Composition of the genus: Type species only.

Diagnosis: Slender, very involute shell with tabulate venter, narrow umbilicus with overhanging umbilical wall and ceratitic suture line.

Etymology: Named after Ussuri Gulf in South Primorye and the Latin ward: discus, meaning disk.

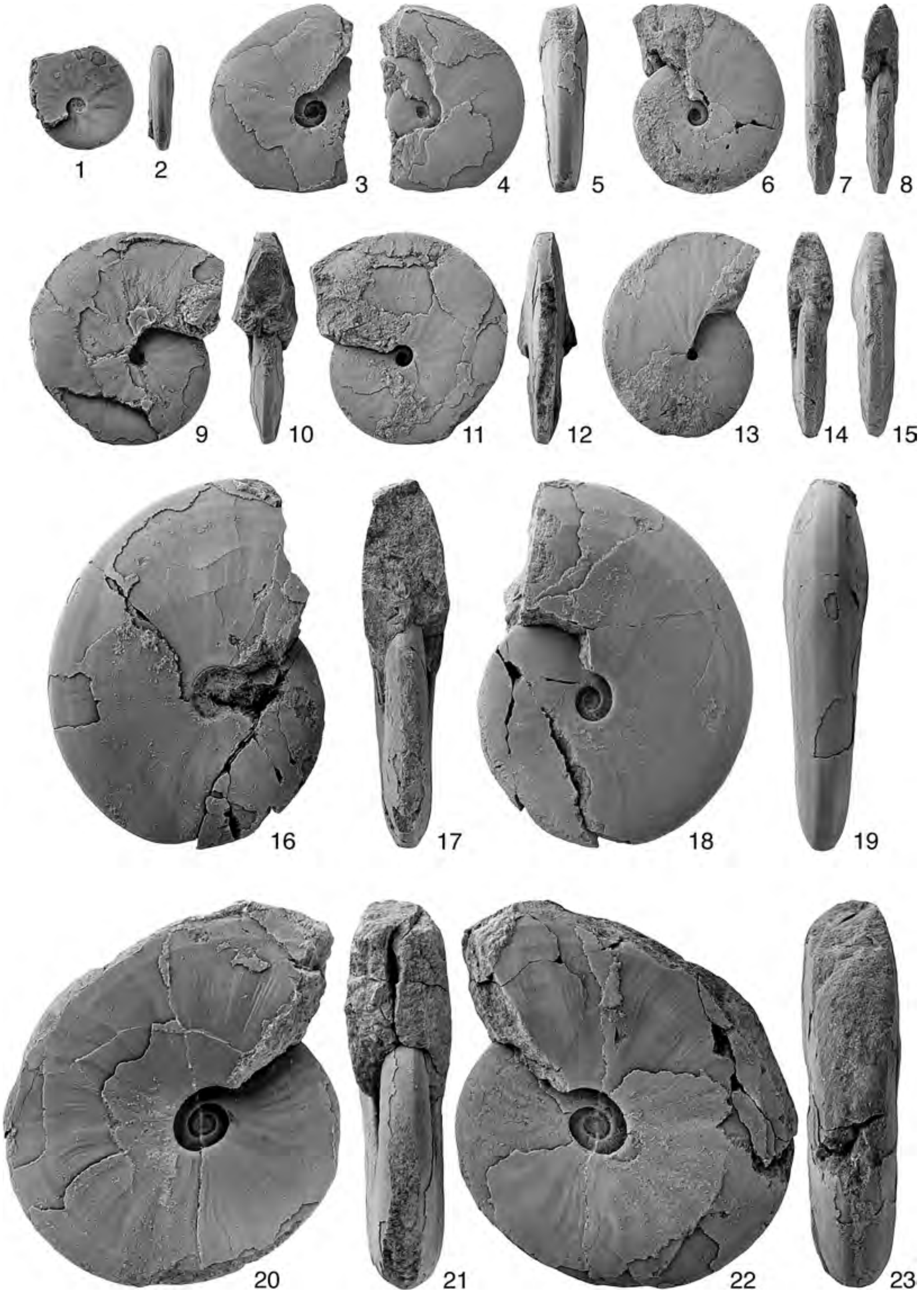
Occurrence: Throughout much of the middle Induan in South Primorye, Russia.

Discussion: *Ussuridiscus* gen. nov. can be easily distinguished from *Khangsaria* Waterhouse, 1994, *Mesokantoa* Waterhouse, 1994, and *Hubeitoceras* Waterhouse, 1994, by its tabulate venter and overhanging umbilical wall. It bears some resemblance to *Radioceras* Waterhouse, 1996a, *Kymatites* Waagen, 1895, and *Koninckites* Waagen, 1895 in terms of its involute shell and tabulate venter, but differs from them by its overhanging umbilical wall. *Zhaojinkoceras* Waterhouse, 1994 is very close to this new genus, but its venter is concave.

Ussuridiscus varaha (Diener, 1895)

Figs. 50.5–50.6, 55–57

Meekoceras (*Kingites*) *varaha* Diener, 1895, p. 52, pl. 1, fig. 2.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

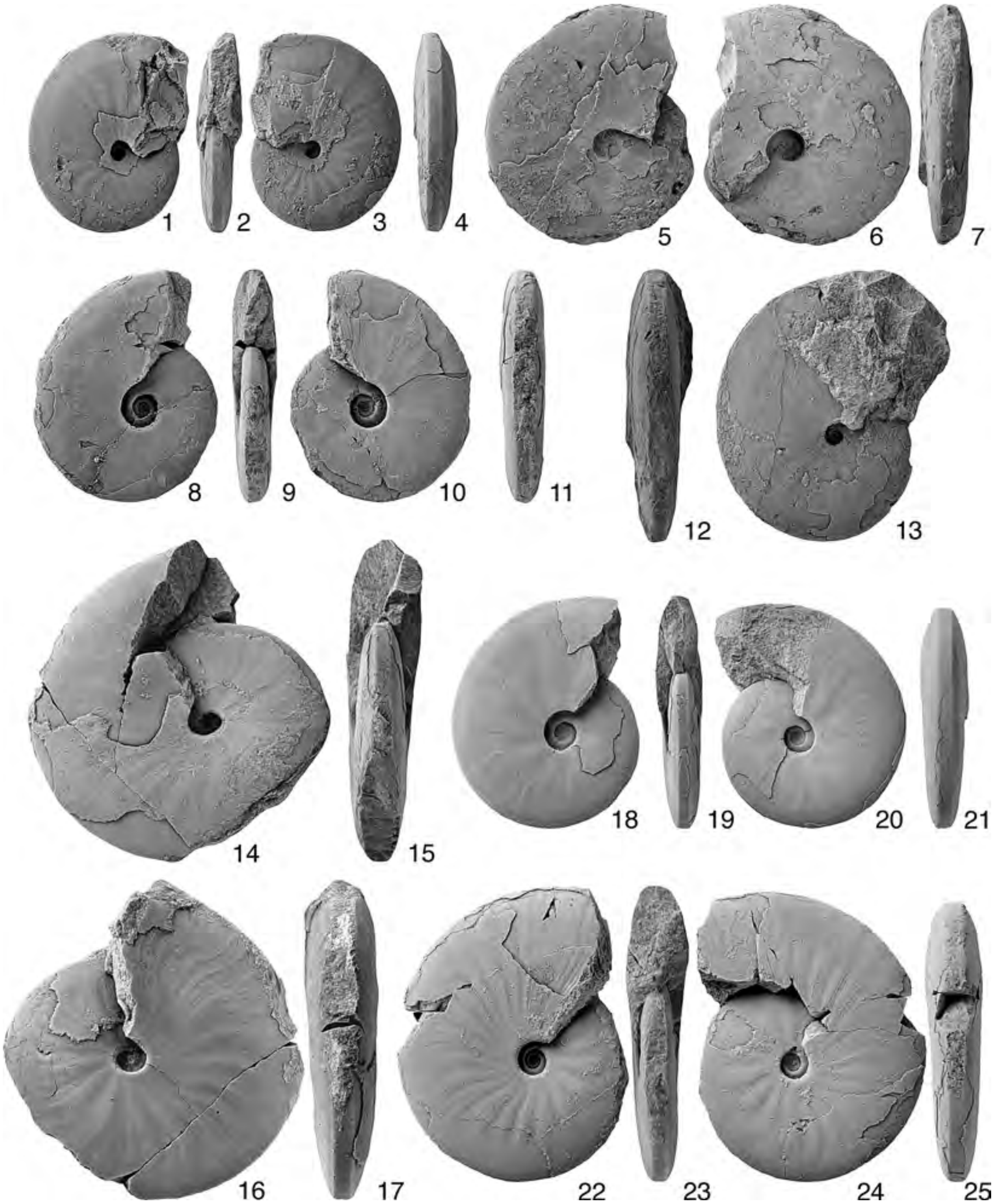


Fig. 56. *Ussuridiscus varaha* (Diener, 1895) gen. nov. 1–17, from AB1011. 1–4, NSM PM23144, ×1.0. 5–7, NSM PM23145, ×1.0. 8–11, NSM PM23146, ×1.0. 12–13, NSM PM23147, ×1.0. 14–17, NSM PM23148, ×1.0. 18–25, from AB1013. 18–21, NSM PM23149, ×1.0. 22–25, NSM PM23150, ×1.0.

←

Fig. 55. *Ussuridiscus varaha* (Diener, 1895) gen. nov. from AB1010. 1–2, NSM PM23137, ×1.0. 3–5, NSM PM23138, ×1.0. 6–8, NSM PM23139, ×1.0. 9–12, NSM PM23140, ×1.0. 13–15, NSM PM23141, ×1.0. 16–19, NSM PM23142, ×1.0. 20–23, NSM PM23143, ×1.0.

Koninckites varaha (Diener). Zakharov, 1968, p. 91, pl. 17, figs. 4, 5, text-fig. 20b.
Hubeitoceras (?) *wangi* Zakharov and Mu in Mu *et al.*, 2007, p. 871, figs. 13.17–13.19, 15.2–15.5.
"*Koninckites*" cf. *timorense* (Wanner). Brühwiler *et al.*, 2008, p. 1165, pl. 3, figs. 1–4, pl. 4, figs. 1–2.

Holotype: CGM 61/596, figured by Diener (1895, p. 52, pl. 1, fig. 2), from the Lower Triassic along Paris Bay in Russian Island, South Primorye, Russia.

Material examined: NSM PM23135, from AB1009, seven specimens, NSM PM23137–23143, from AB1010, five specimens, NSM PM23144–23148, from AB1011, and two specimens, NSM PM23149, 23150, from AB1013.

Description: Very involute, very compressed platycone with subrectangular whorl section, distinctively tabulate to subtabulate venter, rather abruptly rounded ventral shoulders and flat to slightly convex flanks with maximum whorl width at about two thirds of whorl height. Umbilicus varies from narrow to very narrow with low, overhanging wall and abruptly rounded shoulders. Ornamentation consists of fine, sinuous, slightly prorsiradiate growth lines as well as low radial folds, which are pronounced on inner flank. Suture ceratitic with wide ventral lobe divided by fairly high median saddle into two deep branches with a few denticulations at their bases. First lateral saddle lower than second lateral saddle, and third saddle lower than first and second. First lateral lobe deep and wide with many denticulations at base. Some auxiliary elements present on adumbilical flank.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23137	15.6	2.1	7.9	3.2	0.13	0.41
NSM PM23138	24.4	4.9	11.4	5.5	0.20	0.48
NSM PM23139	29.4	4.0	15.0	5.4	0.14	0.36
NSM PM23140	32.1	3.2	17.1	–	0.10	–
NSM PM23141	31.6	2.0	17.4	6.5	0.06	0.37
NSM PM23142	54.6	7.0	28.4	12.0	0.13	0.42
NSM PM23143	27.9	2.6	15.2	6.0	0.09	0.39
NSM PM23144	49.4	8.5	25.0	12.2	0.17	0.49
NSM PM23145	34.2	4.6	17.7	7.4	0.13	0.42
NSM PM23146	33.0	6.6	15.3	6.5	0.20	0.42
NSM PM23147	36.4	3.0	19.9	7.1	0.08	0.36
NSM PM23148	40.2	4.0	20.9	8.6	0.10	0.41
NSM PM23149	29.8	4.9	14.4	6.5	0.16	0.45
NSM PM23150	41.8	4.7	21.6	8.0	0.16	0.37

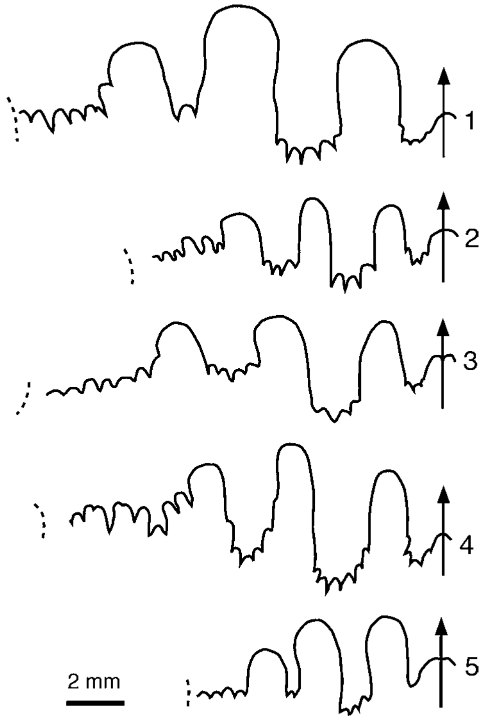


Fig. 57. Suture lines of *Ussuridiscus varaha* (Diener, 1895) gen. nov. 1, NSM PM23143, from AB1010, at H=16 mm. 2, NSM PM23139, from AB1010, at H=12 mm. 3, NSM PM23148, from AB1011, at H=15 mm. 4, NSM PM23147, from AB1011, at H=14 mm. 5, NSM PM23149, from AB1013, at H=9 mm.

Occurrence: Described specimens from AB1009 within the *Lytophiceras* sp. Zone, and from AB1010, AB1011 within the *Gyronites subdharmus* Zone in the middle to upper parts of the Lazurnaya Bay Formation, and from AB1013 within the *Ambitoides fuliginatus* Zone in the lowest part of the Zhitkov Formation, Abrek Bay area, South Primorye. Thus, in this particular area, the species ranges from late Early Induan (late Griesbachian) to early Late Induan (early Dienerian). It also occurs abundantly in the *Gyronites subdharmus* Zone on the western coast of Ussuri Gulf, between Seryj Cape and Nerpa Rock, South Primorye (Zakharov, 1968; Markevich & Zakharov, 2004).

Discussion: *Ussuridiscus varaha* (Diener, 1895) differs from specimens identified as *Meekoceras varaha* Diener by Diener (1897, p. 143) and Kraft and Diener (1909, p. 17) by its flat flanks and overhanging umbilical wall. Aside from its ceratitic suture, it appears to be morphologically very close to the specimen identified as *Aspidites vidarbha* Diener by Kraft and Diener (1909, p. 63, pl. 5, fig. 1). *Hubeitoceras* (?) *wangi* Zakharov and Mu (2007, p. 871) and "*Koninckites*" cf. *timorense* (Wanner) by Brühwiler *et al.* (2008, p. 1165) are also very close in appearance with regard to their tabulate venters, nearly flat flanks and strong auxiliary suture elements, and in all likelihood, are probably conspecific.

According to Diener (1895), he collected the holotype from Paris Bay on Russian Island, South Primorye. Since sediments of Olenekian and Anisian age are well exposed along this seacoast, Zakharov (1968) naturally assumed the holotype's collection horizon to be of Olenekian age. However, there has never been a report of this ammonoid's occurrence at this particular locality other than Diener's in 1895. This species frequently occurs in the Induan of South Primorye, but no Induan strata have been found in the type locality (Markevich & Zakharov, 2004), and the preservation of the holotype is very similar to that of specimens from Induan strata exposed along the western coast of Ussuri Gulf. Taken together, these facts strongly suggest that Diener made an error when recording the source of the type specimen.

Genus ***Gyronites*** Waagen, 1895

Type species: *Gyronites frequens* Waagen, 1895.

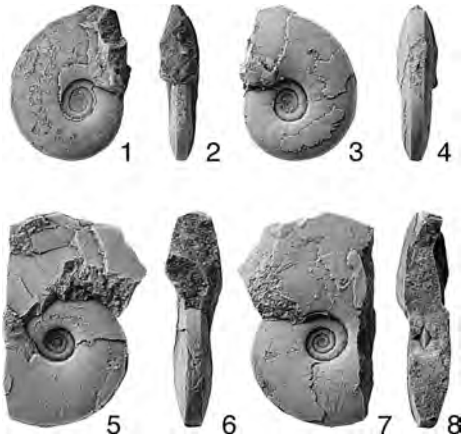


Fig. 58. *Gyronites* sp. indet. from AB1013. 1–4, NSM PM23173, ×1.0. 5–8, NSM PM23174, ×1.0.

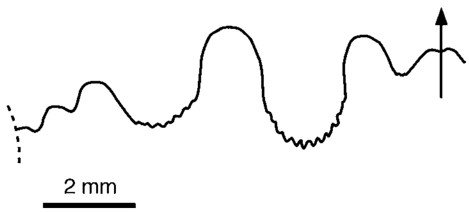


Fig. 59. Suture line of *Gyronite* sp. indet., NSM PM23174, from AB1013, at H=8 mm.

Gyronites sp. indet.

Figs. 58, 59

Material examined: Two specimens, NSM PM23173, 23174, from AB1013.

Description: Moderately evolute, compressed shell with rectangular whorl section, distinctively tabulate venter, angular ventral shoulders, and slightly convex flanks with maximum whorl width on inner flank. Umbilical width moderate to fairly narrow with low, near vertical wall and rounded shoulders. Shell ornamentation consists of weak radial folds as well as fine, sinuous, prorsiradiate growth lines. Suture ceratitic with ventral lobe divided by median saddle into two branches. First lateral saddle lower than second saddle and third

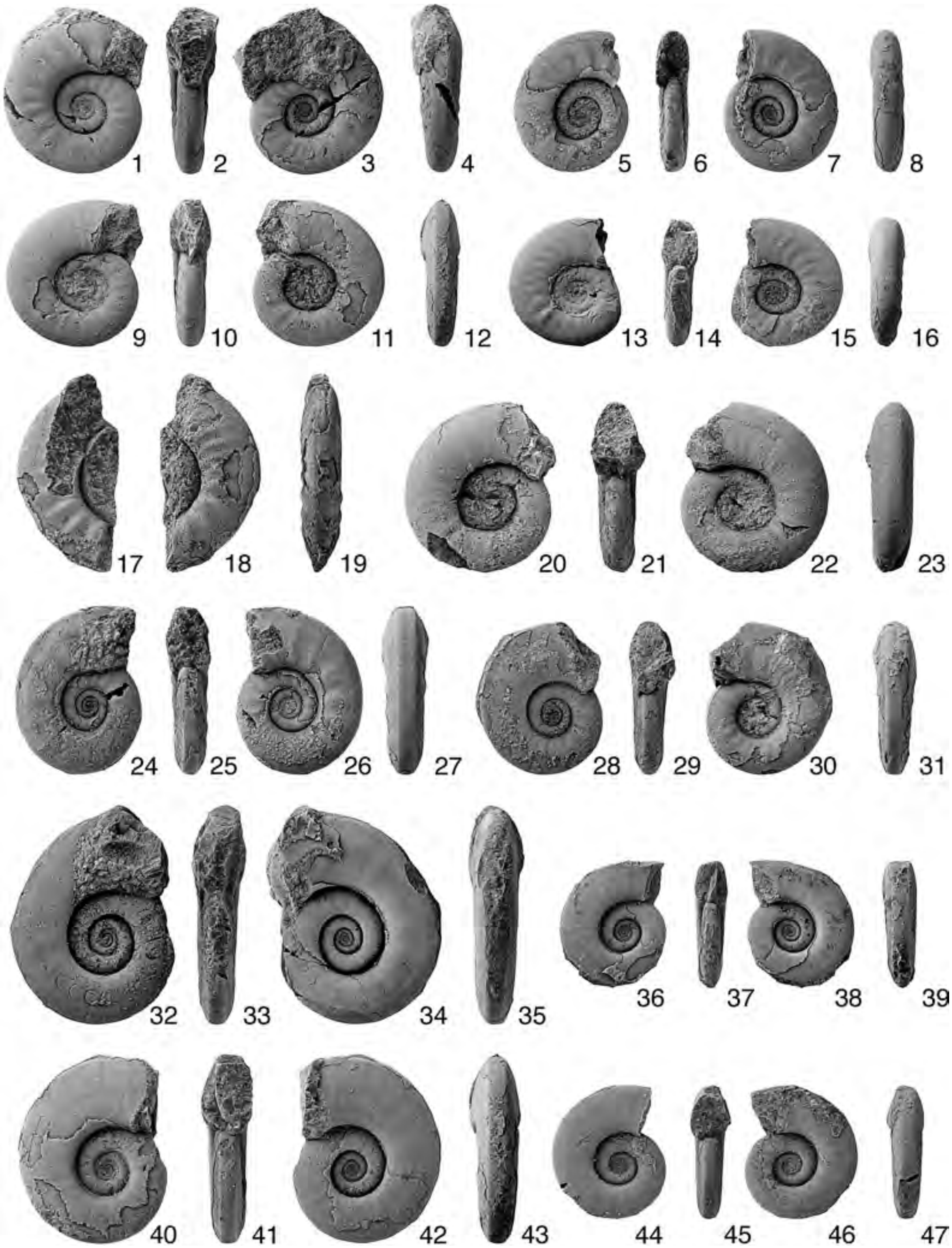


Fig. 60. *Gyronites subdharmus* Kiparisova, 1961 from AB1010. 1–4, NSM PM23151, ×1.0. 5–8, NSM PM23152, ×1.0. 9–12, NSM PM23153, ×1.0. 13–16, NSM PM23154, ×1.0. 17–19, NSM PM23155, ×1.0. 20–23, NSM PM23156, ×1.0. 24–27, NSM PM23157, ×1.0. 28–31, NSM PM23158, ×1.0. 32–35, NSM PM23159, ×1.0. 36–39, NSM PM23160, ×1.0. 40–43, NSM PM23161, ×1.0. 44–47, NSM PM23162, ×1.0.

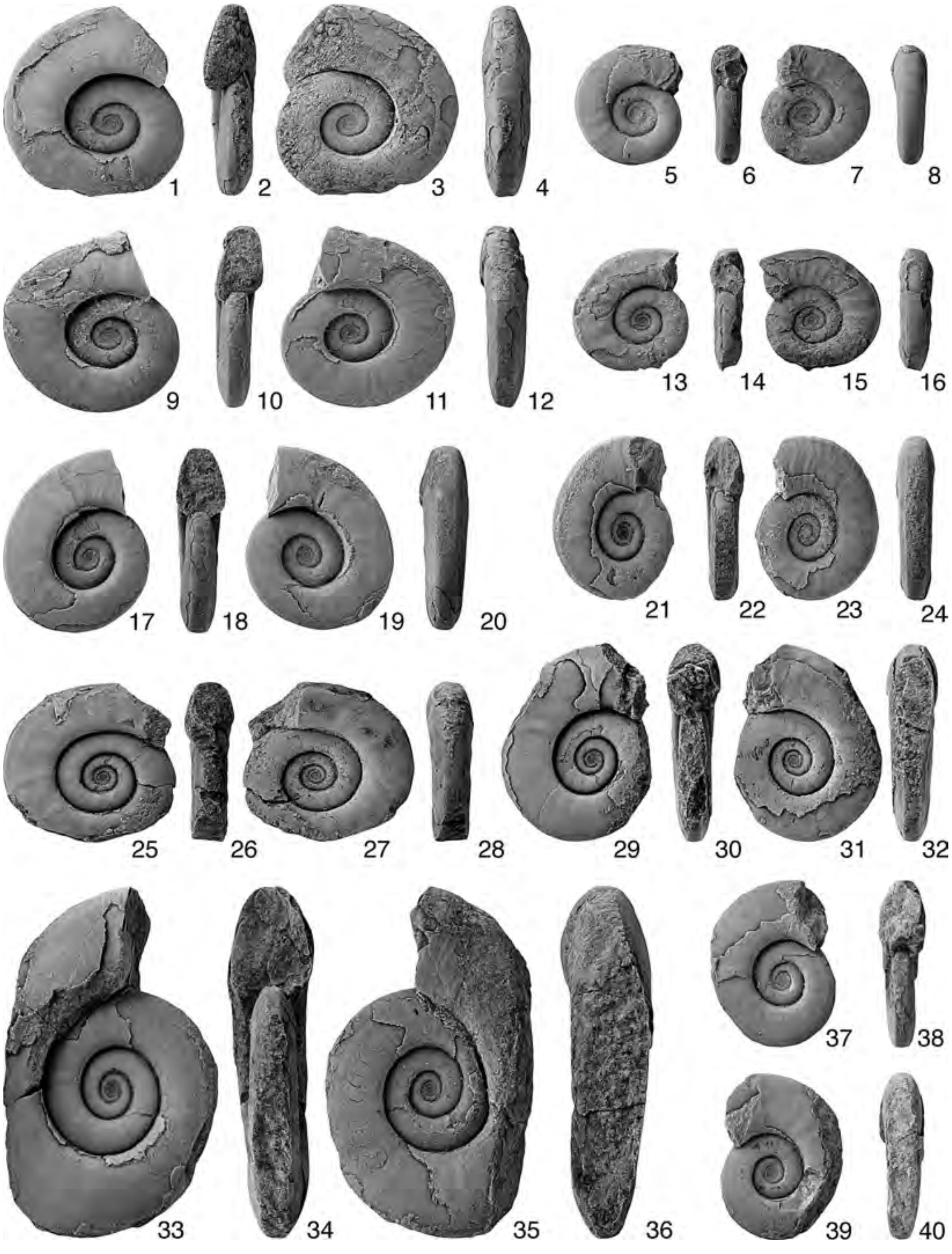


Fig. 61. *Gyronites subdharmus* Kiparisova, 1961 from AB1011. 1–4, NSM PM23163, ×1.0. 5–8, NSM PM23164, ×1.0. 9–12, NSM PM23165, ×1.0. 13–16, NSM PM23166, ×1.0. 17–20, NSM PM23167, ×1.0. 21–24, NSM PM23168, ×1.0. 25–28, NSM PM23169, ×1.0. 29–32, NSM PM23170, ×1.0. 33–36, NSM PM23171, ×1.0. 37–40, NSM PM23172, ×1.0.

saddle even lower. First lateral lobe deep and wide with many denticulations at base. Second lateral lobe about one half depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23173	18.6	5.6	7.3	4.4	0.30	0.60
NSM PM23174	28.3	6.3	13.2	–	0.22	–

Occurrence: Described specimens from AB1013 within the *Ambitoides fuliginatus* Zone (early Late Induan=early Dienerian) in the lowest part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: The described specimens may simply be juvenile *Gyronites* shells. Although they are somewhat similar to *Gyronites frequens* Waagen (1895, p. 292), no definitive species assignment can be made.

Gyronites subdharmus Kiparisova, 1961

Figs. 60–62

Gyronites (?) *subdharmus* Kiparisova, 1961, p. 64, pl. 11, figs. 3–5, text-fig. 23.

Gyronites subdharmus Kiparisova. Zakharov, 1968, p. 60, pl. 6, figs. 1–4, text-fig. 12a.

Gyronites frequens Waagen. Brühwiler *et al.*, 2008, p. 1168, pl. 5, figs. 7–8

Holotype: CGM 54/5504, figured by Kiparisova (1961, p. 64, pl. 11, fig. 3), from the Lower Triassic (Induan, *Flemingites*? beds) in the Abrek Bay area in South Primorye, Russia.

Material examined: Twelve specimens, NSM PM23151–23162, from AB1010, and ten specimens, NSM PM23163–23172, from AB1011.

Description: Evolute, fairly compressed shell with subrectangular whorl section, distinctively tabulate venter, angular ventral shoulders and slightly convex flanks with maximum whorl width on inner flank. Umbilicus fairly wide with low, near vertical wall and rounded shoulders. Ornamentation consists of slightly rusiradiate to rectiradiate, distant folds arising on umbilical shoulder and fading away on ventral shoulder. Folds more prominent near umbilical shoulder, but vary in strength from fairly strong to very weak. Suture ceratitic with ventral lobe divided by median saddle into two short branches. First lateral saddle lower than second saddle, and third saddle lower yet. First lateral lobe deep, and wide with many denticulations at base, and second lateral lobe about one-half depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23151	20.9	8.0	7.1	5.4	0.38	0.76
NSM PM23152	20.5	8.6	7.0	4.4	0.42	0.63
NSM PM23153	20.0	7.8	7.4	5.2	0.39	0.70
NSM PM23154	17.0	6.8	6.1	4.6	0.40	0.75
NSM PM23156	22.4	9.1	8.6	5.8	0.41	0.67
NSM PM23157	29.7	12.4	9.7	7.0	0.42	0.72
NSM PM23158	16.1	6.3	6.2	4.3	0.39	0.69
NSM PM23159	23.5	9.1	8.1	5.8	0.39	0.72
NSM PM23160	16.1	6.5	5.7	4.4	0.40	0.77
NSM PM23161	25.6	10.0	9.5	6.3	0.39	0.66
NSM PM23162	17.5	7.2	6.2	4.2	0.41	0.68
NSM PM23163	28.0	11.8	9.7	6.9	0.42	0.71
NSM PM23164	17.4	7.6	5.5	4.5	0.44	0.82
NSM PM23165	26.5	10.8	9.2	5.8	0.41	0.63
NSM PM23166	17.4	7.5	5.9	4.4	0.43	0.75
NSM PM23167	28.0	12.3	8.9	7.0	0.44	0.77
NSM PM23168	23.7	9.8	8.0	5.4	0.41	0.68
NSM PM23169	25.5	11.8	7.7	5.6	0.46	0.73
NSM PM23170	28.2	12.3	9.0	7.0	0.44	0.78
NSM PM23171	51.1	21.2	16.3	12.1	0.41	0.74
NSM PM23172	24.4	9.9	8.7	5.9	0.41	0.68

Occurrence: Described specimens from AB1010, AB1011 within the *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the middle and upper parts of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye. This species is frequently found in Induan strata on the western coast of Ussuri Gulf between Seryj Cape and Nerpa Rock, South Primorye (Zakharov, 1968; Markevich & Zakharov, 2004).

Discussion: *Gyronites subdharmus* Kiparisova, 1961 is easily distinguished from *G. frequens* Waagen (1895, p. 292) by its more evolute coiling and near vertical umbilical wall. The specimens described by Brühwiler *et al.* (2008, p. 1168) are more evolute than *G. frequense*, and they correspond well with *G. subdharmus*. Although the radial ribs of *G. subdharmus* are much weaker, its evolute shell

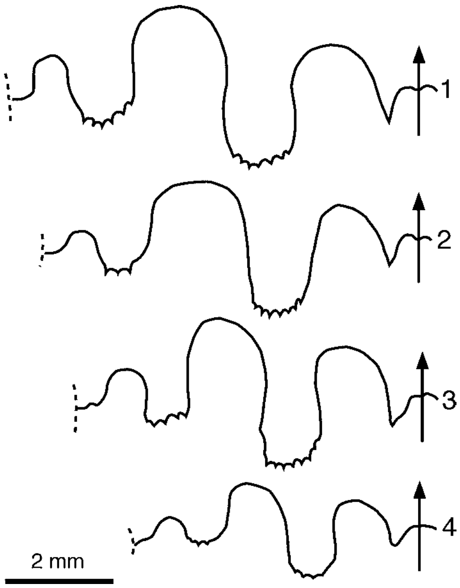


Fig. 62. Suture lines of *Gyronites subdharmus* Kiparisova, 1961. 1, NSM PM23159, from AB1010, at H=7.6 mm. 2, NSM PM23157, from AB1010, at H=7.0 mm. 3, NSM PM23167, from AB1011, at H=6.5 mm. 4, NSM PM23172, from AB1011, at H=5.5 mm.

and tabulate venter invite comparison of shell morphology with *Pleurogyronites kraffti* Tozer (1994, p. 66), *G. plicosus* Waagen (1895, p. 298), *G. rotus* Waagen (1895, p. 300), *G. radians* Waagen (1895, p. 302), *Danubites planidorsatus* Diener (1897, p. 34), and *D. rigidus* Diener (1897, p. 36), as well as specimens identified as *Xenodiscus radians* (Waagen), *X.* cf. *plicosus* (Waagen), *X. rotula* (Waagen) by Kraft and Diener (1909, pl. 23, fig. 4, pl. 25, figs. 1–4) and *Xenodiscoides* sp. indet. by Brühwiler *et al.* (2008, p. 1158). It also is morphologically very close to *G. nangaensis* Waagen (1895, p. 297) and *G. plicatilis* Waagen (1985, p. 315), which were assigned to *Wangyikangia* by Waterhouse (1996a), but its saddles do not exhibit subphylloid characteristics. *Meekoceras dubium* Krafft (1909, p. 50), which is the lectotype of *Himoceras* Waterhouse, 1996a, is also close in appearance, but it has a steep, high umbilical wall.

Genus ***Ambitoides*** Shigeta and Zakharov gen. nov.

Type species: *Ambites fuliginatus* Tozer, 1994.

Composition of the genus: Two species, *Ambites fuliginatus* Tozer, 1994 and *Ambitoides orientalis* sp. nov.

Diagnosis: Discoidal, fairly involute shell with tabulate venter, narrow umbilicus, smooth flanks and ceratitic suture line.

Etymology: From *Ambites* and the Greek suffix: -oides.

Occurrence: Upper Induan in South Primorye, Russia and British Columbia, Canada.

Discussion: *Ambitoides* gen. nov. is morphologically very close to *Ambites* Waagen, 1895, but its suture is ceratitic in contrast to the sub-goniatitic suture typical of *Ambites*. *Radioceras* Waterhouse, 1996a is close to this genus with its tabulate venter and ceratitic suture line, but its shell is very involute with a very narrow umbilicus.

Ambitoides fuliginatus (Tozer, 1994)

Figs. 63, 64

Ambites fuliginatus Tozer, 1994, p. 67, pl. 13, figs. 4, 5, pl. 14, fig. 8, text-fig. 15.

Holotype: GSC 28123, figured by Tozer (1994, p. 67, pl. 14, fig. 8), from the Lower Triassic (Dienerian, *Proptychites candidus* Zone) of the Grayling Formation, near Tuchodi River, British Columbia, Canada.

Material examined: Four specimens, NSM PM23175–23178, from AB1012, two specimens, NSM PM23179, 23180, from AB1013.

Description: Fairly involute, very compressed shell with rectangular whorl section, distinctively tabulate venter, angular ventral shoulders and nearly parallel to slightly convex flanks. Narrow to moderately narrow umbilicus with low, oblique wall and rounded shoulders. Ornamentation consists of fine, slightly sinuous, prorsiradiate growth lines and

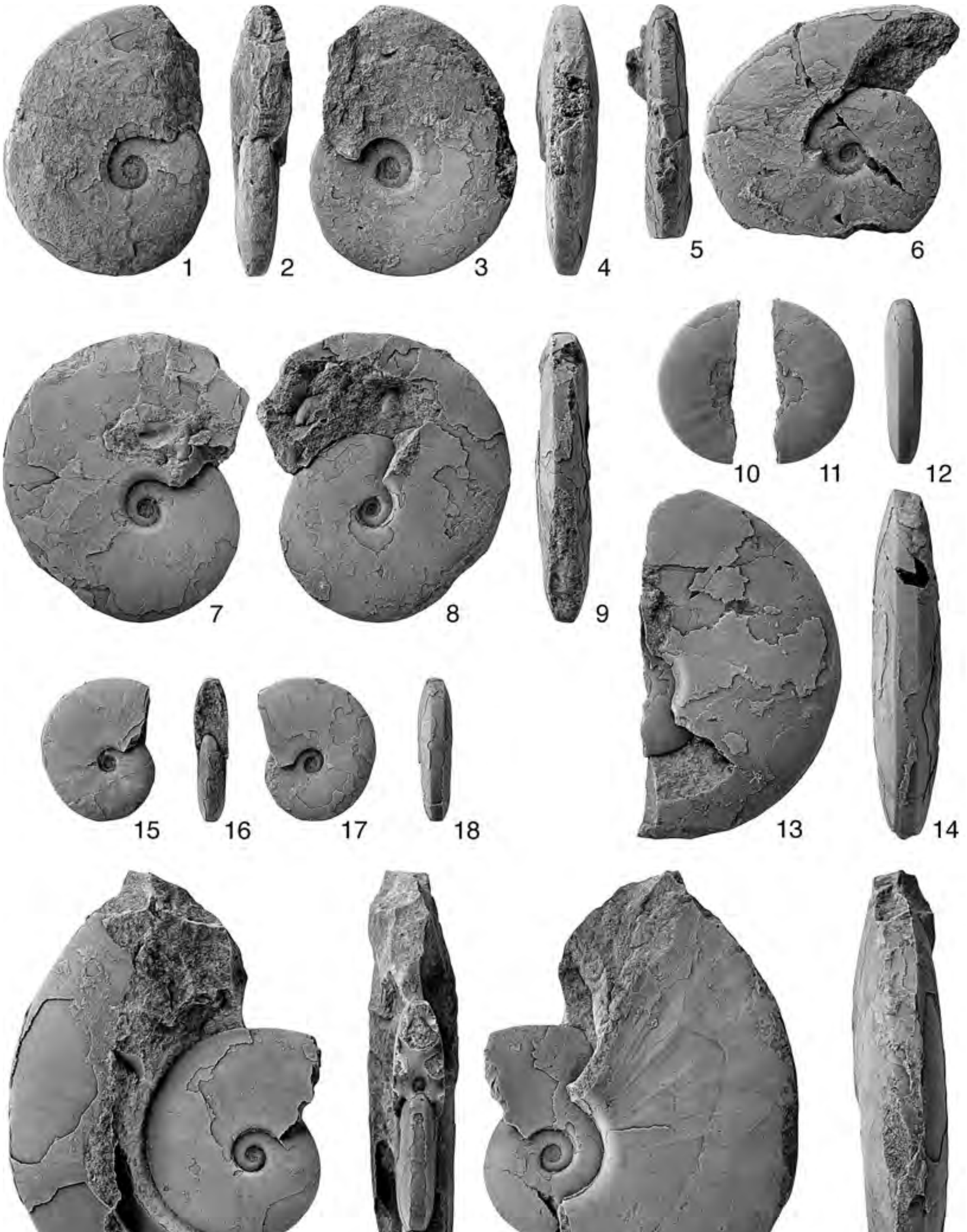


Fig. 63. *Ambitoides fuliginatus* (Tozer, 1994) gen. nov. 1–14, from AB1012. 1–4, NSM PM23175, ×1.0. 5–6, NSM PM23176, ×1.0. 7–9, NSM PM23177, ×1.0. 10–14, NSM PM23178, ×1.0. 15–22, from AB1013. 15–18, NSM PM23179, ×1.0. 19–22, NSM PM23180, ×1.0.

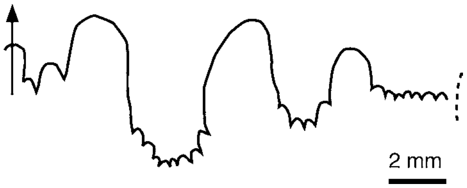


Fig. 64. Suture line of *Ambitoides fuliginatus* (Tozer, 1994) gen. nov., NSM PM23180, from AB1013, at H=15 mm.

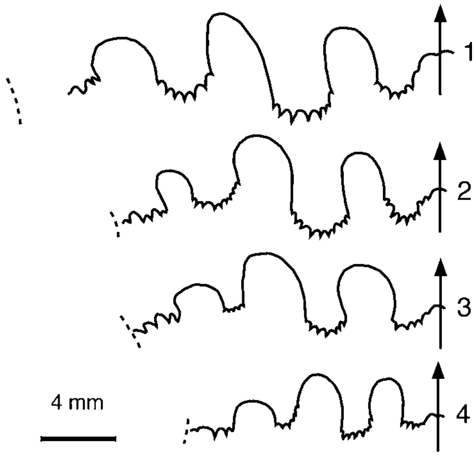


Fig. 65. Suture lines of *Ambitoides orientalis* Shigeta and Zakharov gen. nov. sp. nov. from AB1014. 1, NSM PM23190, paratype, at H=22 mm. 2, NSM PM23189, paratype, at H=17 mm. 3, NSM PM23188, holotype, at H=16 mm. 4, NSM PM23183, paratype, at H=13 mm.

low, radial folds becoming prominent on mid-flanks of body chamber. Suture ceratitic with long denticulate suspensive lobe. Ventral lobe divided by median saddle into two short branches with a few denticulations at each base. First lateral saddle lower than second saddle and third saddle even lower. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe about two thirds depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23175	38.6	4.4	19.2	7.9	0.11	0.41
NSM PM23176	32.0	5.8	15.5	6.3	0.18	0.41
NSM PM23177	37.7	5.8	18.6	7.3	0.15	0.39
NSM PM23178	20.6	3.7	10.0	4.6	0.18	0.46
NSM PM23179	32.8	6.8	15.1	6.4	0.21	0.42

Occurrence: Described specimens from AB1012, AB1013 within the *Ambitoides fuliginatus* Zone (early Late Induan=early Dienerian) in the uppermost part of the Lazurnaya Bay Formation and lowest part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species also occurs in the *Proptychites candidus* Zone (early Dienerian) in northeastern British Columbia, Canada (Tozer, 1994).

Discussion: Morphologically, *Ambitoides fuliginatus* (Tozer, 1994) is very close to *Ambites discus* Waagen (1895, p. 152), *A. magunmilicatus* Waagen (1895, p. 154) and *A. ferruginus* Tozer (1994, p. 67), but its suture is definitely ceratitic. It is also somewhat similar to "*Meekoceras*" *hodgsoni* Diener (1897, p. 133), but its venter is distinctively more tabulate and its whorls are not as compressed.

Ambitoides orientalis Shigeta and Zakharov sp. nov.

Figs. 65–67

? *Ambites fuliginatus* Tozer, 1994, p. 67, pl. 13, fig. 7.

Type specimens: Holotype, NSM PM23188, from AB1014; paratypes, nine specimens, NSM PM23181–23187, 23189, 23190, from AB1014.

Diagnosis: *Ambitoides* with narrow, subtabulate venter, vertical umbilical wall, abruptly rounded umbilical shoulder, fine spiral lirae on shell surface and ceratitic suture line.

Etymology: From the Latin word: orientalis, meaning oriental.

Description: Fairly involute, very compressed shell with subrectangular whorl section, narrow subtabulate venter, subangular ventral shoulders, and slightly convex flanks with maximum whorl width near mid-flank. Narrow to fairly narrow umbilicus with moderately high, vertical wall and abruptly rounded shoulders. Ornamentation consists of very

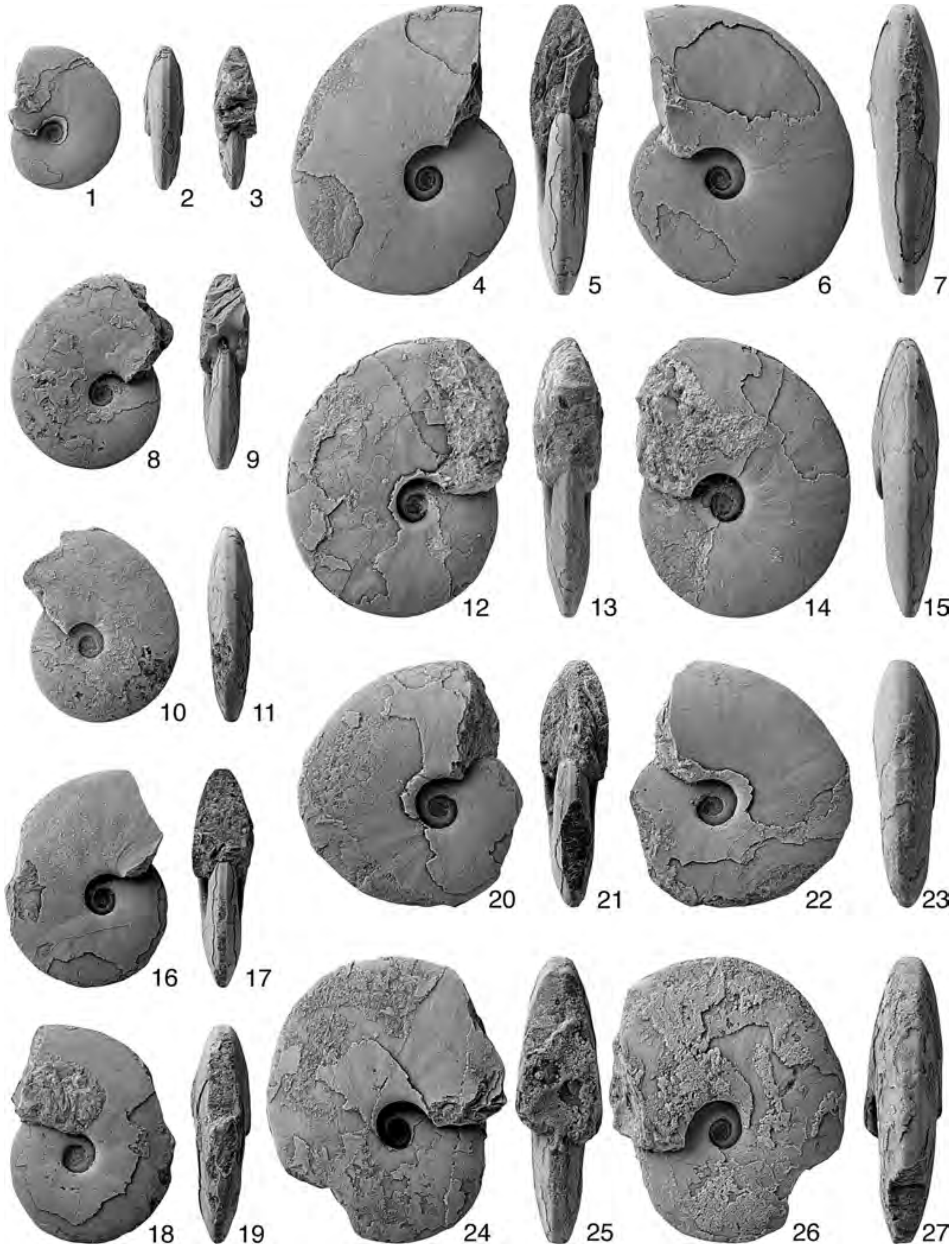


Fig. 66. *Ambitoides orientalis* Shigeta and Zakharov gen. nov. sp. nov. from AB1014. 1–3, NSM PM23181, paratype, ×1.0. 4–7, NSM PM23182, paratype, ×1.0. 8–11, NSM PM23183, paratype, ×1.0. 12–15, NSM PM23184, patratype, ×1.0. 16–19, NSM PM23185, paratype, ×1.0. 20–23, NSM PM23186, paratype, ×1.0. 24–27, NSM PM23187, paratype, ×1.0.

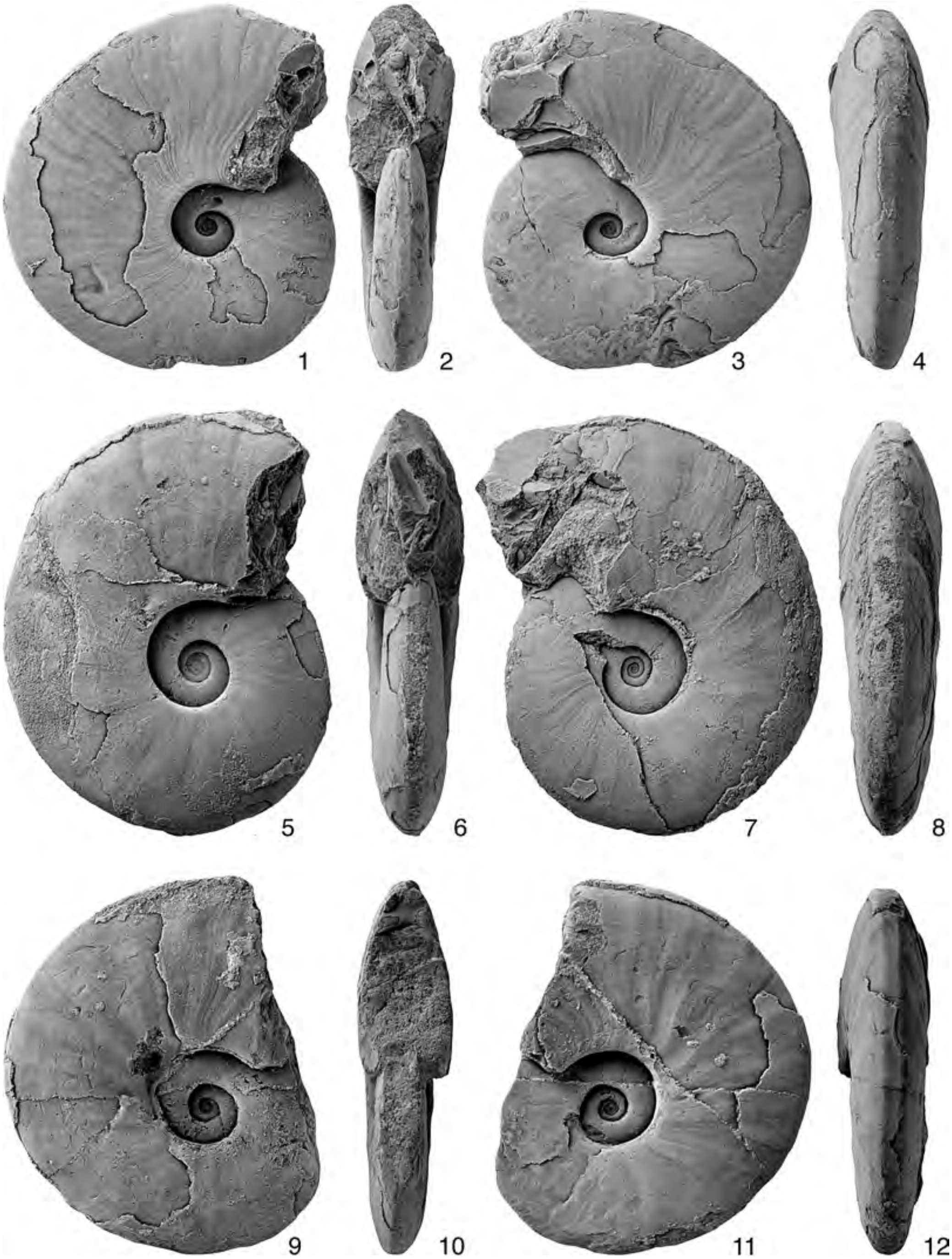


Fig. 67. *Ambitoides orientalis* Shigeta and Zakharov gen. nov. sp. nov. from AB1014. 1–4, NSM PM23188, holotype, ×1.0. 5–8, NSM PM23189, paratype, ×1.0. 9–12, NSM PM23190, paratype, ×1.0.

fine spiral lirae and slightly sinuous, prorsiradiate growth lines as well as low, radial folds, which become more prominent on body chamber. Suture ceratitic with long denticulate suspensive lobe, and wide ventral lobe divided by median saddle into two branches with many denticulations at each base. First lateral saddle lower than second saddle and third saddle even lower. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe about two thirds depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23181	20.8	3.3	11.0	5.5	0.16	0.50
NSM PM23182	41.9	8.0	20.3	9.6	0.19	0.47
NSM PM23183	29.0	5.2	14.2	6.3	0.18	0.44
NSM PM23184	39.5	7.1	19.0	8.6	0.18	o.45
NSM PM23185	31.6	5.8	15.0	7.5	0.18	0.50
NSM PM23186	35.4	6.7	17.2	9.0	0.19	0.52
NSM PM23187	40.5	6.7	20.7	9.2	0.17	0.44
NSM PM23188	49.8	9.1	24.0	11.9	0.18	0.50
NSM PM23189	57.9	14.4	26.8	14.3	0.25	0.53
NSM PM23190	50.8	12.8	23.3	11.7	0.25	0.50

Occurrence: Described specimens from *Clypeoceras spitiense* “bed” (AB1014, early Late Induan=early Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: *Ambitoides orientalis* sp. nov. differs from *Ambites discus* Waagen (1895, p. 152), *A. magunmilicatus* Waagen (1895, p. 154) and *A. ferruginus* (Tozer 1994, p. 67) by its serrated lateral lobes, and differs from *Ambitoides fuliginatus* (Tozer 1994, p. 67) by its vertical umbilical wall. One of Tozer’s paratypes of *A. fuliginatus* (Tozer 1994, pl. 13, fig. 7) has a very narrow, subtabulate venter, radial folds and fine spiral lirae, and is probably quite similar to *Ambitoides orientalis*.

Genus ***Abrekites*** Shigeta and Zakharov gen. nov.

Type species: *Abrekites editus* sp. nov.

Composition of the genus: Two species, *Abrekites editus* sp. nov. and *A. planus* sp. nov.

Diagnosis: Discoidal, fairly involute shell with tabulate venter, fairly narrow umbilicus, overhanging umbilical wall, abruptly rounded umbilical shoulder and ceratitic suture line.

Etymology: Named after Abrek Bay in South Primorye.

Occurrence: Lower part of the Lower Olenekian (lower Smithian) in South Primorye, Russia.

Discussion: *Abrekites* gen. nov. is easily distinguished from *Ambites* Waagen, 1895 and *Ambitoides* gen. nov. by its overhanging umbilical wall and from *Sisupalia* Waterhouse, 1996b by its ceratitic suture line.

Abrekites editus Shigeta and Zakharov sp. nov.

Figs. 68, 69.1–69.12

Type specimens: Holotype, NSM PM23193, from AB1021; paratypes, two specimens, NSM PM23191, 23192, from AB1021.

Diagnosis: *Abrekites* with raised umbilical shoulders and low radial folds on inner flanks.

Etymology: Species name refers to its “rising” umbilical shoulder, from the Latin word: editus, meaning rising.

Description: Fairly involute, very compressed shell with rectangular whorl section, tabulate venter, subangular ventral shoulders and slightly convex flanks with maximum thickness at mid-flank. Umbilicus fairly narrow with moderately high, overhanging wall and raised, abruptly rounded shoulders. Ornamentation consists of low radial folds on inner flanks as well as fine, slightly sinuous, prorsiradiate growth lines. Suture ceratitic with long denticulate suspensive lobe, and wide ventral lobe divided by low median saddle into two wide branches with many denticulations at each base. First lateral saddle lower than second saddle, and third saddle wide, but even lower. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe about two thirds depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23191	28.2	3.4	12.7	5.4	0.12	0.43
NSM PM23192	32.2	6.3	15.9	6.5	0.20	0.41

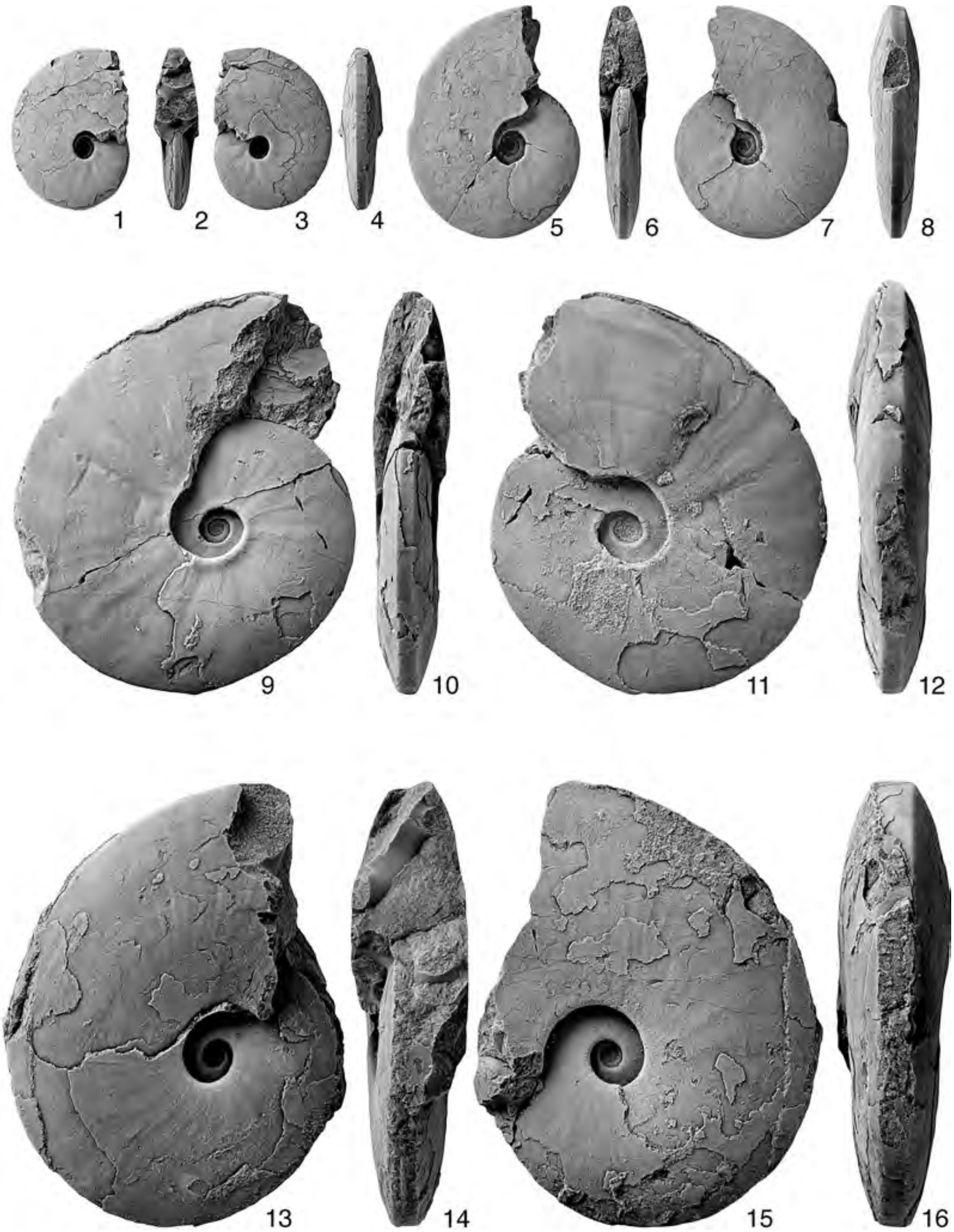


Fig. 68. 1–12, *Abrekites editus* Shigeta and Zakharov gen. nov. sp. nov. from AB1021. 1–4, NSM PM23191, paratype, ×1.0. 5–8, NSM PM23192, paratype, ×1.0. 9–12, NSM PM23193, holotype, ×1.0. 13–16, *Abrekites planus* Shigeta and Zakharov gen. nov. sp. nov., NSM PM23194, holotype, from AB1021, ×1.0.

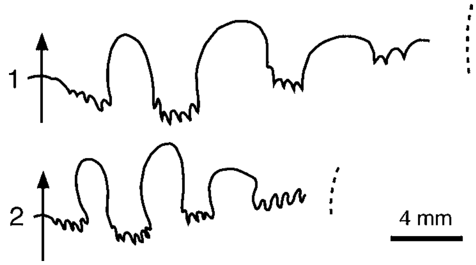


Fig. 69. Suture lines of *Abrekites editus* Shigeta and Zakharov gen. nov. sp. nov. from AB1021. 1, NSM PM23193, holotype, at H=21 mm. 2, NSM PM23192, paratype, at H=14 mm.

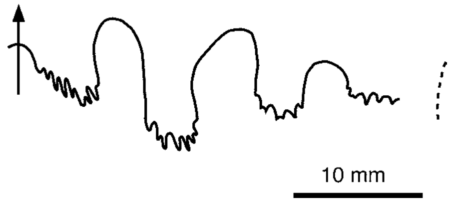


Fig. 70. Suture line of *Abrekites planus* Shigeta and Zakharov gen. nov. sp. nov, NSM PM23194, holotype, from AB1021, at H=29 mm.

NSM PM23193	49.0	10.5	22.5	10.8	0.21	0.48

Occurrence: Described specimen from AB1021 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) of the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: *Abrekites editus* sp. nov. is very close to the juvenile shell of *Arctoceras strigatus* Brayard and Bucher (2008, p. 52, pl. 25, fig. 2) in that it has raised umbilical shoulders and radial folds, but the latter has very noticeable strigation on its flanks, a subtabulate to broadly rounded venter, and a typical Arctoceratidae suture line.

Abrekites planus Shigeta and Zakharov sp. nov.

Figs. 69.13–69.16, 70

Holotype: NSM PM23194, from AB1021.

Diagnosis: *Abrekites* with flat, smooth inner flanks, non-raised umbilical shoulders and weak radial ribs near mid-flank.

Etymology: Species name refers to its flat, inner flank, from the Latin word: planus, meaning flat.

Description: Fairly involute, very compressed shell with rectangular whorl section, tabulate venter, subangular ventral shoulders, flat inner flanks and slightly convex outer flanks with maximum whorl width at mid-flank. Umbilicus fairly narrow with moderately high, overhanging wall and abruptly rounded shoulders. Ornamentation consists of low, radial ribs on mid-flank as well as fine, slightly sinuous, prorsiradiate growth lines. Inner flanks smooth. Suture ceratitic with long denticulate suspensive lobe and wide ventral lobe divided by low median saddle into two wide branches with many denticulations at each base. First lateral saddle lower than second saddle, and third saddle even lower. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe about two thirds depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23194	62.8	11.4	30.7	15.4	0.18	0.50

Occurrence: Described specimen from AB1021 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) of the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: *Abreckites planus* sp. nov. is easily distinguished from *A. editus* sp. nov. by its non-raised umbilical shoulder and smooth, flat inner flanks.

Family Prionitidae Hyatt, 1900

Genus ***Radioprionites*** Shigeta and Zakharov gen. nov.

Type species: *Radioprionites abrekensis* sp. nov.

Composition of the genus: Three species, *Meekoceras boreale* Diener, 1895, *M. subcristatum* Kiparisova, 1947, and *Radioprionites abrekensis* sp. nov.

Diagnosis: Discoidal, fairly involute shell with tabulate to subtabulate venter, narrow umbilicus, vertical umbilical wall, prominent radial folds on flanks and ceratitic suture line.

Etymology: Genus name refers to the Latin word: radio, meaning radial in reference to the radial folds, and *Prionites*.

Occurrence: Lower part of the Lower Olenekian (lower Smithian) in South Primorye, Russia.

Discussion: *Radioprionites* gen. nov. is close to some representatives of Meekoceratidae such as *Ambites* Waagen, 1895, *Ambitoides* gen. nov. and *Radioceras* Waterhouse, 1996a, but differs by its prominent radial folds. *Jolinkia* Waterhouse, 1996b and *Sisupalia* Waterhouse, 1996b are similar and have radial folds, but the former has a concave, narrow venter and the latter has a goniatitic suture line.

This new genus is assigned to the Prionitidae based on the tabulate venter and very sharp ventral shoulders on its juvenile whorls, as well as a long, denticulate suspensive lobe. It can be easily distinguished from *Hemiprionites* Spath, 1929, by its prominent radial folds.

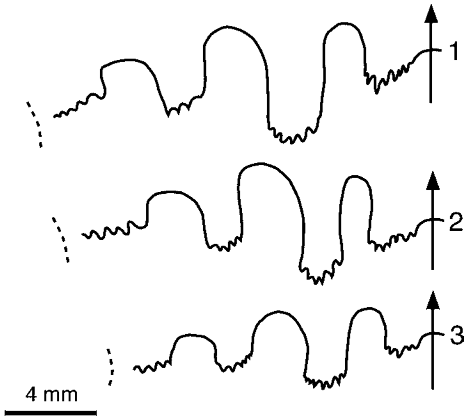


Fig. 71. Suture lines of *Radioprionites abrekensis* Shigeta and Zakharov gen. nov. sp. nov. from AB1025. 1, NSM PM23197, paratype, at H=16.5 mm. 2, NSM PM23195, holotype, at H=16.0 mm. 3, NSM PM23198, paratype, at H=13.5 mm.

Radioprionites abrekensis Shigeta and Zakharov sp. nov.

Figs. 71–73

Prionites aff. *tuberculatus* Waagen, 1895. Zakharov, 1968, p. 125, pl. 23, figs. 4, 5.

Type specimens: Holotype, NSM PM23195, from AB1025; paratypes, seven specimens, NSM PM23196–23202, from AB1025.

Diagnosis: As for the genus.

Etymology: Named after Abrek Bay in South Primorye.

Description: Fairly involute, very compressed shell characterized by slightly convex flanks with maximum whorl width on inner flank at one third whorl height. Venter varies from tabulate with very sharp angular shoulders on juvenile whorls to subtabulate with subangular to abruptly rounded shoulders on mature whorls. Umbilicus narrow with moderately high, vertical wall and rounded shoulders. Ornamentation consists of distant, low, radial folds that arise on umbilical shoulder, develop great intensity near mid-flank and disappear near venter, as well as fine, slightly sinuous, prorsiradiate growth lines. Suture ceratitic with long denticulate suspensive lobe, and wide ventral lobe divided by low median saddle into two wide branches with many denticulations at each base. First lateral saddle lower, narrower than second saddle, and third saddle wide, but even lower. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe about two thirds depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23195	48.0	8.5	23.0	13.0	0.18	0.57
NSM PM23196	27.0	4.0	13.3	7.5	0.15	0.56
NSM PM23197	34.5	6.3	16.4	9.4	0.18	0.57
NSM PM23198	40.3	6.0	20.5	11.1	0.15	0.54
NSM PM23199	27.0	3.9	13.0	7.8	0.14	0.60
NSM PM23201	41.5	5.7	21.0	10.5	0.14	0.50

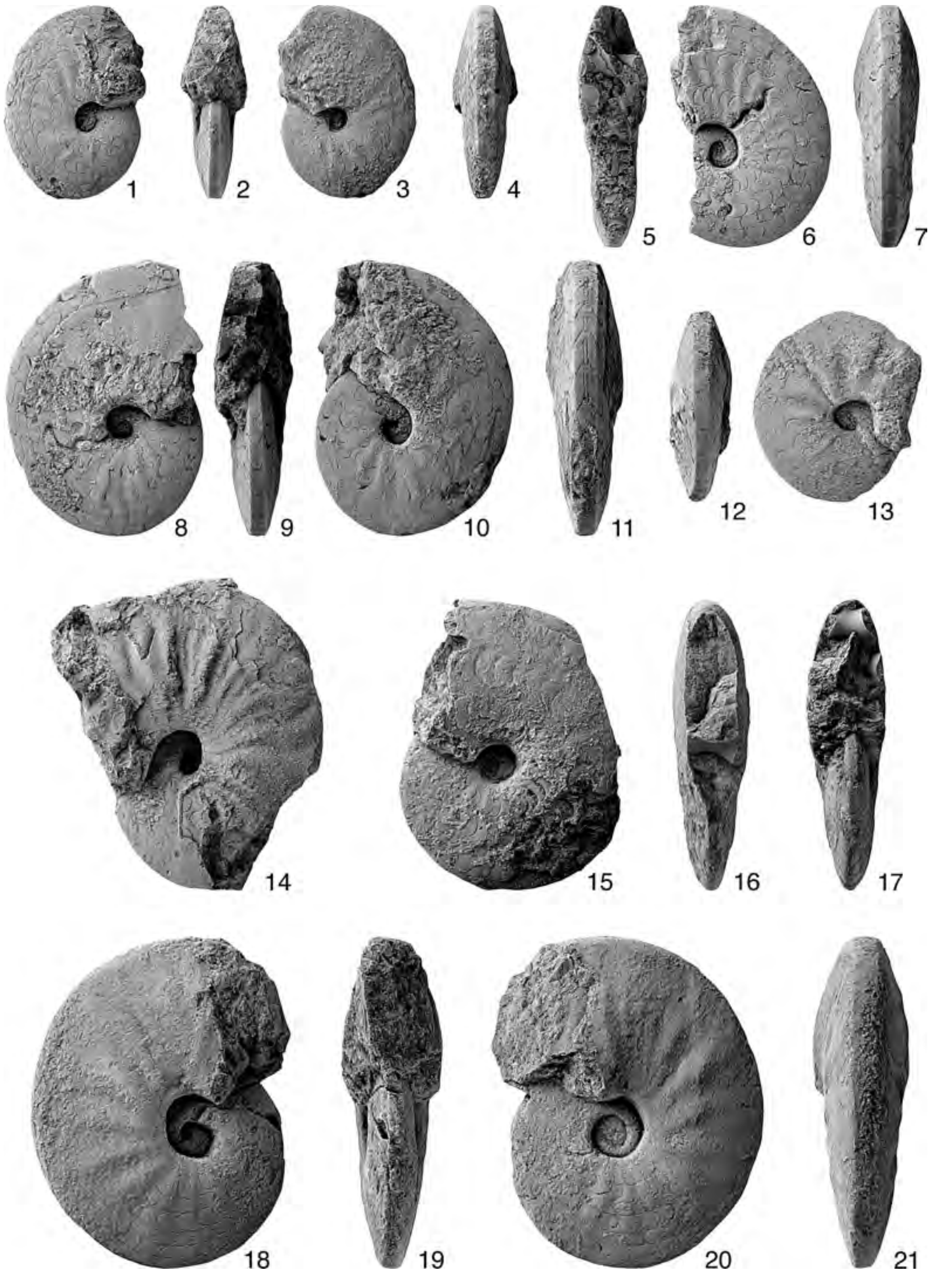


Fig. 72. *Radioprionites abrekensis* Shigeta and Zakharov gen. nov. sp. nov. from AB1025. 1–4, NSM PM23196, paratype, ×1.0. 5–7, NSM PM23197, paratype, ×1.0. 8–11, NSM PM23198, paratype, ×1.0. 12–13, NSM PM23199, paratype, ×1.0. 14, NSM PM23200, paratype, ×1.0. 15–17, NSM PM23201, paratype, ×1.0. 18–21, NSM PM23195, holotype, ×1.0.

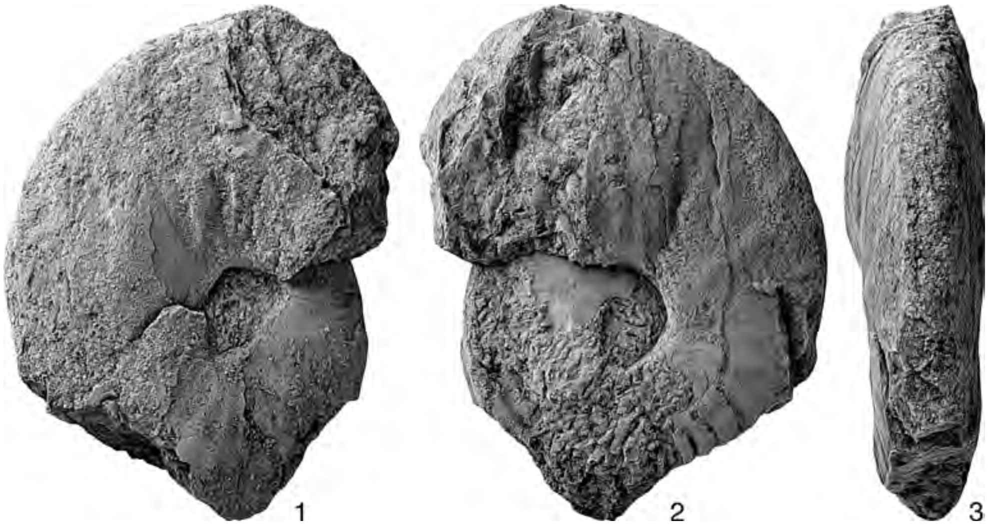


Fig. 73. *Radioprionites abrekensis* Shigeta and Zakharov gen. nov. sp. nov. 1–3, NSM PM23202, paratype, from AB1025, ×1.0.

NSM PM23202	66.8	10.4	33.0	17.4	0.16	0.53

Occurrence: Described specimens from *Radioprionites abrekensis* "bed" (AB1025, lower Early Olenekian=lower Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species also occurs in beds of Early Olenekian age on the eastern coast of Ussuri Gulf, near Golyj Cape (=Kom-Pikho-Sakho Cape) and Yuzhnorechensk Village, South Primorye (Zakharov, 1968)

Discussion: *Radioprionites abrekensis* sp. nov. differs from *Meekoceras boreale* Diener (1895, p. 49) and *M. subcristatum* Kiparisova (1947, p. 150) by its narrower third saddle. The specimens assigned to *Prionites* aff. *tuberculatus* Waagen by Zakharov (1968, p. 125, pl. 23, figs. 4, 5) and herein synonymized with *R. abrekensis*, are identical with respect to whorl morphology and ornamentation.

Genus ***Hemiprionites*** Spath, 1929

Type species: *Goniodiscus typus* Waagen, 1895.

Hemiprionites sp. indet.

Fig. 74

Material examined: NSM PM23203 from AB1026.

Description: Fairly involute, very compressed shell with rectangular whorl section, distinctively tabulate venter, very sharp, angular ventral shoulders and slightly convex flanks with maximum whorl width just above umbilical shoulders. Narrow umbilicus with moderately high, vertical wall and abruptly rounded shoulders. Ornamentation consists of fine, slightly sinuous, prorsiradiate growth lines, and radial folds, which are very pronounced on flanks.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23203	19.5	3.0	10.0	6.0	0.15	0.60

Occurrence: Described specimen from *Balhaeceras balhaense* "bed" (AB1026, middle Early Olenekian=middle Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: It is possible that the described

Fig. 74. *Hemiprionites* sp. indet. 1–4, NSM PM23203, from AB1026, ×2.0.

specimen is actually a juvenile shell of *Hemiprionites dunajensis* Zakharov, 1968, which displays a similar shell shape. However, no definitive assignment can be made.

Family Flemingitidae Hyatt, 1900
Genus ***Ussuriflemingites*** Shigeta and Zakharov gen. nov.

Type species: *Ussuriflemingites primorensis* sp. nov.

Composition of the genus: Two species, *Ussuriflemingites primorensis* sp. nov. and *U. abrekensis* sp. nov.

Diagnosis: Very compressed, fairly evolute shell with subtabulate to narrowly rounded venter, moderately narrow umbilicus, low to moderately high umbilical wall, radial folds,and ceratitic suture line.

Etymology: Genus name refers to Ussuri Gulf in South Primorye and *Flemingites*.

Occurrence: Upper Induan (Dienerian) to lower part of the Lower Olenekian (lower Smithian) in South Primorye, Russia.

Discussion: *Ussuriflemingites* gen. nov. differs from *Anaflemingites* Kummel and Steele, 1962 and *Rohillites* Waterhouse, 1996b, by its more involute coiling and narrower umbilicus, and from *Galfettites* Brayard and Bucher, 2008 and *Anaxenaspis* Kiparisova, 1956, by its subtabulate venter. Its ceratitic suture line characterized by subphylloid saddles, in conjunction with spiral lirae ornamentation and radial ribs justify assignment of this genus to the Flemingitidae.

Ussuriflemingites abrekensis Shigeta and Zakharov sp. nov.
Figs. 75, 77, 78

Type specimens: Holotype, NSM PM23208, from AB1016; paratypes, nine specimens, NSM PM23204–23207, 23209–23213, from AB1016.

Diagnosis: *Ussuriflemingites* with fine spiral lirae on outer flanks and prominent radial folds.

Etymology: Named after Abrek Bay in South Primorye.

Description: Fairly evolute, very compressed shell with tabulate to subtabulate venter, subangular or abruptly rounded ventral shoulders and slightly convex flanks with maximum whorl width at mid-flank. Fairly narrow umbilicus with moderately high, slightly oblique wall and rounded shoulders. Ornamentation consists of fine spiral lirae on outer flanks as well as prominent, slightly sinuous, radial folds. Suture ceratitic with subphylloid saddles and wide ventral lobe divided by low, wide median saddle into two branches with many denticulations at each base. First lateral saddle lower than second saddle, and third saddle even lower. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe about two thirds depth of first lobe. Suspensive lobe long with many denticulations.

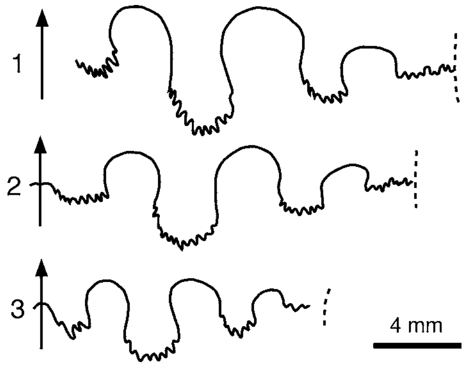


Fig. 75. Suture lines of *Ussuriflemingites abrekensis* Shigeta and Zakharov gen. nov. sp. nov. from AB1016. 1–2, NSM PM23208, holotype. 1, at H=18 mm. 2, at H=16 mm. 3, NSM PM23210, paratype, at H=12 mm.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23204	37.7	8.2	17.7	9.1	0.22	0.51
NSM PM23205	57.6	13.5	24.5	12.3	0.23	0.50
NSM PM23206	56.1	16.4	24.1	9.7	0.29	0.40
NSM PM23207	39.8	10.8	18.3	10.5	0.27	0.57
NSM PM23208	55.0	13.0	24.9	12.8	0.24	0.51
NSM PM23209	54.0	16.2	21.8	10.0	0.30	0.46
NSM PM23210	37.7	9.2	16.1	8.6	0.24	0.53

Occurrence: Described specimens from *Paranorites varians* Zone (AB1016, Late Induan=Dienerian) in the lower main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: *Ussuriflemingites abrekensis* sp. nov. exhibits some affinities with *Pleurambites frechi* Tozer (1994, p. 68), but is easily distinguished by its more involute coiling, narrower umbilicus, subphylloid saddles and serrated ventral lobe.

Ussuriflemingites primoriensis Shigeta and Zakharov sp. nov.

Figs. 76, 79–81

Type specimens: Holotype, NSM PM23214, from AB1021; paratypes, six specimens, NSM PM23215–23220, from AB1021.

Diagnosis: *Ussuriflemingites* with weak, low, radial folds.

Etymology: Named after Primorye.

Description: Fairly evolute, very compressed shell with elliptical whorl section and gently convex flanks with maximum whorl width at mid-flank. Subtabulate venter with ventral shoulders varying from abruptly rounded on juvenile whorls to more gently rounded on larger specimens. Fairly narrow to moderately wide umbilicus with low to moderately high, vertical to slightly oblique wall, and rounded shoulders. Ornamentation consists of weak, low, radial folds as well as fine, slightly sinuous, prorsiradiate growth lines. Suture ceratitic with wide ventral lobe divided by wide median saddle into two small branch-

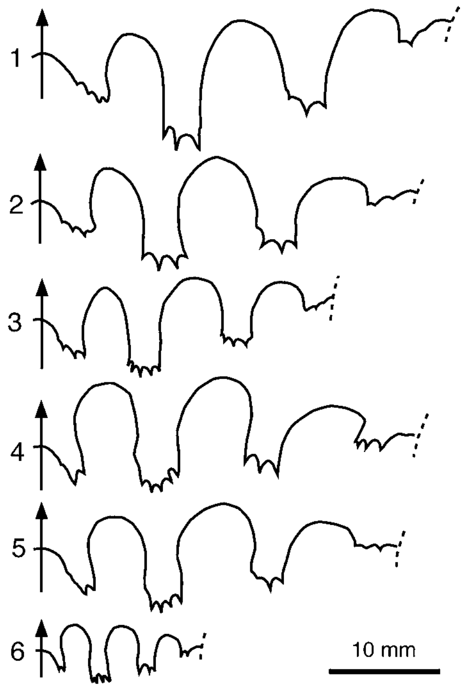
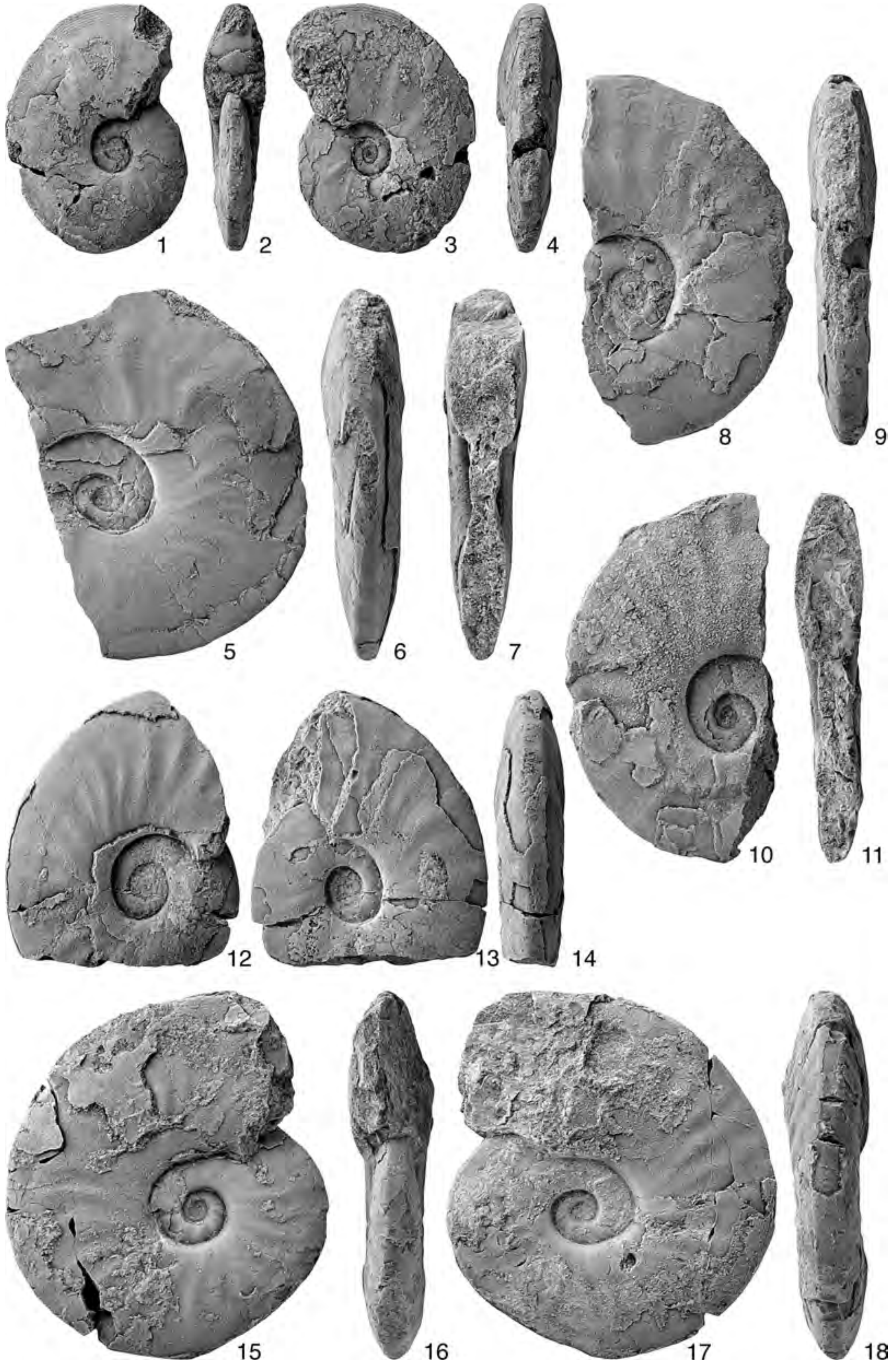


Fig. 76. Suture lines of *Ussuriflemingites primoriensis* Shigeta and Zakharov gen. nov. sp. nov. from AB1021. 1–3, NSM PM23214, holotype. 1, at H=36 mm. 2, at H=32 mm. 3, at H=25 mm. 4, NSM PM23216, paratype, at H=33 mm. 5, NSM PM23218, paratype, at H=31 mm. 6, NSM PM23219, paratype, at H=15 mm.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

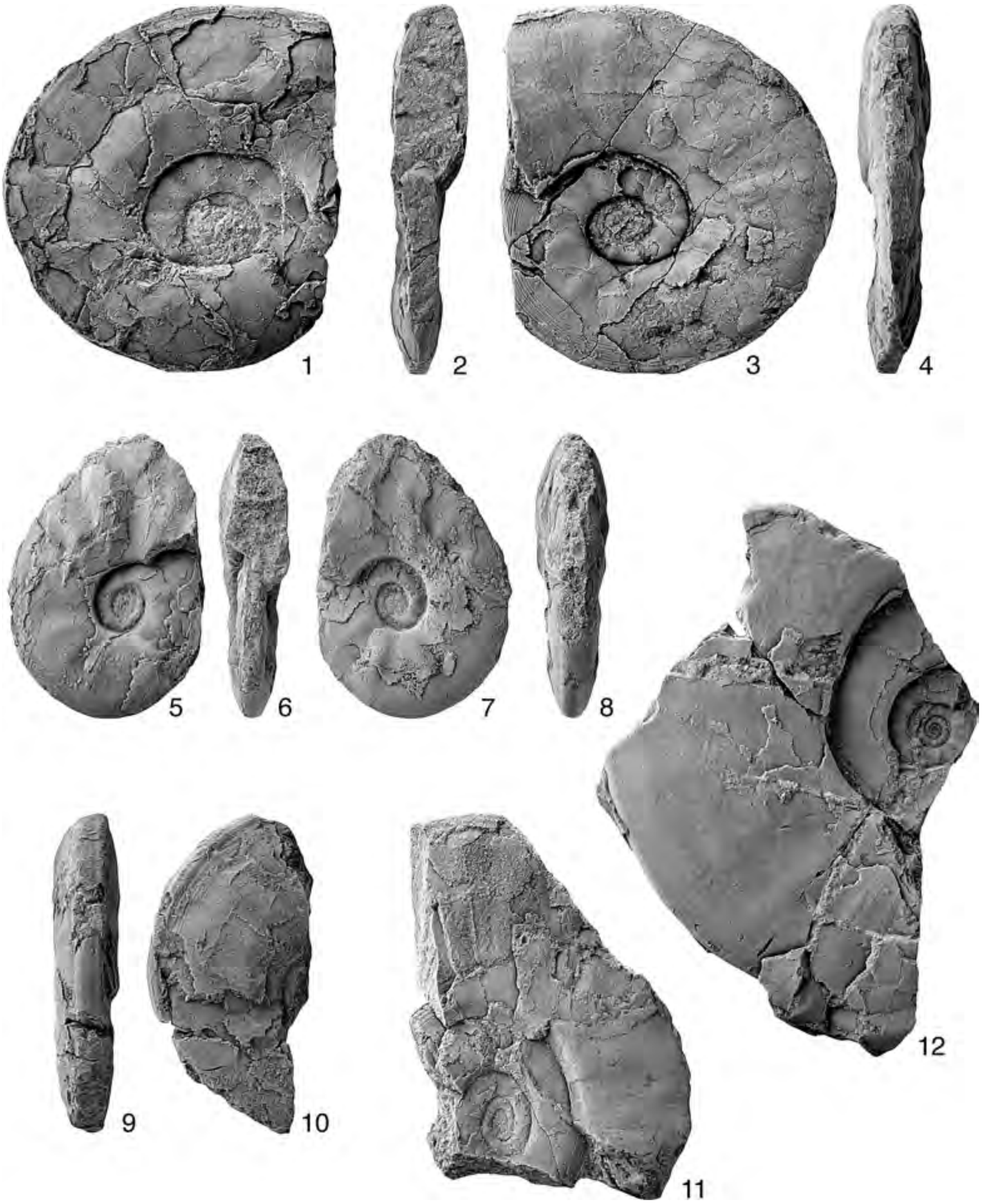


Fig. 78. *Ussuriflemingites abrekensis* Shigeta and Zakharov gen. nov. sp. nov. from AB1016. 1–4, NSM PM23209, paratype, ×1.0. 5–8, NSM PM23210, paratype, ×1.0. 9–10, NSM PM23211, paratype, ×1.0. 11, NSM PM23212, paratype, ×1.0. 12, NSM PM23213, paratype, ×1.0.

←

Fig. 77. *Ussuriflemingites abrekensis* Shigeta and Zakharov gen. nov. sp. nov. from AB1016. 1–4, NSM PM23204, paratye, ×1.0. 5–7, NSM PM23205, parartpe, ×1.0. 8–11, NSM PM23206, paratype, ×1.0. 12–14, NSM PM23207, paratype, ×1.0. 15–18, NSM PM23208, holotype, ×1.0.

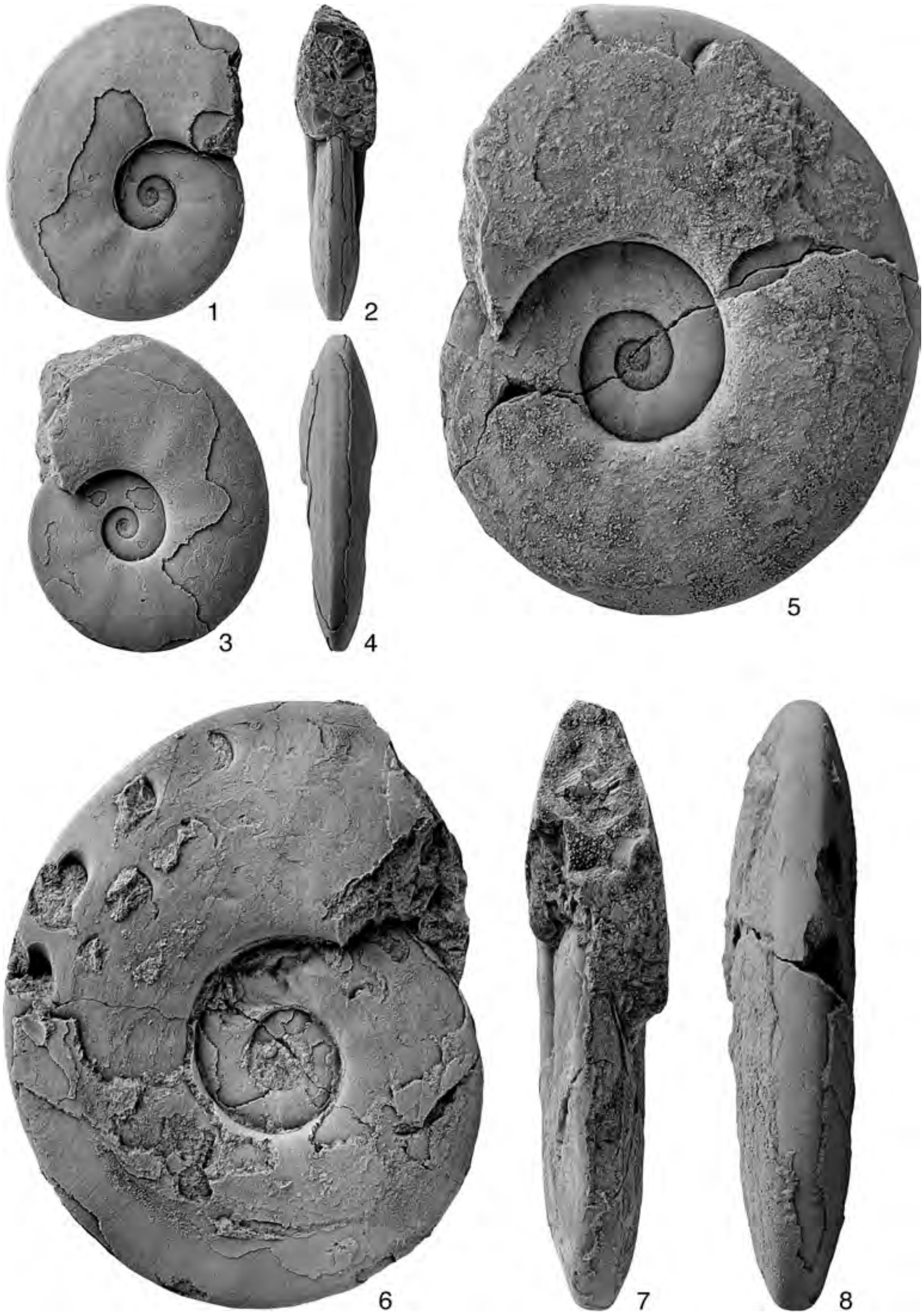


Fig. 79. *Ussuriflemingites primoriensis* Shigeta and Zakharov gen. nov. sp. nov. from AB1021. 1–4, NSM PM23215, paratype, ×1.0. 5–8, NSM PM23216, paratype, ×1.0.

Fig. 80. *Ussuriflemingites primoriensis* Shigeta and Zakharov gen. nov. sp. nov. from AB1021. 1–4, NSM PM23217, paratype, ×1.0. 5–7, NSM PM23218, paratype, ×1.0.

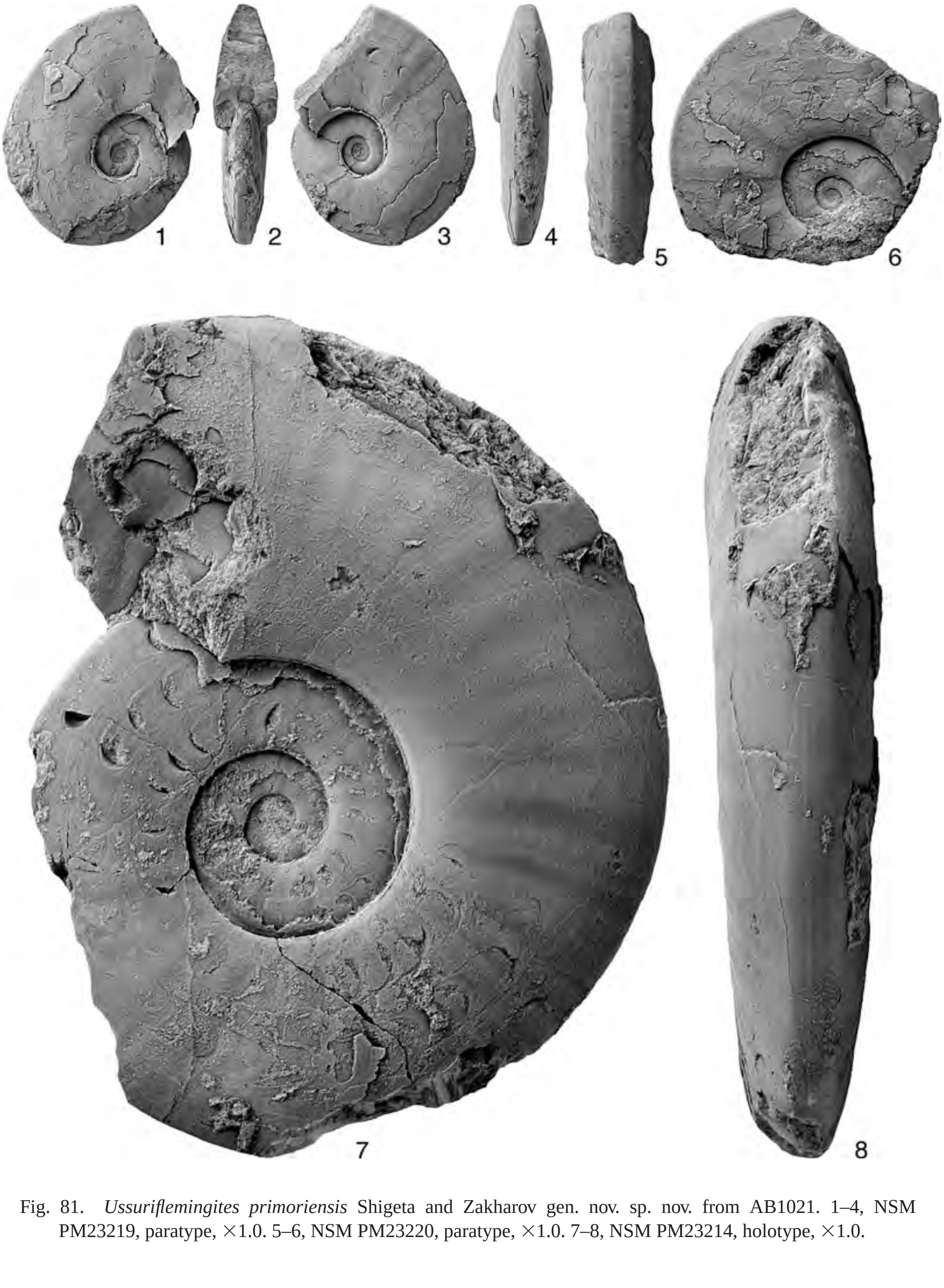


Fig. 81. *Ussuriflemingites primoriensis* Shigeta and Zakharov gen. nov. sp. nov. from AB1021. 1–4, NSM PM23219, paratype, ×1.0. 5–6, NSM PM23220, paratype, ×1.0. 7–8, NSM PM23214, holotype, ×1.0.

es with a few denticulations at each base. First lateral saddle lower than second saddle, and third saddle even lower and asymmetrical. First lateral lobe deep, narrow with denticulations at base, and second lateral lobe about two thirds depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23214	123.0	41.0	48.5	25.4	0.33	0.52
NSM PM23215	44.0	12.0	19.8	10.0	0.27	0.51
NSM PM23216	86.5	27.8	33.3	17.9	0.32	0.54
NSM PM23217	75.7	23.9	29.4	15.5	0.32	0.53
NSM PM23218	83.6	29.1	31.7	14.3	0.35	0.45
NSM PM23219	34.6	9.1	16.0	7.5	0.26	0.47

Occurrence: Described specimens from AB1021 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: *Ussuriflemingites primoriensis* sp. nov. is easily distinguished from *U. abrekensis* sp. nov. by its weak, low, radial folds and lack of fine spiral lirae.

Genus ***Balhaeceras*** Shigeta and Zakharov gen. nov.

Type species: *Balhaeceras balhaense* sp. nov.

Composition of the genus: Type species only.

Diagnosis: Very compressed, fairly evolute shell with tabulate venter, fairly narrow umbilicus with very low, vertical umbilical wall and ceratitic suture line with subphylloid saddles.

Etymology: Named after the ancient kingdom of Balhae (A.D. 698–926), which occupied the southern parts of Manchuria and Primorye, and the northern part of the Korean peninsula.

Occurrence: Middle part of the Lower Olenekian (middle Smithian) in South Primorye, Russia.

Discussion: *Balhaeceras* gen. nov. is morphologically close to *Prionolobus* Waagen, 1895 of the Meekoceratidae, but its subphylloid saddles justify its assignment to the Flemingitidae. It differs from *Rohillites* Waterhouse, 1996b by the absence of strigation, from *Anaflemingites* Kummel and Steele, 1962 and *Ussuriflemingites* gen. nov, by its very low umbilical wall and parallel flanks, and from *Galfettites* Brayard and Bucher, 2008 and *Anaxenaspis* Kiparisova, 1956, by its tabulate venter.

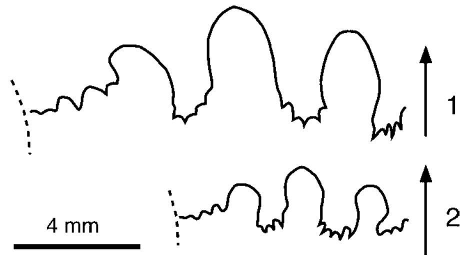


Fig. 82. Suture lines of *Balhaeceras balhaense* Shigeta and Zakharov gen. nov. sp. nov., NSM PM23221, holotype, from AB1026. 1, at H=13 mm. 2, at H=8 mm.

Balhaeceras balhaense Shigeta and Zakharov sp. nov.

Figs. 82, 83.1–83.4

Prionolobus subevolvense Zakharov, 1968, p. 70, pl. 7, figs. 7–9.

Holotype: NSM PM23221, from AB1026.

Diagnosis: As for the genus.

Etymology: Named after the ancient kingdom of Balhae (A.D. 698–926).

Description: Fairly evolute, very compressed shell with subrectangular whorl section, tabulate to weakly concave venter, subangular ventral shoulders and flat flanks with maximum whorl width at two thirds of whorl height. Umbilicus fairly narrow with very low, vertical wall and narrowly rounded shoulders. Ornamentation consists only of weak, low, radial folds. Suture ceratitic with subphylloid saddles, and wide ventral lobe divided by median saddle into two branches with denticula-

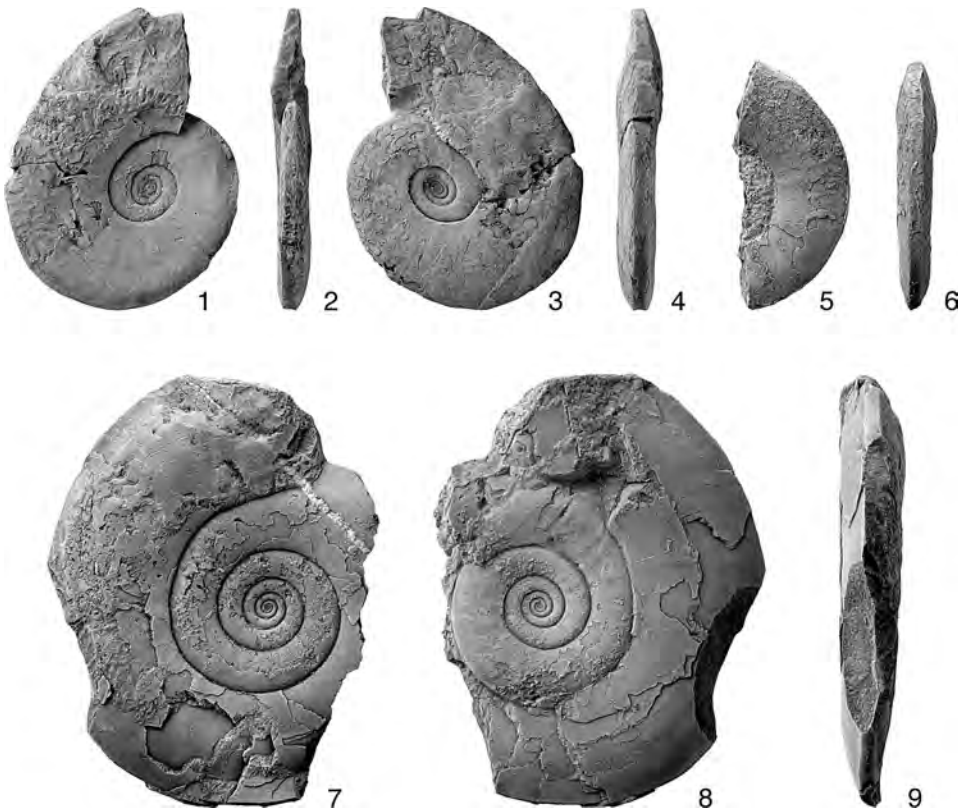


Fig. 83. 1–4, *Balhaeceras balhaense* Shigeta and Zakharov gen. nov. sp. nov., NSM PM23221, holotype, from AB1026, ×1.0. 5–9, *Rohillites laevis* Shigeta and Zakharov sp. nov. from AB1021. 5–6, NSM PM23222, paratype, ×1.0. 7–9, NSM PM23223, holotype, ×1.0.

tions at each base. First lateral saddle lower than second saddle, and third saddle even lower, and asymmetrical. First lateral lobe wide, deep with many denticulations at base, and second lateral lobe nearly equal in size to first lobe. A few auxiliary elements present on adumbilical flank.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23221	30.5	9.2	13.5	4.2	0.30	0.31

Occurrence: Described specimen from *Balhaeceras balhaense* "bed" (AB1026, middle Early Olenekian=middle Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: A specimen collected from Early Olenekian strata on the western coast of Ussuri Gulf, near Tri Kamnya Cape, and designated by Zakharov (1968, p. 70) as the holotype of *Prionolobus subevolvens*, is very close to *Balhaeceras balhaense* sp. nov., but differs by its slightly convex flanks (maximum thickness at mid flank) and wider umbilicus. It likely belongs either to the genus *Anaflemingites* Kummel and Steele, 1962, or *Rohillites* Waterhouse, 1996b. Three specimens, collected from the eastern coast of Ussuri Gulf, near Golyj Cape and illustrated by Zakhrov (1968, pl. 7, figs. 7–9) as paratypes of *P. subevolvens*, share many similarities with *B. balhaense* sp. nov. including a very low, vertical umbilical wall and narrowly rounded shoulders, and they are likely conspecific.

Genus ***Rohillites*** Waterhous, 1996b

Type species: *Flemingites rohilla* Diener, 1897.

Rohillites laevis Shigeta and Zakharov sp. nov.
Figs. 83.5–83.9, 84

Type specimens: Holotype, NSM PM23223, from AB1021; paratype, NSM PM23222, from AB1021.

Diagnosis: *Rohillites* with narrow tabulate venter, very low umbilical wall, spiral lirae restricted to outer flank, and without other noticeable ornamentation.

Etymology: From the Latin word: laevis, meaning smooth in reference to the absence of marked ribs and folds.

Description: Very evolute, very compressed shell with narrow, tabulate venter, angular ventral shoulders and slightly convex flanks with maximum whorl width at two thirds of whorl height. Fairly wide umbilicus with very low wall and narrowly rounded shoulders. Ornamentation consists of spiral lirae restricted to outer flank as well as fine, radial growth lines. Suture ceratitic with subphylloid saddles, and wide ventral lobe divided by median saddle into two branches with denticulations at each base. First lateral saddle lower and narrower than second saddle, and third saddle lower and narrower than second. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe shallower than first lobe.

Measurements (mm):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23223	49.7	20.2	16.1	6.8	0.41	0.42

Occurrence: Described specimens from AB1021 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

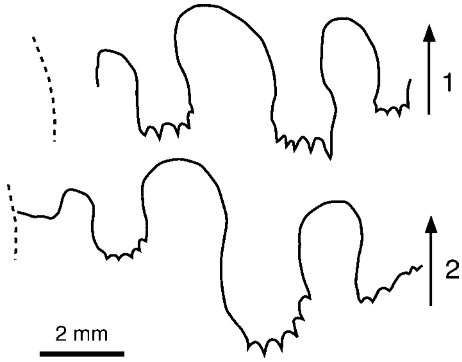


Fig. 84. Suture lines of *Rohillites laevis* Shigeta and Zakharov sp. nov. from AB1021. 1, NSM PM23222, paratype, at H=9 mm. 2, NSM PM23223, holotype, at H=10 mm.

Discussion: *Rohillites laevis* sp. nov. is easily distinguished from other species of *Rohillites* such as *R. rohilla* (Diener, 1897, p. 93), *R. bruehwileri* Brayard and Bucher (2008, p. 46), and *R. sobolevi* Brayard and Bucher (2008, p. 47), by the absence of conspicuous ribs and folds. It is clearly distinguished from *Galfettites simplicitatis* Brayard and Bucher (2008, p. 48) by its tabulate venter, and from *Ussuriflemingites primorensis* sp. nov. by its more evolute whorls and the presence of spiral lirae on its outer flanks. Although the holotype of *Prionolobus subevolvene* Zakharov (1968, p. 70) probably could be assigned to either *Anaflemingites* Kummel and Steele, 1962 or *Rohillites* Waterhouse, 1996b, it also could be considered as very close to *Rohillites laevis* sp. nov., except for its lack of spiral lirae.

Genus ***Palaeokazakhstanites*** Zakharov, 1978

Type species: *Wyomingites ussuriensis* Zakharov, 1968.

Discussion: *Palaeokazakhstanites* was initially placed within the Sibiritidae by Zakharov (1978), and then later assigned to the

Meekoceratidae by Tozer (1981) and Shevyrev (1986). Waterhouse (1996b) commented that it appears to belong to the xenodiscids. We believe its ornamentation, consisting of spiral lirae and radial ribs, along with its subtabulate venter and ceratitic suture line, justify the placement of this genus within the Flemingitidae. Its shell is very similar to the juvenile shell of *Rohillites* Waterhouse, 1996b, and both possibly belong to the same evolutionary lineage or they may even be congeneric.

Palaeokazakhstanites ussuriensis
(Zakharov, 1978)

Figs. 85, 86

Wyomingites ussuriensis Zakharov, 1968, p. 64, pl. 6, figs. 6–9, text-fig. 12c.

Holotype: DVGI 10/801 figured by Zakharov (1968, p. 64, pl. 6, fig. 6), from the lower part of the Lower Olenekian (*Hedenstroemia bosphorensis* Zone) on the western coast of Ussuri Gulf, near Tri Kamnya Cape in South Primorye, Russia.

Material examined: Seven specimens, NSM PM23224–23230, from AB1021, four specimens, NSM PM23231–23234, from AB1022.

Description: Very small, moderately evolute, fairly compressed shell with elliptical whorl section, narrow, subtabulate venter, angular to abruptly rounded ventral shoulders and gently convex flanks with maximum whorl width at mid-flank. Moderately wide umbilicus with moderately high, slightly oblique wall and rounded shoulders. Ornamentation consists of fine spiral lirae on outer flanks, as well as irregularly spaced, slightly sinuous, prorsiradiate or rursiradiate ribs, which become very faint on inner flanks and disappear on ventral shoulders. Suture ceratitic with wide ventral lobe divided by low median saddle into two branches. First lateral saddle equal to second saddle, but third saddle lower. First lateral lobe deep, wide with many denticulation at base, and second lateral lobe about one-half depth of first lobe.

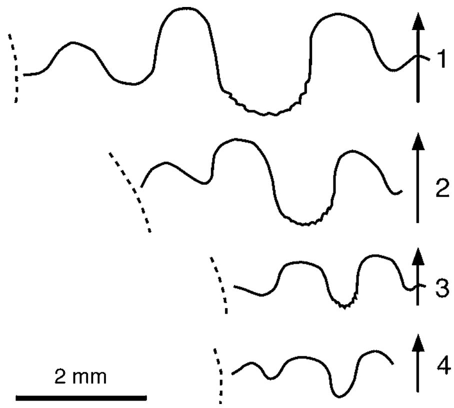


Fig. 85. Suture lines of *Palaeokazakhstanites ussuriensis* (Zakharov, 1968). 1, NSM PM23232, from AB1022, at H=6 mm. 2, NSM PM23231, from AB1022, at H=4 mm. 3, NSM PM23227, from AB1021, at H=3 mm. 4, NSM PM23225, from AB1021, at H=3 mm.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23224	9.8	3.7	3.7	2.6	0.38	0.70
NSM PM23225	12.8	4.6	4.8	3.4	0.36	0.71
NSM PM23226	9.8	3.4	3.8	3.0	0.35	0.79
NSM PM23227	11.2	4.1	3.9	3.0	0.37	0.77
NSM PM23228	18.6	6.9	6.8	5.1	0.37	0.75
NSM PM23231	11.9	5.1	4.9	3.8	0.43	0.78
NSM PM23232	14.8	4.9	6.0	4.8	0.33	0.80
NSM PM23233	10.7	3.8	4.5	3.1	0.36	0.69
NSM PM23234	20.2	7.7	7.5	5.5	0.38	0.73

Occurrence: Described specimens from AB1021, AB1022 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species also occurs in the *Hedenstroemia bosphorensis* Zone on the western coast of Ussuri Gulf, near Tri Kamnya Cape, South Primorye (Zakharov, 1968; Markevich & Zakharov, 2004).

Discussion: *Palaeokazakhstanites ussuriensis* (Zakharov, 1968) is very similar to *Rohillites bruehwileri* Brayard and Bucher (2008, p. 46), but the maximum shell size of each species appears to be quite different. All specimens of *P. ussuriensis* found thus far are

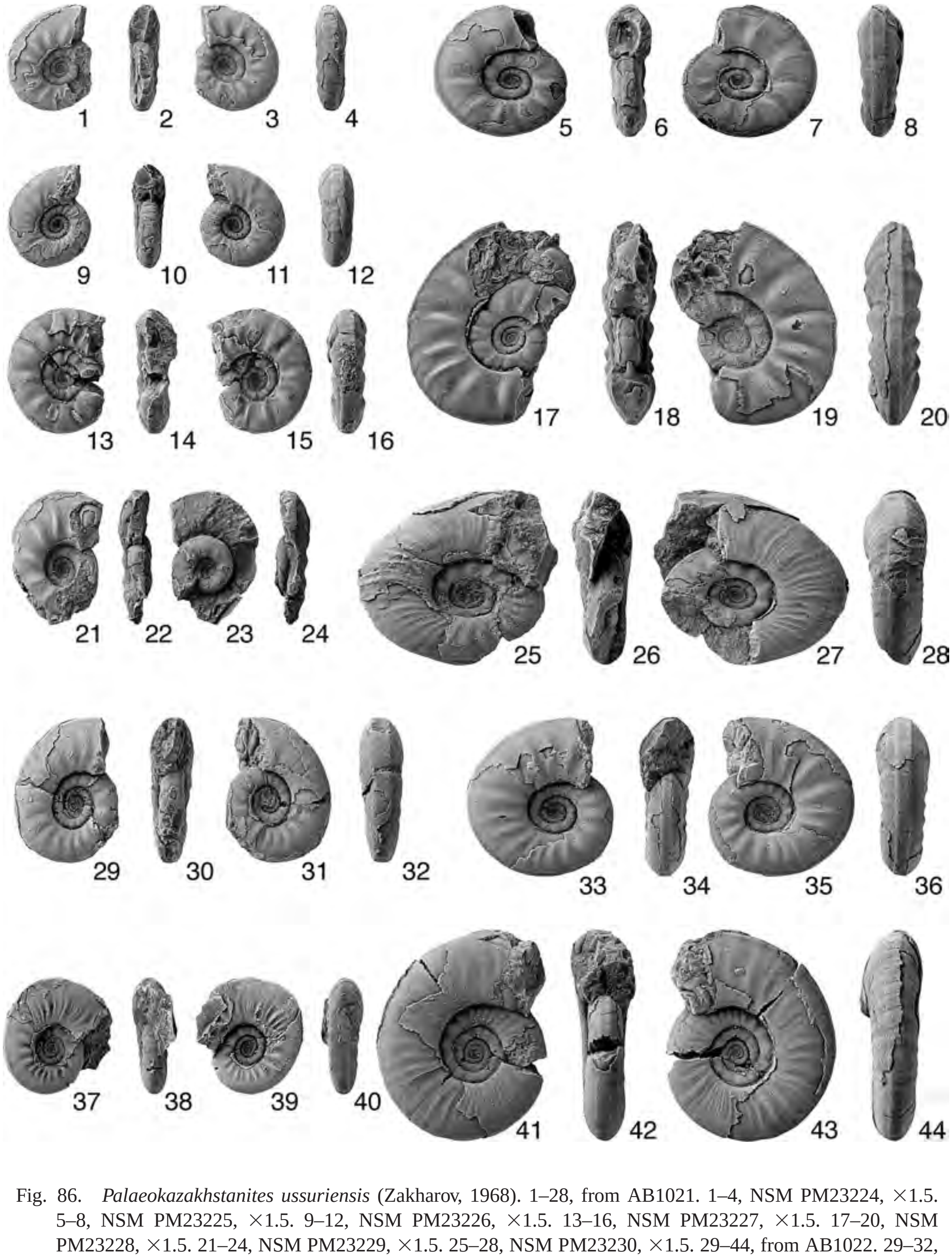


Fig. 86. *Palaeokazakhstanites ussuriensis* (Zakharov, 1968). 1–28, from AB1021. 1–4, NSM PM23224, ×1.5. 5–8, NSM PM23225, ×1.5. 9–12, NSM PM23226, ×1.5. 13–16, NSM PM23227, ×1.5. 17–20, NSM PM23228, ×1.5. 21–24, NSM PM23229, ×1.5. 25–28, NSM PM23230, ×1.5. 29–44, from AB1022. 29–32, NSM PM23231, ×1.5. 33–36, NSM PM23232, ×1.5. 37–40, NSM PM23233, ×1.5. 41–44, NSM PM23234, ×1.5.

less than 3 cm in diameter, whereas of the six illustrated specimens of *R. bruehwileri*, all are larger than 3 cm and two are nearly 6 cm in diameter. These two species may, in fact, be conspecific, but this cannot be confirmed without a thorough statistical analysis, which would require many additional specimens.

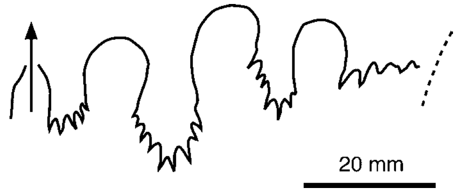


Fig. 87. Suture line of *Euflemingites prynadai* (Kiparisova, 1947), NSM PM23235, from AB1027, at H=55 mm.

Genus ***Euflemingites*** Spath, 1934

Type species: *Flemingites guyerdetiformis* Welter, 1922.

Euflemingites prynadai (Kiparisova, 1947b)

Figs. 87–90

Flemingites prynadai Kiparisova, 1947b, p. 135, pl. 29, fig. 1, pl. 30, fig. 1, text-fig. 18; Kiparisova, 1954, p. 18, pl. 8, fig. 1; Kiparisova, 1961, p. 76, pl. 15, fig. 1, text-fig. 36.

? *Euflemingites tsotengensis* Chao, 1959, p. 209, pl. 5, figs. 1–2, text-fig. 14.

Euflemingites sp. indet. Zakharov, 1968, p. 88, pl. 16, fig. 3.

Euflemingites prynadai (Kiparisova). Zakharov, 1997, pl. 1, fig. 6.

Holotype: CGM 71/5504 figured by Kiparisova (1947b, p. 135, pl. 29, fig. 1, pl. 30, fig. 1), from the Lower Triassic (Olenekian, *Flemingites* beds) on the western coast of Ussuri Gulf, near Tri Kamnya Cape in South Primorye, Russia.

Material examined: NSM PM23235, from AB1027.

Description: Moderately evolute, fairly large shell with arched venter, indistinct ventral shoulders and gently convex flanks forming an elliptical whorl section with maximum whorl width at mid-flank. Umbilicus moderately wide with moderately high, vertical wall and rounded shoulders. Ornamentation consists of rather weak, slightly rursiradiate ribs as well as conspicuous, dense strigation covering entire shell. Spiral ridges number about 25 between umbilical shoulder and mid-line of venter. Suture ceratitic with subphylloid saddles, and wide ventral lobe divided by narrow, high median saddle into two branches with denticulations at each base. First lateral saddle lower than second saddle, and third saddle even lower. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe about one-half depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23235	165.0	52.0	60.0	49.0	0.32	0.77

Occurrence: Described specimens from *Arctoceras subhydaspis* "bed" (AB1027, middle Early Olenekian=Middle Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species also occurs in the *Hedenstroemia bosphorensis* Zone, on the western coast of Ussuri Gulf, near Tri Kamnya Cape, and in the Yuzhnorechensk area, South Primorye (Zakharov, 1968; Markevich & Zakharov, 2004).

Discussion: Although the present specimen is somewhat deformed and is missing about one-third of its whorls, its distinctive features enable us to identify it without doubt as *Euflemingites prynadai*.

This species apparently differs from *E. cirratus* (White, 1879, p. 116) by possessing a greater number of spiral ridges, but in order for this to be considered as diagnostic, one must define the intraspecific variation of strigate ridge density for a sufficient number of specimens of both species. *E. tsotengensis* Chao (1959, p. 209) is very close to this species, and in fact, may be conspecific.

Fig. 88. *Euflemingites prynadai* (Kiparisova, 1947), NSM PM23235, from AB1027, ×1.0.

Fig. 89. *Euflemingites prynadai* (Kiparisova, 1947). 1–2, NSM PM23235, from AB1027, ×1.0.

Fig. 90. *Euflemingites prynadai* (Kiparisova, 1947), NSM PM23235, from AB1027, ×1.0.

Family Proptychidae Waagen, 1895
Genus ***Dunedinites*** Tozer, 1963

Type species: *Dunedinites pinguis* Tozer, 1963.

Dunedinites magnumbilicatus
(Kiparisova, 1961)
Figs. 91, 92.1–92.4

Prosphingites magnumbilicatus Kiparisova, 1961, p. 114, pl. 25, fig. 4, text-fig. 78.

Holotype: CGM/121/5504, figured by Kiparisova (1961, p. 114, pl. 25, fig. 4), from the Lower Triassic (Olenekian?) in the Abrek Bay area in South Primorye, Russia.

Material examined: NSM PM23236, from AB1010.

Description: Moderately involute, somewhat globular shell with very depressed, semicircular whorl section, and convex flanks gradually converging to a circular venter from abruptly rounded umbilical shoulder. Moderately wide, deep umbilicus with high, vertical wall. Shell ornamentation consists of very fine, forward projected plications on body chamber as well as very fine, growth lines. Suture ceratitic with narrow saddles, and wide ventral lobe divided by narrow median saddle into two branches with denticulations at each base. First lateral saddle nearly equal to second saddle, and third saddle lower. First lateral lobe deep, narrow with many denticulations at base, and second lateral lobe nearly equal to first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23236	30.0	11.5	9.0	21.0	0.38	2.33

Occurrence: Described specimen from AB1010 within the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: *Dunedinites magnumbilicatus* (Kiaparisova, 1961) is very close to *D. pinguis* Tozer (1963, p. 23), and to *D. subtabulatus* (Brühwiler *et al.*, 2008, p. 1175), which they assigned to *Anotoceras*, but differs by its vertical umbilical wall. It exhibits some affinities with *Anotoceras nala* (Diener, 1897, p. 54) of the family Otoceratidae Hyatt, 1900 (Anotoceratidae Waterhouse, 1994), but can be easily distinguished by its circular venter and abruptly rounded umbilical shoulder.

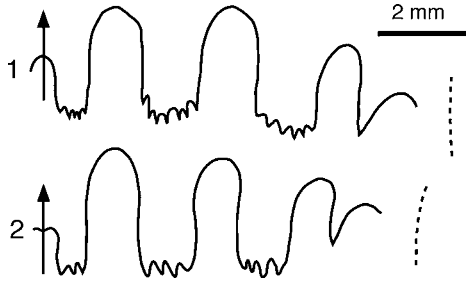


Fig. 91. Suture lines of *Dunedinites magnumbilicatus* (Kiparisova, 1961), NSM PM23236, from AB1010. 1, at H=9 mm. 2, at H=6 mm.

The holotype was collected by N. K. Trifonova in 1948 from the dark-grey, fine-grained, calcareous sandstone in the Abrek Bay section, and Kiparisova (1961) believed that this particular horizon was of Olenekian age. However, this sandstone is typical of the upper part of the Lazurnaya Bay Formation (Induan), and it is highly probable that the holotype was actually collected from this horizon, as was our specimen.

Genus ***Bukkenites*** Tozer, 1994

Type species: *Bukkenites nitidus* Tozer, 1994.

Bukkenites? sp. indet.
Figs. 92.5–92.6, 93

Material examined: NSM PM23237 from AB1008.

Description: Fairly involute shell with elliptical whorl section, rounded venter, rounded ventral shoulders and slightly convex flanks with maximum whorl width near umbilicus.

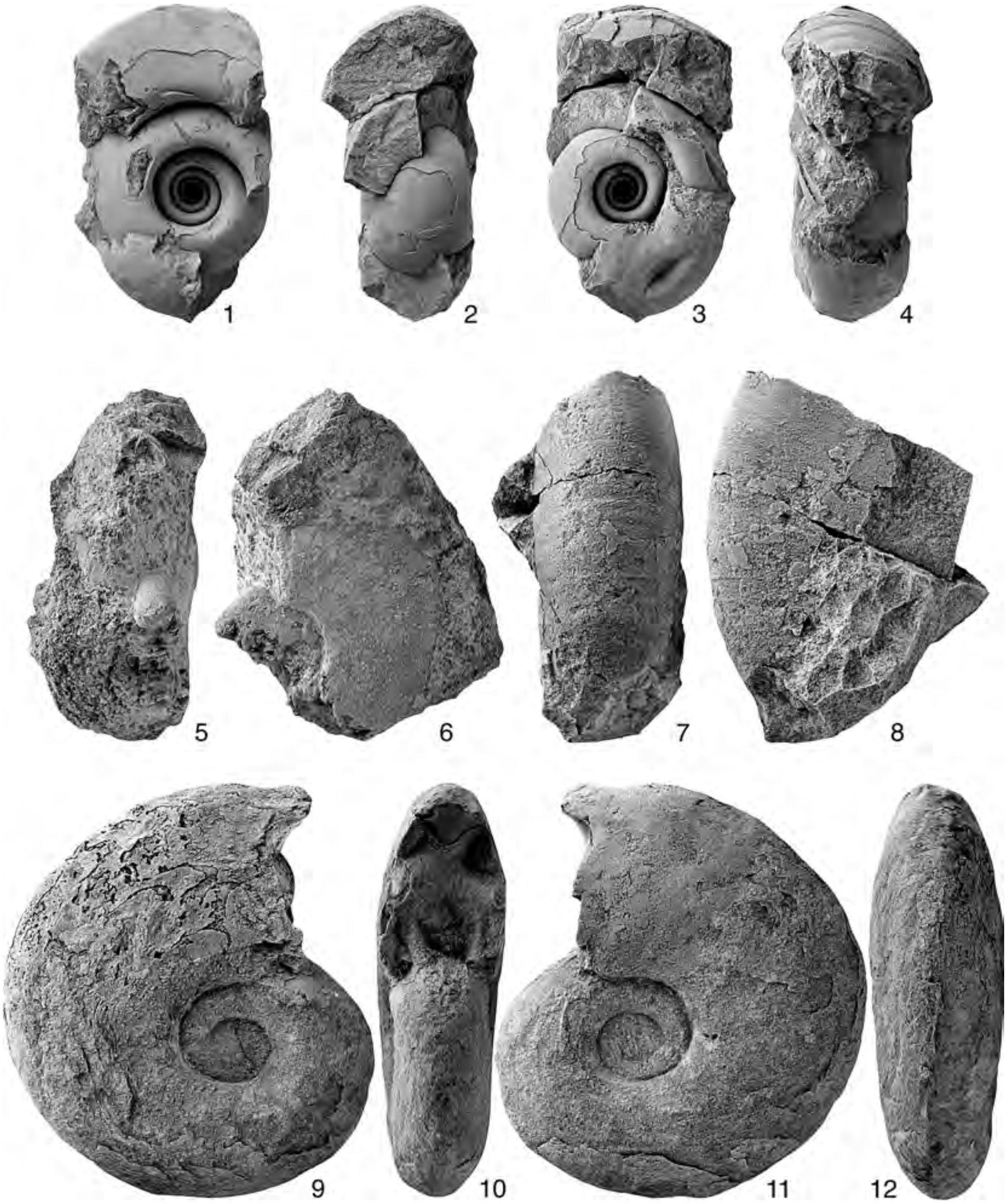


Fig. 92. 1–4, *Dunedinites magnumbilicatus* (Kiparisova, 1961), NSM PM23236, from AB1010, ×1.0. 5–6. *Bukkenites*? sp. indet., NSM PM23237, from AB1008, ×1.0. 7–12, *Pseudoproptychites hiemalis* (Diener, 1895). 7–8, NSM PM23238, from AB1009, ×1.0. 9–12, NSM PM23239, from AB1010, ×1.0.

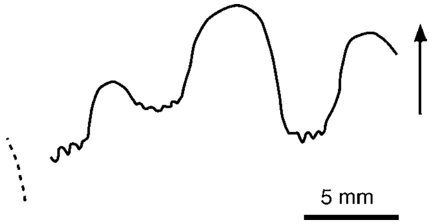


Fig. 93. Suture line of *Bukkenites*? sp. indet., NSM PM23237, from AB1008, at H=19 mm.

Fig. 94. Suture line of *Pseudoproptychites hiemalis* (Diener, 1895), NSM PM23240, from AB1010, at H=22 mm.

Umbilicus fairly narrow with moderately high, vertical wall and rounded shoulders. Shell ornamentation not preserved. Suture ceratitic with denticulate suspensive lobe, but with no discrete auxiliary lobe. First lateral saddle lower than second saddle, and third saddle even lower. First lateral lobe deep, wide with denticulations at base, and second lateral lobe two thirds depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23237	19.3	4.9	9.2	6.6	0.25	0.72

Occurrence: Described specimen from AB1008 within the *Lytophiceras* sp. Zone (Early Induan=Griesbachian) in the middle part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: The assignment of this fragmental specimen to *Bukkenites* is uncertain and is based only on the similarity of its morphology and suture with the Proptychitidae.

Genus ***Pseudoproptychites*** Bando, 1981

Type species: *Proptychites scheibleri* Diener, 1897.

Pseudoproptychites hiemalis (Diener, 1895)

Figs. 92.7–92.12, 94, 95

Proptychites hiemalis Diener, 1895, p. 34, pl. 2, figs. 2, 4, pl. 5, fig. 4.

Proptychites hiemalis. Zakharov, 1968, p. 93, pl. 17, figs. 6, 7, text-figure 20c.

Lectotype: Designated by Zakharov (1968, p. 93), is CGM 40/596, original of Diener (1895, p. 34, pl. 2, fig. 6) from the Induan of the Shamara Bay area, along the western coast of Ussuri Gulf in South Primorye, Russia.

Material examined: NSM PM23238, from AB1009, two specimens, NSM PM23239, 23240, from AB1010.

Description: Fairly involute, fairly compressed shell (outer whorls) with arched venter, indistinct ventral shoulders and slightly convex flanks with maximum whorl width at mid-flank. Whorl section varies from elliptical for outer whorls to ovoid for involute inner whorls. Fairly narrow, deep umbilicus with very high, vertical wall on inner whorls, and moderately high, gently inclined wall with broadly rounded shoulder on outer whorls. Shell surface smooth with very fine, prorsiradiate, nearly straight growth lines. Suture ceratitic with somewhat differentiated auxiliaries. Lateral saddles high, narrow and slanted slightly toward umbilicus. First lateral lobe wide, deep with many denticulations at base, and second lateral lobe about two thirds depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23239	56.2	13.3	27.3	18.1	0.24	0.66
NSM PM23240	65.2	12.8	33.5	21.0	0.20	0.63

Occurrence: Described specimens from AB1009 within the *Lytophiceras* sp. Zone (Early Induan=Griesbachian), and AB1010 within the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the

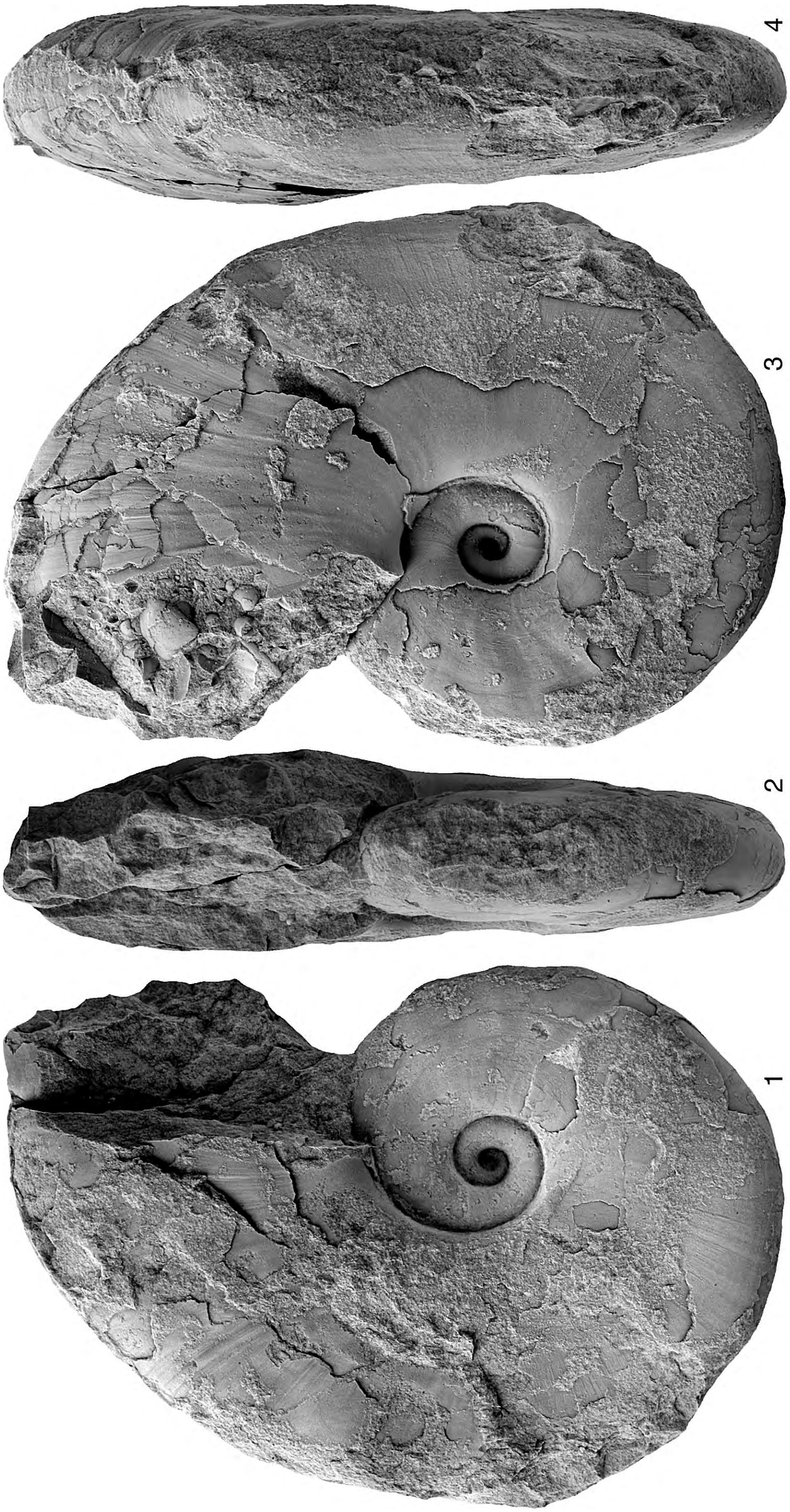


Fig. 95. *Pseudoproptychites hiemalis* (Diener, 1895). 1–4, NSM PM23240, from AB1010, ×1.0.

middle to upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: Larger specimens are somewhat similar to *Proptychites* Waagen, 1895, but the globular whorl section of its juvenile stage, and its slender lateral saddles and strongly denticulated lateral lobes justify the assignment of this species to *Pseudoproptychites*. This species is close to *P. scheibleri* (Diener, 1897, p. 79), but differs in having fairly compressed whorls at later growth stages. The specimen identified as *Proptychites hiemalis* by Zakharov (1968, p. 93, pl. 17, figs. 6, 7) has a wider umbilicus than the type specimens and our specimens as well, but it is probably conspecific.

Genus ***Pachyproptychites*** Diener, 1916

Type species: *Proptychites otoceratoides* Diener, 1895.

Discussion: Vavilov and Zakharov (1976) suspected that the holotype of *Proptychites otoceratoides* Diener (1895, p. 36) was actually a poorly preserved specimen of *Arctoceras* Hyatt, 1900. However, *Pachyproptychites* is quite different from *Arctoceras* in shell shape and suture line, and no *Pachyproptychites*-like forms have been discovered among the poorly preserved specimens of *Arctoceras*. Thus, *Pachyproptychites* is probably a valid genus. It is very close to *Bukkenites* Tozer, 1994, but differs by having an auxiliary lobe similar to *Proptychites* Waagen, 1895.

Spath (1934) considered the funnel-shaped umbilicus of *Pachyproptychites* to be a highly significant component of its diagnosis. However, most of the holotype's umbilicus is obscured by matrix. Judging from the umbilical edge or shoulder that is visible in one small area, the umbilical wall appears to be overhanging.

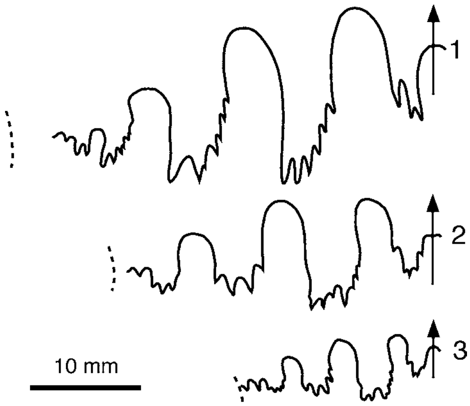


Fig. 96. Suture lines of *Pachyproptychites otoceratoides* (Diener, 1895) from AB1011. 1, NSM PM23242, at H=34 mm. 2, NSM PM23241, at H=25 mm. 3, NSM PM23241, at H=15 mm.

Pachyproptychites otoceratoides
(Diener, 1895)
Figs. 96, 97

Proptychites otoceratoides Diener, 1895, p. 36, pl. 3, fig. 2.
Pachyproptychites otoceratoides (Diener). Diener, 1916, p. 101.
Proptychites abrekensis Kiparisova, 1961, p. 100, pl. 19, fig. 2, text-fig. 61.

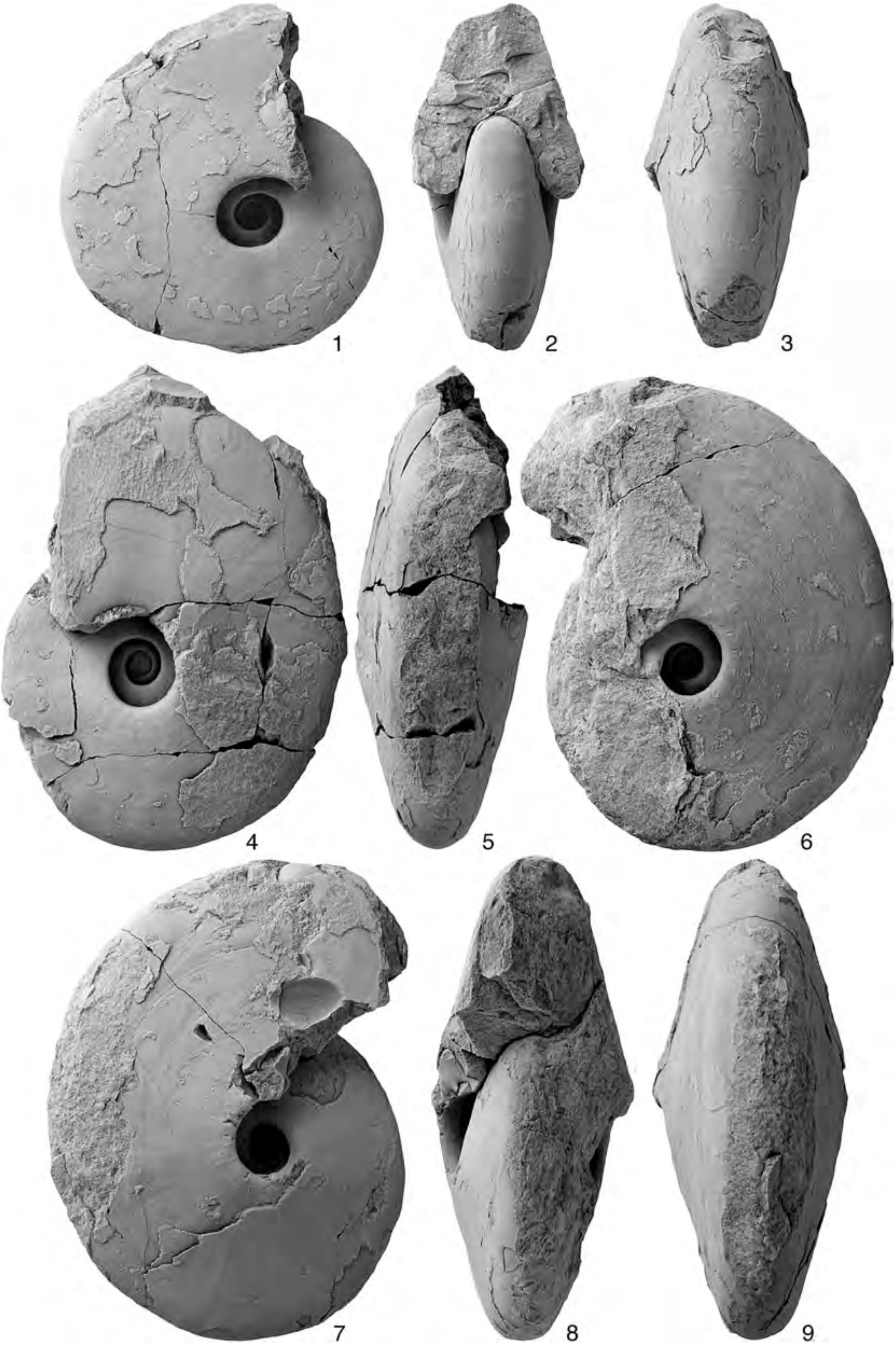
Holotype: CGM 43/596, figured by Diener (1895, p. 36, pl. 3, fig. 2) from the Lower Triassic of the Paris Bay area of Russian Island, South Primorye, Russia.

Material examined: Two specimens, NSM PM23241, 23242, from AB1011.

Description: Very involute, fairly compressed shell with whorl section characterized by swollen dorsum, and flanks tapering to a rounded venter with indistinct shoulders. Maximum whorl width occurs on umbilical shoulders. Narrow umbilicus with high, overhanging wall and abruptly rounded shoulders. Or-

→

Fig. 97. *Pachyproptychites otoceratoides* (Diener, 1895) from AB1011. 1–5, NSM PM23241, ×1.0. 6–9, NSM PM23242, ×1.0.


1
2
3
4
5
6
7
8
9

namentation consists of very weak spiral lirae as well as fine, sinuous prorsiradiate growth lines. Suture ceratitic with wide ventral lobe divided by narrow, high median saddle into two branches with denticulations at each base. Lateral saddles high and slightly slanted toward umbilicus. First lateral lobe wide, deep with many denticulations at base, and second lateral lobe about two thirds depth of first lobe. Suspensive lobe includes discrete auxiliary lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23241	51.3	10.6	23.8	21.2	0.21	0.89
NSM PM23242	73.7	11.0	35.9	29.0	0.15	0.81

Occurrence: Described specimens from AB1011 within the upper *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: *Proptychites abrekensis*, described by Kiparisova (1961, p. 100) from Induan strata of the Abrek Bay area, has a shell shape and suture line that is similar to *Pachyproptychites otoceratoides*, and it almost certainly is conspecific.

The holotype of *P. otoceratoides* (Diener 1985, p. 36) was supposedly collected from Paris Bay on Russian Island, South Primorye, where Olenekian and Anisian strata are well exposed along the seacoast. However, as Vavilov and Zakharov (1976) have already pointed out, there have been no specimens of *P. otoceratoides* collected from this area other than by Diener (1895). Although this species does occur in the Induan of the Abrek Bay area, Induan strata have not been found in the type locality area (Zakharov, 1968; Markevich & Zakharov, 2004). The preservation of the holotype is very similar to that of specimens found in Induan deposits along the western coast of Ussuri Gulf. These inconsistencies certainly suggest that Diener may have been mistaken when recording the locality that yielded *P. otoceratoides*.

Fig. 98. Suture line of *Proptychites alterammonoides* (Krafft, 1909), NSM PM23243, from AB1013, at H=24 mm.

Genus ***Proptychites*** Waagen, 1895

Type species: *Ceratites lawrencianus* de Koninck, 1863.

Proptychites alterammonoides (Krafft, 1909)

Figs. 98, 99

Koninckites alterammonoides Krafft, 1909, p. 70, pl. 16, figs. 1, 2.
Aspidites crassus Krafft, 1909, p. 58, Pl. 8, fig. 1.

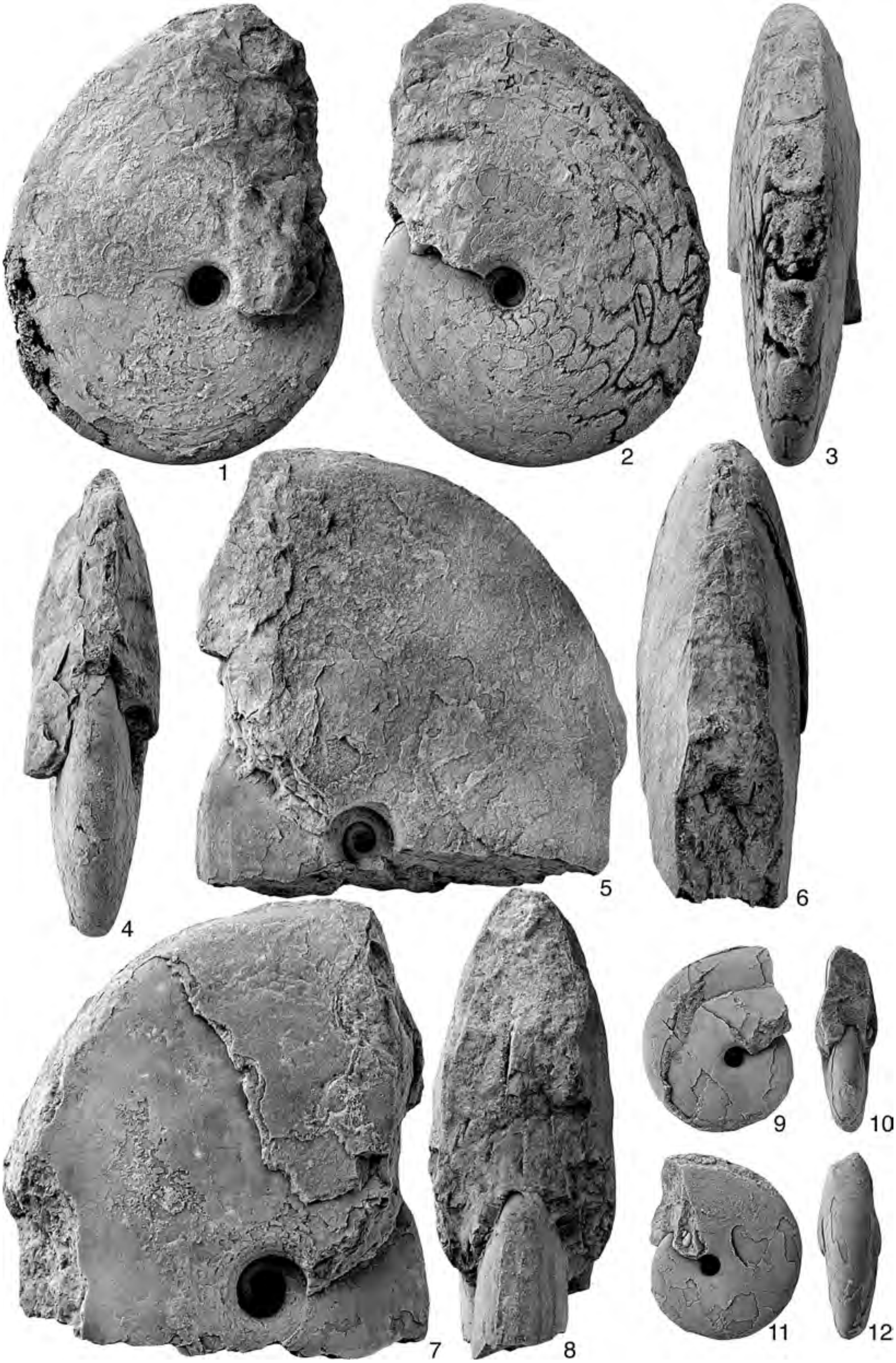
Lectotype: Specimen designated by Waterhouse (1996a, p. 67), is GSI 9451, original of Krafft (1909, p. 70, pl. 16, fig. 1) from the "*Meekoceras*" beds one mile north of Lilang, Spiti area, northwest Himalayan region.

Material examined: Three specimens, NSM PM23243–23245, from AB1013.

Description: Very involute, very compressed shell with elliptical whorl section, arched venter, rounded ventral shoulders and slightly convex flanks with maximum whorl width on inner flank at one fourth of whorl height. Narrow, deep umbilicus with high, vertical or overhanging wall and rounded shoulders. Ornamentation consists of very weak spi-

→

Fig. 99. *Proptychites alterammonoides* (Krafft, 1909) from AB1013. 1–4, NSM PM23243, ×1.0. 5–8, NSM PM23244, ×1.0. 9–12, NSM PM23245, ×1.0.


1
2
3
4
5
6
7
8
9
10
11
12

ral lirae on outer flank of juvenile shell as well as fine, sinuous growth lines. Suture ceratitic with wide ventral lobe divided by median saddle into two branches with denticulations at each base. Lateral saddles high and slightly slanted toward umbilicus. First lateral lobe wide, deep with many denticulations at base, and second lateral lobe about two thirds depth of first lobe. Suspensive lobe includes discrete auxiliary lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23243	65.6	6.0	37.8	19.4	0.09	0.51
NSM PM23244	43.2	5.3	23.3	14.0	0.12	0.60
NSM PM23245	25.2	3.9	13.7	8.0	0.15	0.58

Occurrence: Described specimens from AB1013 within the *Ambitoides fuliginatus* Zone (early Late Induan=early Dienerian) in the lowest part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species also occurs in the "*Meekoceras*" beds of the northwest Himalayan region (Krafft, 1909), which is correlated with the Late Induan (Dienerian) (Waterhouse, 2002).

Discussion: *Proptychites alterammonoides* is very close to several slender, very involute species of *Proptychites*, but differs by the position of maximum whorl width, which for this species, is at one fourth of whorl height versus a mid-flank position for *P. khoorensis* Waagen (1895, p. 176), *P. trilobatus* Waagen (1895, p. 178), and *P. subgrandis* Guex (1978, p. 108), and an umbilical shoulder position for *P. oldhamianus* Waagen (1895, p. 166), *P. tenuistriatum* (Krafft, 1909, p. 34), *P. markhami* Diener (1897, p. 75) and *P. chuluensis* Waterhouse (1996a, p. 68). *P. abundans* Waterhouse (1996a, p. 67) is similar in regard to its position of maximum whorl width, but it has thicker whorls. Although one of the illustrated specimens of *Aspidites crassus* Krafft (1909, p. 58, Pl. 8, fig. 1, GSI 9406) was drawn with rather thick whorls, it is actually more slender and is very much similar to this species. More than likely, it is conspecific.

Genus ***Paranorites*** Waagen, 1895

Type species: *Paranorites ambiensis* Waagen, 1895.

Paranorites varians (Waagen, 1895)

Figs. 100–102

Meekoceras varians Waagen, 1895, p. 247, pl. 29, figs. 2–5.

Lectotype: Designated by Waterhouse (1996a, p. 45), is GSI 7170, original of Waagen (1895, p. 247, pl. 29, fig. 2) from the Lower Ceratite Limestone of the Salt Range.

Material examined: Three specimens, NSM PM23246–23248, from AB1016, one specimen, NSM PM23250, from AB1019

Description: Moderately involute, very compressed shell with subrectangular whorl section, subtabulate venter, rounded ventral shoulders and parallel flanks with weak curvature at mid-flank. Umbilicus fairly narrow with moderately high, vertical wall and rounded shoulders. Ornamentation consists of very weak radial folds as well as fine, sinuous prorsiradiate growth lines. Suture ceratitic with first lateral saddle lower, narrower than second saddle, and second lateral saddle slightly slanted toward umbilicus. First lateral lobe wide, deep with many denticulations at base, and second lateral lobe about two thirds depth of first lobe. Suspensive lobe includes discrete auxiliary lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23246	39.0	8.6	20.7	10.6	0.22	0.51
NSM PM23247	42.0	8.9	22.3	10.8	0.21	0.48
NSM PM23248	77.3	15.6	37.9	17.9	0.20	0.47
NSM PM23250	108.1	23.5	50.1	28.6	0.22	0.57

Occurrence: Described specimens from *Paranorites varians* Zone (AB1016 and AB1019, Late Induan=Dienerian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species also occurs in the Lower Ceratite Limestone of the Salt Range (Waagen, 1895).

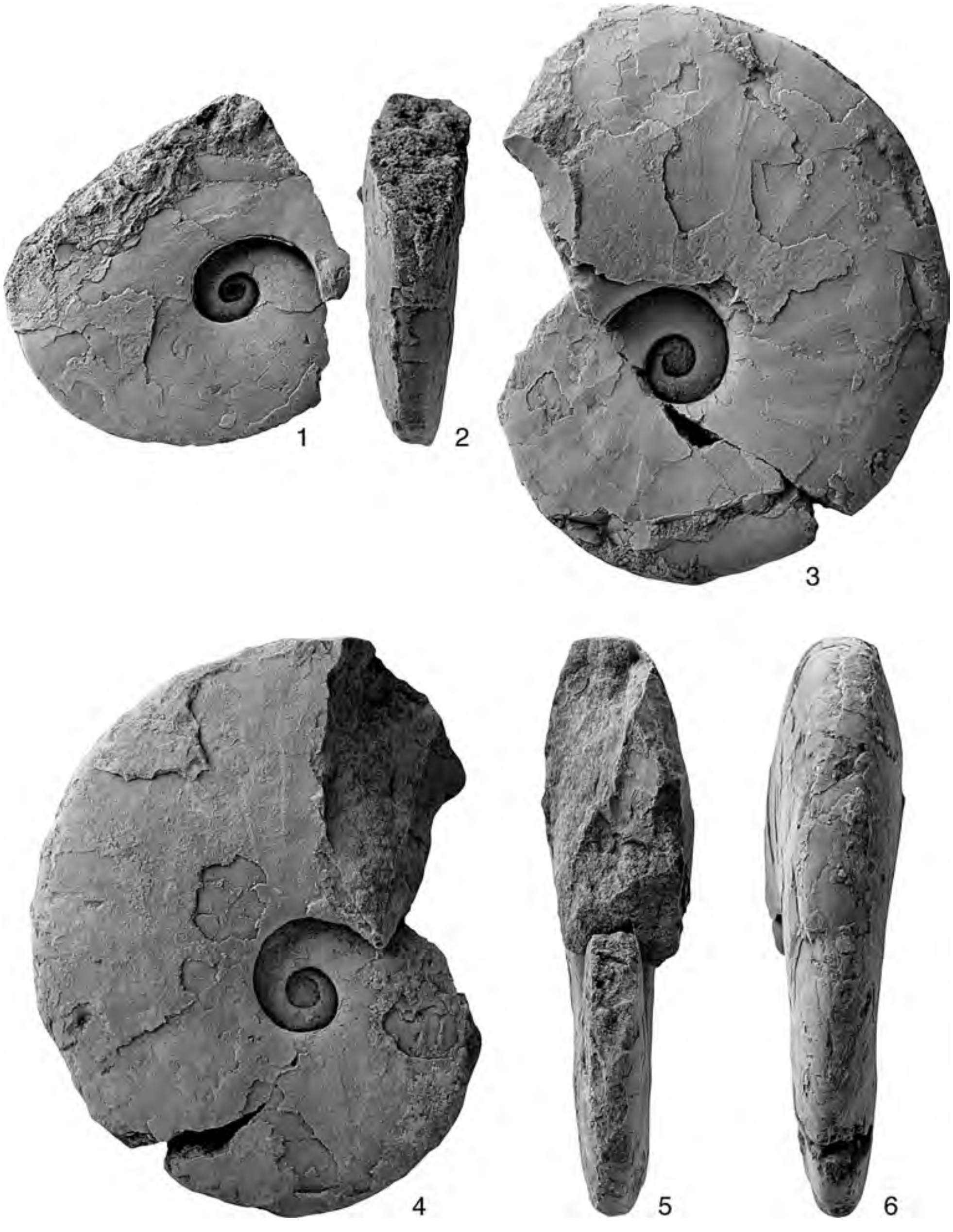


Fig 100. *Paranorites varians* (Waagen, 1895) from AB1016. 1–2, NSM PM23247, ×1.0. 3–6, NSM PM23248, ×1.0.

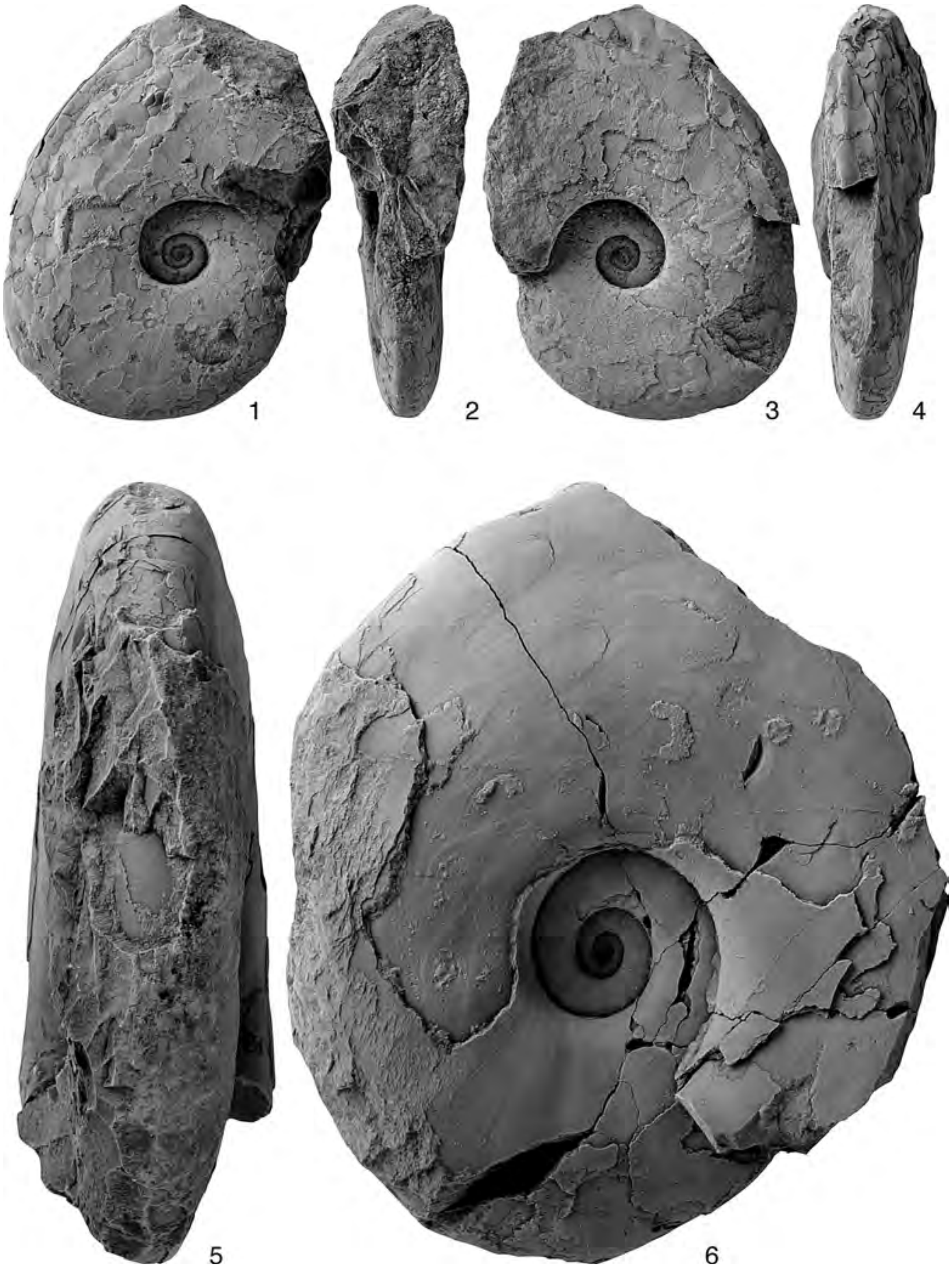


Fig. 101. *Paranorites varians* (Waagen, 1895). 1–4, NSM PM23246, from AB1016, ×1.0. 5–6, NSM PM23250, from AB1019, ×1.0.

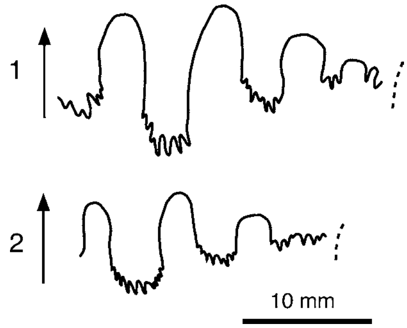


Fig. 102. Suture lines of *Paranorites varians* (Waagen, 1895) from AB1016. 1, NSM PM23248, at H=21 mm. 2, NSM PM23247, at H=21 mm.

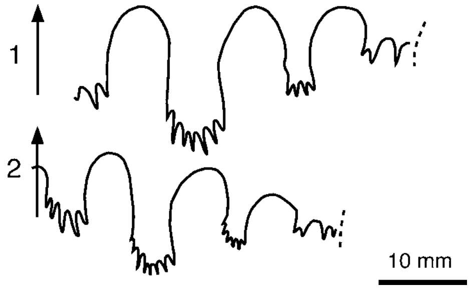


Fig. 103. Suture lines of *Kummelia*? sp. indet., NSM PM23249, from AB1019. 1, at H=41 mm. 2, at H=34 mm.

Discussion: Although the opposite side of the holotype (GSI 7170) is partly weathered away, it is apparent from Waagen's hand-drawn illustration (1895, pl. 29, fig. 2) that the specimen was reconstructed with its whorl section much too wide (W/H=0.65). The actual comparison of whorl width and height is given as 0.53 (Waagen, 1895, p. 249), which is very similar to our described specimens.

This species was originally described as *Meekoceras* Hyatt, 1879 by Waagen (1895, p. 247), but the slender, moderately involute shell with its subtabulate venter and vertical umbilical wall leads us to assign this species to *Paranorites*, as already suggested by Waterhouse (1996a, p. 44).

Genus ***Kummelia*** Waterhouse, 1996a

Type species: *Paranorites kummeli* Bando, 1981.

Kummelia? sp. indet.

Figs. 103–105

Material examined: NSM PM23249 from AB1019.

Description: Quite large, moderately involute, fairly compressed shell with elliptical whorl section and rounded venter with rounded ventral shoulders. Flanks convex with maximum whorl width varying from mid-flank to one third of whorl height. Fairly narrow umbilicus with moderately high, vertical wall and rounded shoulders. Ornamentation consists of weak radial folds only on middle growth stage as well as fine, sinuous, fairly rusiradiate growth lines. Suture ceratitic with moderately developed auxiliaries, and wide ventral lobe divided by median saddle into two branches with denticulations at each base. First lateral saddle highest, second saddle slanted slightly toward umbilicus, and third saddle lower. First lateral lobe wide, deep with many denticulations at base, and second lateral lobe about two thirds depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23249	106.8	30.3	43.6	31.6	0.28	0.72

Occurrence: Described specimens from *Paranorites varians* Zone (AB1019, late Late Induan=late Dienerian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: The assignment of the specimen to *Kummelia* is uncertain, and it based only on the similarity of its morphology with *Kummelia*. It is very close to *Kummelia kummeli* (Bando, 1981, p. 155), which is the type species of the genus, but differs by its wider

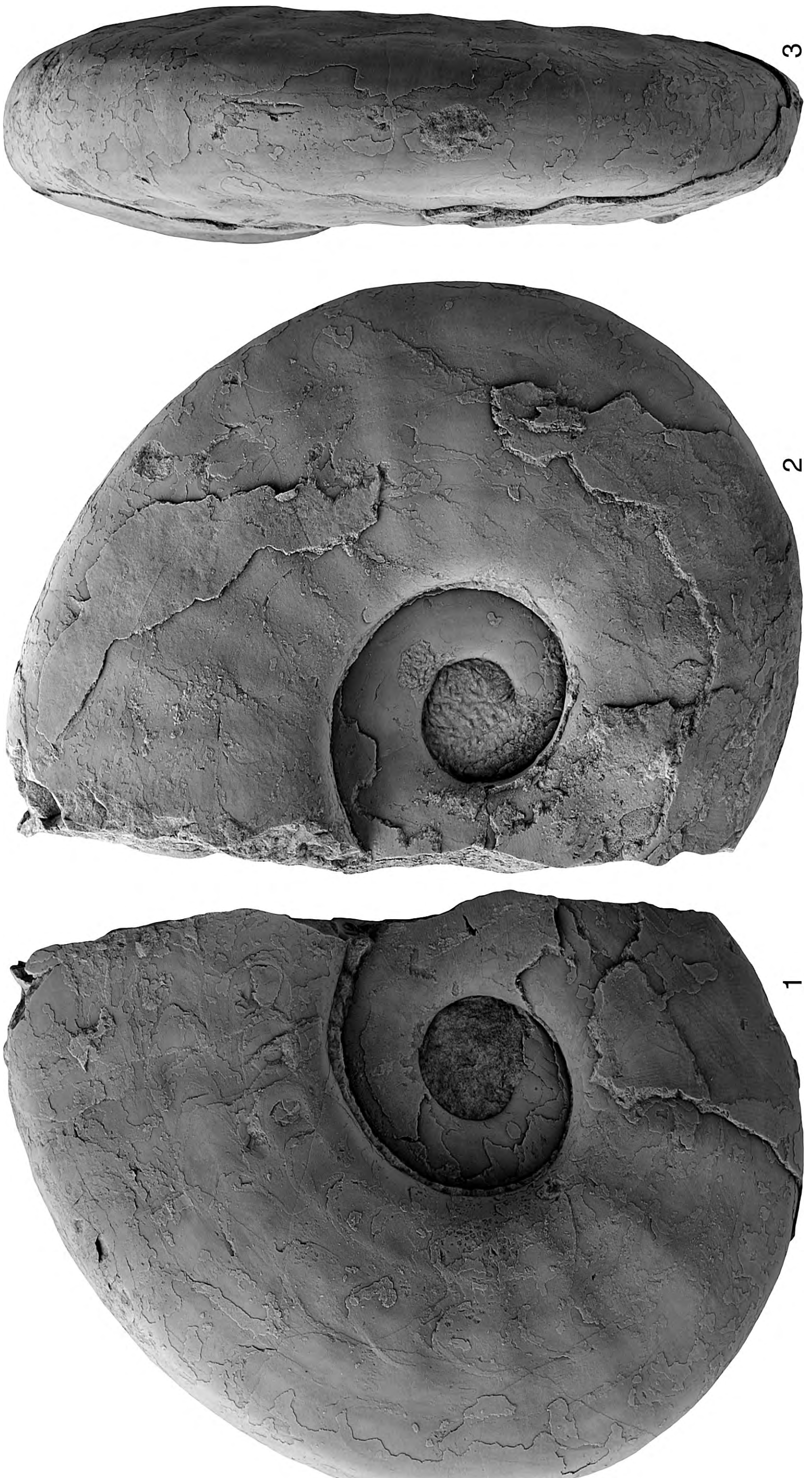


Fig. 104. *Kummelia*? sp. indet. from AB1019. 1–3, NSM PM23249, ×1.0.

Fig. 105. *Kummelia*? sp. indet., NSM PM23249, from AB1019, ×1.0.

venter and the presence of radial folds on the middle growth stage.

Family Arctoceratidae Arthaber, 1911

Genus ***Arctoceras*** Hyatt, 1900

Type species: *Ceratites polaris* Mojisisovics, 1886.

Arctoceras septentrionale (Diener, 1895)

Figs. 106, 107

Meekoceras (*Koninckites*) *septentrionale* Diener, 1895, p. 53, pl. 1, fig. 1.

Discoproptychites septentrionalis (Diener). Kiparisova, 1956, p. 77.

Proptychites (*Discoproptychites*) *septentrionale* (Diener). Kiparisova, 1961, p. 103, pl. 23, figs. 1–4, text-figs. 63–65.

Submeekoceras ussuriense Kiparisova, 1961, p. 73, pl. 14, fig. 1, text-fig. 34.

Proptychites (*Discoproptychites*) *prynadai* Burij, 1962, p. 87, pl. 3, figs. 1, 2, text-fig. 5.

Arctoceras septentrionale (Diener). Zakharov, 1968, p. 75, pl. 8, fig. 4, pl. 9, figs. 1, 2, pl. 10, figs. 1–4, text-fig. 14.

Arctoceras aff. *septentrionale* (Diener). Zakharov, 1968, p. 78, pl. 11, figs. 1, 2, pl. 12, fig. 1.

Holotype: CGM 71/596, figured by Diener (1895, p. 53, pl. 1, fig. 1), from the Lower Triassic of Ajax Bay on Russian Island, South Primorye, Russia.

Material examined: Two specimens, NSM PM23251, 23252, from AB1022, one specimen, NSM PM23253, from AB1024, two specimens, NSM PM23254, 23255, from AB1025.

Description: Fairly involute, fairly compressed shell with elliptical whorl section, arched venter, indistinct ventral shoulders, and slightly convex flanks with maximum whorl width at mid-flank. Narrow umbilicus with moderately high, vertical wall and abruptly rounded or subangular shoulders. Ornamentation consists of very weak spiral lirae on outer flanks as well as weak radial folds and fine, sinuous prorsiradiate growth lines. Suture ceratitic with wide ventral lobe divided by median saddle into two branches with denticulation at each base. First lateral saddle higher than second saddle, and third saddle lower. First lateral lobe deep, wide with many strong denticulations at base, and second lateral lobe shallower than first lobe with few denticulations. Suspensive lobe includes discrete auxiliary lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23251	20.2	5.0	9.3	6.4	0.25	0.69
NSM PM23252	27.0	6.3	13.0	9.3	0.23	0.72
NSM PM23253	45.2	7.5	23.7	13.3	0.17	0.56
NSM PM23254	42.1	7.5	20.2	12.0	0.18	0.59
NSM PM23255	66.2	11.4	34.8	–	0.17	–

Occurrence: Described specimens from AB1022, AB1024 within the *Clypeoceras timorense* Zone and from AB1025 within the *Radioprionites abrekensis* “bed”, early Early Olenekian (early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species also occurs frequently in the lower part of the *Owenites koeneni* Zone and the *Hedenstroemia bosphorensis* Zone of South Primorye (Zakharov, 1968; Markevich & Zakharov, 2004).

Fig. 106. Suture line of *Arctoceras septentrionale* (Diener, 1895), NSM PM23252, from AB1022, at H=10 mm.

Discussion: *Arctoceras septentrionale* is the type species of *Discoproptychites* Kiparisova, 1956, but the genus was later synonymized with *Arctoceras* by Zakharov (1978), Tozer (1981) and Shevyrev (1986). Later, Waterhouse (1996a, p. 88) indicated that the sutures, as represented by Kiparisova (1956) and Diener (1895), exhibit a well-developed second lateral lobe with many strong denticulations, unlike the constricted paucidenticulate second lateral lobe of typical *Arctoceras*, and suggested that *Discoproptychites* is not the same as *Arctoceras*. However, Kummel (1961) illustrated the suture line of several specimens of *A. tuberculatum* (Smith, 1932), and each suture includes a well-developed second lateral lobe very much like the figures in Kiparisova (1956) and Diener (1895). Therefore, the suggestion of Waterhouse (1996a) must be rejected.

Submeekoceras ussuriense Kiparisova (1961, p. 73) and *Proptychites* (*Discoproptychites*) *prynadai* Burij (1962, p. 87), which were both collected from Golyj Cape (=Kom-Pikho-Sakho Cape), South Primorye, are very close to adult specimens of *A. septentrionale* (Diener) and are probably conspecific.

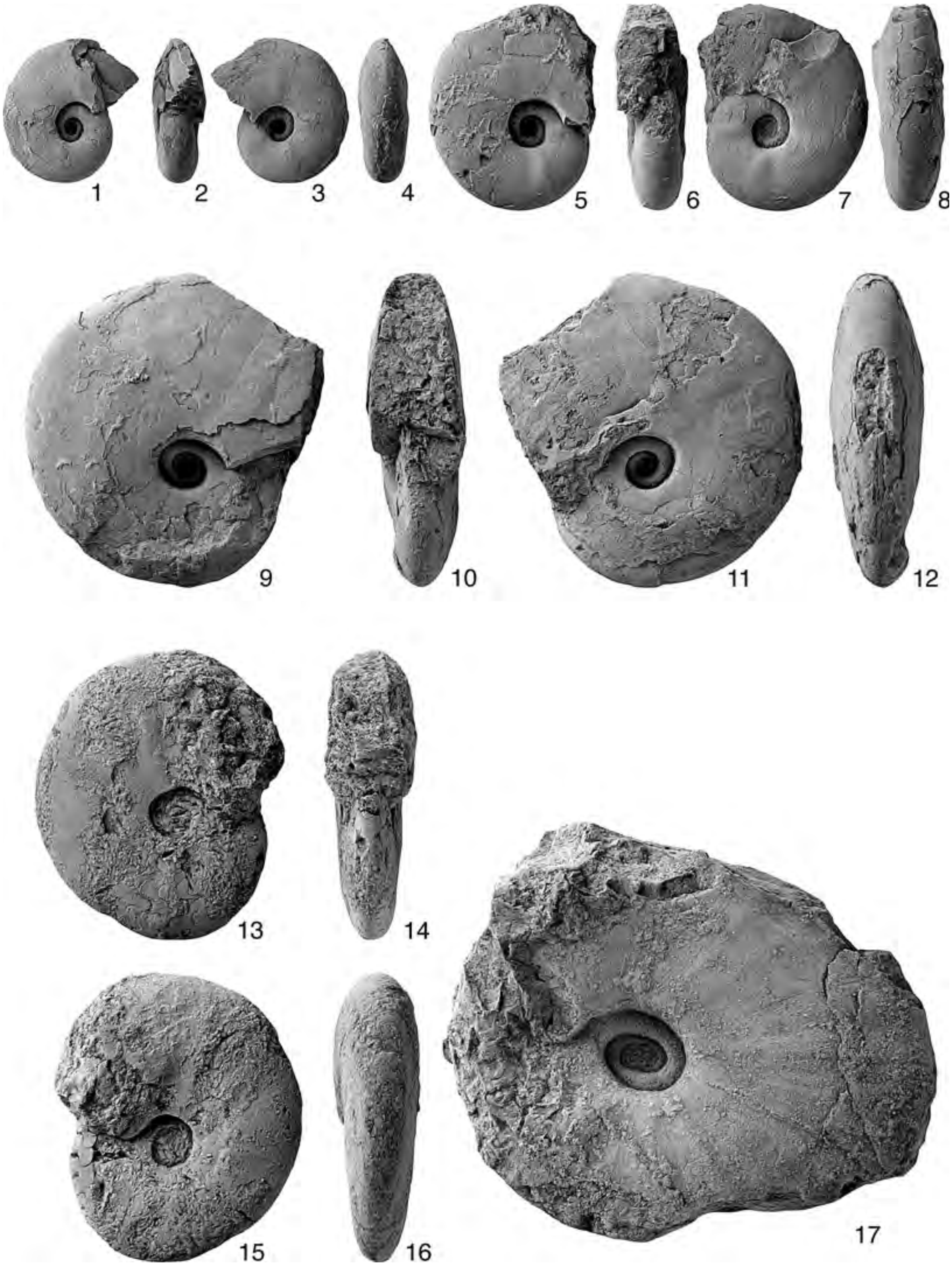


Fig. 107. *Arctoceras septentrionale* (Diener, 1895). 1–4, NSM PM23251, from AB1022, ×1.0. 5–8, NSM PM23252, from AB1022, ×1.0. 9–12, NSM PM23253, from AB1024, ×1.0. 13–16, NSM PM23254, from AB1025, ×1.0. 17, NSM PM23255, from AB1025, ×1.0.

Arctoceras subhydaspis (Kiparisova, 1961)

Figs. 108–112

Paranorites subhydaspis Kiparisova, 1961, p. 89, pl. 18, fig. 1, text-fig. 48.

Paranorites labogensis Zharnikova, 1962, p. 85, pl. 2, fig. 1, text-fig. 4.

Arctoceras labogense (Zharnikova). Zakharov, 1968, p. 78, pl. 12, figs. 2, 3, text-figs. 15a, 16a–d.

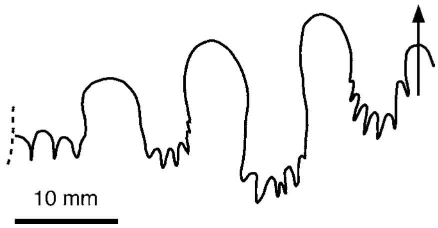


Fig. 108. Suture line of *Arctoceras subhydaspis* (Kiparisova, 1961), NSM PM23256, from AB1027, at H=35 mm.

Holotype: CGM 84/5504, figured by Kiparisova (1961, p. 89, pl. 18, fig. 1), from the Lower Triassic of the Abrek Bay area in South Primorye.

Material examined: Three speciems, NSM PM23256–23258, from AB1027.

Description: Fairly large, moderately evolute shell with ovoid whorl section, rounded venter, rounded ventral shoulders and convex flanks with maximum whorl width at mid-flank. Umbilicus moderately wide with moderately high, vertical wall and abruptly rounded shoulders with prominent tubercles. Ornamentation consists of weak radial folds on juvenile whorls and distant, radial, sinuous, fold-like ribs on adult whorls as well as clearly visible very fine, sinuous, prorsiradiate growth lines and very weak spiral lirae on outer flanks. Suture ceratitic with wide ventral lobe divided by median saddle into two branches with many denticulations at each base. First lateral saddle higher than second saddle, and third saddle even lower. First lateral lobe deep, wide with many strong denticulations at base, and second lateral lobe shallower than first lobe. Suspensive lobe includes discrete auxiliary lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23256	–	–	40.6	25.0	–	0.62
NSM PM23257	–	–	60.7	40.0	–	0.66
NSM PM23258	175.0	63.5	67.0	43.4	0.36	0.65

Occurrence: Described specimens from *Arctoceras subhydaspis* “bed” (AB 1027, middle Early Olenekian=middle Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye. *A. subhydaspis* frequently occurs above the *Arctoceras septentrionale* Zone in South Primorye (Zakharov, 1968; Markevich & Zakharov, 2004).

Discussion: *Arctoceras subhydaspis* was originally described as *Paranorites* Waagen, 1895 by Kiparisova (1961), but its umbilical tuberculation justifies its assignment to the genus *Arctoceras*. It is very similar to *A. labogense* (Zharnikova, 1962, p. 85) from the Lower Olenekian of South Primorye, but Zharnikova (1962) maintained that the rib strength is different on the adult shell of each species. However, this difference is barely perceptible and is probably due to intraspecific variation. Therefore, *A. labogense* is synonymized with *A. subhydaspis* on the basis of their similar shell morphology.

This species is very close to *A. tuberculatum* (Smith, 1932, p. 62), but differs by its wider umbilicus. *A. gigas* Tozer (1994, p. 75) is also close, but is more evolute.

The juvenile shell of *A. subhydaspis* is very similar to *A. septentrionale* (Diener, 1895, p. 53), which is always found stratigraphicaly below it (Markevich & Zakharov, 2004), and thus, both species probably belong to the same evolutionary lineage.

Family Clypeoceratidae Waterhouse, 1996a

Genus ***Clypeoceras*** Smith, 1913

Type species: *Aspidites superbus* Waagen, 1895.

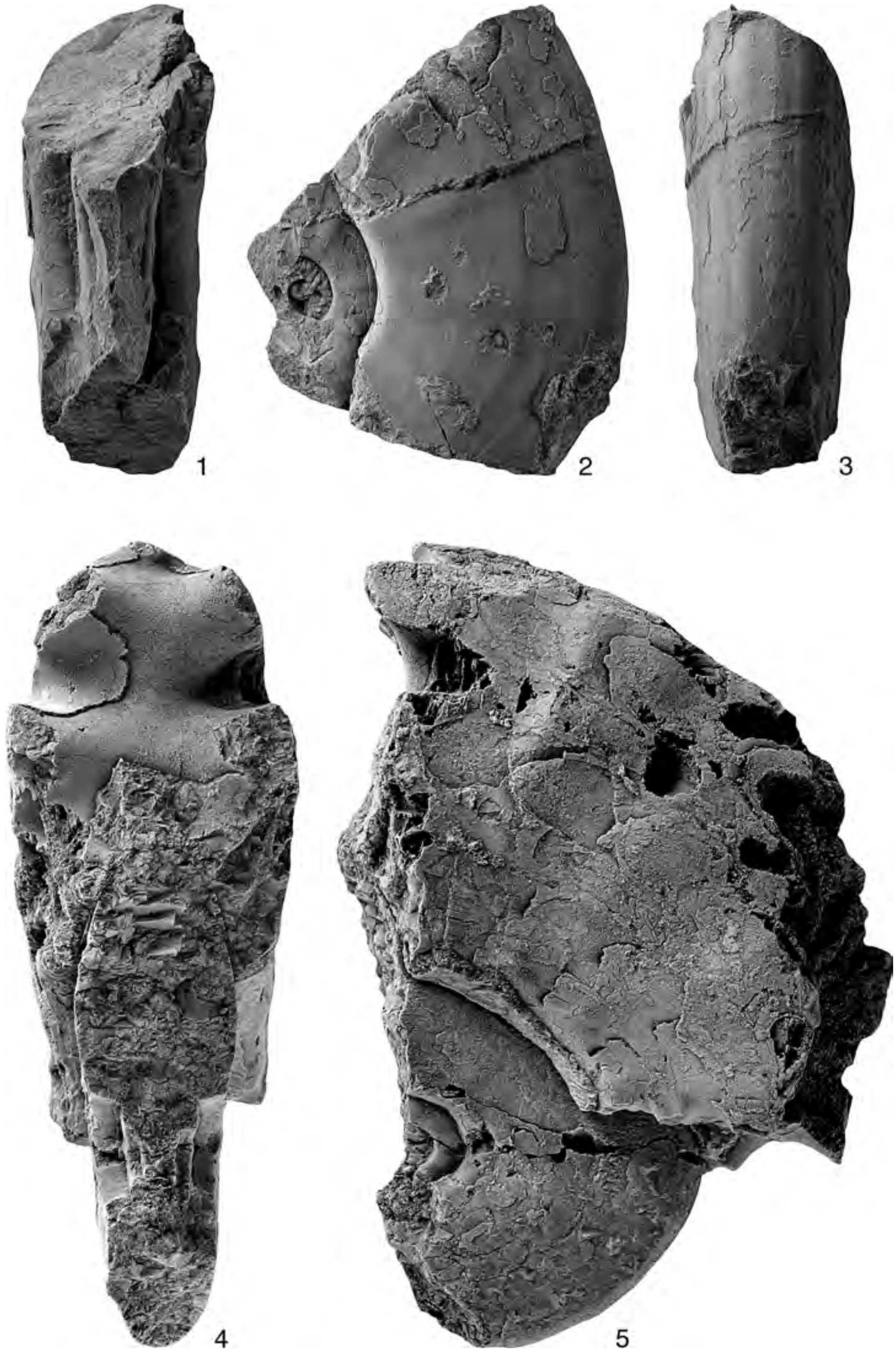


Fig. 109. *Arctoceras subhydaspis* (Kiparisova, 1961) from AB1027. 1–3, NSM PM23256, ×1.0. 4–5, NSM PM23257, ×1.0.

Fig. 110. *Arctoceras subhydaspis* (Kiparisova, 1961), NSM PM23258, from AB1027, ×0.9.

Fig. 111. *Arctoceras subhydaspis* (Kiparisova, 1961). 1–2, NSM PM23258, from AB1027, ×0.9.

Fig. 112. *Arctoceras subhydaspis* (Kiparisova, 1961), NSM PM23258, from AB1027, ×0.9.

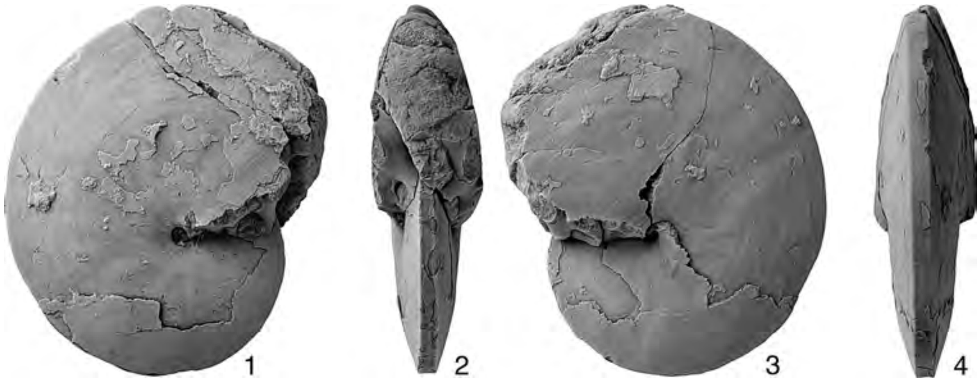


Fig. 113. *Clypeoceras spitiense* (Krafft, 1909). 1–4, NSM PM23259, from AB1014, ×1.0.

Clypeoceras spitiense (Krafft, 1909)

Figs. 113, 114

Aspidites spitiensis Krafft, 1909, p. 54, pl. 4, figs. 4, 5, pl. 16, figs. 3–8.

Clypeoceras spitiense (Krafft). Waterhouse, 1996a, p. 50, pl. 2, figs. 21, 22, text-fig. 4j.

Lectotype: Designated by Waterhouse (1996a, p. 50), GSI 9391, original of Krafft (1909, p. 54, pl. 4, fig. 4) from the "*Meekoceras*" beds, five miles south of Ensa, Spiti area, northwest Himalayan region.

Material examined: NSM PM23259, from AB1014.

Description: Very involute, very compressed shell, with narrow tabulate venter, angular ventral shoulders and gently convex flanks with maximum whorl width at midflank. Very narrow, nearly occluded umbilicus with low, oblique wall and rounded shoulders. Ornamentation consists of weak radial folds on inner flank and fine, sinuous prorsiradiate growth lines. Suture ceratitic with wide ventral lobe divided by median saddle into two branches with many denticulations at each base. Lateral saddles elongated, and second saddle slanted slightly toward umbilicus. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe about two thirds depth of first lobe. Suspensive lobe includes numerous, poorly differentiated auxiliaries.

Fig. 114. Suture line of *Clypeoceras spitiense* (Krafft, 1909), NSM PM23259, from AB1014, at H=21 mm.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23259	47.1	0.6	29.7	12.0	0.01	0.40

Occurrence: Described specimen from *Clypeoceras spitiense* "bed" (AB1014, early Late Induan=early Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species also occurs in the "*Meekoceras*" beds of the northwest Himalayan region (Krafft, 1909), which is correlatable with the Upper Induan (Dienerian) (Waterhouse, 2002).

Discussion: Although the described specimen shares a similar shell morphology with the lectotype of *Clypeoceras spitiense* (Krafft, 1909), there are a few differences in their suture lines. The first lateral saddle of our specimen is more slender than that of the lectotype (Krafft, 1909, pl. 4, fig. 4c), and the second lateral saddle is slanted slightly toward the umbilicus. However, Krafft (1909) illustrated very similar saddles for other specimens of *C. spitiense* (e.g., GSI 9457, pl. 16, fig. 7). Therefore, it seems reasonable that we identify our specimen as *C. spitiense*.

Clypeoceras timorense (Wanner, 1911)

Figs. 115–124

Meekoceras timorense Wanner, 1911, p. 185, pl. 6, figs. 2, 3, pl. 7, figs. 5, 6, text-fig. 2; Welter, 1922, p. 129.

Koninckites timoresis (Wanner). Spath, 1934, p. 156; Kiparisova, 1947b, p. 136, pl. 29, fig. 4, pl. 30, fig. 2, text-fig. 20; Kiparisova, 1961, p. 82, pl. 16, figs. 2–4, 6, text-figs. 39–42; Zakharov, 1968, p. 89, pl. 17, figs. 1–3, text-fig. 20a.

Lectotype: Designated by Spath (1934, p. 156), is original of Wanner (1911, p. 185, pl. 6, fig. 2) from the "*Meekoceras*" beds of Nifoekoko, Timor.

Material examined: Eighteen specimens, NSM PM23260–22277, from AB1021, one specimen, NSM PM23278, from AB1022, three specimens, NSM PM23279–23281, from AB1024.

Description: Fairly large, very involute, very compressed shell with narrow, highly variable (concave, bicarinate or tabulate) venter with angular shoulders on juvenile whorls, becoming subtabulate with abruptly rounded shoulders on mature whorls. Flanks gently convex with maximum width at mid-flank. Narrow umbilicus with moderately high, vertical or overhanging wall and abruptly rounded shoulders. Ornamentation consists of weak radial folds as well as fine, sinuous prorsiradiate growth lines. Suture ceratitic with wide ventral lobe divided by median saddle into two branches with many denticulations at base. First lateral saddle subphylloid and smaller than second saddle. First lateral lobe narrow, deep with many denticulations at base, and second lateral lobe about two thirds depth of first lobe. Suspensive lobe includes numerous, well differentiated auxiliaries.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23260	14.2	1.9	7.9	3.9	0.13	0.49
NSM PM23261	21.2	2.4	11.4	4.3	0.11	0.38
NSM PM23262	20.1	2.4	11.5	4.9	0.12	0.42
NSM PM23263	18.6	2.2	10.4	4.9	0.12	0.47
NSM PM23264	24.0	2.2	13.4	6.1	0.09	0.46
NSM PM23265	30.3	3.4	16.7	7.7	0.11	0.46
NSM PM23266	31.5	2.6	17.2	7.9	0.08	0.46
NSM PM23267	26.0	2.0	14.5	6.4	0.08	0.44
NSM PM23268	45.0	5.5	23.0	10.0	0.12	0.43
NSM PM23269	44.1	4.6	23.7	11.7	0.10	0.49
NSM PM23270	47.8	4.9	25.6	12.4	0.10	0.48
NSM PM23271	51.2	5.6	27.0	11.5	0.11	0.43
NSM PM23272	50.0	5.5	25.4	14.0	0.11	0.55
NSM PM23273	91.2	13.8	43.8	22.3	0.15	0.51
NSM PM23274	29.8	2.9	16.5	6.5	0.10	0.39
NSM PM23275	63.9	7.0	34.4	17.0	0.11	0.49
NSM PM23276	112.0	17.2	52.3	27.5	0.15	0.53
NSM PM23277	28.3	2.6	15.2	6.2	0.09	0.41
NSM PM23278	56.5	4.9	30.0	11.2	0.09	0.37
NSM PM23279	54.1	5.2	29.2	12.0	0.10	0.41
NSM PM23280	66.5	5.7	35.8	13.5	0.09	0.41

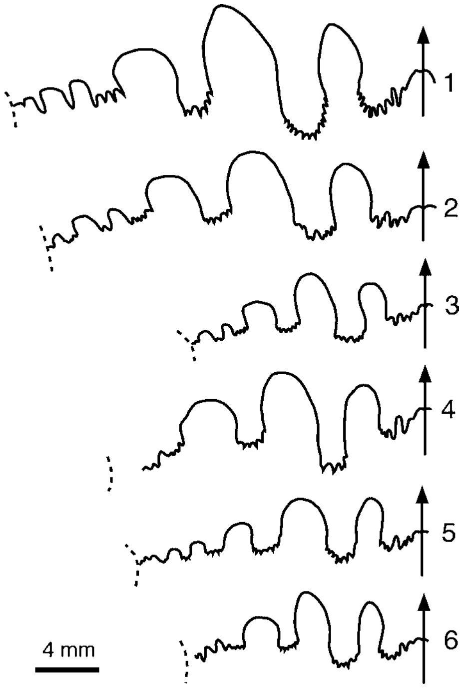


Fig. 115. Suture lines of *Clypeoceras timorense* (Wanner, 1911) from AB1021. 1, NSM PM23270, at H=26 mm. 2, NSM PM23269, at H=24 mm. 3, NSM PM23269, at H=16 mm. 4, NSM PM23271, at H=20 mm. 5, NSM PM23265, at H=18 mm. 6, NSM PM23274, at H=15 mm.

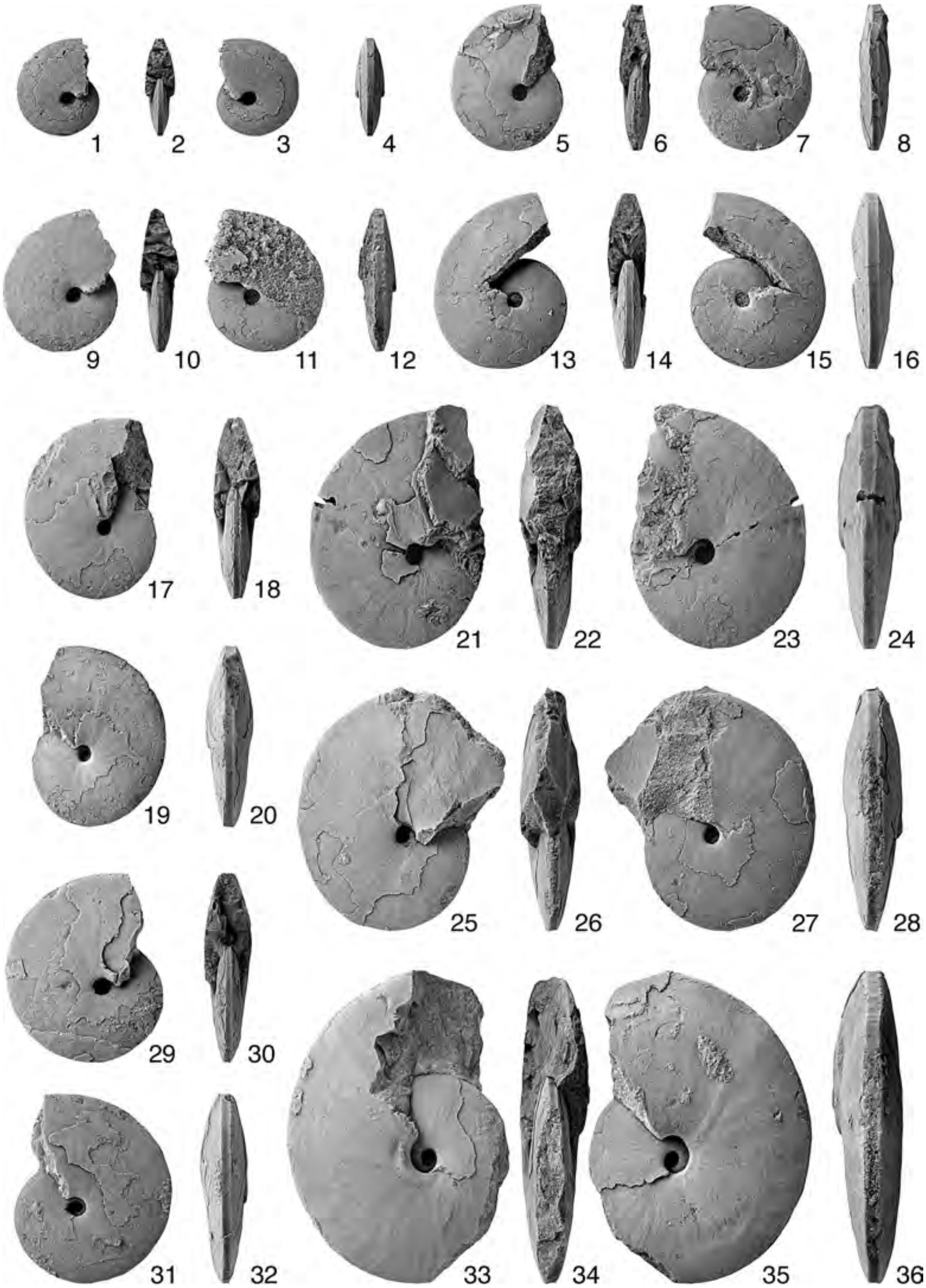


Fig. 116. *Clypeoceras timorense* (Wanner, 1911) from AB1021. 1–4, NSM PM23260, ×1.0. 5–8, NSM PM23261, ×1.0. 9–12, NSM PM23262, ×1.0. 13–16, NSM PM23263, ×1.0. 17–20, NSM PM23264, ×1.0. 21–24, NSM PM23265, ×1.0. 25–28, NSM PM23266, ×1.0. 29–32, NSM PM23267, ×1.0. 33–36, NSM PM23268, ×1.0

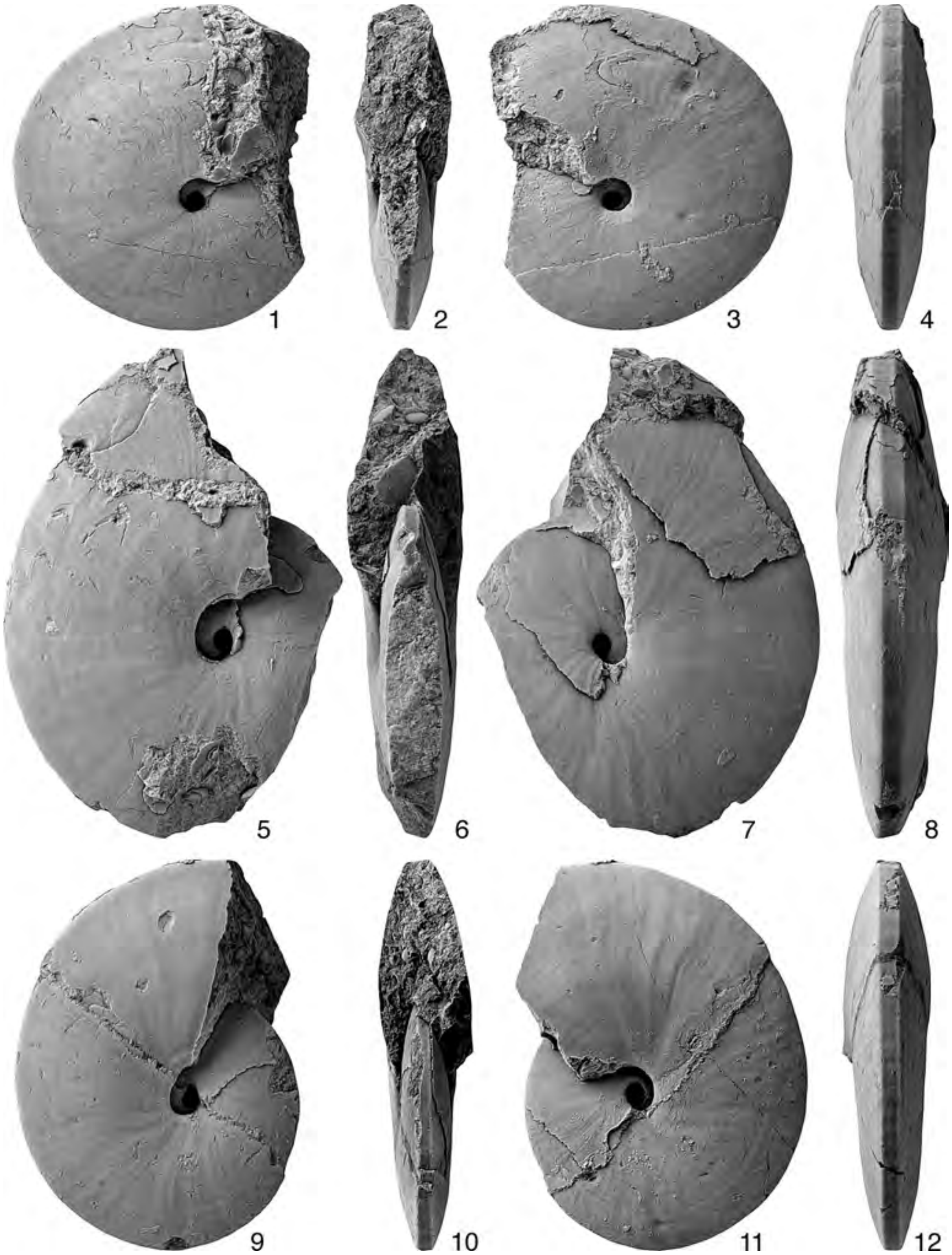
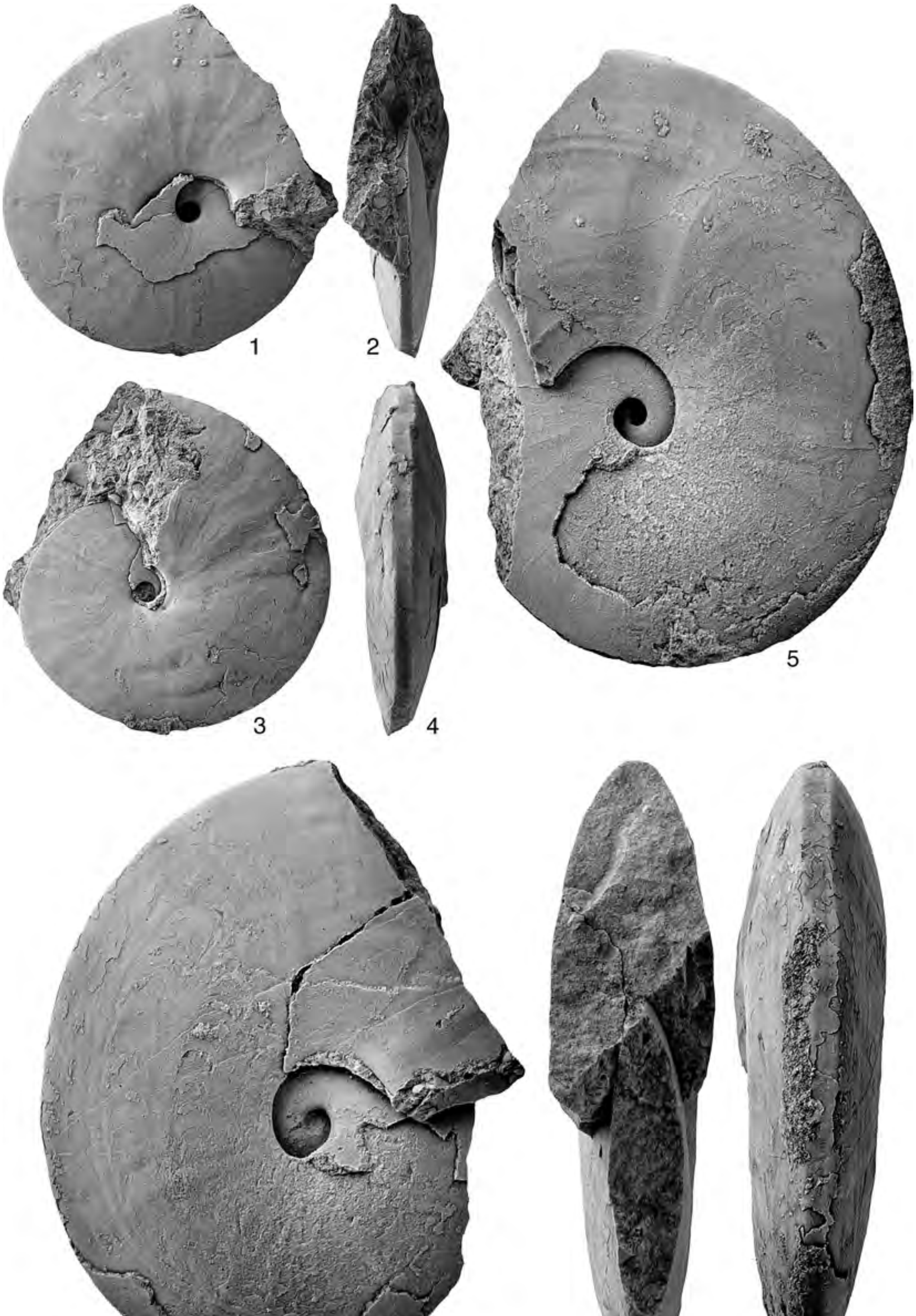


Fig. 117. *Clypeoceras timorense* (Wanner, 1911) from AB1021. 1–4, NSM PM23269, ×1.0. 5–8, NSM PM23270, ×1.0. 9–12, NSM PM23271, ×1.0.

→

Fig. 118. *Clypeoceras timorense* (Wanner, 1911) from AB1021. 1–4, NSM PM23272, ×1.0. 5–8, NSM PM23273, ×1.0.


1
2
3
4
5
6
7
8

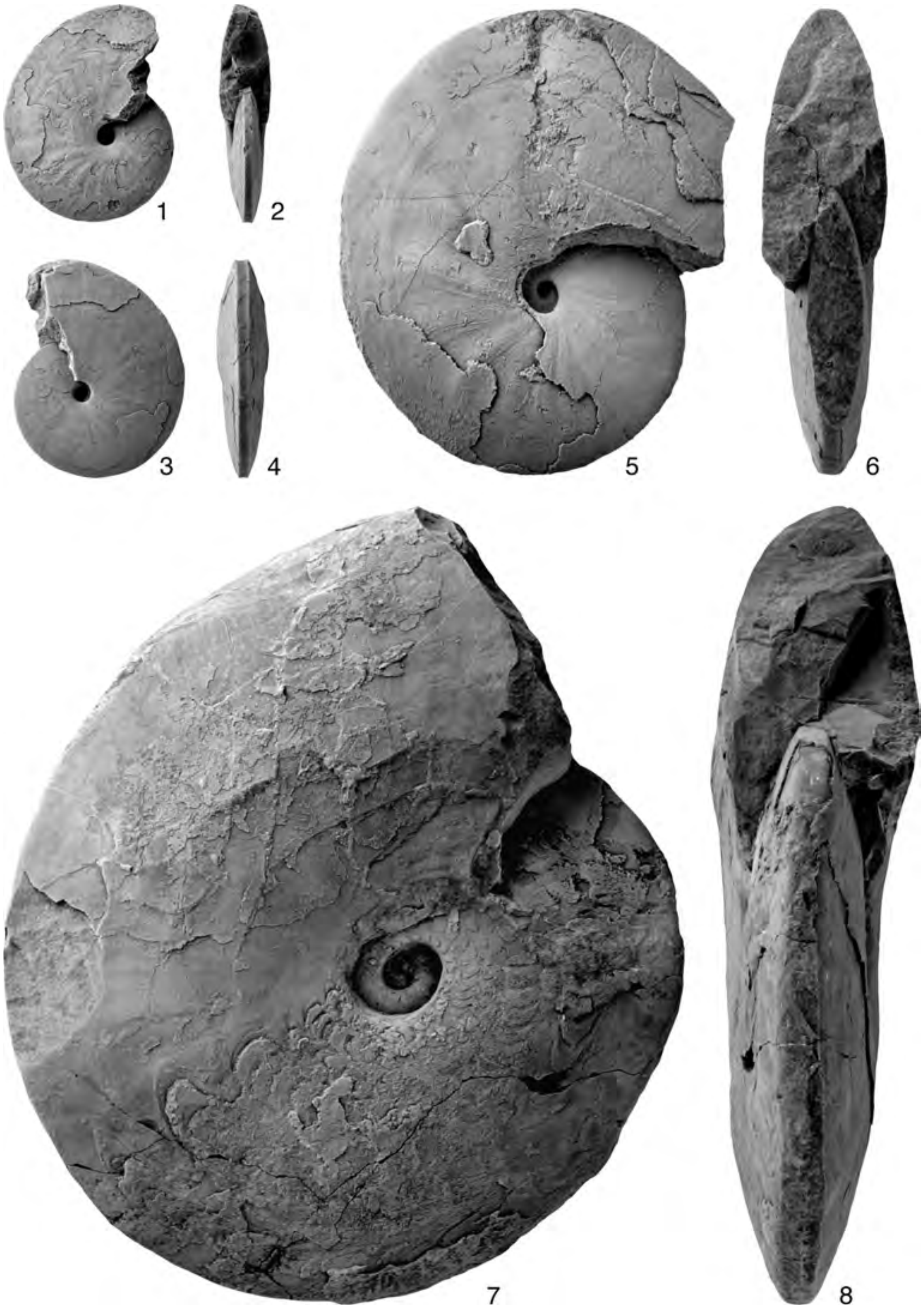


Fig. 119. *Clypeoceras timorense* (Wanner, 1911) from AB1021. 1–4, NSM PM23274, ×1.0. 5–6, NSM PM23275, ×1.0. 7–8, NSM PM23276, ×1.0.

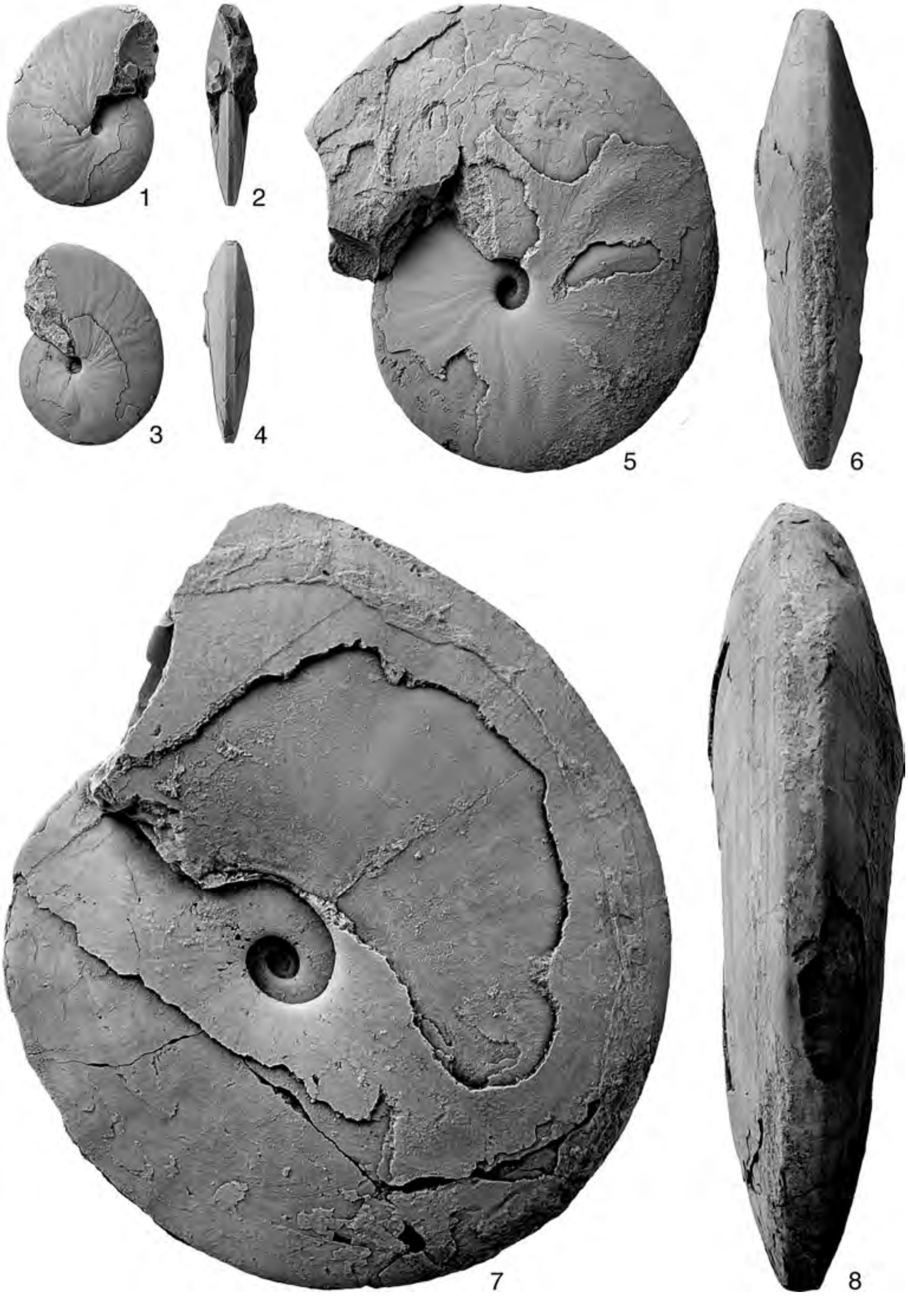


Fig. 120. *Clypeoceras timorense* (Wanner, 1911) from AB1021. 1–4, NSM PM23277, ×1.0. 5–6, NSM PM23275, ×1.0. 7–8, NSM PM23276, ×1.0.

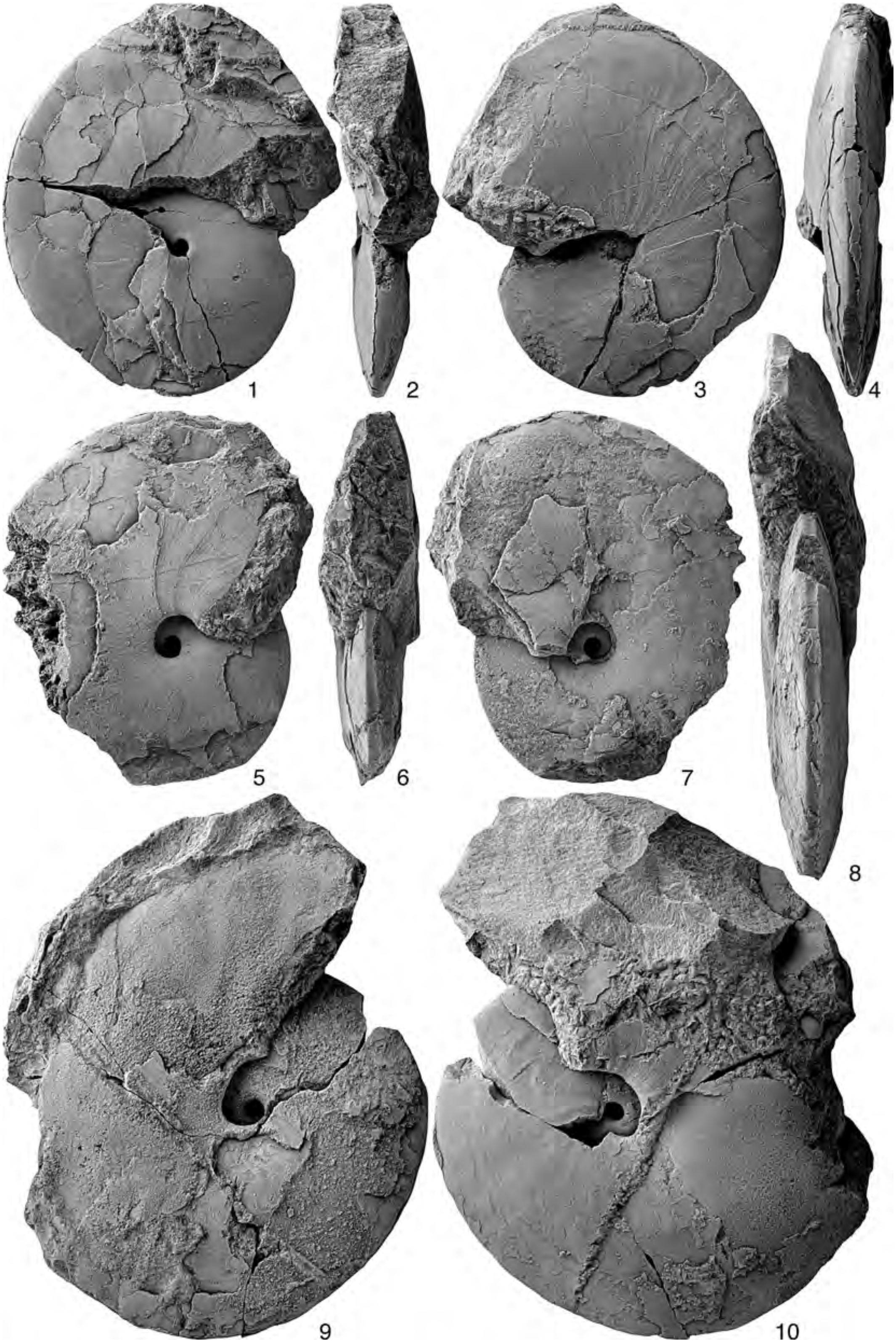

1
2
3
4
5
6
7
8
9
10

Fig. 122. *Clypeoceras timorense* (Wanner, 1911), NSM PM23281, from AB1024, ×0.9.

←
Fig. 121. *Clypeoceras timorense* (Wanner, 1911). 1–4, NSM PM23278, from AB1022, ×1.0. 5–7, NSM PM23279, from AB1024, ×1.0. 8–10, NSM PM23280, from AB1024, ×1.0.

Fig. 123. *Clypeoceras timorense* (Wanner, 1911). 1–2, NSM PM23281, from AB1024, ×0.9.

Fig. 124. *Clypeoceras timorense* (Wanner, 1911), NSM PM23281, from AB1024, ×0.9.

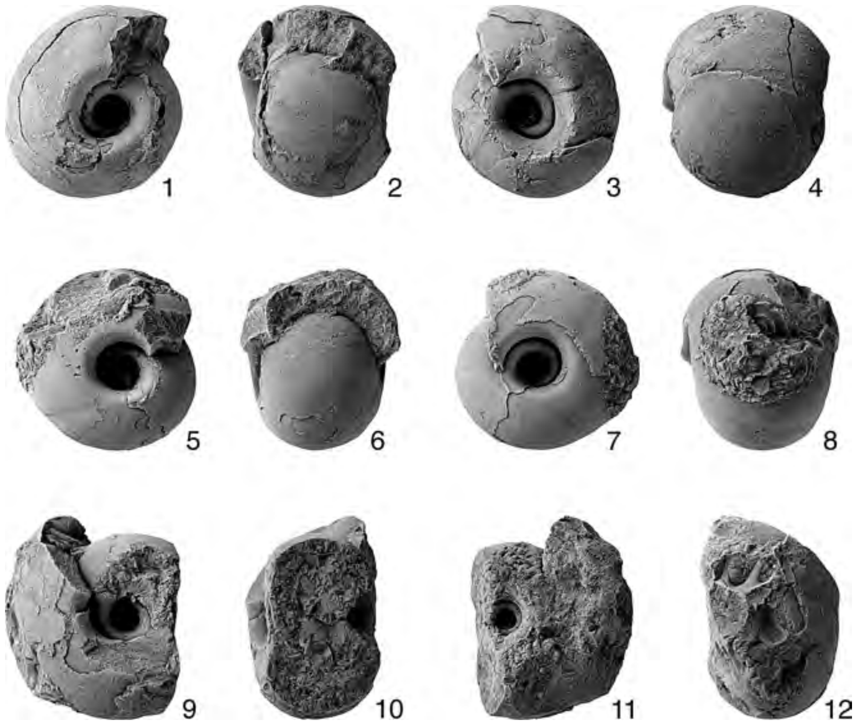


Fig. 125. *Prosphingitoides* sp. indet. 1–4, NSM PM23282, from AB1027, ×1.5. 5–8, NSM PM23283, from AB1022, ×1.5. 9–12, NSM PM23284, from AB1022, ×1.5.

NSM PM23281	142.0	19.0	77.3	35.0	0.13	0.45

Occurrence: Described specimens from AB1021, AB1022 and AB1024 within the *Clypeoceras timorense* Zone (early Early Olenekian = early Smithian) of the main part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species is abundant in the *Hedenstroemia bosphorensis* Zone on the western coast of Ussuri Gulf, near Tri Kamnya Cape, South Primorye (Zakharov, 1968; Markevich & Zakharov, 2004), and in the "*Meekoceras*" beds of Timor (Wanner, 1911; Spath, 1934), which are correlatable with the early Early Olenekian (early Smithian).

Discussion: Spath (1934, p. 156) changed the generic assignment of this species from *Meekoceras* Hyatt, 1879 to *Koninckites* Waagen, 1895, but its tabulate venter, very steep umbilical wall, and the well-differentiated auxiliaries within its suspensive lobe enable us to assign it to the genus *Clypeoceras*.

Clypeoceras timorense is very close to *C. ensanum* (Krafft, 1909, p. 56), but differs by its high, vertical or overhanging umbilical wall. *C. spitiense* (Krafft, 1909, p. 54) is also very close, but its umbilicus is very narrow or nearly occluded. This species exhibits some similarities to *Wailiceras aemulus* Brayard and Bucher (2008, p. 38) and *Koninckites lingyuensis* Chao (1959, p. 220) from South China, both of which are probably conspecific, but differs by its narrow venter.

Family Paranannitidae Spath, 1930

Genus ***Prosphingitoides*** Shevyrev, 1995

Type species: *Prosphingites austini* Hyatt and Smith, 1905.

Prosphingitoides sp. indet

Figs. 125, 126

Material examined: Two specimens, NSM

Fig. 126. Suture line of *Prosphingitoides* sp. indet., NSM PM23283, from AB1022, at H=5 mm.

PM23283, 23284, from AB1022, one specimen, NSM PM23282, from AB1027.

Description: Very involute, very depressed shell with semicircular whorl section and convex flanks gradually converging to an arched venter from abruptly rounded umbilical shoulders. Fairly narrow, deep umbilicus with high, vertical wall. Ornamentation consists only of very weak, prorsiradiate constrictions and fine growth lines. Suture ceratitic with ventral lobe divided by median saddle into two branches with denticulations at each base. First lateral saddle higher than second saddle, and third saddle lower than second saddle. First lateral lobe deep, wide with many denticulations at base, and second lateral lobe about two thirds depth of first lobe.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23282	15.4	4.6	6.9	13.3	0.30	1.93
NSM PM23283	14.1	3.6	5.3	11.5	0.25	2.17
NSM PM23284	15.4	3.9	6.5	–	0.25	–

Occurrence: Described specimens from AB1022 within the *Clypeoceras timorense* Zone and from the *Arctoceras subhydaspis* “bed” (AB1027), early to middle Early Olenekian (early to middle Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: It is entirely possible that our specimens represent the juvenile whorls of *Prosphingites ovalis* Kiparisova (1960, p. 137), which was synonymized with *Prosphingitoides austini* (Hyatt and Smith, 1905, p. 72) by Shevyrev (1995). However, no definitive assignment can be made.

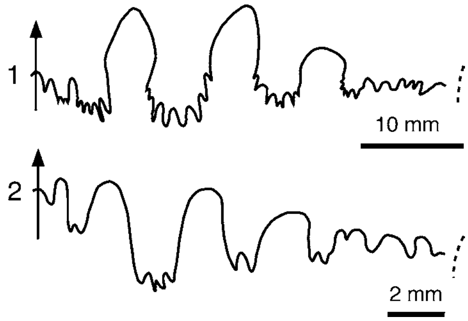


Fig. 127. Suture lines of *Parahedenstroemia kiparisovae* Shigeta and Zakharov sp. nov. from AB1014. 1, NSM PM23285, holotype, at H=41 mm. 2, NSM PM23286, paratype, at H=15 mm.

Superfamily Sageceratoidea Hyatt, 1884
Family Hedenstroemiidae
Genus ***Parahedenstroemia*** Spath, 1934

Type species: *Hedenstroemia acuta* Krafft, 1909.

Parahedenstroemia kiparisovae Shigeta and Zakharov sp. nov.
Figs. 127, 128

Type specimens: Holotype, NSM PM23285, from AB1014; paratypes, three specimens, NSM PM23286–23288, from AB1014.

Diagnosis: *Parahedenstroemia* with acute venter at juvenile stage, becoming narrowly rounded at mature stage, narrow umbilicus and ceratitic suture with adventitious and numerous well-individualized auxiliary elements.

Etymology: Named for L. D. Kiparisova, who energetically studied the Triassic fauna of South Primorye.

Description: Very involute, very compressed shell with somewhat oxyconic whorl section, acute venter at juvenile stage, becoming narrowly rounded at mature stage, and gently convex flanks with maximum width at mid-flank. Umbilicus narrow with moderately high, oblique wall and rounded shoulders. Shell surface smooth with fine, sinuous prorsiradiate growth lines. Suture ceratitic with

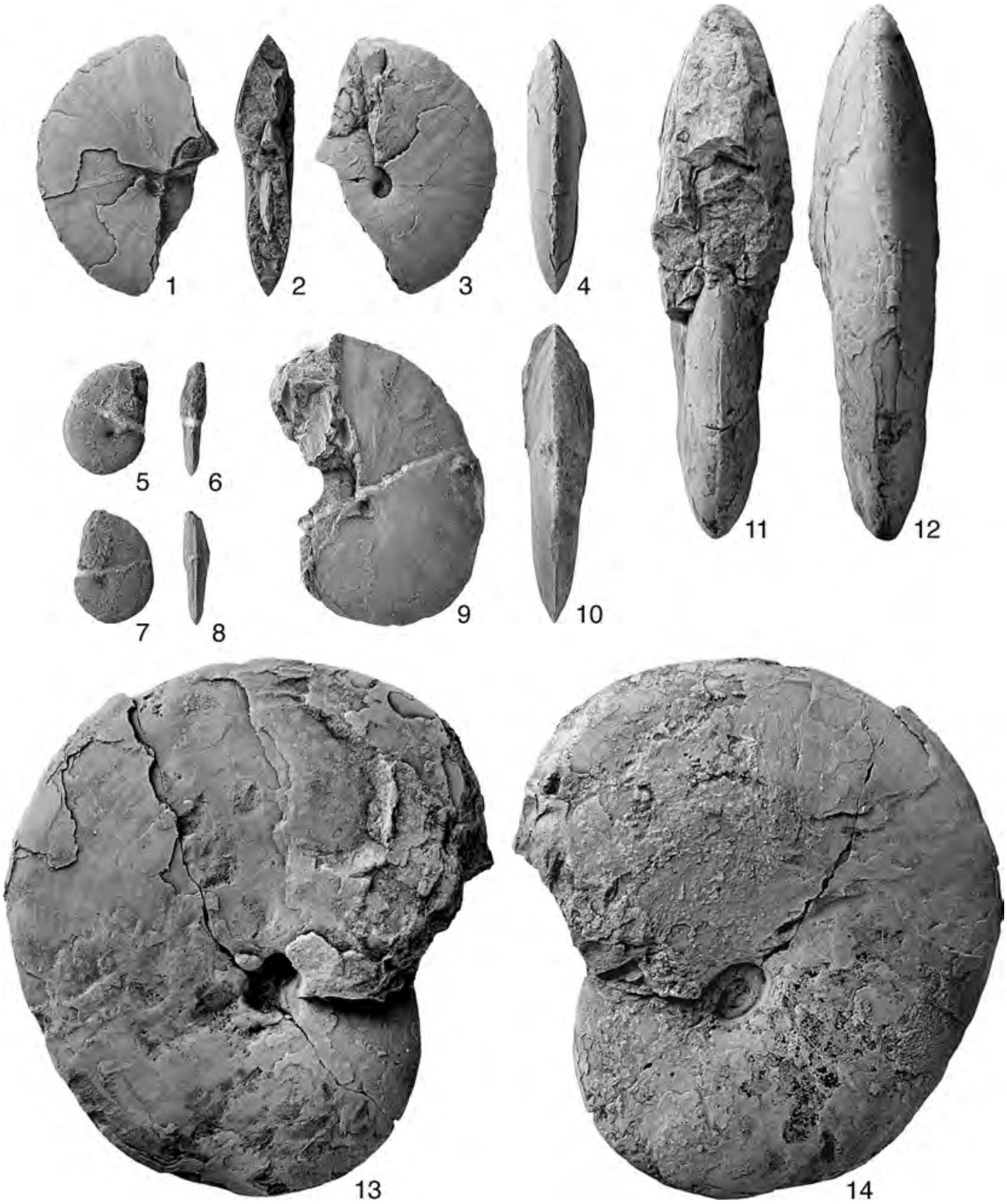


Fig. 128. *Parahedenstroemia kiparisovae* Shigeta and Zakharov sp. nov. from AB1014. 1–4, NSM PM23286, paratype, ×1.0. 5–8, NSM PM23287, paratype, ×1.0. 9–10, NSM PM23288, paratype, ×1.0. 11–14, NSM PM23285, holotype, ×1.0.

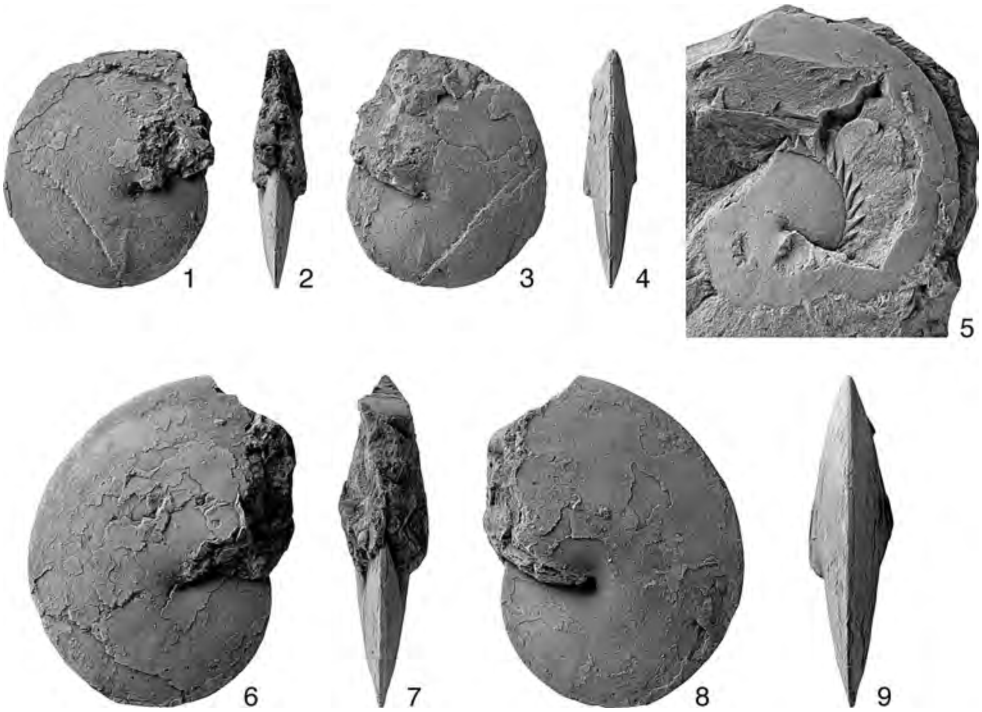


Fig. 129. *Pseudosageceras multilobatum* Noetling, 1905. 1–4, NSM PM23289, from AB1024, ×1.0. 5, NSM PM23290, from AB1022, ×1.0. 6–9, NSM PM23291, from AB1022, ×1.0.

wide ventral lobe with low median and adventitious saddles. First lateral lobe nearly equal to second saddle, becoming subphylloid at mature stage. First lateral lobe wide, deep with many denticulations at base, and second lateral lobe about two thirds depth of first lobe. Suspensive lobe wide with numerous well-individualized auxiliary elements.

Measurements (*mm*):

Specimen no.	D	U	H	W	U/D	W/H
NSM PM23285	74.5	8.7	40.6	16.2	0.12	0.40
NSM PM23286	25.6	2.5	13.8	6.6	0.10	0.48
NSM PM23287	16.4	1.2	9.0	3.5	0.07	0.39
NSM PM23288	40.7	2.6	21.3	7.9	0.06	0.37

Occurrence: Described specimens from *Clypeoceras spitiense* "bed" (AB1014, early Late Induan=early Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: The acute venter and hedenstromitid suture line of this species enable us to assign it to the genus *Parahedenstroemia*. It differs from other representatives of *Parahedenstroemia* such as *P. acuta* (Krafft, 1909, p. 157) and *P. conspicienda* Zakharov (1968, p. 57), by its umbilicus, which is neither occluded nor extremely narrow. Since both species are of early Early Olenekian (early Smitian) age, our new species is the oldest representative of *Parahedenstroemia*.

Fig. 130. Suture line of *Pseudosageceras multilobatum* Noetling, 1905, NSM PM23291, from AB1022, at H=14 mm.

Genus ***Pseudosageceras*** Diener, 1895

Type species: *Pseudosageceras* sp. indet. Diener, 1895.

Pseudosageceras multilobatum
Noetling, 1905
Figs. 129, 130

Pseudosageceras sp. indet. Diener, 1895, p. 28, pl. 1, fig. 8.
Pseudosageceras multilobatum Noetling, 1905a, p. 181, pls. 19–27; Noetling, 1905b, pl. 23, fig. 4, pl. 25, fig. 1, pl. 26, fig. 3; Krafft and Diener, 1909, p. 145, pl. 21, fig. 5; Smith, 1932, p. 87, pl. 4, figs. 1–3, pl. 5, figs. 1–6, pl. 25, figs. 7–16, pl. 60, fig. 32, pl. 63, figs. 1–6; Collignon, 1933, p. 56, pl. 11, fig. 2; Spath, 1934, p. 54, text-fig. 6a; Kiparosova, 1947, p. 127, pl. 25, figs. 3, 4; Chao, 1959, p. 183, pl. 1, figs. 9, 12; Kummel and Steele, 1962, p. 701, pl. 102, figs. 1, 2; Hada, 1966, pl. 4, fig. 6; Kummel and Erben, 1968, p. 112, pl. 19, fig. 9; Shevyrev, 1968, p. 79, pl. 1, figs. 1, 2; Weitschat and Lehmann, 1978, p. 95, pl. 10, fig. 2; Tozer, 1994, p. 83, pl. 18, fig. 1, text-fig. 17; Brayard and Bucher, 2008, p. 70, pl. 37, figs. 1–5.

Lectotype: Designated by Spath (1934, p. 54), is original of Noetling (1905a, p. 181, pl. 19, fig. 1, pl. 24, fig. 12) from the Ceratite Marls of Salt Range, Pakistan.

Material examined: One specimen, NSM PM23289, from AB1024, two specimens, NSM PM23290, 23291, from AB1022.

Description: Very involute, very compressed oxycone with very narrow, bicarinate venter and weakly convex flanks, convergent from occluded umbilicus to venter. Surface smooth without ornamentation. Suture line ceratitic with many adventitious elements. Lateral lobes trified, other lobes bified.

Measurements (*mm*):

Specimen no.	D	U	H	W	W/H
NSM PM23289	30.2	0.0	18.7	6.2	0.33
NSM PM23291	43.8	0.0	28.0	10.0	0.36

Occurrence: Described specimens from AB1022, AB1024 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: The specimen Diener (1895, p. 28) described as *Pseudosageceras* sp. indet from the Early Triassic of the Shamara Bay area, South Primorye is only a partial phargmocone, but it displays the same shell shape and suture as *Pseudosageceras multilobatum* Noetling, and it is probably conspecific. *P. multilobatum* is one of the most cosmopolitan species of the Early Triassic.

Scaphopods (by Y. Shigeta)

Systematic descriptions basically follow the classification by Palmer (1974), Skelton and Benton (1993), and Steiner and Kabat (2001).

Abbreviations for shell dimensions: L=shell length; D=diameter of anterior aperture.

Institution abbreviations: NSM=National Museum of Nature and Science, Tokyo.

Class Scaphopoda Bronn, 1862
Order Dentalioida Palmer, 1974
Family Laevidentaliidae Palmer, 1974
Genus ***Laevidentalium*** Cossmann, 1888

Type species: *Dentalium incertum* Deshayes, 1825.

Laevidentalium? sp. indet.
Fig. 131

Material examined: NSM PM23344 from AB1014, and NSM PM23345 from AB1016.

Description: Shell slender, tapering, moderately curved, with circular cross section. Shell wall thin to moderately thick. Ornamentation consists of oblique, circular annulations of various strength as well as fine growth lines. Internal mould smooth.

Measurements (*mm*):

Specimen no.	L	D
NSM PM23344	12.4	2.1
NSM PM23345	9.6	1.4

Occurrence: Described specimens from AB1014 within the *Clypeoceras spitiense* "bed" (early Late Induan=early Dienerian) and from AB1016 within the *Paranorites vari-*

Fig. 131. *Laevidentalium*? sp. indet. 1, NSM PM23344, from AB1014. 2, NSM PM23345, from AB1016. Scale bar=2 mm.

ans Zone (Late Induan=Dienerian) in the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: The assignment of the specimens to *Laevidentalium* is uncertain and is based only on the similarity of their morphology with *Laevidentalium*. The described specimens are somewhat similar to *L. bangtoupoensis* Stiller (2001, p. 620) from the Upper Anisian of Qingyan, South-western China.

Gastropods (by A. Kaim)

Systematic descriptions basically follow the classification by Bouchet *et al.* (2005). Morphological terms are those used in the Treatise on Invertebrate Paleontology (Cox, 1960) and the glossary of malacological terms by Arnold (1965).

Abbreviations for shell dimensions: For bellerophontids (according to Yochelson, 1960): L=length, W=width, T=thickness; all others: H=shell height; D=shell diameter.

Institution abbreviation: NSM=National Museum of Nature and Science, Tokyo.

Class Gastropoda Cuvier, 1798
Order Amphigastropoda Simroth, 1906
Superfamily Bellerophontoidea McCoy, 1852
Family Euphemitidae Knight, 1956
Genus ***Warthia*** Waagen, 1880

Type species: *Warthia brevisinuata* Waagen, 1880.

Warthia zakharovi Kaim sp. nov.
Figs. 132–134

Type specimens: Holotype, NSM PM23322; four paratypes, NSM PM23323–23326, all from AB1016.

Diagnosis: *Warthia* with wide shell in comparison to its thickness and weakly depressed selenizone.

Etymology: In honor of Yuri D. Zakharov.

Description: Shell globular, almost as long as wide and lacking ornamentation. Slit short and broad at base of U-shaped sinus. Selenizone weakly depressed. Umbilicus absent.

Measurements (*mm*):

Specimen no.	L	W	T
NSM PM23322	10.3	10.1	8.9
NSM PM23323	10.8	10.0	7.7
NSM PM23324	14.3	12.7	11.2
NSM PM23325	14.5	10.8	9.8
NSM PM23326	9.2	9.4	7.5
NSM PM23329	13.0	12.1	11.1
NSM PM23330	17.6	17.5	15.0

Occurrence: Type specimens from AB1016 within the *Paranorites varians* Zone (Late Induan=Dienerian) in the lower main part of the Zhitokv Formation, Abrek Bay area, South Primorye, where this species locally forms a coquina composed mostly of *Warthia* shells.

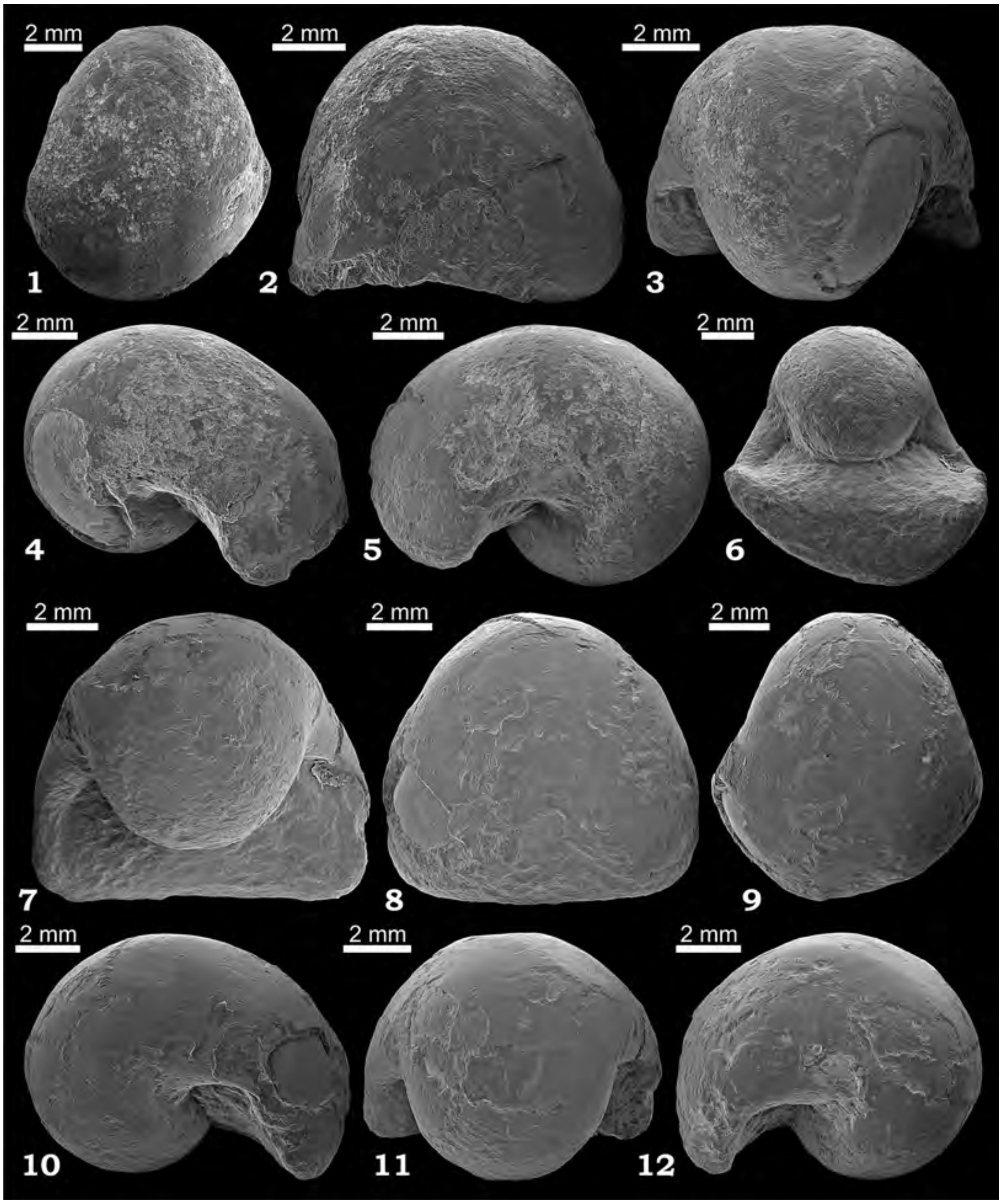


Fig. 132. *Warthia zakharovi* Kaim sp. nov. from AB1016. 1–5, NSM PM23323, paratype. 6–12, NSM PM23322, holotype. All SEM images.

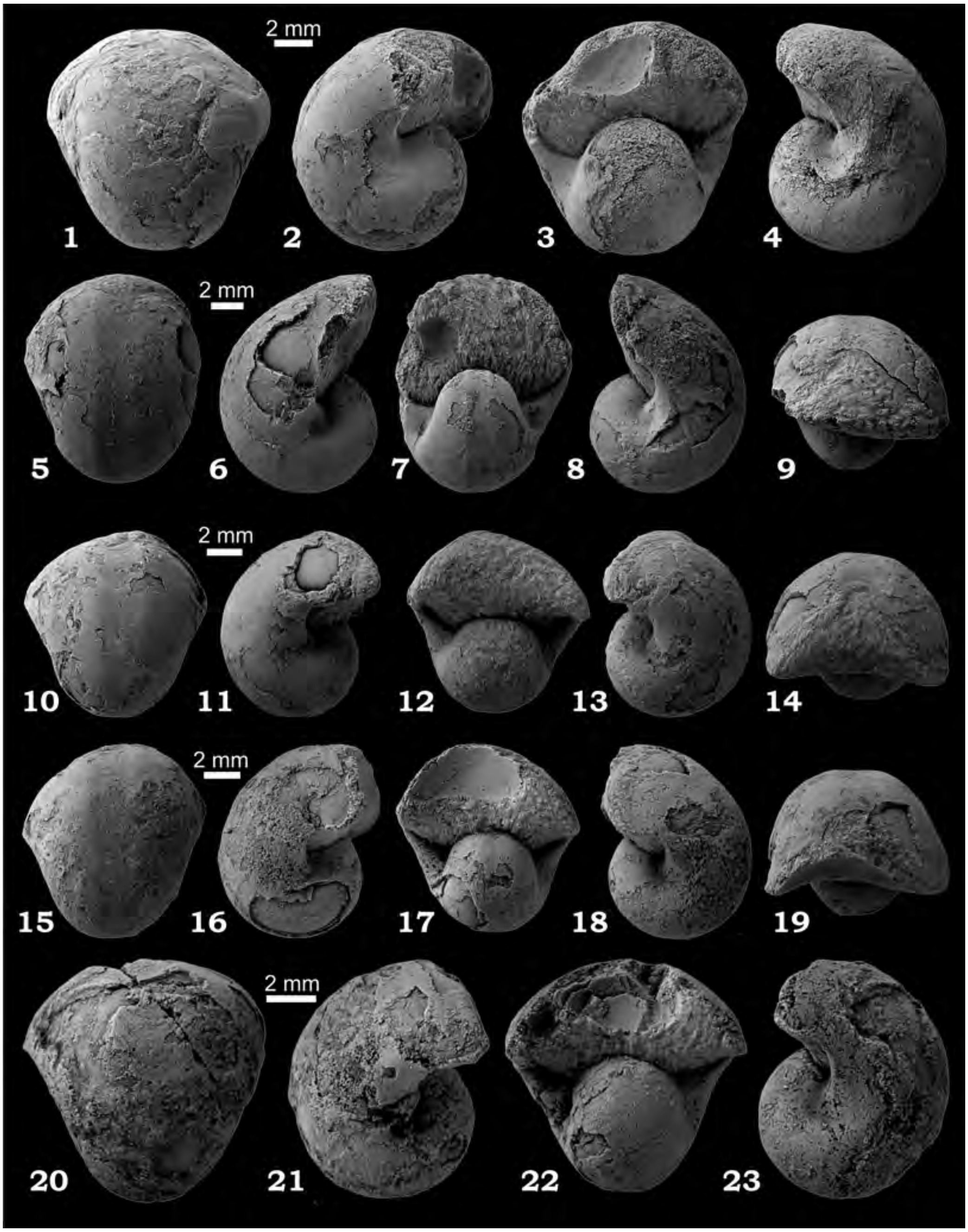


Fig. 133. *Warthia zakharovi* Kaim sp. nov. from AB1016. 1–4, NSM PM23324, paratype. 5–9, NSM PM23325, paratype. 10–14, NSM PM23322, holotype. 15–19, NSM PM23323, paratype. 20–23, NSM PM23326, paratype. All light images by Y. Shigeta.

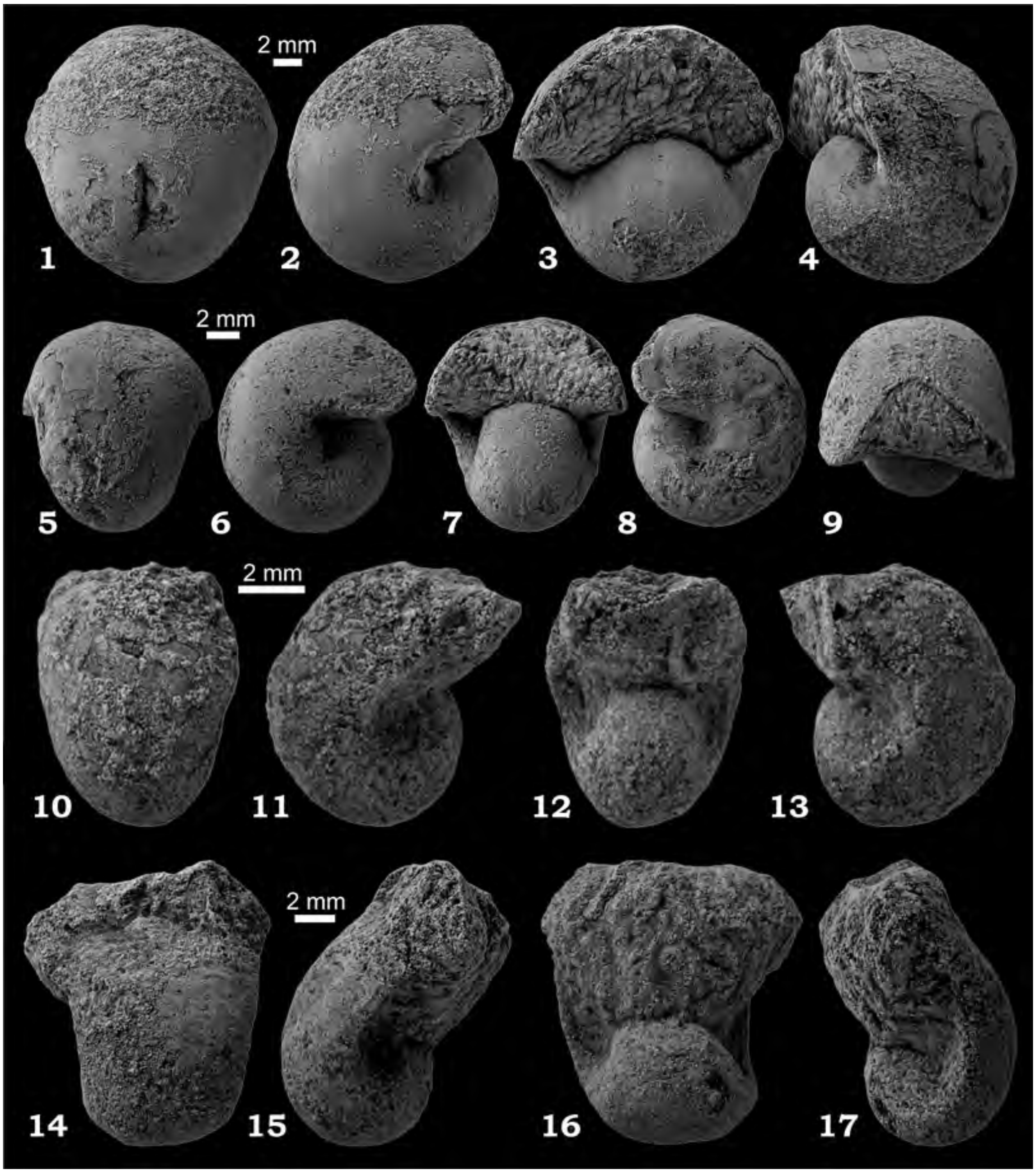


Fig. 134. *Warthia zakharovi* Kaim sp. nov. 1–4, NSM PM23330, from AB1021. 5–9, NSM PM23329, from AB1008. 10–13, NSM PM23327, from AB1004. 14–17, NSM PM23328, from AB1004. All light images by Y. Shigeta.

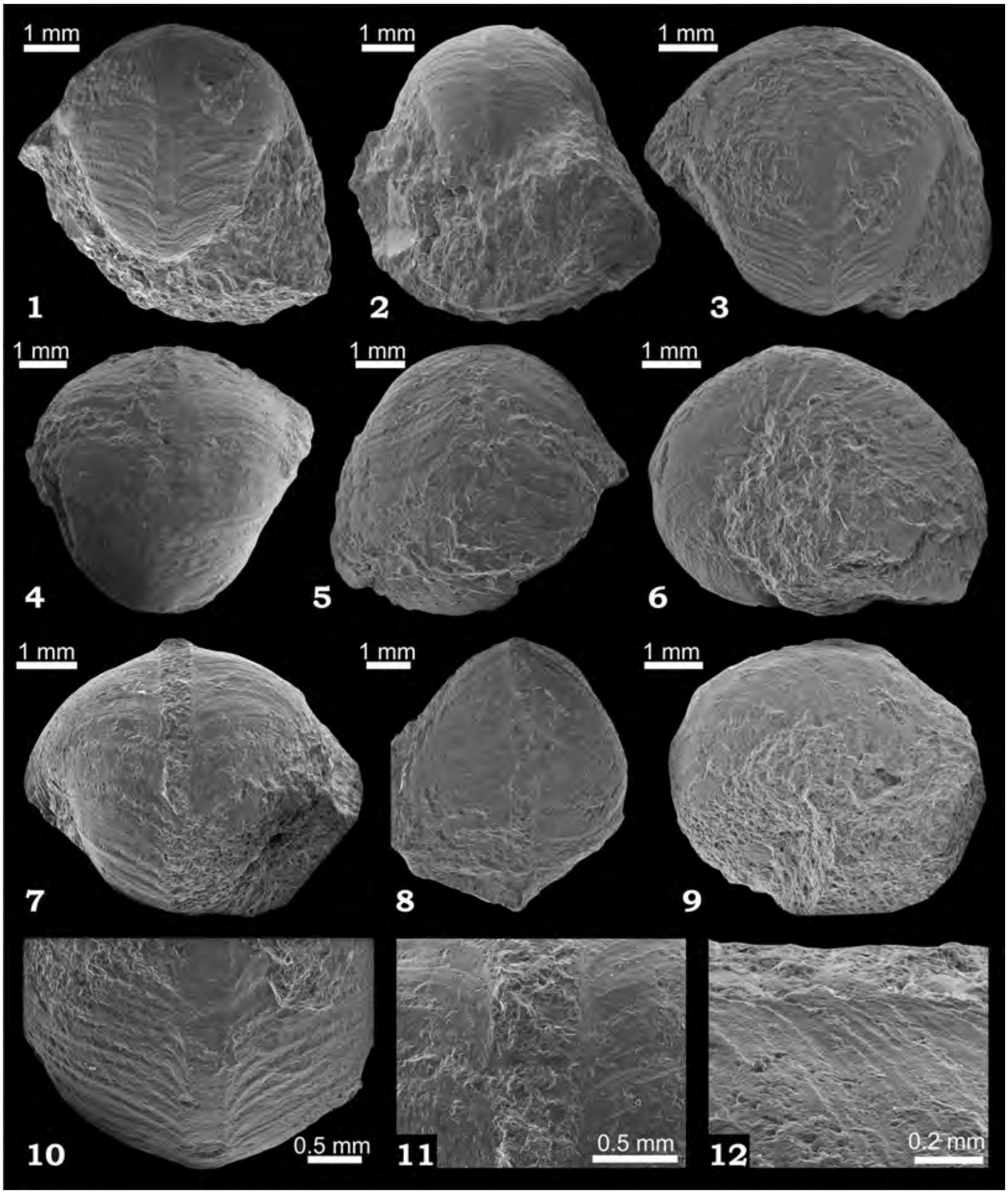


Fig. 135. *Bellerophon abrekensis* Kaim sp. nov. from AB1010. 1–6, 10, NSM PM23332, paratype. 7–9, 11–12, NSM PM23333, paratype. All SEM images.

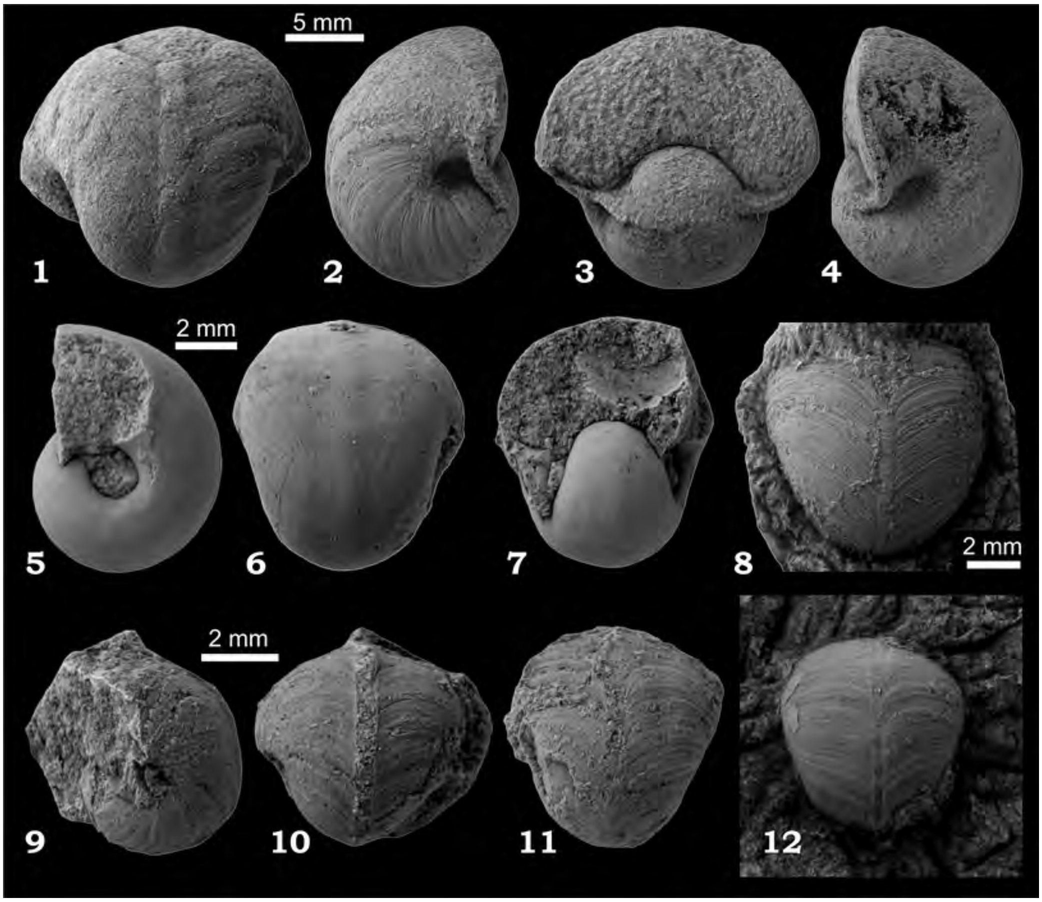


Fig. 136. *Bellerophon abrekensis* Kaim sp. nov. from AB1010. 1–4, NSM PM23331, holotype. 5–7, NSM PM23343, inner mould. 8, NSM PM23334, paratype. 9–10, NSM PM23333, paratype. 11, NSM PM23332, paratype. 12, NSM PM23335, paratype. All light images by Y. Shigeta.

Additional specimens from AB1004, AB1008, and AB1021. Two specimens, (NSM PM23327 and PM23328) from AB1004 (Early Induan=Griesbachian), are poorly preserved and tentatively assigned to *W. zakharovi*. Fossiliferous horizon at AB1008 (Early Induan=Griesbachian) yielded only a single specimen, NSM PM23329. The largest shell, NSM PM23330, came from AB1021 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian).

Discussion: *Warthia zakharovi* sp. nov. differs from other species of the genus in having a strongly globular shell and weakly depressed selenizone. Poorly preserved shells of the putative euphemitid bellerophontid *Euphemites guizhouensis* Pan, 1982 from the Lower Triassic of China are much more compressed as is also the case of the poorly constituted genus *Stachella* (for discussion see Yochelson & Hongfu, 1985).

Family Bellerophontidae McCoy, 1852

Genus ***Bellerophon*** Montfort, 1808

Type species: *Bellerophon vasulites* Montfort, 1808.

Bellerophon abrekensis Kaim sp. nov.

Figs. 135, 136

Bellerophon sp. indet. Bittner, 1899b, p. 28, pl. 4, figs. 26–28.

non *Bellerophon asiaticus* Wirth, 1936, p. 441, fig. 14: 7a, b.

Bellerophon asiaticus Wirth. Kiparisova 1947a, p. 121, pl. 24, figs. 6, 7.

Type specimens: Holotype, NSM PM23331; four paratypes, NSM PM23332–23335, all from AB1010.

Diagnosis: *Bellerophon* with well developed collabral ornamentation on adults composed of sets of thicker ribs with numerous, smaller intercalated ribs. Selenizone slightly elevated. Moderately thick inductura well developed on adult specimens. No spiral ornamentation.

Etymology: After type locality.

Description: Shell strongly globular, wider than long. Shell ornamented with collabral ribs bent posteriorly towards selenizone. In adults, ribs differentiated into sets of stronger and weaker ribs. Selenizone long and slightly elevated. Umbilicus well developed, but partially obscured in adults by well developed inductura extending over the parietal region of aperture.

Measurements (*mm*):

Specimen no.	L	W	T
NSM PM23331	16.3	17.7	11.8

Occurrence: Type specimens from AB1010 within the *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Bay Formation, where this species is relatively common. Additional specimens with rather imperfect preservation from AB1012 (one specimen, NSM PM23336) and AB1013 (three specimens, NSM PM23337-23339). Fossiliferous horizons at AB1012 and AB1013 are within the *Ambitoides fuliginatus* Zone (early Late Induan=early Dienerian).

Discussion: *Bellerophon abrekensis* sp. nov. is seemingly conspecific with “*Bellerophon* sp. indet.” sensu Bittner (1899b) from the Lower Triassic of South Primorye, Far East Russia, which was later indentified as “*Bellerophon asiaticus*” by Kiparisova (1947a). I agree with Yochelson and Hongfu (1985) that specimens discussed by Bittner (1899b) and Kiparisova (1947a) are not conspecific with *Retispira asiatica* (Wirth, 1936), a species based on poorly preserved material from Sichuan Province of China. Yochelson and Hongfu (1985) based their concept of this species on a new material from Guizhou Province of China, which clearly displays spiral ornamentation that is diagnostic of the genus *Retispira*. I could not confirm such ornamentation on any of the well preserved specimens from Abrek Bay, and therefore, I retained the genus *Bellerophon* for *B. abrekensis*. On the other hand I concur with the opinion of Yochelson and Hongfu (1985) that the specimens from Far East Russia could be synonimized with *B. panxianensis* Yu in Wang and Xi (1980). I examined a latex cast of the holotype of the latter species and it is clearly an anomphalous form, while *B. abrekensis* sp. nov. has a well developed umbilicus.

Order Vetigastropoda Salvini-Plawen, 1980

Superfamily Trochonematoidea Zittel, 1895

Family Lophospiridae Wenz, 1938

Genus ***Worthenia*** de Koninck, 1883

Type species: *Turbo tabulatus* Conrad, 1835.

Worthenia sp. indet.

Fig. 137

Material examined: Single specimen NSM PM23340 from AB1010.

Description: Shell turbiniform, small-sized and slightly higher than wide. Ornamentation consists of five spiral cords. Two cords located at the upper portion of the lateral flank and three others at the lower portion, including also a cord situated at the base demarcation. Interspace between both sets of cords is relatively wide and slightly concave. Protoconch, selenizone, aperture, and umbilical area not

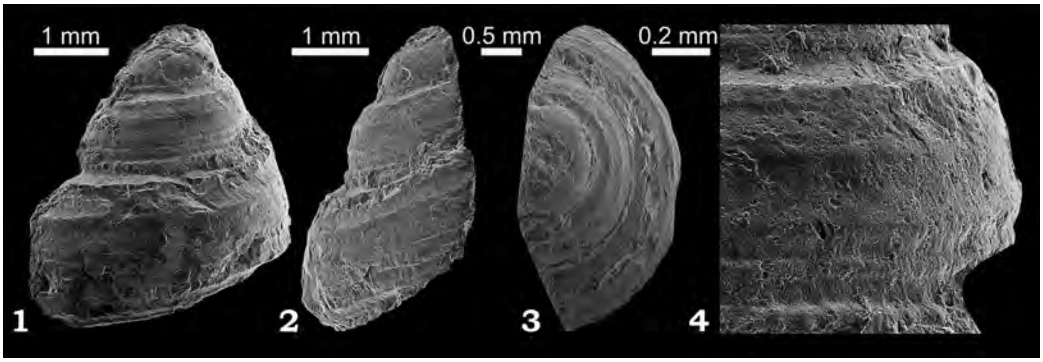


Fig. 137. *Worthenia* sp. indet. from AB1010. 1–4, NSM PM23340. All SEM images.

preserved on available specimen.

Measurements (*mm*):

Specimen no.	H	D	H/D
NSM PM23340	4.00	3.43	1.17

Occurrence: Described specimen from AB1010 within the *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: The described specimen is similar to *Worthenia windowblindensis* Batten and Stokes, 1986 from the Lower Triassic Sinbad Limestone, Utah, USA. The latter species has a slightly different cord arrangement with the widest cord interspace in the upper portion of the lateral flank. Having at hand only a single specimen of imperfect preservation, I decided to leave the species from Abrek Bay in open nomenclature.

Superfamily Trochoidea Rafinesque, 1815
Family Paraturbinidae Cossmann, 1916
Genus ***Chartronella*** Cossmann, 1902

Type species: *Chartronella digoniata* Cossmann, 1902.

Chartronella maedai Kaim sp. nov.
Fig. 138

Type specimens: Holotype, NSM PM23341; paratype, NSM PM23342, both from AB1014.

Diagnosis: *Chartronella* with strong spiral keel and subsidiary sutural and basal cords. Shell is additionally ornamented by weaker spiral ribs on the interspaces between the cords and medial keel.

Etymology: In honor of Haruyoshi Maeda.

Description: Shell turbiniform, small-sized and clearly higher than wide. Ornamentation consists of strong medial keel and subsidiary spiral cords at the suture and base demarcation, respectively. Additional fine spiral ribs appear on lateral flank on interspaces between cords and medial keel. On fourth whorl of the holotype, there are three spiral ribs between sutural cord and medial keel and one spiral rib between keel and basal cord. Aperture and umbilical area not preserved on available specimens.

Measurements (*mm*):

Specimen no.	H	D	H/D
NSM PM23341	6.67	4.86	1.37
NSM PM23342	5.77	4.46	1.29

Occurrence: Type specimens from AB1014 within the *Clypeoceras spitiense* "bed" (early Late Induan=early Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: *Chartronella maedai* sp. nov. differs from the type of the genus *C. digoniata* Cossmann, 1902 by having only one strong keel, while the latter species has two keels. (see e.g., Gründel 1997; Nützel 2005). *C. uni-*

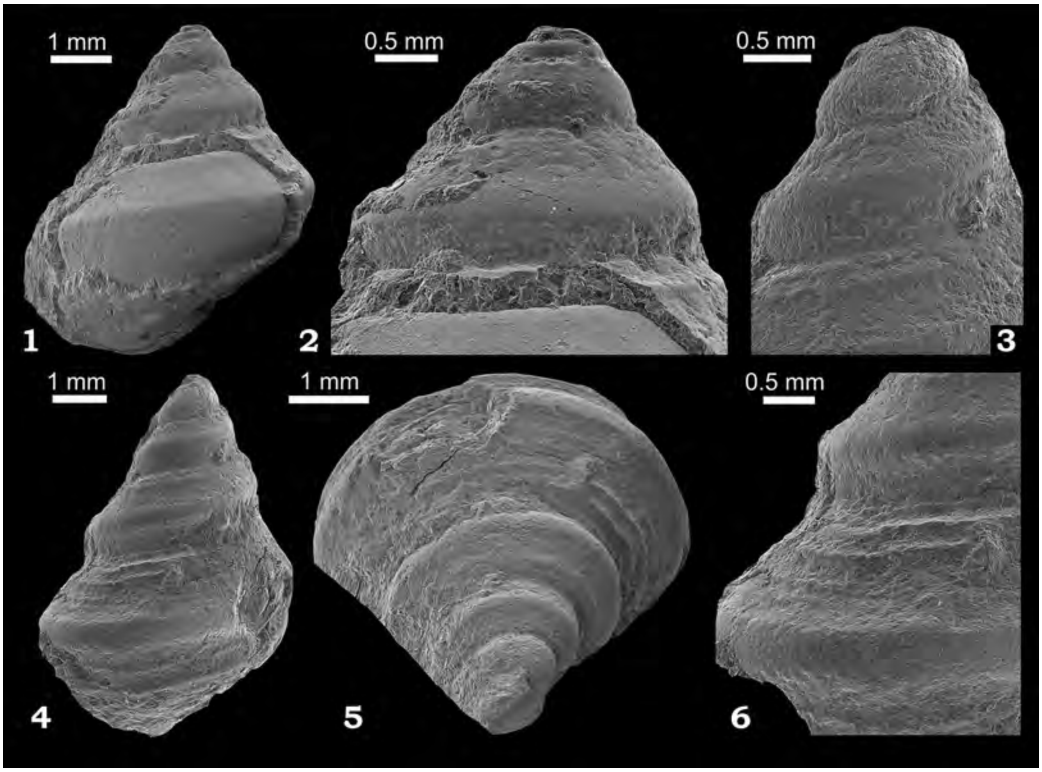


Fig. 138. *Chartronella maedai* Kaim sp. nov. from AB1014. 1–2, NSM PM23342, paratype. 3–6, NSM PM23341, holotype. All SEM images.

costata Batten and Stokes, 1986 has only a medial keel and no sutural and basal cords. *C. pagina* Batten and Stokes, 1986 has axial ornament, a feature lacking in *C. maedai*. Moreover, *C. maedai* has well developed fine spiral ribs, which are absent in the aforementioned species. Similar to, or even conspecific is *Chartronella* sp. indet. of Batten and Stokes (1986) from the Sinbad Limestone, Utah, USA, which also has a medial keel and two cords, but no fine spiral ribs are visible on the single specimens from Batten and Stokes (1986). However, this absence may be preservational bias.

Order Neritimorpha Koken, 1896
Superfamily Neritoidea Rafinesque, 1815
Family Trachyspiridae Nützel, Frýda, Yancey, and Anderson, 2007

Trachyspiridae gen. et sp. indet.
Fig. 139

Material examined: Three protoconchs, NSM PM23292–23294, from AB1014.

Description: Protoconch is turbiniform in shape and consists of about three whorls. Whorls are convex and rapidly expanding covering majority of spire. Initial whorl smooth while remaining whorls ornamented by sinusoidal axial ribs with sinus at periphery. Teleconch unknown.

Measurements (*mm*):

Specimen no.	H	D	H/D
NSM PM23292	0.71	0.67	1.06

Occurrence: Described specimens from *Clypeoceras spitiense* “bed” (AB1014, early Late Induan=early Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay

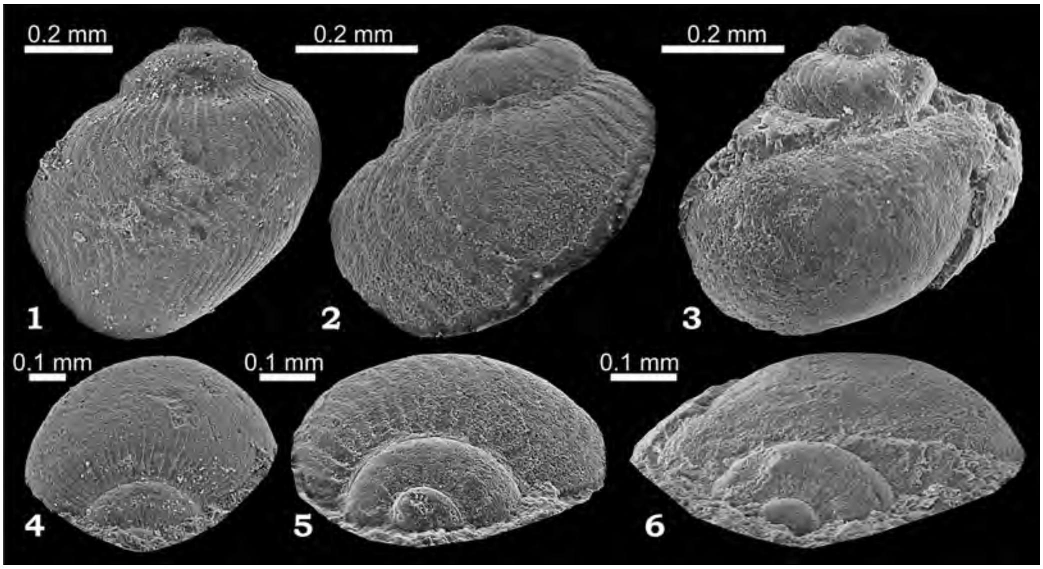


Fig. 139. Trachyspiridae gen. et sp. indet. from AB1014. 1, 4, NSM PM23292. 2, 5, NSM PM23293. 3, 6, NSM PM23294. All SEM images.

area, South Primorye.

Discussion: The trachysprid protoconchs from Abrek Bay are very similar to the Pennsylvanian trachyspirid protoconchs illustrated by Nützel *et al.* (2007). The only difference is the absence of a faint spiral pattern on the specimens from Abrek Bay, which is clearly visible on the Pennsylvanian specimens. This absence, however, might result from the poorer preservation of the Triassic shells.

Family Neritidae Rafinesque, 1815
Genus ***Abrekopsis*** Kaim gen. nov.

Type species: *Naticopsis* (*Naticopsis*) *depressispirus* (Batten and Stokes, 1986).

Composition of the genus: Type species only.

Diagnosis: Naticopsid- or neritid-like shell with short protoconch having a wide initial whorl. Teleoconch starts with collabral terrace-like ornamentation.

Etymology: After type locality and -opsis common ending in neritimorphs.

Occurrence: Upper part of the Lower Induan (Upper Griesbachian) to Upper Induan (Dienerian) in South Primorye, Russia, and the Smithian (Early Triassic) of Utah and Nevada, USA (Batten & Stokes, 1986).

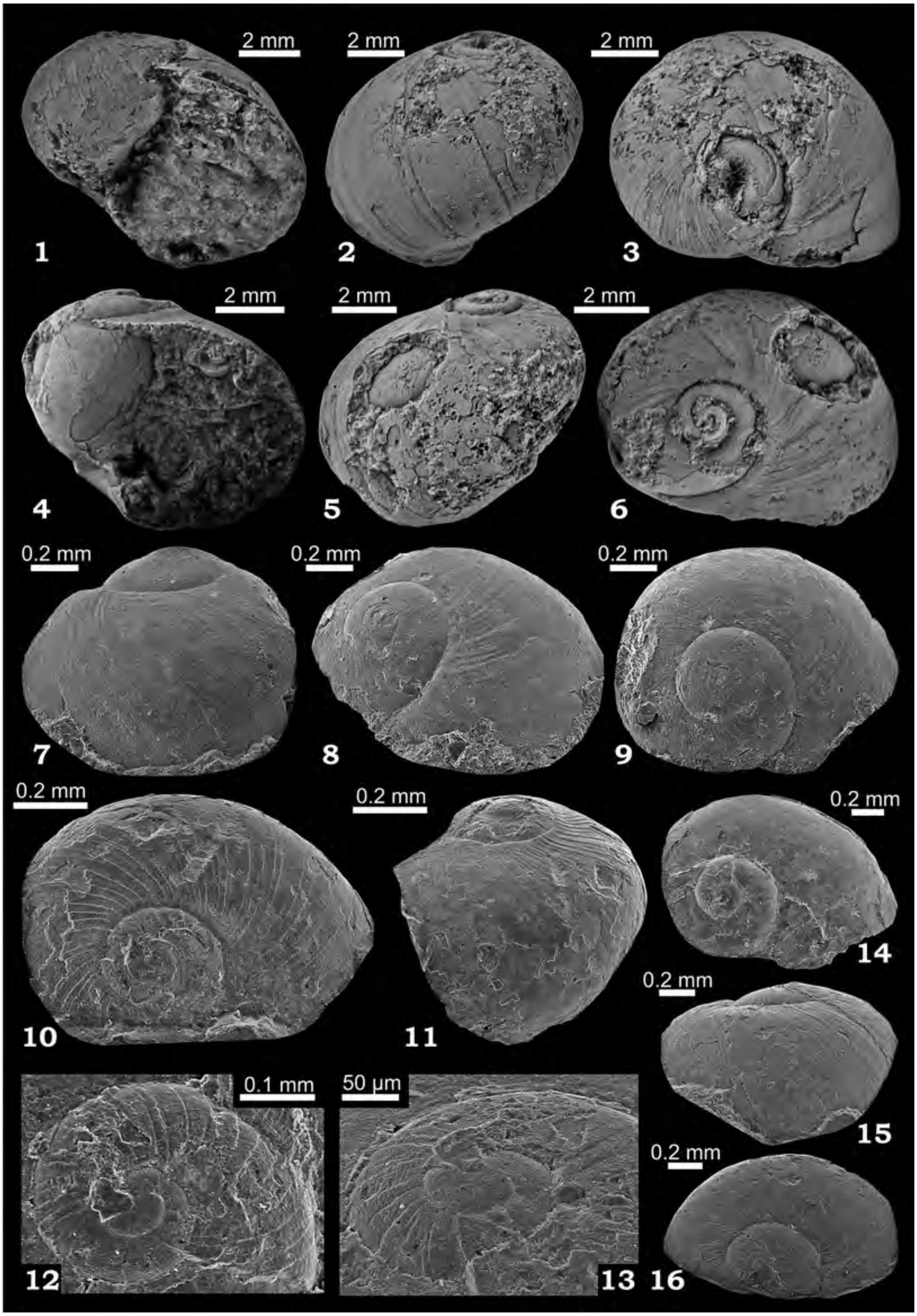
Discussion: The protoconch morphology of *Abrekopsis* seems to be intermediate between the naticopsid type (see e.g., Nützel *et al.*, 2007) and the characteristic neritoid type.

Abrekopsis depressispirus (Batten and Stokes, 1986)
Fig. 140

Naticopsis (*Naticopsis*) *depresispirus* Batten and Stokes, 1986, p. 12, figs. 11–13.

→

Fig. 140. *Abrekopsis depressispirus* (Batten and Stokes, 1986) gen. nov. 1–3, NSM PM23302, from AB1016. 4–6, NSM PM23303, from AB1016. 7–9, NSM PM23295, from AB1010. 10–11, NSM PM23297, from AB1014. 12–14, NSM PM23298, from AB1014. 15–16, NSM PM23296, from AB1013. 1–6, light images by Y. Shigeta; 7–16 SEM images.


2 mm
2 mm
2 mm
1
2
3
2 mm
2 mm
2 mm
4
5
6
0.2 mm
0.2 mm
0.2 mm
7
8
9
0.2 mm
0.2 mm
0.2 mm
10
11
14
0.2 mm
15
0.1 mm
50 µm
0.2 mm
12
13
16

Holotype: AMNH 42975, figured by Batten and Stokes (1986, p. 12, fig. 11) from the Lower Triassic (Spathian) of the Virgin Limestone at Blue Diamond Mine, Nevada, USA.

Material examined: NSM PM23295, from AB1010, NSM PM23296, from AB1013, five specimens, NSM PM23297–23301, from AB1014, and six specimens, NSM PM23302–23307, from AB1016.

Description: Neritoid shell with flattened upper whorl surface. Every succeeding whorl embraces majority of spire. Protococh slightly more than one whorl with initial part wide and flattened. Protoconch not ornamented apart from a faint granular pattern. Teleoconch starts with collabral terrace-like ornamentation and faint spiral pattern. Later on, shells are smooth apart from prosocline growth lines. Early whorls have weakly incised suture, which later becomes indistinct. Umbilicus absent. Aperture D-shaped. No teeth or inductura visible on available material.

Measurements (*mm*):

Specimen no.	H	D	H/D
NSM PM23302	7.70	8.93	0.86
NSM PM23303	7.17	8.12	0.88

Occurrence: Described specimens from AB1010 within the *Gyronites subdharmus* Zone in the upper part of the Lazurnaya Bay Formation, and from AB1013 within the *Ambitoides fuliginatus* Zone, from AB1014 within the *Clypeoceras spitiense* “bed”, and from AB1016 within the *Paranorites varians* Zone, all from the Zhitokv Formation, Abrek Bay area, South Primorye. Thus, in this particular area, the species ranges from late Early Induan (late Griesbachian) to Late Induan (Dienerian). Also known from Smithian of Utah and Spathian of Nevada (both Early Triassic), USA (Batten & Stokes 1986).

Discussion: The adult specimens of *Abrekopsis depressispirus* (Batten and Stokes, 1986) from the Abrek Bay area are very similar to the paratypes from the Smithian of the Sinbad Limestone of Utah (Batten & Stokes 1986). Unfortunately, this identification cannot be fully supported because juveniles have not yet been reported from the Sinbad Limestone.

Order Caenogastropoda Cox, 1960
Superfamily Acteoninoidea Cossmann, 1895
Family Soleniscidae Knight, 1931
Genus ***Strobeus*** de Koninck, 1881

Type species: *Strobeus ventricosus* de Koninck, 1881.

Strobeus shigetai sp. nov.

Fig. 141

Type specimens: Holotype, NSM PM23308, from AB1013; paratypes, NSM PM2309, 2310, from AB1014.

Diagnosis: *Strobeus* with faint axial lirae, bulbous first whorl and strongly globular shell outline.

Etymology: In honor of Yasunari Shigeta, who collected the type specimens.

Description: Shell strongly globular with sutures covered by thin layer of following whorl. Protoconch paucispiral, beginning with bulbous embryonic whorl. Demarcation between protoconch not clearly visible, but probably expressed by enhanced prosocline growth line after 1.5–2.0 whorls. Teleoconch with rapidly expanding whorls and ornamented with faint prosocline, apparently collabral axial lirae. Aperture and umbilicus not visible on available specimens.

Measurements (*mm*):

Specimen no.	H	D	H/D
NSM PM23308	1.49	1.05	1.42
NSM PM23309	1.83	1.48	1.23
NSM PM23310	0.76	0.63	1.21

Occurrence: Described specimens from AB1013 within the *Ambitoides fuliginatus* Zone and from AB1014 within the *Clypeoceras spitiense* “bed”, both of early Late Induan (early Dienerian) age in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: *Strobeus shigetai* sp. nov. dif-

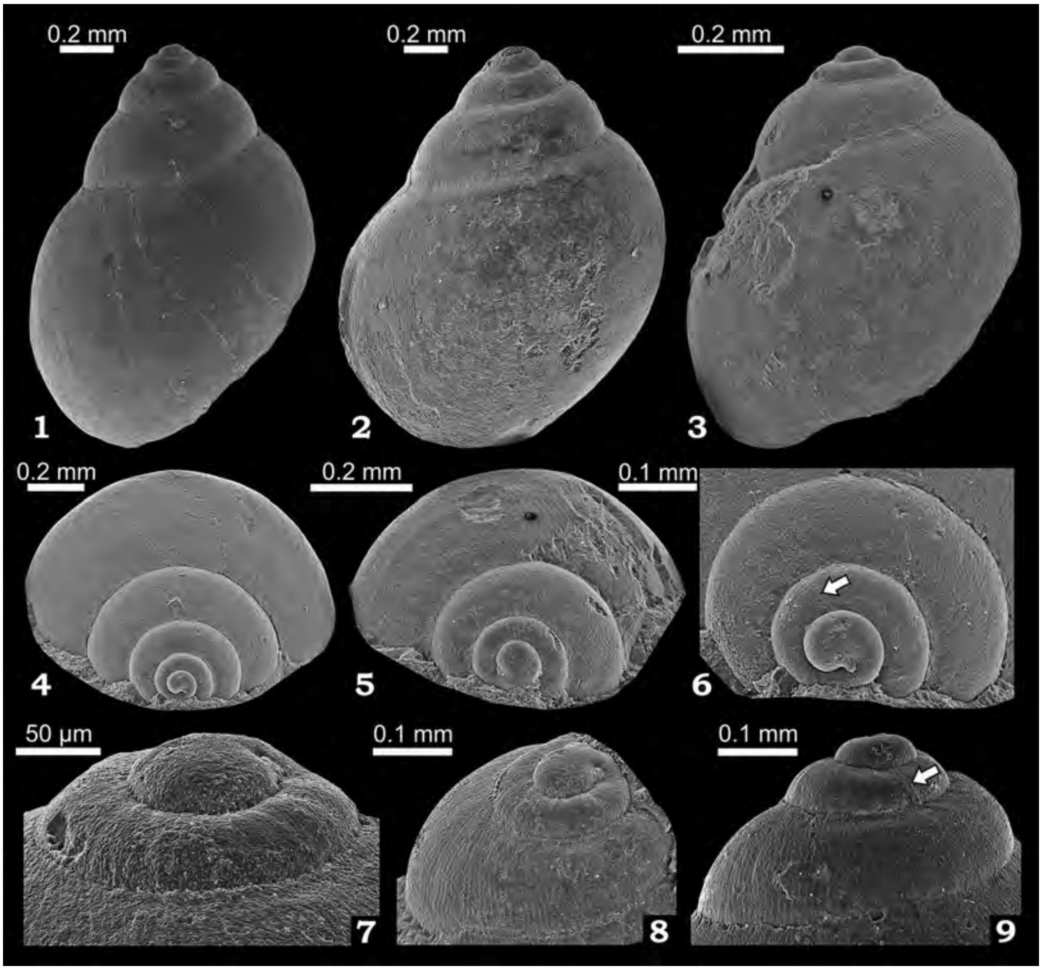


Fig. 141. *Strobeus shigetai* Kaim sp. nov. 1, 4, 6, 9, NSM PM23308, holotype, from AB1013. 2, NSM PM23309, paratype, from AB1014. 3, 5, 7, 8, NSM PM23310, paratype, from AB1014. Possible protoconch/teleoconch demarcation indicated by arrows. All SEM images.

fers from other species of the genus in having axial ornamentation. It remains uncertain if the species from the Smithian Sinbad Limestone of Utah identified by Batten and Stokes (1986, p. 29) as *S*. cf. *paludinaeformis* (Hall, 1858) is conspecific with *S. shigetai* sp. nov., since it is not that well preserved and no ornamentation is reported. While the Abrek Bay specimens are definitely juveniles, the more elongated nature of the American specimens may represent adolescence or maturity. A similar type of collabral ornamentation is observed by Yoo (1988) in a Carboniferous soleniscid from Australia.

Superfamily Zygopleuroidea Wenz, 1938
Family Zygopleuridae Wenz, 1938
Subfamily Coelostylininae Cossmann 1909
Genus ***Coelostylina*** Kittl, 1894

Type species: *Melania conica* Münster, 1841.

Coelostylina sp. indet.
Fig. 142

Material examined: Four specimens, NSM PM23311–23314, from AB1010.

Description: High spired and elongated

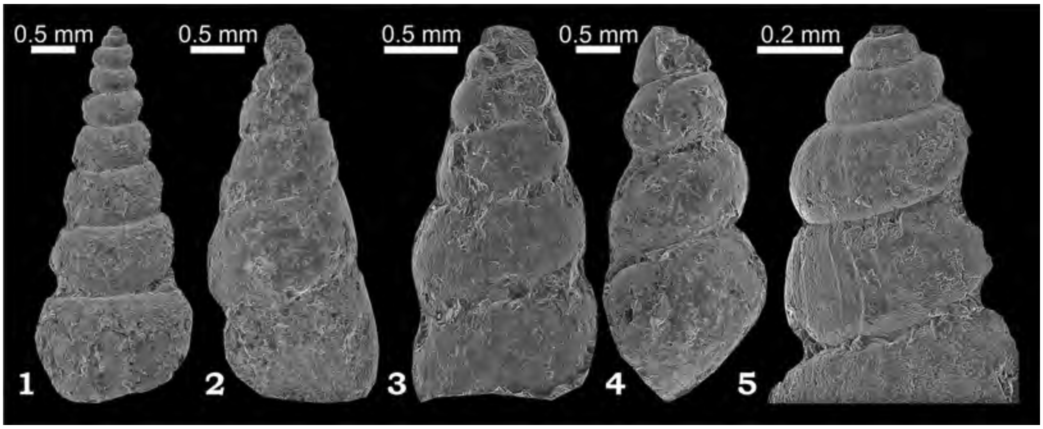


Fig. 142. *Coelostylina* sp. indet. from AB1010. 1, 5, NSM PM23311. 2, NSM PM23312. 3, NSM PM23313. 4, NSM PM23314. All SEM images.

shells with moderately expanding whorls. Initial three whorls more rounded and more inflated than remaining ones. Sutures weakly to moderately incised. There is a sector of the shell on the fourth whorl with enhanced opisthocyrtic growth lines, which may be a demarcation between protoconch and teleoconch. Otherwise, the teleoconch is smooth. Aperture and umbilicus could not be observed.

Measurements (*mm*):

Specimen no.	H	D	H/D
NSM PM23311	4.17	1.75	2.38
NSM PM23312	3.57	1.64	2.17
NSM PM23313	2.50	1.22	2.04
NSM PM23314	4.17	1.83	2.28

Occurrence: Described specimens from AB1010 within the *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Formation, Abrek Bay area, South Primorye.

Discussion: This species is similar to "*Coelostylina* species b" sensu Batten and Stokes (1986, p. 25). The imperfect preservation of both forms persuades me to leave them in open nomenclature. The smooth early whorls of the shells from Abrek Bay suggest that this species may not belong to the zygopleurids, but rather to the pseudomelaniids. This, however, should be substantiated by better preserved juvenile shells.

Genus ***Omphaloptycha*** von Ammon, 1893

Type species: *Chemnitzia nota* von Ammon, 1878.

Omphaloptycha hormolira Batten and Stokes, 1986

Fig. 143

Omphaloptycha hormolira Batten and Stokes, 1986, p. 26, figs. 41–43.

Holotype: AMNH 43010, figured by Batten and Stokes (1986, p. 26, fig. 41) from the Lower Triassic (Smithian) of the Sinbad Limestone at locality AMNH 3026, Utah, USA.

Material examined: One specimen, NSM PM23315, from AB1011, six specimens, NSM PM23316–23321, from AB1014.

Description: Shell moderately high-spired with moderately incised sutures and moderately inflated whorls. Two earliest whorls almost smooth apart from some fine granular sculpture. Next two whorls ornamented with orthocline to weakly opisthocyrtic axial ribs. Approximately 60 ribs per whorl. At height of about 0.8 mm, ribs disappear, which may indicate end of protoconch. No other clear demar-

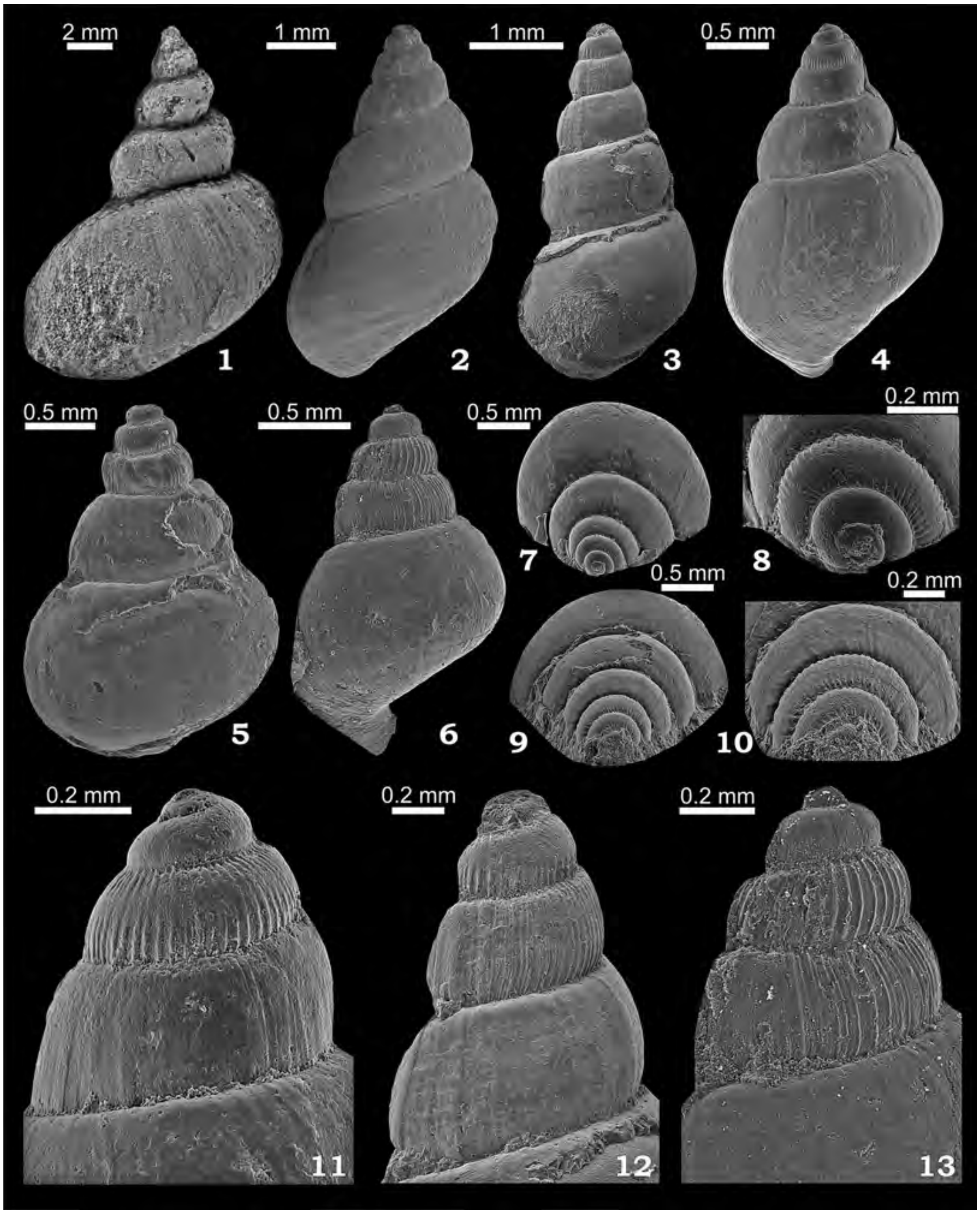


Fig. 143. *Omphaloptycha hormolira* Batten and Stokes, 1986. 1, NSM PM23315, from AB1011. 2, NSM PM23316, from AB1014. 3, 9, 10, 12, NSM PM23317, from AB1014. 4, 7, 8, 11, NSM PM23318, from AB1014. 5, NSM PM23319, from AB1014. 6, 13, NSM PM23320, from AB1014. 1, light image by Y. Shigeta; 2–13 SEM images.

cation visible on the specimens at hand. Teleoconch whorls smooth apart from growth lines, which are weakly opisthocyrtic on whorl periphery. Whorls expand at similar rate apart from last whorl of largest specimen, which is much more expanded. Aperture and umbilicus could not be observed.

Measurements (*mm*):

Specimen no.	H	D	H/D
NSM PM23315	15.30	11.38	1.34
NSM PM23316	5.00	3.00	1.67
NSM PM23317	3.85	1.92	0.50
NSM PM23318	2.78	1.72	1.61

Occurrence: Described specimens from AB1011 within the *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Formation, and from AB1014 within the *Clypeoceras spitiense* "bed" (early Late Induan=early Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: Species of *Omphaloptycha* are generally difficult to classify due to the simplicity of shell morphology. The material from Abrek Bay is similar to the Smithian *O. hormolira* described by Batten and Stokes (1986) from the Sinbad Limestone in Utah, USA, in having a generally similar gross morphology and lirate protoconch. The *Omphaloptycha* from the Abrek Bay area may represent a new species; however, a detailed comparison with the type material of *O. hormolira* is necessary to substantiate this assumption. The American species is rather poorly illustrated–especially concerning its early whorls–which impedes meaningful taxonomical comparisons.

Bivalves (by T. Kumagae and K. Nakazawa)

Systematic classification is primarily based on Moore (1969).

Abbreviations for shell dimensions: RV=right valve; LV=left valve; H=valve height; L=valve length; pU=pre-umbonal length; Lh=hinge length; $\alpha°$=angle between hinge line and growth axis.

Institution abbreviations: NSM=National Museum of Nature and Science, Tokyo.

Class Bivalvia Linné, 1758
(Buonanni, 1681)
Subclass Pteriomorphia Beurlen, 1944
Order Mytiloida Ferussac, 1822
Superfamily Mytilacea Rafinesque, 1815
Family Mytilidae Rafinesque, 1815
Subfamily Modiolinae Keen, 1958
Genus ***Modiolus*** Lamarck, 1799

Type species: *Mytilus modiolus* Linné, 1758.

"***Modiolus***" sp. indet.

Fig. 144.1

Material examined: One specimen, NSM PM23363, from AB1010.

Description: Shell small, elongate, modioliform and inflated. Umbo not prominent, obtuse, subterminal and prosogyrate. Anterior lobe small, but set off from rest of shell. Anterior margin straight, forming a near right angle with somewhat concave ventral margin. Posterodorsal margin nearly straight or feebly arched. Posterior margin broadly rounded, forming an abrupt curvature with ventral margin. Oblique, rounded ridge runs from umbo to posteroventral edge. Shell surface entirely ornamented with faint concentric lines. Weak radial costae parallel to oblique ridge, vanishing toward anterior side and weakened on anteroventral area. Inner structures unknown.

Measurements (*mm*):

Specimen no.	H	L	H/L	Remarks
NSM PM23363	7.1	11.6	0.61	RV

Occurrence: Described specimen from AB1010 in the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: Although the present specimen is similar to *Modiolus* s.l. in external shell morphology (modioliform), it cannot be assigned to it with certainty because its shell surface is clearly ornamented with both radial and concentric sculptures. Modioline bivalves generally have only concentric costae with minor exceptions (e.g., Recent *Geukensia* or Devonian *Phthonia* in Moore, 1969). Even though its internal characters could not be confirmed, it is tentatively placed in *Modiolus*.

Order Pterioida Newell, 1965
Suborder Pteriina Newell, 1965
Superfamily Ambonychiacea S. A. Miller, 1877
Family Myalinidae Frech, 1891
Genus ***Promyalina*** Kittl, 1904

Type species: *Promyalina hindi* Kittl, 1904.

Promyalina schamarae (Bittner, 1899)

Fig. 144.2–144.3

Myalina schamarae Bittner, 1899b, p. 19, pl. 4, figs. 20–25; Vozin and Tikhomirova, 1964, p. 22, pl. 10, figs. 6–8.

Promyalina schamarae (Bittner). Dagys and Kurushin, 1985, p. 62, pl. 11, figs. 2–7; Kurushin and Truschelev in Dagys *et al.*, 1996, p. 29, pl. 4, figs. 16–19.

Type: Not designated in Bittner (1899b) or in other previous studies.

Material examined: One specimen, NSM PM23373, from AB1010, three specimens, NSM PM23374–23376, from AB1012.

Description: Shell small, equivalve, myaliniform, subround to subquadrate in outline (H/L ratio about 1.2) and moderately inflated. Umbo small, terminal and prosogyrate. Posterodorsal margin straight, forming an angle of 55° with growth axis. Posterior margin forms an angle of about 140° with posterodorsal margin, rounded and passing to broadly arched ventral margin. Surface nearly smooth, except for irregular faint concentric lamellae. Inner surface smooth.

Measurements (*mm*):

Specimen no.	H	L	H/L	α°	Remarks
NSM PM23373	24.3	21.9	1.11	–	LV*
NSM PM23374	23.5+	24.8	–	54	art.**
NSM PM23375	22.8	17.5	1.31	56	art.**

* incomplete shell, ** internal mold, art.: articulated shells.

Occurrence: Described specimens from AB1010 in the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian), and from AB1012 in the *Ambitoides fuliginatus* Zone (early Late Induan=early Dienerian) in the upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye. This species also occurs in the *Gyronites subdharmus* Zone on the western coast of Ussuri Gulf and in the Artyom area, South Primorye (Bittner, 1899b; Markevich & Zakharov, 2004), as well as in the Lower Triassic of Northeastern Siberia, Russia (Vozin & Tikhomirova, 1964; Dagys *et al.*, 1996).

Discussion: The specimens from the Lazurnaya Bay Formation of the Abrek Bay area are undoubtedly conspecific with Bittner's specimen (Bittner, 1899b, p. 19, pl. 4, figs. 20–25). This species characteristically possesses a convex anterior margin and as such, is distinguished from other Early Triassic *Promyalina*; namely, *P. putiatinensis* (Kiparisova), *P. kochi* (Spath), and *P. groenlandica* Newell. Even though the Siberian specimens have been synonymized with *P. schamarae* (Vozin & Tikhomirova, 1964; Dagys & Kurushin, 1985; Dagys *et al.*, 1996), some of them can be distinguished from *P. schamarae* by their shorter height and more rounded shell shape and they could be separated as a subspecies.

Promyalina putiatinensis (Kiparisova, 1938)

Fig. 144.4–144.5

Myalina vetusta Benecke. Bittner, 1899b, p. 17, pl. 4, figs. 17–19.

Myalina putiatinensis Kiparisova, 1938, p. 261, pl. 6, figs. 10–12; Newell and Kummel 1942, p. 957, pl. 3, figs. 9, 10.

Promyalina putiatensis (Kiparisova). Ciriacks, 1963, p. 75, pl. 16, figs. 1–5.

Promyalina putiatinensis (Kiparisova). Gan and Yin, 1978, p. 315, pl. 110, fig. 4; Yin and Yin in Yang *et al.*, 1983, p. 168, pl. 22, figs. 14, 15.

Syntype: Specimens figured by Kiparisova (1938, p. 261. Pl. 6, figs. 10, 12) as holotype, from the Lower Triassic of the Putiatin Island in South Primorye, Russia.

Material examined: Two specimens, NSM PM23377, 23378, from AB1004.

Description: Shell small, inequilateral, subquadrate or myaliniform, prosocline, higher than long (H/L=1.6) and weakly inflated. Umbo small, terminal, and prosogyrate. Posterodorsal margin straight, about three fourths as long as shell length, forming an angle of about 68° with growth axis. Posterior margin slightly convex, forming a rounded posteroventral margin. Anterior margin long, nearly straight or weakly arcuate and partly depressed near umbo.

Measurements (*mm*):

Specimen no.	H	L	H/L	α°	Remarks
NSM PM23377	21.7	13.2	1.64	65	RV**
NSM PM23378	24.9	16.1	1.55	70	RV**

** internal mold.

Occurrence: Described specimens from AB1004 in the *Lytophiceras* sp. Zone (early Induan=Griesbachian) in the lower part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye. This species also occurs in the Lower Triassic of Putiatin Island, South Primorye (Bittner, 1899b; Kiparisova, 1938), the *Lingula* Zone (Lower Triassic) of the Dinwoody Formation, Wyoming and Idaho, Western-Central USA (Newell & Kummel, 1942; Ciriacks, 1963) and the Lower Triassic of Guizhou and Qinghai Provinces, China (Gan & Yin, 1978; Yang *et al.*, 1983).

Discussion: The angle between the hinge line and growth axis (α) of the figured specimens is about 68°. Based on illustrations in previous studies, and as pointed out by Kiparisova (1938, p. 292), this angle is rather variable as demonstrated by the following specimens: South Primorye: 55–70°, China: 50–60°, and USA: 60–65°.

Superfamily Pteriacea Gray, 1847
Family Pteriidae Gray, 1847
Genus ***Pteria*** Scopoli, 1777

Type species: *Mytilus hirundo* Linné, 1758.

Pteria ussurica (Kiparisova, 1938)
Fig. 144.6–144.8

Gervilleia cf. *exporrecta* Lepsius. Bittner, 1899b, p. 15, pl. 3, figs. 1–6 not 7–16.

?*Gervilleia* aff. *exporrecta* Lepsius. Spath, 1930, p. 48, pl. 10, fig. 11a, b; pl. 12, fig. 4.

Gervillella aff. *exporrecta* (Lepsius). Spath, 1935, p. 69, pl. 22, fig. 9a–c.

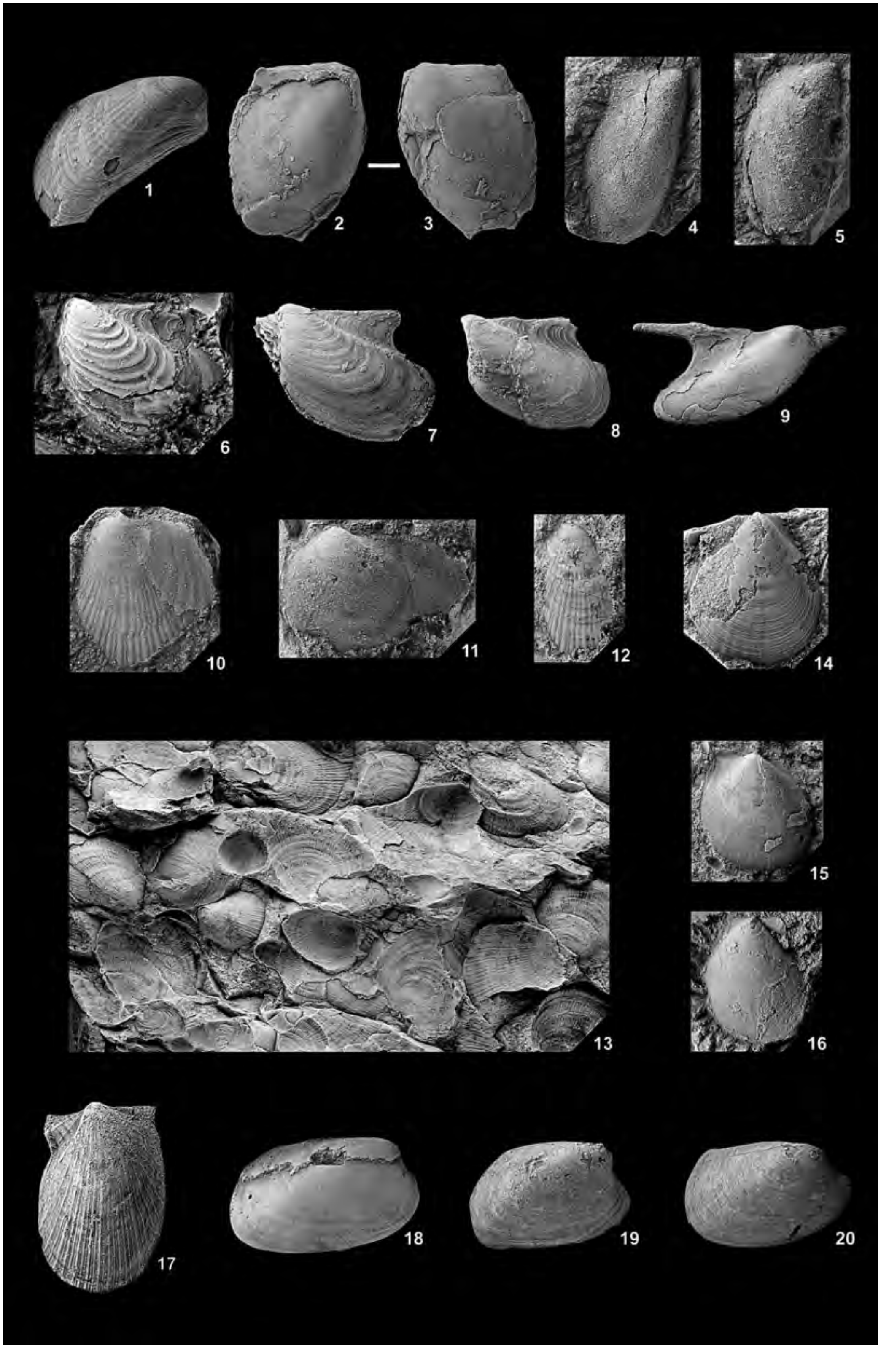
Gervillia usssurica Kiparisova, 1938, p. 241, pl. 6, figs. 5–8; Newell and Kummel, 1942, p. 959.

Avicula usssurica (Kiparisova). Kiparisova and Krishtofovich, 1954, p. 10, pl. 1, figs. 15, 16, 18.

Syntype: Specimens figured by Kiparisova (1938, p. 241. Pl. 6, figs. 5, 6, 8; figs. 5, 6 are

→

Fig. 144. 1, “*Modiolus*” sp. indet., NSM PM23363, from AB1010, right valve, ×2.5. 2–3, *Promyalina schamarae* (Bittner, 1899), NSM PM23375, from AB1012, internal mold of articulated valves (2: right valve, 3: left valve). 4–5, *Promyalina putiatinensis* (Kiparisova, 1938) from AB1004. 4, NSM PM23377, internal mold of right valve, ×1.25. 5, NSM PM23378, internal mold of right valve, ×1.0. 6–8, *Pteria ussurica* (Kiparisova, 1938). 6, NSM PM23380, from AB1010, incomplete left valve, ×2.5. 7, NSM PM23384, from AB1014, left valve, ×2.5. 8, NSM PM23383, from AB1014, incomplete left valve, ×1.5. 9, *Bakevellia*? sp. indet., NSM PM23346, from AB1021, internal mold of right valve, ×2.5. 10–13, *Claraia stachei* Bittner, 1901. 10, NSM PM23347, from AB1007, incomplete left valve, ×1.25. 11, NSM PM23349, from AB1007, incomplete left valve, ×2.5. 12, NSM PM23350, from AB1010, fragmental valve, ×2.5. 13, NSM PM23351, from AB1012, shell concentration, ×0.8. 14, *Entolioides* sp. indet., NSM PM23352, from AB1014, right valve, ×2.5. 15–16, *Leptochondria minima* (Kiparisova, 1938). 15, NSM PM23359, from AB1010, left valve, ×2.5. 16, NSM PM23353, from AB1014, right valve, ×3.5. 17, *Eumorphotis multiformis* (Bittner, 1899), NSM PM23357, from AB1014, left valve, ×0.8. 18–20, *Trigonodus orientalis* Bittner, 1899 from AB1021. 18, NSM PM23419, incomplete right valve, ×1.5. 19, NSM PM23417, right valve, ×1.8. 20, NSM PM23418, right valve, ×1.8.


1
2
3
4
5
6
7
8
9
10
11
12
14
13
15
16
17
18
19
20

photographs taken from Bittner's originals, corresponding to figs. 2, 3) as holotype, from the Lower Triassic of the Shamara River, western coast of Ussuri Gulf, South Primorye, Russia.

Material examined: Three specimens, NSM PM23379–23381, from AB1010, one specimen, NSM PM23382, from AB1013, three specimens, NSM PM23383–23385, from AB1014.

Description: Shell small, inequilateral, oblique, bialate, and moderately convex. Umbo narrowly rounded, elevated above hinge line, subterminal and slightly prosogyrate. Hinge line straight, forming an angle of about 40° with growth axis. Anterior auricle small and demarcated from body. Posterior auricle elongate, pointed, and separated by shallow depression from main body of valve. Ventral margin gently arched. Coarse, regular concentric ribs on flank and irregular faint lamellae on wings. Inner surface smooth.

Measurements (*mm*):

Specimen no.	H	L	H/L	α°	Remarks
NSM PM23379	6.5	11.6	0.56	38	RV**
NSM PM23380	9.7	10.9+	–	47	LV
NSM PM23381	6.9	8.1	0.85	40	LV
NSM PM23382	5.5	4.4	1.26	–	LV*
NSM PM23383	10.4	15.7+	–	37	LV
NSM PM23384	8.8	11.4	0.77	40	LV

* imcomplete shell, ** internal mold.

Occurrence: Described specimens range from AB1010 in the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Bay Formation to AB1014 in the *Clypeoceras spitiense* "bed" (early Late Induan=early Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye. This species is also reported from the Lower Triassic of the Shamara River and Russian Island, South Primorye (Bittner, 1899b; Kiparisova, 1938) as well as the Lower Triassic of Greenland, where it occurs with *Otoceras*? and *Ophiceras* (Spath, 1930). The species is also common in the *Claraia* zone (Lower Triassic) of the upper Dinwoody Formation in Wyoming and Idaho, Western-Central USA (Newell & Kummel, 1942; Ciriacks, 1963).

Discussion: The present species was first described as *Gervilleia* cf. *exporrecta* Lepsius, 1878 by Bittner (1899b), but Kiparisova (1938) later erected a separate species, *Gervillia ussurica*, for some of the specimens. Afterward, Kiparisova and Krishtofovich (1954) confirmed a single ligament groove in the ligament area and emended the species as *Avicula* (=*Pteria*) *ussurica*. Ozaki and Shikama (1954) reported the occurrence of *Gervilleia* cf. *exporrecta* from the *Eumorphotis multiformis* bearing limestone in Gunma Prefecture, Central Japan. Nakazawa (1959) clarified the characteristics of this taxon's hinge and confirmed that the Japanese specimens belong to *Pteria* as is the case for the specimens from South Primorye. The Japanese species, which was separated as subspecies *P. ussurica yabei*, is almost identical to *P. ussurica*, but can be distinguished from the latter by the wider angle between its umbonal ridge and hinge margin and the more robust shape of its main body. The species is now known from various parts of Southwest Japan (Nakazawa, 1971; Kambe, 1963). Another species related to *P. ussurica* was described from South China as a new subspecies, *P. ussurica variabilis* by Chen and Lan (in EGFLC, 1976). It differs from *P. ussurica* by the presence of weak radial striae in the umbonal area.

Family Bakeveliidae King, 1850

Genus ***Bakevellia*** King, 1848

Type species: *Avicula antiqua* von Münster in Goldfuss, 1836.

Bakevellia? sp. indet.

Fig. 144.9

Material examined: One specimen, NSM PM23346, from AB1021.

Description: Shell small in size, narrow, pteriiform, prosocline, inequilateral, bialate, and moderately inflated. Umbo medium-sized, slightly protruding above hinge margin, terminal and orthogyrate. Hinge margin straight, forming an angle of 34° with growth axis. Anterior auricle small and short. Posterior auricle narrow, prolonged posteriorly and sharply pointed and separated by depression from valve body. Internal structures unknown.

Measurements (*mm*):

Specimen no.	H	L	H/L	α°	Remarks
NSM PM23346	6.1	13.4	0.45	34	RV**

** internal mold.

Occurrence: Described specimen from AB1021 in the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: Judging from its external shape, the present specimen is considered as assignable to either of the pteriacean genera, *Pteria* or *Bakevellia*. Since its internal characters cannot be observed, it is difficult to choose the correct genus with any degree of certainty. Although the specimen externally appears to be related to *Pteria ussurica* (Kiparisova) or *P. ussurica yabei* Nakazawa, it differs by its weaker concentric ornament and less robust main body. In addition, the specimen is also characterized by its acutely protruded triangular anterior auricle, prolonged posterior auricle, and oblique, slender body. The consideration of these points brings to attention two other species, which are thought to be related; *Bakevellia acutaurita* Yin and Yin (in Yang *et al.*, 1983, p. 137, pl. 13, figs 17–23) described from the lower Anisian of Qinghai, Northwest China, and *Pteria sturi* (Bittner) described in Allasinaz (1966, p. 652, pl. 42, figs. 4–8) from the Carnian of Lombardia, Italy. After comparing the proximity of the present specimen with the locality and age of these two species, we questionably assign it the genus *Bakevellia*.

Family Aviculopectinidae Meek and Hayden, 1864

Subfamily Aviculopectininae Meek and Hayden, 1864

Genus ***Claraia*** Bittner, 1901a

Type species: *Posidonomya clarae* von Hauer, 1850.

Claraia stachei Bittner, 1901

Fig. 144.10–144.13

Pseudomonotis (*Claraia*) *stachei* Bittner, 1901a, p. 587 (no figure); Kiparisova, 1947, p. 96, pl. 13, figs. 6, 8, 10, 14.

Claraia stachei Bittner. Spath, 1930, p. 46, pl. 9, fig. 1, pl. 10, fig. 5a, b; Newell and Kummel, 1942, p. 955, pl. 3, figs. 5–8; Tozer, 1961, p. 97, pl. 28, figs. 1, 2; Ciriacks, 1963, p. 79, pl. 15, figs. 1–3; Vozin and Tikhomirova, 1964, p. 10, pl. 1, figs. 13, 14; Vu Khuc in Vu Khuc *et al.*, 1965, p. 23, pl. 1, figs. 1–3; Chen in EGFLC, 1976, p. 197, pl. 31, figs. 28, 29; pl. 33, fig. 30; Dang, Trinh Tho and Vu Khuc in Vu Khuc *et al.*, 1991, p. 54, pl. 4, figs. 7–11; Kurushin and Truschelev in Dagys *et al.*, 1996, p. 38, pl. 4, figs. 10, 11; Tong *et al.*, 2006, p. 44, pl. 3, fig. 5; Komatsu *et al.*, 2008, p. 121, text-fig. 2.9.

Type: Not designated in Bittner (1901a) or in other previous studies.

Material examined: Three specimens, NSM PM23347–23349, from AB1007, one specimen, NSM PM23350, from AB1010, one specimen, NSM PM23351, from AB1012.

Description: Shell medium-sized, suborbicular. Left valve feebly inflated, prosocline and concentrically folded. Umbo small, slightly protruded above hinge margin and orthogyrate. Auricles not developed. Surface of shell ornamented with numerous, fine radial costae and irregular, weak concentric plicae. Right valve almost flat, concentrically folded and ornamented with irregular radial costae. Dorsal margin straight. Anterior auricle small, and subquadrate. Byssal notch narrow, debouching inward.

Occurrence: Described specimens range from AB1007 in the *Lytophiceras* sp. Zone (early Induan=Griesbachian) to AB1012 in the *Ambitoides fuliginatus* Zone (early Late

Induan=early Dienerian) in the middle to upper parts of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye. This species also ranges from the upper *Glyptophiceras* bed to the *Proptychites* bed of the Cape Stosch section (Lower Triassic), Greenland (Spath, 1930). It also has been reported from the following localities: *Lingula* and *Claraia* zones of the Dinwoody Formation (Lower Triassic), Wyoming Idaho and Montana, Western-Central USA (Newell & Kummel, 1942; Ciriacks, 1963), Induan of Western Verkhoyansk, Sakha, Northeastern Russsia (Vozin & Tikhomirova, 1964), Lower Triassic of the Pamirs, Central Asia and Armenia, Western Asia (Kiparisova, 1947), Lower Triassic (T_1) distributed in Yunnan and Hunan Province (EGFLC, 1976) and the Yinkeng Formation (Induan), Chaohu, Anhui Province, South China (Tong *et al.*, 2006), and Induan of Vietnam (Vu Khuc *et al.*, 1965, 1991; Komatsu *et al.*, 2008).

Genus ***Eumorphotis*** Bittner, 1901a

Type species: *Pseudmonotis telleri* Bittner, 1898.

Eumorphotis multiformis (Bittner, 1899)

Fig. 144.17

Pseudomonotis multiformis Bittner, 1899b, p. 10, pl. 2, figs. 11–22.

Pseudomonotis (*Eumorphotis*) *multiformis* Bittner. Ogilvie Gordon, 1927, p. 22, pl. 2, fig. 11; Spath, 1935, p. 74, pl. 22, fig. 8; Kiparisova, 1938, p. 224, pl. 2, figs. 4, 5, 9–12; pl. 3, figs. 1–4 (including vars. *regularaecosta*, *rara* and *rudaecosta*)

Eumorphotis multiformis Bittner. Newell and Kummel, 1942, p. 957, pl. 2, figs. 10, 11; Ciriacks, 1963, p. 77, pl. 15, figs. 13–15; Kambe, 1963, p. 38, pl. 1, figs. 1–11; pl. 2, figs. 1–7; Nakazawa, 1971, p. 117, pl. 23, figs. 7–12; Chen in EGFLC, 1976, p. 185, pl. 30, figs. 34, 35; Dang, Trinh Tho and Vu Khuc in Vu Khuc *et al.*, 1991, p. 56, pl. 5, figs. 12–14; Nakazawa *et al.*, 1981, p. 142, pl. 1, figs. 12, 13, pl. 2, fig. 2.

Eumorphotis multiformis shionosawensis Ichikawa and Yabe, 1955, p. 5, pl. 2, figs. 1–15; Kambe, 1963, p. 40, pl. 2, fig. 8.

Type: Not designated in Bittner (1899b) or in other previous studies.

Material examined: Three specimens, NSM PM23355–23357, from AB1014.

Description: Shell (left valve) medium-sized, subcircular, orthocline, higher than long, subinequilateral, and well inflated. Umbo large, prominent, obtuse, located at subanterior to middle of shell and slightly prosogyrate. Posterior end nearly straight. Ventral margin well rounded. Hinge margin almost straight. Anterior auricle narrow, subtrigonal and distinctly delimited from body of valve by sulcation. Posterior wing larger and not clearly defined from body. Shell surface ornamented with numerous radial sculptures increasing in number with growth by insertion. Single secondary rib intercalated between primary ribs and higher order riblets between primary and secondary ribs (1-3-3-2-3-3-1). Growth lines fine and weak.

Measurements (*mm*):

Specimen no.	H	L	H/L	Remarks
NSM PM23355	26.6	21.9	1.21	LV*
NSM PM23356	26.6	21.1+	–	LV*
NSM PM23357	37.5	25.5	1.47	LV

* incomplete shell.

Occurrence: Described specimens from AB1014 in the *Clypeoceras spitiense* “bed” (early Late Induan=early Dienerian) in the lower part of the Zhitokv Formation, Abrek Bay area, South Primorye. The species also occurs in the Lower Triassic of Russian and Putiatin Islands, South Primorye (Bittner, 1899b; Kiparisova, 1938), as well as in the Lower Triassic of the following additional localities: upper Werfen Formation, Dolomites, Italy (Ogilvie Gordon, 1927), upper *Ophiceras* bed, Greenland (Spath, 1930, 1935), Central Alborz Range, Iran (Nakazawa *et al.*, 1981), Spitzbergen, Norway (Frebold, 1939), *Claraia* zone of the Dinwoody Formation in Idaho, Montana and Utah, Western-Central USA (Newell & Kummel, 1942; Ciriacks, 1963), Guizhou and Fujian Province, South China (EGFLC, 1976), Kurotaki, Shionosawa and

Kamura limestones, Japan (Ichikawa & Yabe, 1955; Kambe, 1963; Nakazawa, 1971), and Vietnam (Vu Khuc *et al.*, 1991).

Discussion: The ornamentation of *Eumorphotis multiformis* is quite variable and is described and ordered according to the number, sequence and strength of its radial ribs as well as the mode of its concentric sculpture. Kiparisova (1938) distinguished three varieties based on different types of ornamentation; namely, *E. multiformis* vars. *regularaecosta*, *rudaecosta* and *rara*. The first variety is characterised by regularly arranged radial ribs of the 1st to 3rd or 4th systems. Variety *rudaecosta* is distinguished by coarser, less numerous radiating ribs of the 1st and 2nd system. Also, its 3rd radials are much thinner. Variety *rara* is characterized by 1st radials, which conspicuously intervene in the 2nd to 4th orders, and its radials exhibit the following formula at the lower margin: 1-2-2-2-2-2-2-2-1 or 1-3-3-3-2-3-3-3-1. As noted by Bittner (1899b) and Kiparisova (1938) this taxon exhibits many intermediate forms, which lead us to suggest that the three varieties, with their different forms of sculpture, simply represent a very wide range of intraspecific variation. Furthermore, *E. multiformis* s.s. cannot be clearly distinguished from *E. multiformis* var. *regularaecosta*, and these specimens should be grouped together as *regularaecosta*. The described specimens should also be placed within *regularaecosta*.

In South China three additional varieties or subspecies are proposed; namely, *E. multiformis fasciculiformis* Gan and Yin (1978), *E. multiformis dissimilicostata* Gan and Yin (1978), and *E. multiformis reticulata* Chen (1976). *E. multiformis fasciculiformis* exhibits a *rara* form of ornamentation and *E. multiformis reticulata* cannot be distinguished from the *regularaecosta* form. *E. multiformis dissimilicostata* exhibits a *reguraraecosta* style of ornamentation, but it is somewhat obscured on both lateral sides of the shell by its sculpture, which consists of very distinctive concentric folds in combination with undulating radials This species should be regarded as a legitimate subspecies. *E. multiformis hongshuichuanensis* Zhang (1979), described from Qinghai Province, North China, is distinguished from *E. multiformis* s.s. by its large, circular shape, irregular radial ribs and weak concentric sculpture, but more material must be scrutinized to validate these differences.

Genus ***Leptochondria*** Bittner, 1891

Type species: *Pecten* (*Leptochondria*) *aeolicus* Bittner, 1891.

Leptochondria minima (Kiparisova, 1938)

Fig. 144.15–144.16

Pecten (*Leptochondria*?) ex aff. *alberti* Goldfuss. Bittner, 1899b, p. 6, pl. 2, figs. 1, 2, 4–10, 13?, 14?

?*Pecten albertii* Goldfuss. Philippi, 1903, p. 50, pl. 4, fig. 8.

?*Pseudomonotis* cf. *iwanowi* Bittner. Yehara, 1928, p. 170, pl. 16, figs. 13, 14.

Pecten (*Velopecten*) *minimus* Kiparisova, 1938, p. 246, pl. 4, figs. 10, 12a, b, pl. 5, figs. 1–6; Kiparisova and Krishtofovich, 1954, p. 12, pl. 3, figs. 3–7.

Leptochondria? *minima* (Kiparisova). Nakazawa, 1961, p. 260, pl. 12, figs. 16, 17.

Eopecten minimus (Kiparisova). Kambe, 1963, p. 47, pl. 5, figs. 17–21.

Leptochondria minima (Kiparisova). Kurushin and Truschelev in Dagys *et al.*, 1996, p. 40, pl. 7, figs. 7, 8.

Holotype: Specimen figured by Kiparisova (1938, p. 246, pl. 5, fig. 5), from the Lower Triassic on Russian Island (Karpinsky Bay) in South Primorye, Russia.

Material examined: Two specimens, NSM PM23358, 23359, from AB1010, three specimens, NSM PM23353, 23360, 23361, from AB1014, one specimen, NSM PM23362, from AB1021.

Description: Shell small in size, subcircular, acline, equilateral and height nearly equal to length. Left valve weakly inflated. Umbo small, slightly protruded, obtuse, lying near middle of hinge margin and orthogyrate. Hinge margin straight, and about three-fourths of shell in length. Anterior and posterior auricles obtusely trigonal, small and indistinctly delimited from body. Dorsal edge straight. Ventral margin circular. Surface ornamented with fine radial ribs and faint concentric lines, except for both auricles. Right valve feebly convex or almost flat. Umbo small, obtuse and situated near middle of straight hinge margin. Small posterior auricle delimited from body of shell by sulcation. Anterior auricle obtuse with a narrow subauricular notch. Posterior auricle trigonal, smaller than anterior auricle. Shell surface smooth.

Measurements (*mm*):

Specimen no.	H	L	Lh	H/L	Lh/L	Remarks
NSM PM23353	6.1	4.7	3.2	1.31	0.68	RV
NSM PM23358	5.0	4.7	4.0	1.06	0.85	LV
NSM PM23359	6.9	7.2	4.4	0.96	0.61	LV
NSM PM23360	6.8	6.2	4.6	1.09	0.74	LV*
NSM PM23361	4.8	4.1	–	1.18	–	LV
NSM PM23362	5.7	5.8	2.7+	0.98	–	LV

* incomplete shell.

Occurrence: Described specimens range from AB1010 in the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Bay Formation to AB1021 in the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) of the Zhitkov Formation, Abrek Bay area, South Primorye. Although this species is primarily a Lower Triassic taxon, it does occur in the Middle Triassic upper Muschelkalk of Austria (Philippi, 1903). It also occurs in the following additional Lower Triassic localities: Shamara River and Russian Island, South Primorye (Bittner, 1899b; Kiparisova, 1938), as well as from the Lower Triassic of the following additional localities: upper Muschelkalk, Austria (Philippi, 1903), Werfen Formation (Central Dolomites), Southern Alps, Italy (Frech, 1907), Taho limestone, Ehime Prefecture (Yehara, 1928), Kurotaki limestone, Kochi Prefecture, Narawara Formation, Kyoto Prefecture (Nakazawa, 1961, 1971), Kamura limestone, Miyazaki Prefecture, southwest Japan (Kambe, 1963), Qinghai Province, Western China (EGFLC, 1976), Chernokhrebetnaya River, Krasnoyarsk (east Taymyr) and the Kengdey River, Sakha, Northeastern Russsia (Dagys *et al.*, 1996)

Discussion: Kiparisova (1938) recognized two varieties of the species, namely, *Leptochondria minima* vars. *laevis* and *reticulatus*. The former is characterized by a nearly smooth shell surface and the latter by a cancellate sculpture created by relatively distinct radial costae and regularly arranged concentric sculpture. They are linked with *L. minima* s.s. by gradational forms, which represent infraspecific variation. Wittenburg (1909) reported *Pecten* (=*Leptochondria*) *albertii* var. *virgalensis* from the Lower Triassic of the Salt Range, Pakistan. This taxon is characterised by numerous radial ribs and is very similar to *Leptochondria* ex aff. *alberti* of Bittner (1899b) (=*L. minima* Kipariosva, 1938). Wittenburg (1909) identified the South Primorye species as var. *sibirica* without making a clear distinction between vars. *virgalensis* and *sibirica*. *L. albertii* var. *sibirica* is herein treated as an invalid name. Nakazawa (1981) described *L. minima* from Kashmir of India, and a Pakistani-Japanese Research Group (1985) reported it from the Salt Range. However, these taxa were later reassigned to *L. virgalensis* by Nakasawa (1996). *L. virgalensis* differs from *L. minima* by its slightly larger size, more numerous radial ribs and a slightly higher shell. Furthermore, the somewhat stronger radial ribs of *L. virgalensis* are arranged in wider intervals.

Kiparisova (1938) reassigned a specimen, originally described as *Pecten* (*Velopecten*) cf. *albertii* in Frech (1907, p. 35, pl. 4, fig. 8) from the Werfen Beds of Hungary, to *Leptochondria minima*, but the specimen can be distinguished from *L. minima* by its strong but less numerous radial ribs. The other European species also need further examination. The specimens figured by Chen (in EGFLC, 1976, p. 159, pl. 29, figs. 1–3) differ from *L. minima* by their differentiated and stronger radial ornaments.

Family Entoliidae Korobkov, 1960
Genus ***Entolioides*** Allasinaz, 1972

Type species: *Pecten zitteli* Wöehrmann and Koken, 1892.

Entolioides sp. indet.
Fig. 144.14

Material examined: Two specimens, NSM PM23352, 23354, from AB1014.

Description: Shell small in size, suborbicular, equilateral, higher than long and slightly inflated. Umbo small, sharply pointed, situated at middle of hinge margin and orthogyrate. Antero- and posterodorsal margins nearly straight. Ventral end rounded. Shell surface nearly smooth, but ornamented with numerous fine, sharp concentric lines and broad low concentric folds in addition to 10–15 wide, feeble, radial ribs. Both auricles small, subequal sized, rectangular, trigonal and ornamented with fine riblets, well defined from disc.

Measurements (*mm*):

Specimen no.	H	L	H/L	Remarks
NSM PM23352	9.5	8.4	1.14	RV*

* incomplete shell.

Occurrence: Described specimens from AB1014 in the *Clypeoceras spitiense* “bed” (early Late Induan=early Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: As noted by Allasinaz (1972), *Entolioides* is distinguished from *Entolium* Meek, 1865, by its distinct radial ribs. Since the shell surface of the present specimens is ornamented with feeble, but distinct radial ribs, they can be placed within *Entolioides*. Chen (in EGFLC, 1976) described several entoliid species with weak radial costae or threads; that is, Lower Triassic *Entolium discites* (p. 208, p1. 34, figs. 7, 8), *E. discites microtis* (figs. 12, l3), and Upper Triassic *E. tenuistriatum rotundum* (p. 209, pl. 34, figs. 35–39). The last taxon exhibits distinct numerous radial ribs. *E. discites latum* Yin and Yin (in Yang *et al.*, 1983: p. 146, pl. 15. figs. 15–18), reported from the Middle Triassic of Qinghai, NW China, also is ornamented with differentiated numerous radial ribs similar to *E. discites microtis* figured in Chen (1976). Except for *E. discites*, the other three subspecies should undoubtedly be assigned to *Entolioides*. Nakazawa (1961) noted the presence of obsolete radial ribs in *E.* cf. *discites* sp. b (p. 254, pl. 12, figs. 3–4) from the Maizuru Zone of Japan. This species is similar to *E. discites* described by Chen (in EGFLC, 1976). These two species possibly should be assigned to *Entolioides*. An examination of the individual variation of *E. discites* is needed, since these two species exhibit forms that are intermediate between *Entolium* and *Entolioides*.

Subclass Palaeoheterodonta Newell, 1965
Order Unionoida Stoliczka, 1871
Superfamily Unionacea Fleming, 1828
?Family Pachycardiidae Cox, 1961
Genus ***Trigonodus*** Sandberger in Alberti, 1864

Type species: *Trigonodus sandbergeri* Alberti, 1864.

Trigonodus orientalis Bittner, 1899
Fig. 144.18–144.20

Trigonodus orientalis Bittner, 1899b, p. 21, pl. 3, fig. 27.
Trigonodus orientalis Bittner. Kiparisova, 1938, p. 217, pl. 2, figs. 1, 2.

Type: Not designated in Bittner (1899b) or in other previous studies.

Material examined: Five specimens, NSM PM23415–23419, from AB1021.

Description: Shell small, moderately inflated, subquadrate to elongately ovate (H/L ratio about 0.6), equivalve and inequilateral. Umbo small, subterminal and prosogyrate. Umbonal ridge feeble, rounded, and running to posteroventral end. Anterodorsal margin recurvate. Anterior end short and rounded. Posterodorsal margin straight, almost parallel to broadly arcuate ventral margin. Posterior end gently arched and slightly truncated. Surface smooth, ornamented with fine concentric lines.

Measurements (*mm*):

Specimen no.	H	L	H/L	Remarks
NSM PM23415	6.5	9.5	0.68	LV
NSM PM23416	7.1	11.8	0.60	RV
NSM PM23417	9.5	14.1	0.67	RV
NSM PM23418	9.4	14.5	0.65	RV
NSM PM23419	11.9	19.9	0.60	RV

Occurrence: Described specimens from AB1021 in the *Clypeoceras timorense* Zone (early Early Olenekian = early Smithian) of the Zhitkov Formation, Abrek Bay area, South Primorye. *Trigonodus orientalis* was originally described by Bittner (1899b) based on a specimen from the Lower Triassic of Paris Bay, Russian Island, South Primorye. Kiparisova (1938) also reported the species from the Lower Triassic of Russian Island.

Discussion: Judging from the illustrations, the specimen originally described by Bittner (1899b) exhibits dimensional ratios of H/L = 0.71 and pU/L = 0.26, whereas the ratios for Kiparisova's (1938) two specimens are H/L = 0.65, 0.73 and pU/L = 0.26, 0.25. Accordingly, the described specimens are slightly longer (H/L = around 0.64) and their umbo is more anteriorly located (pU/L = around 0.17). These differences may simply reflect intraspecific variation.

Genus ***Unionites*** Wissmann, 1841

Type species: *Unionites muensteri* Wissman, 1841.

Unionites canalensis (Catullo, 1848)

Fig. 145.1–145.4

Tellina canalensis Catullo, 1848, p. 56, pl. 4, fig. 4 (not seen).

Anodontophora (*Myacites*) *canalensis* (Catullo). Bittner, 1899b, p. 23, pl. 3, figs. 34–38; Ogilvie Gordon, 1927, p. 28, pl. 2, fig. 28.

Myacites canalensis (Catullo). Bittner, 1901b, p. 85, pl. 9, figs. 11, 12.

Anodontphora canalensis (Catullo). Frech, 1904, p. 10, text-fig. 15; Matsushita, 1926, pl. 8, fig. 12; Ozaki and Shikama, 1954, p. 44, text-fig. 4; Kambe, 1963, p. 48, pl. 5, figs. 24, 25.

Pleuromya canalensis (Catullo). Frech, 1907, p. 40, pl. 7, fig. 2.

Homomya canalensis (Catullo). Leonardi, 1935, p. 35, pl. 1, figs. 13–15.

Unionites canalensis (Catullo). Yabe, 1956, p. 287, pl. 16, figs. 12a, b; Ciriacks, 1963, p. 81, pl. 16, figs. 11, 12; Nakazawa, 1971, p. 126, pl. 24, figs. 14a, b, 15; Nakazawa *et al.*, 1981, p. 143, pl. 2, figs. 6–8; Yin and Yin in Yang *et al.*, 1983, p. 136, pl. 13, fig. 3; Neri and Posenato, 1985, p. 94, pl. 2, fig. 8.

Type: Details unknown.

Material examined: Four specimens, NSM PM23420–23423, from AB1010, one specimen, NSM PM23424, from AB1021.

Description: Shell small in size, gently inflated, elongately ovate (H/L ratio about 0.5), equivalve and inequilateral. Umbo large, elevated from dorsal margin, orthogyrate and located at about two-fifths of valve length from anterior end. Umbonal ridge somewhat elevated, but rounded. Anterodorsal margin recurvate. Posterodorsal margin long, almost straight. Anterior margin well rounded. Lunule narrow, deep. Escutcheon narrow. Posterior margin nearly straight, sub-truncated, and forming an angle of 70° with broadly arched ventral margin. Surface ornamented with numerous faint concentric striae.

Measurements (*mm*):

Specimen no.	H	L	H/L	pU	pU/L	Remarks
NSM PM23420	17.3	32.7+	–	10.4	–	RV*
NSM PM23421	12.7	24.2	0.52	9.0	0.37	LV
NSM PM23422	15.2	30.4	0.50	12.0	0.39	LV
NSM PM23423	14.3	30.8	0.46	12.7	0.41	RV
NSM PM23424	15.6	28.8	0.54	9.3	0.32	RV

* incomplete shell.

Occurrence: Described specimens from AB1010 in the lower *Gyronites subdharmus* Zone (late Early Induan = late Griesbachian) in upper part of the Lazurnaya Bay Formation, and from AB1021 in the *Clypeoceras timo-*

rense Zone (early Early Olenekian=early Smithian) of the Zhitkov Formation, Abrek Bay area, South Primorye. *Unionites canalensis* is also reported from various other Lower Triassic localities as follows: Shamara River, South Primorye, Russia (Bittner, 1899b), Bakony region, Hungary (Bittner, 1901b; Frech, 1904), Werfen Formation, Dolomites, Italy (Frech, 1907; Ogilvie Gordon, 1927; Leonardi, 1935; Neri & Posenato, 1985), *Claraia* zone of the Dinwoody Formation, Wyoming and Montana, Western-Central USA (Ciriacks, 1963), Central Alborz Range, Iran (Nakazawa *et al.*, 1981), Qilian Mountain, Qinghai Province, Northwest China (Yang *et al.*, 1983), and Miyazaki, Kochi and Gunma Prefectures, Japan (Matsushita, 1926; Ozaki & Shikama, 1954; Yabe, 1956; Kambe, 1963; Nakazawa, 1971).

Discussion: *Unionites* is a very common Lower Triassic bivalve in South Primorye, and Bittner (1899b) described two species of *Anodontphora* (=*Unionites*), namely, *U. canalensis* and *U. fassaensis*. *U. canalensis* is distinguished from *U. fassaensis* by its more elongated and subquadrangular shape, and its more developed umbonal ridge, which runs from the umbo to the posteroventral extremity. Also, *U. canalensis* is generally larger than *U. fassaensis*. Ichikawa and Yabe (in Yabe, 1956, p. 284, pl. 16, figs. 1–7) proposed a new variety, *U. canalensis* var. *bittneri*, from a limestone block in the Kwanto Massif of East Japan. It differs from *U. canalensis* of South Primorye by its less elongate outline and more anterior position of the umbo. This species also exhibits intermediate forms between *U. canalensis* and *U. fassaensis*. Among the specimens described by Bittner (1899b), Ichikawa and Yabe (Yabe, 1956) assigned some specimens (pl. 3, figs. 34–36) to *U. canalensis* var. *bittneri*. Nakazawa (1971), however, treated this variety as intraspecific variation, after examining illustrations of the species reported from various parts of the world.

Unionites fassaensis (Wissmann, 1841)

Fig. 145.5–145.9

Myacites fassaensis Wissmann, 1841, p. 9, pl. 16, fig. 2a–c; Curioni, 1856, p. 320, pl. 6, fig. 1.

Anoplophora fassaensis (Wissmann). Frech, 1907, p. 40, pl. 7, fig. 3a–f.

Anodontophora (*Myacites*) *fassaensis* (Wissmann). Bittner, 1899b, p. 22, pl. 3, figs. 28–33; Ogilvie Gordon, 1927, p. 27, pl. 1, fig. 25.

Myacites (*Anodontophora*) *fassaensis* Wissmann. Arthaber, 1906, p. 257, pl. 34. fig. 10.

Pleuromya fassaensis (Wissmann). Assmann, 1915, p. 631, pl. 36, fig. 8a, b.

Homomya fassaensis (Wissmann). Bender, 1921, p. 55, pl. 1, fig. 6a–c, pl.2, figs. 6–9; Leonardi, 1935, p. 32, pl. 1, figs. 5, 6.

Anodontophora fassaensis (Wissmann). Matsushita, 1926, pl. 8, fig. 11; Hsu, 1936–37, p. 317, pl. 1, figs. 15, 16; Newell and Kummel, 1942, p. 958, pl. 2, fig. 13; Yabe, 1956, p. 286, pl. 16, figs. 8–11; Kambe, 1963, p. 50, pl. 5, figs. 28–32, pl. 6, figs. 1, 2; Vu Khuc in Vu Khuc *et al.*, 1965, p. 26, pl. 2, figs. 14, 15.

Myophoria aff. *laevigata* (Ziethen). Matsushita, 1926, pl. 8, fig. 14.

Unionites fassaensis (Wissmann). Ciriacks, 1963, p. 82, pl. 16, fig. 13; Nakazawa, 1971, p. 127, pl. 25, figs. 1–4; Chen, Ma and Zhang, 1974, p. 326, pl. 174, figs. 2, 3, 7; Gan and Yin, 1978, p. 371, pl. 122, fig. 5; Nakazawa *et al.*, 1981, p. 144, pl. 2, figs. 11,12; Yin and Yin in Yang *et al.*, 1983, p. 135, pl. 13, figs. 1,2; Dang, Trinh Tho and Vu Khuc in Vu Khuc *et al.*, 1991, p. 81, pl. 5, figs. 19, 20; Kurushin and Truschelev in Dagys *et al.*, 1996, p. 68, pl. 4, figs. 20, 21.

Type: Not designated in Wissmann (1841) or in other previous studies.

Material examined: Nine specimens, NSM PM23425–23433, from AB1010, five specimens, NSM PM23434–23438, from AB1012, and two specimens, NSM PM23439–23440, from AB1014.

Description: Shell small in size, moderately inflated, trigonally ovate (H/L ratio about 0.7), equivalve and inequilateral. Umbo small, slightly prosogyrate, located at about two-fifths of valve length from front. Anterodorsal margin somewhat recurvate. Posterodorsal margin straight or slightly convex. Anterior margin well rounded. Lunule narrow. Posterior margin nearly straight, sub-truncated, forming an angle of 80° with arched ventral margin. Posterior ridge weakly elevated. Escutcheon narrow. Surface of main body ornamented with fine concentric growth lines. Entire inner margin smooth.

Measurements (*mm*):

Specimen no.	H	L	H/L	pU	Pu/L	Remarks
NSM PM23425	6.1	8.7	0.71	3.9	0.45	RV
NSM PM23426	14.6	18.4	0.79	6.6	0.36	RV
NSM PM23427	9.6	13.7	0.70	4.9	0.35	RV
NSM PM23428	10.5	15.4	0.68	7.9	0.51	LV*
NSM PM23429	12.1	20.3	0.60	7.4	0.36	RV**
NSM PM23430	13.0	18.7	0.69	7.8	0.42	LV
NSM PM23431	6.4	9.2	0.69	2.9	0.32	LV
NSM PM23432	5.7	9.0	0.63	4.3	0.48	RV
NSM PM23433	11.2	16.7+	–	–	–	LV*
NSM PM23434	12.1	16.1	0.76	7.1	0.44	LV*
NSM PM23435	11.7	16.5	0.71	8.0	0.48	RV*
NSM PM23436	12.8	19.7	0.65	7.1	0.36	LV*
NSM PM23437	11.7	16.9	0.69	7.8	0.46	LV*
NSM PM23439	5.7	9.6	0.60	5.0	0.53	RV*
NSM PM23440	14.2	22.0+	–	8.5	–	LV**

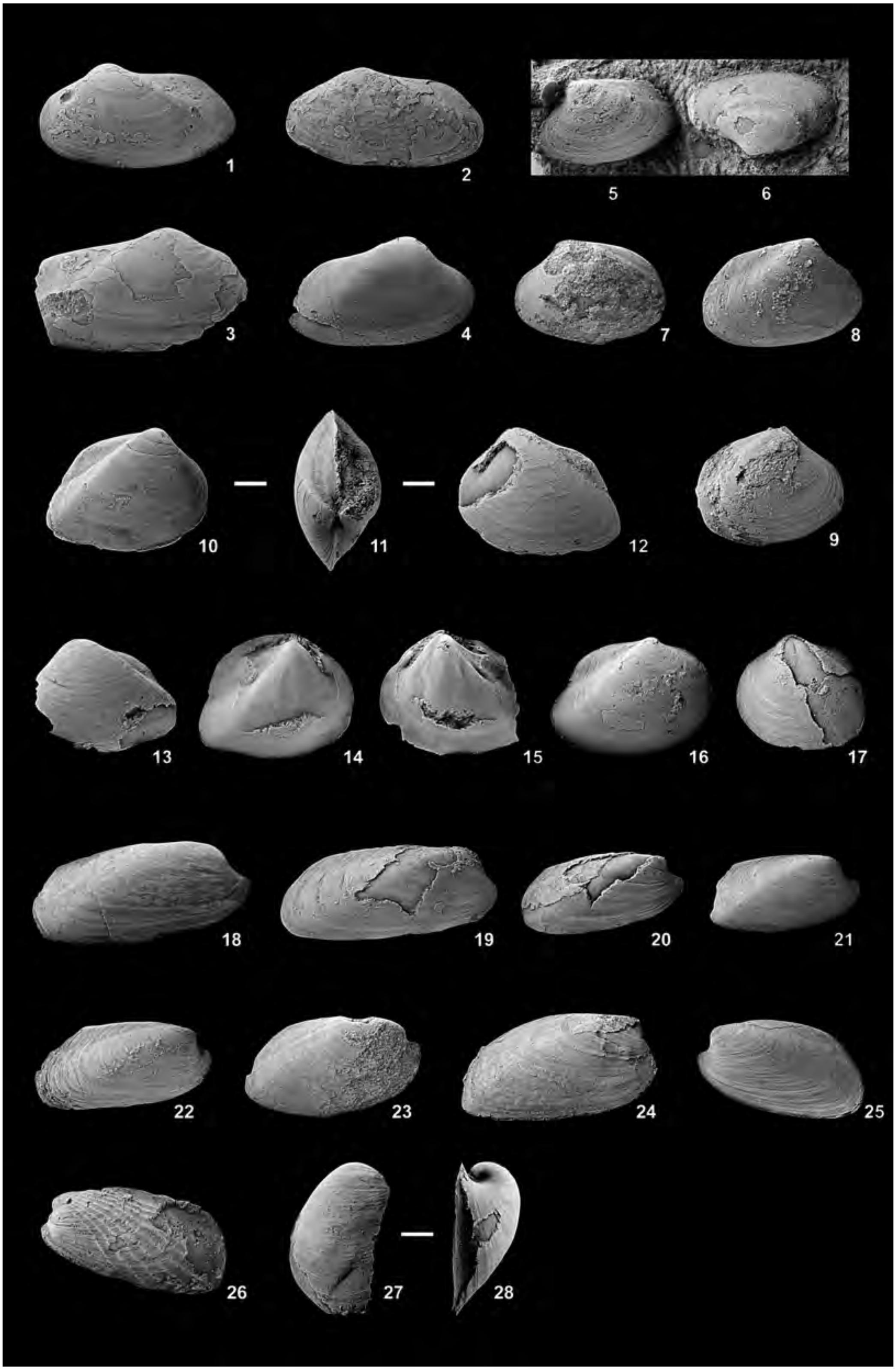
* incomplete shell, ** internal mold.

Occurrence: Described specimens from AB1010 in the lower *Gyronites subdharmus* Zone, and from AB1012 in the *Ambitoides fuliginatus* Zone in the upper part of the Lazurnaya Bay Formation, and from AB1014 in the *Clypeoceras spitiense* "bed" in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye. Thus, in this particular area, the species ranges from late Early Induan (late Griesbachian) to early Late Induan (early Dienerian). The species also occurs in the Lower Triassic on the western coast of Ussuri Gulf, Shamara River and Askold Island, South Primorye (Bittner, 1899b; Kiparisova, 1938). It also has been reported from various other Lower Triassic localities as follows: Olenek and Indigirka Rivers, Siberia, Russia (Dagys *et al.*, 1996), Werfen Formation, Dolomites, Italy (Curioni, 1856; Arthaber, 1906; Frech, 1907; Ogilvie Gordon, 1927; Leonardi, 1935), *Claraia* zone of the Dinwoody Formation, Wyoming, Western-Central USA (Newell & Kummel, 1942; Ciriacks, 1963), Central Alborz Range, Iran (Nakazawa *et al.*, 1981), Olenekian of Vietnam (Vu Khuc *et al.*, 1965, 1991), Qinghai, Zhejiang and Guizou Provinces, China (Hsu, 1936–37; Chen, Ma & Zhang, 1974; Gan & Yin, 1978; Yang *et al.*, 1983), and Miyazaki, Kochi and Gunma Prefectures, Japan (Matsushita, 1926; Yabe, 1956; Kambe, 1963; Nakazawa, 1971).

Discussion: The species differs from *Unionites canalensis* (Catullo) by its shorter length, less prominent beak and more centrally located umbo. The H/L ratio is less than 0.7, but that of the subspecies, *U. fassaensis* var. *brevis* (Bittner, 1901b), is about 0.75. The described specimens are quite similar to *U. fassaensis* (s.s.) in shell form and for all practical purposes, are identical with it.

→

Fig. 145. 1–4, *Unionites canalensis* (Catullo, 1848). 1, NSM PM23421, from AB1010, left valve, ×1.25. 2, NSM PM23422, from AB1010, left valve, ×1.0. 3, NSM PM23420, from AB1010, incomplete right valve, ×1.0. 4, NSM PM23424, from AB1021, right valve, ×1.0. 5–9, *Unionites fassaensis* (Wissmann, 1841) from AB1010. 5, NSM PM23431, left valve, ×2.5. 6, NSM PM23432, right valve, ×2.5. 7, NSM PM23430, incomplete left valve, ×1.25. 8, NSM PM23427, right valve, ×1.8. 9, NSM PM23426, right valve, ×1.25. 10–15, *Neoschizodus* cf. *laevigatus* (Ziethen, 1830). 10–12, NSM PM23367, from AB1021, right valve, dorsal view, incomplete left valve, ×1.8. 13, NSM PM23366, from AB1021, incomplete left valve, ×1.0. 14, NSM PM23365, from AB1021, internal mold of right valve, ×1.8. 15, NSM PM23364, from AB1010, internal mold of left valve, ×1.25. 16–17, *Neoschizodus* cf. *ovatus* (Goldfuss, 1838) from AB1013. 16, NSM PM23371, right valve, ×1.8. 17, NSM PM23372, incomplete left valve of immature individual, ×2.5. 18–25, *Triaphorus* aff. *multiformis* Kiparisova, 1966 from AB1021. 18, NSM PM23413, right valve, ×1.25. 19, NSM PM23391, right valve, ×1.25. 20, NSM PM23409, right valve, ×1.8. 21, NSM PM23414, right valve, ×1.8. 22, NSM PM23390, right valve, ×1.25. 23, NSM PM23392, right valve, ×1.8. 24, NSM PM23412, right valve, ×1.8. 25, NSM PM23411, left valve, ×1.8. 26, *Myoconcha* sp. indet., NSM PM23386, from AB1010, incomplete left valve, ×2.5. 27–28, *Ochotomya*? sp. indet., NSM PM23441, from AB1010, flank view and anterior view of imcomplete left valve, ×2.5.


1
2
5
6
3
4
7
8
10
11
12
9
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

Order Trigonioida Dall, 1889
Superfamily Trigoniacea Lamarck, 1819
Family Myophoriidae Bronn, 1849
Genus ***Neoschizodus*** Giebel, 1855

Type species: *Lyrodon laevigatum* Goldfuss, 1837.

***Neoschizodus* cf. *laevigatus* (Ziethen, 1830)**
Fig. 145.10–145.15

Myophoria cf. *laevigata* Alberti. Bittner, 1899b, p. 19, pl. 3, figs. 17–23, 25 (not 24, 26).
cf. *Trigonia laevigata* Ziethen, 1830, p. 94, pl. 71, figs. 2, 6 (not seen).
cf. *Lyrodon laevigatum* (Ziethen). Goldfuss, 1837, p. 107, pl. 135, fig. 12 (not seen).
cf. *Myophoria laevigata* (Ziethen). Philippi , 1903, p. 53, pl. 5, fig. 9a, b; Ciriacks, 1963, p. 82, pl. 16, figs. 18, 19.
cf. *Neoschizodus laevigatus* (Ziethen). Kiparisova, 1972, p. 91, pl. 12, fig. 11; Newell and Boyd, 1975, p. 142, text-fig. 82; Dang and Vu Chau in Vu Khuc *et al.*, 1991, p. 89, pl. 11, fig. 17; Kurushin and Truschelev in Dagys *et al.*, 1996, p. 71, pl. 9, figs. 14, 15.
cf. *Myophoria* (*Neoschizodus*) *laevigata* (Ziethen). Chen in EGFLC, 1976, p. 40, pl. 20, figs. 1–6.
cf. *Neoschizodus* cf. *laevigatus* (Ziethen). Nakazawa, 1960, p. 10, pl. 6, figs. 21–32; Neri and Posenato, 1985, p. 95, pl. 2, fig. 1.

Material examined: One specimen, NSM PM23364, from AB1010, and six specimens, NSM PM23365–23370, from AB1021.

Description: Shell small, equivalve, moderately inflated, trigonally subobate, longer than high (H/L ratio about 0.8) and inequilateral. Umbo small, prominent, sharply rounded, orthogyrate or somewhat opisthogyrate. Umbonal ridge elevated and subangular to rounded. Anterodorsal margin recurvate. Anterior margin rounded, passing to widely arched ventral margin. Lunule narrow. Posterodorsal margin straight. Posterior margin truncated. Posteroventral edge subangulated. Posterior area slightly concave. Flank evenly convex. Escutcheon wide, surface smooth and concentrically striated. Entire inner margin smooth. Anterior adductor muscle scar oval, situated in front of myophoric buttress. Posterior adductor scar circular, lying at posterodosal margin. Pallial line entire. Dentition myophorian type.

Measurements (*mm*):

Specimen no.	H	L	H/L	Remarks
NSM PM23364	14.6	17.7	0.82	LV**
NSM PM23365	13.9	13.4	1.04	RV**
NSM PM23366	17.3	21.9+	–	LV*
NSM PM23367	10.8	13.9	0.78	art.
NSM PM23368	15.5+	16.8	–	LV**
NSM PM23369	18.0	16.5+	–	LV*
NSM PM23370	10.6	13.1	0.81	RV**

* incomplete shell, ** internal mold, art.: articulated shells.

Occurrence: Described specimens from AB1010 in the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in the upper part of the Lazurnaya Bay Formation and from AB1021 in the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) of the Zhitkov Formation, Abrek Bay area, South Primorye. The specimens described by Bittner (1899b) are from the Lower Triassic of Paris Bay, Russian Island.

Discussion: *Neoschizodus laevigatus*, originally described from the Muschelkalk of Germany, is a cosmopolitan species and as such, occurs in various forms, which exhibit slightly different features in the shape of its shell as well as its posterior ridge. Bittner (1899b) noted these slight variations in the specimens from South Primorye. Among the specimens figured as *Myophoria* cf. *laevigatus*, the large specimens (pl. 3, figs. 17, 18) are clearly distinguished from those in figs. 24 and 26, which exhibit a low indistinct posterior ridge, a relatively low-inclined posterior area and a well rounded ventral margin. The former is related to typical *N. laevigatus*, and the latter is similar to *N. ovatus* (Goldfuss), whereas the smaller specimens (figs. 19–21, 23, 25), which have a distinct posterior ridge and well rounded ventral margin, are considered to be intermediate. The described specimens in the present article also exhibit characteristics of the two forms mentioned above. The specimens shown in Fig. 145.10–145.15 are of the *N. lae-*

vigatus (s.s.) type, while those in Fig. 145.16–145.17 are of the *N. ovatus* type. Compared with specimens of *N. laevigatus* from Germany (e.g., Newell & Boyd, 1975, p. 142, fig, 82A–D), the South Primorye specimens differ by their more rounded posterior ridge and more rounded posteroventral corner. The intermediate smaller samples of Bittner (1899b) are tentatively assigned to *N.* cf. *laevigatus*, but additional material is needed to permit a more certain assignment.

Neoschizodus cf. ***ovatus*** (Goldfuss, 1838)

Fig. 145.16–145.17

Myophoria cf. *laevigata* Alberti. Bittner, 1899b, p. 19, pl. 3, figs. 24, 26.

Myophoria laevigata var. *ovalis* Philippi? Kiparisova, 1938, p. 219, pl. 1, fig. 20 (no description).

cf. *Lyrodon ovatum* Goldfuss, 1838, p. 197, pl. 135, fig. 11 (not seen).

cf. *Neoschizodus ovatus* (Goldfuss). Neri and Posenato, 1985, p. 96, pl. 2, figs. 11, 12; Dang, Trinh Tho and Vu Khuc in Vu Khuc *et al.*, 1991, p. 89, pl. 6, fig. 1.

cf. *Neoschizodus* (*Leviconcha*) *ovatus* (Goldfuss). Farsan, 1972, p. 180, pl. 46, figs. 2, 3.

cf. *Myophoria ovata* (Goldfuss). Leonardi, 1935, p. 41, pl. 1, fig. 29.

Material examined: Two specimens, NSM PM23371, 23372, from AB1013.

Description: Shell small in size, weakly inflated, subquadrate to trigonally oval and inequilateral. Umbo small and orthogyrate. Umbonal ridge broadly rounded. Anterodorsal margin recurvate. Anterior margin rounded, passing to broad curvature of ventral margin. Posterior margin truncated. Posteroventral margin well rounded. Posterior area slightly concave. Surface smooth, ornamented with fine concentric lines.

Measurements (*mm*):

Specimen no.	H	L	H/L	Remarks
NSM PM23371	9.3	14.0	0.67	RV
NSM PM23372	7.6	8.0	0.95	LV*

* incomplete shell.

Occurrence: Described specimens from AB1013 in the *Ambitoides fuliginatus* Zone (early Late Induan=early Dienerian) in the lowest part of the Zhitkov Formation, Abrek Bay area, South Primorye. The species also occurs in the Lower Triassic of Russian and Putiatin Islands (Bittner, 1899b; Kiparisova, 1938)

Discussion: As mentioned above, the present species is distinguished from *Neoschizodus laevigatus* (s.s.) by its more rounded posterior ridge and more circular shell outline. It is similar to *N. ovatus* (e.g., Leonardi, 1935, p. 41, pl. 1, fig. 29; Farsan, 1972, p. 180, pl. 46, figs. 2, 3). *Myophoria laevigatus* var. *ovalis*, illustrated by Kiparisova (1938), is probably conspecific with the present species.

Subclass Heterodonta Neumayr, 1884
Order Veneroida H. Adams and A. Adams, 1856
Superfamily Carditacea Fleming, 1820
Family Permophoridae van de Poel, 1959
Subfamily Permophorinae van de Poel, 1959
Genus ***Triaphorus*** Marwick, 1953

Type species: *Pleurophorus zelandicus* Trechmann, 1918.

Triaphorus aff. ***multiformis*** Kiparisova, 1966

Fig. 145.18–145.25

aff. *Triaphorus multiformis* Kiparisova, in Kiparisova *et al.*, 1966, p. 73, pl. 31, figs. 5–9.

aff. *Triaphorus multiformis*, Kurushin and Truschelev in Dagys *et al.*, 1996, p. 73, pl. 29, fig. 9.

Material examined: Three specimens, NSM PM23387–23389, from AB1010, twenty-four specimens, NSM PM23390–23413, from AB1021, and one specimen, NSM PM23414, from AB1022.

Description: Shell small in size, moderately inflated, transversely suboval, somewhat extended posteriorly (H/L ratio about 0.5), equivalve and inequilateral. Umbo small, nearly terminal and prosogyrate. Subangular to rounded ridge running from umbo to posteroventral edge. Anterodorsal margin short and depressed. Anterior margin short and narrowly rounded. Posterodorsal margin slightly convex. Lunule narrow and deep. Posterior margin nearly straight or gently arched and truncated obliquely. Ventral margin slightly curved. Surface ornamented with irregular fine concentric lines. Weak radial ribs on posterior area. Inner structures unknown.

Measurements (*mm*):

Specimen no.	H	L	H/L	pU	pU/L	Remarks
NSM PM23387	8.0	15.6	0.51	3.4	0.22	RV
NSM PM23388	5.2	10.0	0.52	1.7	0.17	LV*
NSM PM23389	5.2	10.9	0.48	3.0	0.28	RV
NSM PM23390	10.3	21.7	0.47	2.6	0.12	LV
NSM PM23391	11.8	27.0	0.44	2.6	0.09	RV*
NSM PM23392	8.7	15.1	0.57	1.8	0.12	RV
NSM PM23393	8.3	17.2	0.49	2.8	0.17	LV*
NSM PM23394	7.9	14.0	0.57	2.2	0.15	RV
NSM PM23395	9.2	16.2+	–	3.5	–	LV
NSM PM23396	8.7	14.8+	–	1.9	–	LV*
NSM PM23397	10.0	19.1	0.52	3.4	0.18	RV
NSM PM23398	4.9	9.3	0.53	1.6	0.17	LV
NSM PM23399	10.3	13.1+	–	3.9	–	LV*
NSM PM23400	4.9	8.8	0.55	2.4	0.28	LV*
NSM PM23401	7.7	15.2+	–	2.0	–	LV*
NSM PM23402	6.6	12.8+	–	0.9	–	RV
NSM PM23403	4.9	9.3	0.53	0.6	0.06	RV
NSM PM23404	10.1	14.7	0.69	2.6	0.17	LV*
NSM PM23405	6.3	11.9	0.53	2.1	0.18	RV
NSM PM23406	4.6	7.2	0.64	1.1	0.15	RV
NSM PM23407	8.2	16.9	0.48	2.7	0.16	LV*
NSM PM23408	3.4	7.2	0.47	1.4	0.19	LV
NSM PM23409	6.0	14.0	0.43	2.1	0.15	RV*
NSM PM23410	7.3	14.1	0.52	1.4	0.10	RV*
NSM PM23411	7.8	14.3	0.55	1.5	0.11	LV
NSM PM23412	9.6	16.7	0.58	1.9	0.11	RV
NSM PM23413	8.3	18.1	0.46	3.0	0.17	RV
NSM PM23414	6.5	13.1	0.50	2.3	0.17	RV

* incomplete shell.

Occurrence: Described specimens from AB1010 in the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in upper part of the Lazurnaya Bay Formation, and from AB1021 and AB1022 in the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: Since the internal structures of the specimens cannot be observed, it is difficult to ascertain their generic position with full confidence. However, the external features of the present specimens are quite similar to *Triaphorus multiformis* from the Upper Triassic strata of Siberia. For these reasons, they are herein assigned to *Triaphorus*. The described specimens differ from *T. multiformis* by their smaller size and slightly less elongate form.

Subfamily Myoconchinae Newell, 1957

Genus ***Myoconcha*** J. de C. Sowerby, 1824

Type species: *Myoconcha crassa* J. de C. Sowerby, 1824.

Myoconcha sp. indet.

Fig. 145.26

Material examined: NSM PM23386, from AB1010.

Description: Shell small, moderately inflated and transversely subquadrate (H/L ratio about 0.6). Umbo small, subterminal and prosogyrate. Anterior end short, narrowly rounded and concentrically striated. Posterodorsal margin nearly straight. Posterior end gently arched and subtruncated. Ventral margin nearly straight. Ornamented posteriorly by coarse, radial ribs, which together with concentric lines, form a reticulate pattern. Internal structures unknown.

Measurements (*mm*):

Specimen no.	H	L	H/L	Remarks
NSM PM23386	7.3	11.5	0.64	LV

Occurrence: Described specimen from AB1010 in the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: Since the internal characters cannot be observed, it is difficult to identify the present specimen with certainty. The elongate, posteriorly expanded shape and subterminal umbo remind one of several different taxa; namely, the Permian *Netschajewia* Yakovlev, the Triassic *Curionia* Rossi

Ronchetti, the Lower Jurassic *Kalentera* Marwick and the Permian?-Jurassic *Myoconcha* J. de C. Sowerby. Among these *Myoconcha* is more closely related to the present specimen by its developed radial ornament. Regarding this point the Permian taxon *Stutchburia* Etheridge is also similar to the described specimen, but differs by its subquadrangle shape. "*Modiolus*" sp. indet. (this paper) is also ornamented with radial ribs, but differs by its sinuated ventral margin and its more delicate radials.

Subclass Anomalodesmata Dall, 1889
Order Phoradomyoida Newell, 1965
Superfamily Phoradomyacea Gary, 1847
Family Ceratomyidae Arkell, 1934
Genus ***Ochotomya*** Polubotko, 1966

Type species: *Ochotomya anyuensis* Polubotko in Kiparisova *et al.*, 1966.

Ochotomya? sp. indet.
Fig. 145.27–145.28

Material examined: NSM PM23441, from AB1010.

Description: Shell small, thin, gibbous, strongly inflated and orbicular. Umbo large, obtuse, elevated above dorsal margin, prosogyrate and slightly incoiled. Anterior, posterior and ventral margins well rounded. Surface smooth, ornamented with fine concentric lines. Internal structures unknown.

Measurements (*mm*):

Specimen no.	H	L	H/L	Remarks
NSM PM23441	9.5	7.0+	–	LV*

* incomplete shell.

Occurrence: Described specimen from AB1010 in the lower *Gyronites subdharmus* Zone (late Early Induan=late Griesbachian) in upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

Discussion: Approximately one-third of the present specimen's posterior portion has been broken off, but based on growth lines, its shape is reasonably presumed to be orbicular. If we disregard its Lower Triassic stratigraphical origin and instead consider just its gibbous, strongly incurved umbo and the general shape of its left valve, the specimen could then be assignable to either the Jurassic-Cretaceous *Buchia* Rouillieror or the Middle-Upper Triassic *Ochotomya* Polubotko or the Devonian-Triassic *Megalodon* J. de C. Sowerby. *Buchia* has inequivalve shells consisting of a strongly convex left valve and a nearly flat right valve. In contrast, *Ochotomya* and *Megalodon* have equivalve shells. Unfortunately, only one valve (left) is at hand, and its generic position cannot be ascertained with certainty. It is tentatively referred to *Ochotomya* based on its distribution in Upper (and probably Lower and Middle) Triassic strata in Northeast Asia, South Primorye, Japan, North America and other areas (Polubotko in Kiparisova *et al.*, 1996, p. 196).

Brachiopods (by A. M. Popov)

Early Triassic brachiopods are generally rare and sparse worldwide (Dagys, 1993; Chen *et al.*, 2005). They have been sporadically reported from the Himalayas (Bittner, 1899a, Sun *et al.*, 1981; Chen, 1983; Ager & Sun, 1988), North America (Girty, 1927; Newell & Kummel, 1942; Hoover, 1979), Greenland (Frebold, 1939), Russian Far East (Bittner, 1899b, Dagys, 1965), North Caucasus, Mangyshlak and Balkans (Dagys, 1974), and South China (Chen & Shi, 1999; Chen *et al.*, 2002, 2005).

One of the most abundant and best-preserved Early Triassic brachiopod faunas in the world has been reported from the Lower Triassic successions in South Primorye. Some of these brachiopods have been described by previous authors (Bittner, 1899b; Dagys, 1965, 1974). More recently, I also found considerably rich brachiopods from the Lower Triassic sequences of the Abrek Bay area, South Primorye. These newly found brachiopods are generally very small and include inarticulated and articulated forma. They are described as below.

A number brachiopod taxa, found out recently together with *Abrekia sulcata* Dagys (?*Piarorhynchella* sp.nov., Wellerellidae gen. et sp. nov. A, Wellerellidae gen. et sp. nov. B, Pontisiinae gen. et sp. nov., ?Rhynchonellidae gen. et sp. nov.), are resulted and figured for fuller characteristic of the given assemblage.

Systematic classifications follow the revised versions of the Treatise on Invertebrate Paleontology. Part H. Brachiopoda (Kaesler ed., 2000, 2002).

Abbreviations for shell dimensions: L=shell length; Lv=ventral valve length; Ld=dorsal valve length; W=shell width; T=shell thickness.

Institution abbreviations: CGM=Central Research Geological Prospecting Museum (CNIGR Museum), St. Petersburg; DVGI=Far Eastern Geological Institute, Vladivostok; IGIG=Institute of Geology and Geophysics, Novosibirsk.

Subphylum Linguliformea Williams *et al.*, 1996

Class Lingulata Goryansky and Popov, 1985

Order Lingulida Waagen, 1885

Superfamily Linguloidea Menke, 1828

Family Lingulidae Menke, 1828

Genus ***Lingula*** Bruguiere, 1797

Type species: *Lingula anatina* Lamarck, 1801.

Lingula borealis Bittner, 1899

Fig. 146.5–146.6

Lingula borealis Bittner, 1899b, p. 25, pl. 4, figs. 1–7; Moisseiev, 1947, p. 64, pl. 6, figs. 5–7; Kiparisova, 1954, p. 9, pl. 1, figs. 3–5; Dagys, 1965, p. 10, pl. 1, figs. 1–4.

Lectotype: CGM 221/103, figured by Bittner (1899b, p. 25, Pl. 4, fig. 1) and designated by Dagys (1965, p. 10, pl. 1, fig. 2), from the Lower Triassic in the Paris Bay area of Russian Island, South Primorye, Russia.

Material examined: Six specimens, DVGI 2052/28–30, 41–43, from AB1005, two specimens, DVGI 2052/26, 40, from AB1006, seven specimens, DVGI2052/27, 34–39, from AB1008, which are ventral and dorsal valves, partly represented by molds or cores with shell fragments.

Description: Large shells for genus (see measurements below); elongately oval in outline; anterior and posterior margins rounded; side borders subparallel; posterior parts of both valves moderately elevated along median longitudinal line, with two slopes gradually down to lateral margins. Shell surface generally smooth except for concentric delicate growth lines. Dorsal interior paired muscular scars weakly impressed. Ventral interior with a pair of foremost adductor scars positioned near anterior end of median elevation, extending anterior-laterally; both external and internal oblique muscle scars conspicuous.

Occurrence: The *Lytophiceras* sp. Zone (Early Induan=Griesbachian) of the middle part of the Lazurnaya Bay Formation of AB1005, AB1006 and AB1008, Abrek Bay area, South Primorye. This species also occurs in the Induan of Idaho, western USA and Olenekian? of Mangyshlak, Kazakhstan.

Measurements (*mm*):

Specimen no.	L	W	L/W
DVGI 2052/27	7.0	4.6	1.52
DVGI 2052/34	4.9	3.8	1.29
DVGI 2052/35	4.9	2.8	1.75
DVGI 2052/36	>8.5	7.4	>1.15
DVGI 2052/37	6.6	3.5	1.89
DVGI 2052/38	3.6	1.3	2.77
DVGI 2052/39	4.1	2.5	1.64
DVGI 2052/26	10.0	5.3	1.87
DVGI 2052/40	5.0	2.2	2.27
DVGI 2052/29	6.5	3.5	1.86
DVGI 2052/28	9.0	4.1	2.20
DVGI 2052/30	4.3	2.8	1.54
DVGI 2052/41	5.5	2.2	2.50
DVGI 2052/42	>6.0	2.7	>2.22
DVGI 2052/43	7.8	5.6	1.39

Discussion: Lingula has long been regarded as a living fossil as the genus has undergone little morphological changes since its origina-

Fig. 146. 1–4, 7–8, *Orbiculoidea* sp. indet., 1, DVGI 2052/31, from AB1006, dorsal valve exterior, ×3.0. 2, DVGI 2052/32, from AB1008, dorsal valve interior, ×3.0. 3, DVGI 2052/63, from AB1008, dorsal valve exterior, ×3.0. 4, DVGI 2052/55, from AB1006, dorsal valve interior, ×3.0. 7, DVGI 2052/56, from AB1006, dorsal valve interior, ×3.0. 8, DVGI 2052/29, from AB1006, ventral valve exterior, ×3.0. 5–6, *Lingula borealis* Bittner, 1899. 5, DVGI 2052/54, from AB1008, dorsal valve exterior, ×3.0. 6, DVGI 2052/26, from AB1007, ventral valve exterior, ×3.0.

tion in Early Palaeozoic (Rudwick, 1970). However, several recent studies reveal that the pre-Cretaceous specimens previously ascribed to *Lingula* may represent various genera, for example, the Carboniferous-Cretaceous *Lingularia* Biernat and Emig, 1993, the Early Permian *Semilingula* Popov (in Egorov & Popov, 1990) and the Late Permian *Lunoglossa* Xu and Xie, 1985. The convincing fossil records of *Lingula* are confined in the post-Jurassic strata (Holmer & Popov, 2000; Emig, 2003). As such, the pre-Cretaceous *Lingula* requires further studies and revisions.

Although their generic assignment remains problematic due to poorly preserved material, lingulids, as disaster taxa, were extremely abundant in the aftermath of the end-Permian mass extinction worldwide (i.e., Broglio Loriga, 1968; Rowell, 1970; Broglio Loriga *et al.*, 1980; Liao, 1980; Rodland & Bottjer, 2001). In particular, the well-illustrated study by Broglio Loriga (1968) exhibits *Lingula tenuissima* Bronn, 1837 (Bronn, 1850–1851) from the lowest Triassic of Dolomites, northern Italy bears comparable internal features with those of *Lingula anatina* Lamarck, 1801, Type species of the genus, from the Recent Oceans. This fact indicates that true *Lingula* may have occurred earlier in Early Triassic. Consequently, I assign tentatively these Primoryan specimens to *Lingula* with question mark.

The described specimens agree with Bittner's (1899b) description for the species. The South Primorye species also approaches externally *Lingula keuperea* Zenker (1834, p. 394, pl. 5, b), from which the Bittner's species is distinguished by its more convex valves and less curved growth lines at anterior margins.

Superfamily Discinoidea Gray, 1840

Family Discinidae Gray, 1840

Genus ***Orbiculoidea*** d'Orbigny, 1847

Type species: *Orbicula forbessi* Davidson, 1848.

Orbiculoidea sp. indet.

Fig. 146.1–146.4, 146.7–146.8

Material examined: Three specimens, DVGI 2052/31, 33, 44, from AB1004, four specimens, DVGI 2052/54–57, from AB1005, one specimen , DVGI 2052/58, from AB1006, ten specimens, DVGI 2052/32, 45–53, from AB1007, five specimens, DVGI 2052/59–63, from 1008, which are ventral and dorsal valves, partly represented by molds or cores with fragments of shell.

Description: Shell large, up to 14 mm in length and 11 mm in width; oval to subcircular in outline. Both valves sculptured with fine, concentrically arranged growth lines. Ventral median groove narrow, but distinct. Dorsal valve flattened posteriorly with small, but distinctive beak extending posteriorly.

Measurements (*mm*):

Specimen no.	L	W	H	L/W
DVGI 2052/33	10.7	7.5	2.5	1.43
DVGI 2052/31	13.8	10.7	5.0	1.29
DVGI 2052/44	5.7	4.0	2.5	1.42
DVGI 2052/45	4.0	4.0	1.0	1.00
DVGI 2052/32	8.6	5.7	2.0	1.51
DVGI 2052/46	6.8	6.0	1.3	1.13
DVGI 2052/47	3.7	3.6	1.0	1.03
DVGI 2052/48	7.5	6.7	2.2	1.12
DVGI 2052/49	4.5	4.5	1.3	1.00
DVGI 2052/50	2.3	2.1	0.5	1.10
DVGI 2052/51	>3.5	6.5	1.5	>0.54
DVGI 2052/52	5.4	4.2	2.0	1.29
DVGI 2052/53	4.2	4.3	0.8	0.98
DVGI 2052/54	5.4	5.1	1.6	1.06
DVGI 2052/55	8.0	5.0	1.7	1.60
DVGI 2052/56	6.5	5.5	1.8	1.18
DVGI 2052/57	4.0	4.0	1.4	1.00
DVGI 2052/58	3.6	3.7	1.3	0.97
DVGI 2052/59	11.0	>8.6	2.0	<1.28
DVGI 2052/60	6.6	5.6	1.9	1.18
DVGI 2052/61	5.6	3.5	0.9	1.60
DVGI 2052/62	>7.6	9.0	2.5	>0.84

Occurrence: The *Lytophiceras* sp. Zone (Griesbachian, Early Induan) of the middle Lazurnaya Bay Formation at AB1004, AB1005, AB1006, AB1007, and AB1008 of the Abrek Bay area, South Primorye. This species also occurs in the Induan in Idaho and Olenekian? in Mangyshlak.

Discussion: The distinctive features of the specimens enable to assign them with reasonable confidence to the genus *Orbiculoidea*. However, a definitive species assignment cannot be made. The described specimens more closely resemble specimen identified as *O. sibirica* Moisseiev (1947, p. 65) by Dagys (1965, p. 16) from Carnian of Pronchishhev Range, North-Eastern Siberia, but differs from it by significantly lesser inflation of ventral valve.

Subphylum Rhynchonelliformea
Class Chileata Williams *et al.*, 1996
Order Rhynchonellida Kuhn, 1949
Superfamily Rhynchonelloidea d'Orbigny, 1847
Family Rhynchonellidae d'Orbigny, 1847
Subfamily Piarorhynchiinae Shi and Grant, 1993
Genus ***Abrekia*** Dagys, 1974

Type species: *Abrekia sulcata* Dagys, 1974.

Abrekia sulcata Dagys, 1974
Figs. 147.1–147.24, 148, 149

Abrekia sulcata Dagys, 1974, p. 99, pl. 31, figs. 3, 4; text-fig. 64.

Holotype: IGIG 394/40, figured by Dagys (1974, p. 99, pl. 31, fig. 3), from the Lower

→

Fig. 147. 1–24, *Abrekia sulcata* Dagys, 1974. 1–4, DVGI 2052/18, from AB1008, ×3.0. 5–8, DVGI 2052/16, from AB1008, ×3.0. 9–12, DVGI 2052/15, from AB1008, ×3.0. 13–16, DVGI 2052/5, from AB1008, ×3.0. 17–20, DVGI 2052/2, from AB1022, ×3.0. 21–24, DVGI 2052/1, from AB1008, ×3.0. 25–28, ?Rhynchonellidae gen. et sp. nov., DVGI 2052/7, from AB1008, ×3.0. 29–32, ?*Piarorhynchella* sp. nov., DVGI 2052/10, from AB1008, ×3.0. 33–36, Wellerellidae gen. et sp. nov. A, DVGI 2052/12, from AB1008, ×3.0. 37–40, Wellerellidae gen. et sp. nov. B, DVGI 2052/4, from AB1008, ×3.0. 41–48, Pontisiinae gen. et sp. nov., from AB1008, ×3.0. 41–44, DVGI 2052/3. 45–48, DVGI 2052/6. Ventral valve view, dorsal valve view, anterior commissure view and lateral view are shown in order in each specimen.

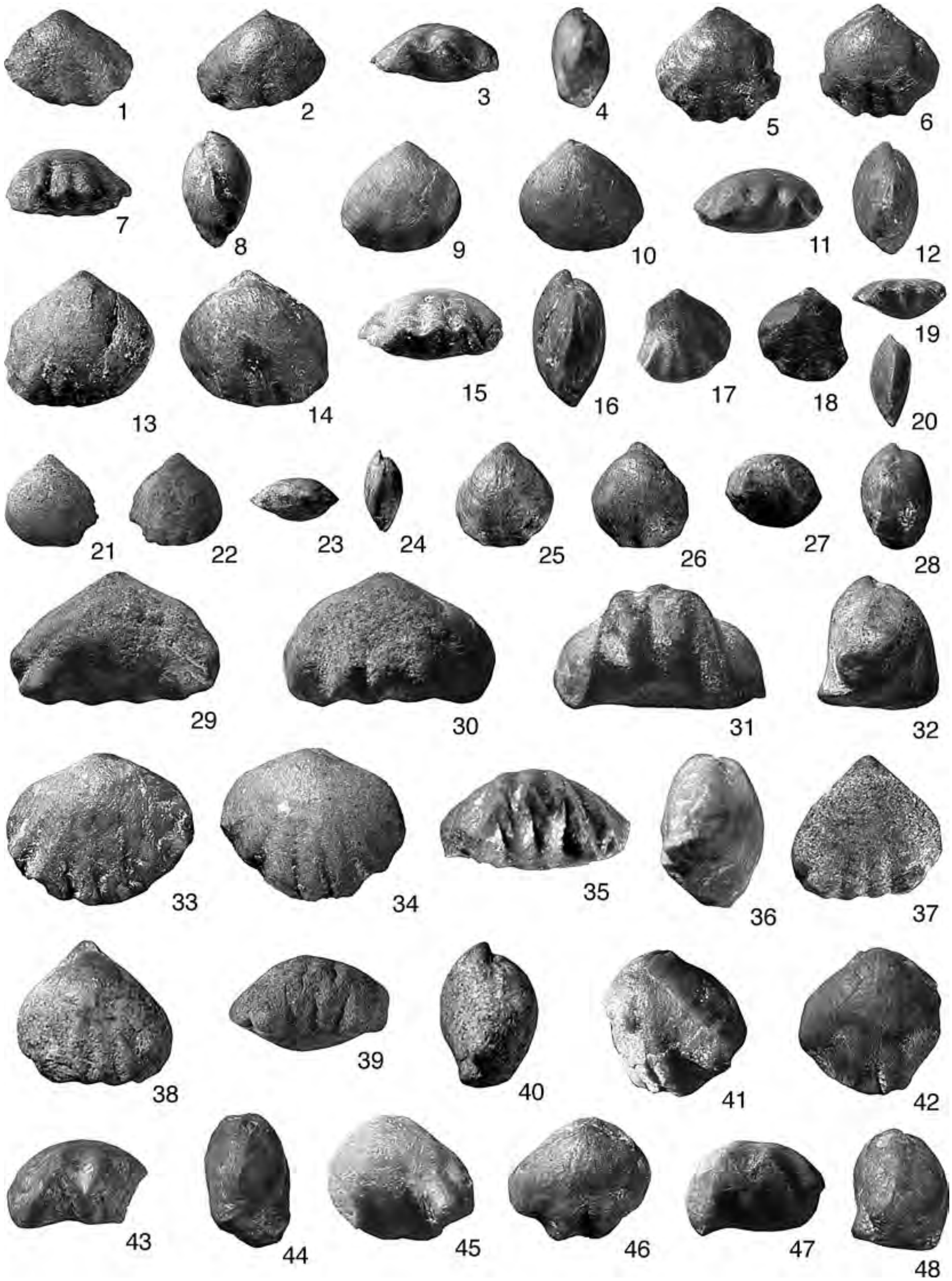

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48

Fig. 148. Holotype of *Abrekia sulcata* Dagys, 1974, IGIG 390/40, from the Induan in the Abrek Bay area, ×2 (after Dagys, 1974, pl. 31, fig. 3). 1, ventral valve view. 2, dorsal valve view. 3, anterior commissure view. 4, lateral view.

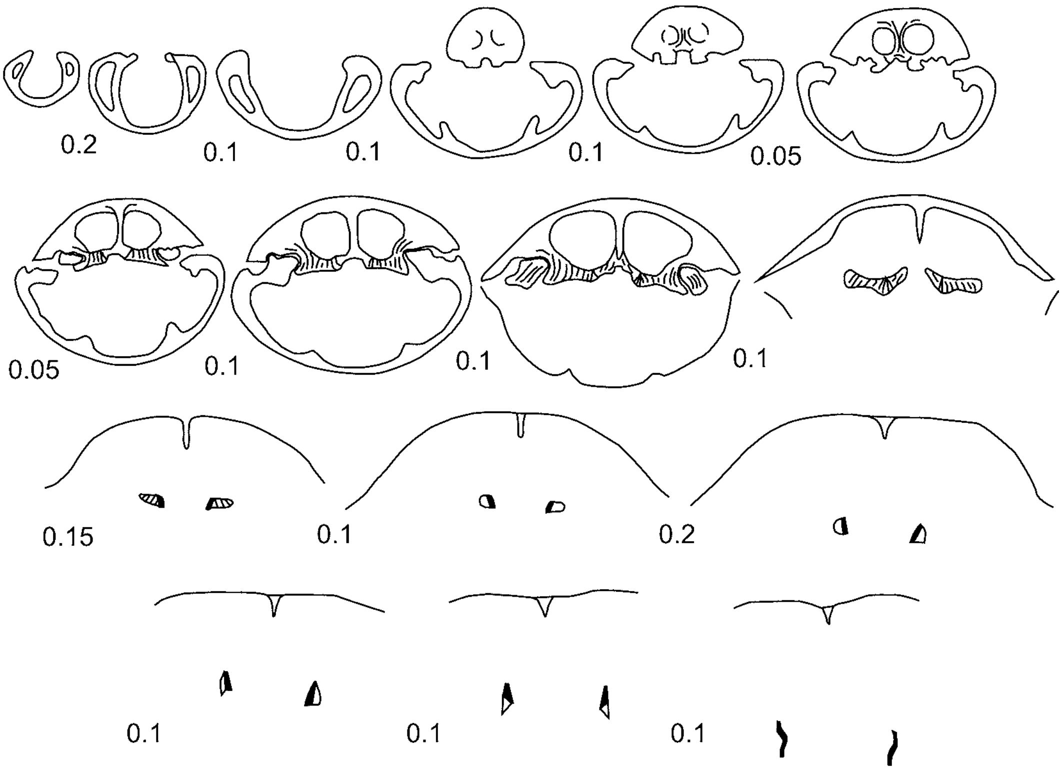


Fig. 149. Serial sections of *Abrekia sulcata* Dagys, 1974, IGIG 390/45, from the Induan in the Abrek Bay area (after Dagys, 1974, text–Fig. 64). By arabic number are shown intervals between adjacent sections.

Triassic (Induan) in the Abrek Bay area in South Primorye, Russia.

Material examined: Five specimens, DVGI 2052/1, 5, 15, 16, 18, from AB1008, and one specimen, DVGI 2052/2, from AB1022.

Description: Shells small in sizes (see measurements below); outline subpentagonal, transversely ovate to rounded, wider than long in adults, but shell width equating or smaller than length in juveniles; equibiconvex in profile; hingeline straight, shorter than greatest shell width positioning at midlength of shell; anterior commissure sulcate. External surface generally smooth, except for tiny, but distinct concentric growth lines.

Ventral valve evenly convex with greatest convexity anterior to umbo; umbo rounded, convex, gradually to lateral margins; beak small, weakly incurved, beyond hingeline; foramen submesothyrid, circular in outline, 0.2–0.5 mm in diameter; ventral valve medially convex to form poorly defined median fold, confined to middle and posterior parts of the shell; a broad median sulcus occurring near anterior margins. Dorsal valve moderately convex; beak small, indistinct; median fold consisting of two distinct costae, originating anterior to beak, extending to anterior margins; intercostal space forming a narrow, but distinct median groove, originating anterior to beak, slightly broadening near anterior margin; one median costa intercalating between two fold costae, but confined to anterior part of shell. External costae rounded in cross section, one costa in ventral median sulcus, three costae on dorsal median fold, and 1–3 costae on each flank.

Ventral interior dental plates short, convergent toward ventral floor. Dorsal septa low, but distinct, extending to a half of valve length; hinge plates rather broad, subhorizontal; crura long, raduliferlike, flattening distally (Fig. 149).

Measurements (*mm*):

Specimen no.	Lv	Ld	W	T
DVGI 2052/1	4.65	4.3	4.65	2.3
DVGI 2052/2	4.3	3.9	4.6	1.9
DVGI 2052/5	6.7	6.2	7.5	3.6
DVGI 2052/15	5.7	5.2	6.3	3.6
DVGI 2052/16	5.1	4.75	6.8	2.7
DVGI 2052/18	4.9	4.7	6.4	2.9

Occurrence: The *Lytophiceras* sp. Zone (Griesbachian, Early Induan) of the middle Lazurnaya Bay Formation at AB1008 and the *Clypeoceras timorense* Zone (early Smithian, early Early Olenekian) of the main part of the Zhitkov Formation at AB1022, Abrek Bay area, South Primorye.

Discussion: Dagys (1974) illustrated several relatively flat, mature specimens to represent his new genus, *Abrekia*, which is therefore considered to be confined to these flat, wider than long shells. In fact, our new collections from the topotype locality show that *Abrekia sulcata* may include morphologically more diverse specimens in terms of shell length, width and thickness. Our measurements show that juveniles often have relatively flat valves and longer than wide outlines, while adults possess relatively inflated valves and wider than long outlines. The present species differs clearly from *Abrekia*? *procreatrix* (Bittner, 1899a, p. 9), another common species in the Lower Triassic of Himalayas, in having distinct median groove/sulcus on the dorsal valve.

In addition, Chen and Shi (2002, p. 154) established *Meishanorhynchia* from the Griesbachian (Early Induan) of the Meishan section, South China. These authors inferred that their new genus could be ancestor of *Abrekia* in light of morphological evolutionary lineages and fossil horizons of both genera. It is true that both genera share similar internal features, a distinct dorsal median sulcus and variously developed costae. These incipient costae of *Meishanorhynchia* appear to be primitive characters of *Abrekia*, which possesses distinct, rounded costae on both valves. Accordingly, I agree with Chen *et al.* (2002) that the South Chinese genus may have given rise to *Abrekia* in late Griesbachian, not Dienerian as suggested by these authors.

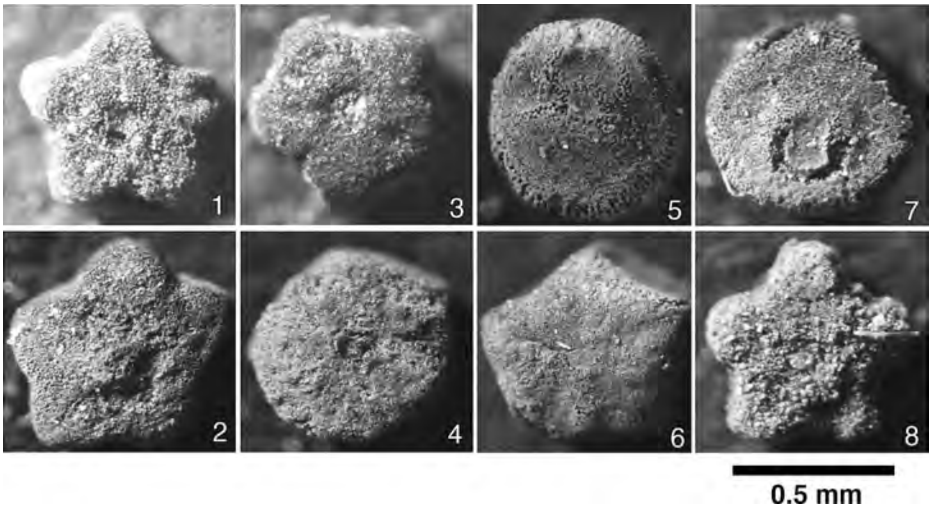


Fig. 150. *Holocrinus* sp. indet. from AB1022. 1, UMUT ME30044, columnal. 2, UMUT ME30046, columnal. 3, UMUT ME30045, columnal. 4, UMUT ME30047, columnal. 5, UMUT ME30050, cirri. 6. UMUT ME30048, columnal. 7, UMUT ME30051, cirri. 8, UMUT ME30049, columnal.

Crinoids (by T. Oji)

The systematic description below basically follows the classification by Rasmussen (1978).

Institution abbreviations: UMUT=University Museum, University of Tokyo.

Class Crinoidea Miller, 1821
Order Isocrinida Siverts-Doreck, 1952
Family Holocrinidae Jaekel, 1918
Genus ***Holocrinus*** Wachsmuth and Springer, 1886

Type species: *Encrinus beyrichi* Picard, 1883.

Remarks: *Holocrinus* possesses pentagonal coloumnals with five petals surrounded by crenulations on the articulation facet, the pattern common to the genus *Isocrinus*. However, *Holocrinus* is distinguished from *Isocrinus* by having elongated high basals, which are very low and usually separated on the surface in the case of Isocrinus.

Holocrinus sp. indet.
Fig. 150

Material examined: Six columnals, UMUT ME30044–30049, two cirrals, UMUT ME30050, 30051, all from AB1022. They were contained in a fine-grained, calcareous turbiditic sandstone. Specimens were removed from the rocks by dissolving the calcareous cement and disintegrate the rock by acetic acid, then were hand-picked using a binocular microscope after sieving and washing.

Description: Columnals small, ranging from 0.6–0.8 mm. Cross section of columnals pentagonal to stellate in outline. Probably due to abrasion, ornamentation disappeared during transportation, only central canal recognized on the articular facet, and no other conspicuous features observable. Some columnals show faint radial furrows, and weak embayment in the petaloid area (ligamentary field). Cirrals approximately 0.7 mm in diameter, as large as columnals. Cirrals rounded in outline. On the articular facet, there is fulcral ridge with two prominent tubercle-like protrusions near the both ends.

Occurrence: Described specimens from AB1022 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: These columnals and cirrals show common characteristics found in most of the taxa of Isocrinida. However, reliably assigned *Isocrinus* has never been reported from the early Triassic. Thus it would be safe to assign these columnals and cirrals to the genus *Holocrinus*. However, poor state of preservation (surface abrasion on the articular facet) prohibit from assigning these to any particular species.

Remark: The size of the columnals and cirrals from the Abrek Bay area are similar, both in the range of 0.6–0.8 mm. Usually columnals of the order Isocrinida are much larger than the cirri, which are components of appendages to the column (stalk). Thus, the size of the cirri is much larger than the usual columnals in this case, if compared with the present small sized columnals. This is probably due to size sorting of crinoid skeletal components, during transportation in a turbidity current. If this interpretation is right, there were originally different sized individuals of *Holocrinus*, and other larger columnals may be found in other localities near the present horizon.

Conodonts (by H. Igo)

The orientation of elements is now largely modified by intensive analyses of multielement reconstruction of conodont animals (e.g., Purnell *et al.*, 2000). All of the specimens described herein are discrete P elements; hence the author applies traditional usage of orientation terms proposed by Sweet (in Clark *et al.*, 1981). The author basically adopted the supra-generic classification proposed by Sweet (1988) herein.

Institution abbreviation: MPC=Micropaleontology Collection, National Museum of Nature and Science, Tokyo.

Order Prioniodinida Sweet, 1988
Family Ellisoniidae Clark, 1972
Genus ***Foliella*** Budurov and Pantic, 1973

Type species: *Polygnathus gardenae* Staesche, 1964.

Foliella gardenae (Staesche, 1964)
Fig. 155.12

Polygnathus gardenae Staesche, 1964, p. 286, pl. 30, figs. 3–6.
Foliella gardenae (Staesche). Budurov and Pantic, 1973, p. 52, pl. 1, figs. 19–20.
Foliella gardenae (Staesche), morphotypes A, B, Kolar-Jurkovsek and Jurkovsek, 1996, p. 8, pl. 1, figs. 1–4, pl. 2, figs. 1–3, pl. 3, fig. 3.
Platyvillosus aff. *gardenae* (Staesche). Buryi, 1979, p. 67, pl. 17, fig. 1.
Furnishius wangcangensis Dai and Tian, in Tian *et al.*, 1983, p. 355, pl. 95, figs. 13–14.

Material examined: MPC6646, from AB1025-1.

Occurrence: Studied specimen from AB1025 within the *Neospathodus* ex gr. *waageni-N. novaehollandiae* Zone with the *Radioprionites abrekensis* "bed" (early Early Olenekian= early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Foliella gardenae was first described from the Upper Campiller Formation (Smithian), South Tirol, Austria. The species was also reported from the Smithian in South Primorye (Buryi, 1979) and the Iska Valley of Slovenia (Kolar-Jurkovsek & Jurkovsek, 1996). *Furnishius wangcangensis* Dai and Tian assignable to this species occurs in the Smithian strata of Sichuan, China (Tian *et al.*, 1983).

Remarks: This species is a pastiniplanate element characterized by an arrow-headed plate with a sharply pointed posterior end. The original Alpine specimens have a rounded subellipsoidal plate, but the plate of the present one exhibits a different outline. The shape of denticles and their arrangement are similar each other but denticles of the present one are fewer in number. The described Slovenian specimens by Kolar-Jurkovsek and Jurkovsek (1996) are similar to the present specimen.

Genus ***Ellisonia*** Müller, 1956

Type species: *Ellisonia triassica* Müller, 1956.

Ellisonia? cf. ***peculiaris*** **(**Sweet, 1970)

Fig. 152.22

cf. *Neospathodus peculiaris* Sweet, 1970a, p. 255, pl. 5, fig. 19; Birkenmajor and Trammer, 1975, pl. 1, fig. 8; Wang, 1978, p. 224, pl. 1, figs. 1–3, 15; Tian *et al.*, 1983, p. 379, pl. 96, fig. 5; Beyers and Orchard, 1991, pl. 5, fig. 9.

Material examined: MPC6612, from AB1021-P2.

Occurrence: Specimen from AB1021 within the lower part of the *Neospathodus* ex gr. *waageni-N. novaehollandiae* Zone with the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Sweet (1970a) described this species from his Zone 5 (upper Dienerian *Neospathodus cristagalli* Zone) in the Mittiwali Member of the Mianwali Formation. Birkenmajor and Trammer (1975) reported this species together with *N. dieneri* Sweet and *N. svalbardensis* Trammer (=*N. pakistanensis* Sweet) from Hornsund, South Spitsbergen. Wang (1978) and Tian *et al.* (1983) recorded the joint occurrence of this species and *N. pakistanensis* in the Lower Triassic formations in Shaanxi and Tibet. Beyers and Orchard (1991) figured a poorly preserved specimen from Fauna 4 (Dienerian) of the Cache Creek Complex, British Columbia, Canada. The occurrence of this species is restricted to the *N. waageni waageni* Subzone of the Chaohu Section, Anhui Province, China (Zhao *et al.*, 2007).

Remarks: The fragmentary specimen illustrated herein resembles Sweet's specimen in characteristic denticulation and the shape of blade. The original one has a long cusp that is twice the length of other denticles. The present specimen retaines only the basal portion of cusp that does not permit further comparison. Identification is tentative.

Family Gondolellidae Lindström, 1970
Subfamily Neogondolellinae Hirsh, 1994
Genus ***Borinella*** Budurov and Sudar, 1994

Type species: *Neogondolella buurensis* Dagis, 1984.

Borinella cf. ***nepalensis*** (Kozur and Mostler, 1976)

Fig. 152.25–152.26

cf. *Gondolella nepalensis* Kozur and Mostler, 1976, p. 9, pl. 1, figs. 1–6.

cf. *Neospathodus labiatus* Goel, 1977, p. 1093, pl. 1, figs. 3–11.

cf. *Neospathodus nepalensis* (Kozur and Mostler). Matsuda, 1982, p. 93, pl. 4, figs. 1–7.

cf. *Neogondolella nepalensis* (Kozur and Mostler). Dagis, 1982, p. 56, pl. 1, figs. 1–3; Dagis, 1984, p. 6, pl. 1, figs. 1–7.

cf. *Borinella nepalensis* (Kozur and Mostler). Orchard, 2007a, pl. 1, figs. 1, 2.

Material examined: Two specimens, MPC6615, 6616, from AB1016-P1.

Occurrence: Specimens from AB1016 within the *Neospathodus dieneri-N. pakistanensis* Zone with the *Paranorites varians* Zone (Late Induan=Dienerian) in the lower main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Borinella nepalensis yields from the *Flemingites* Beds (MO3–12C) of the Mikin Formation Muth, Spiti. The beds should be the uppermost Dienerian (Krystyn *et al.*, 2007). Orchard (2007a) further noted that this species appeared in late Dienerian and its range extended into early Smithian in pelagic environments.

Remarks: Denticles are mostly broken and the surface of narrow platform is more or less attrited. The present specimens are similar to Orchard's (2007a) figured one in development of platform and denticulation.

Genus ***Eurygnathodus*** Staesche, 1964

Type species: *Eurygnathodus costatus* Staesche, 1964.

Eurygnathodus costatus Staesche, 1964

Fig. 152.23–152.24

Eurygnathodus costatus Staesche, 1964, p. 269, pl. 28, figs. 1–6; Budurov and Pantic, 1973, p. 51, pl. 1, figs. 1–15.

Platyvillosus costatus (Staesche). Goel, 1977, p. 1098, pl. 2, figs. 15–21; Wang and Cao, 1981, p. 371, pl. 2, figs. 1–4, 28, 29; Koike, 1982, p. 44, pl. 5, figs. 1–9; Matsuda, 1984, p. 128, pl. 6, figs. 6–10; Duan, 1987, pl. 3, fig. 4; Koike, 1988, pl. 1, fig. 1–57, pl. 2, figs. 1–37; Wang and Zhong, 1994, p. 404, pl. 1, figs. 15, 23.

Platyvillosus paracostatus Wang and Cao, 1981, p. 371, pl. 2, figs. 9–10.

Material examined: MPC6613, from AB1016-P1, MPC6614, from AB1021-P2.

Description: Two dextral and sinistral segminiplanate elements; outline of platform slender blade-like with narrowly rounded posterior and sharply pointed anterior ends; length 0.50 and 0.52 mm; width 0.16 to 0.21 mm; giving length to width ratio 2.5 to 3.1; and upper surface of platform transversed by 11 rows of ridged denticles.

Occurrence: Described specimens from AB1016 within the *Neospathodus dieneri-N. pakistanensis* Zone with the *Paranorites varians* Zone (early Late Induan = early Dienerian) and from AB1021 within the *N.* ex gr. *waageni-N. novaehollandiae* Zone with the *Clypeoceras timorense* Zone (early Early Olenekian = early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Staesche's original ones were recorded from the middle part of the "Campiller Schichten" on South Tirol (Staesche, 1964; Budurov & Pantic, 1973). Goel (1977) described this species from the Dienerian limestone exposed at Khar in the Spiti Valley, India. Orchard (2007a), however, pointed out that the stratigraphic levels of Goel's specimens could be Smithian rather than Dienerian. Matsuda (1984) collected this species from beds immediately below the first appearance of *N. waageni* Sweet in Kashmir. Koike's (1988) *Platyvillosus costatus* occurred abundantly in the Smithian part of the Taho Limestone in Shikoku, Japan. Wang and Cao (1981) and Wang and Zhong (1994) announced the occurrence of this species and similar ones, *Eurygnathodus paracostatus*, in the upper Dienerian in Lichuan, Hubei and other regions of South China. The above-mentioned records suggest that *E. costatus* persisted in Dienerian to Smithian and did not range into Spathian.

Remarks: The element collected from AB1016-P1 is sinistral with slightly concave line in right edge of the anterior part of platform. Ridged denticles in a posterior half of the platform are discontinuous. The other element from AB1021-P2 is dextral one with a convex profile in right side of a posterior half of the platform. This type is similar to *Eurygnathodus paracostatus* (Wang and Cao, 1981) in platform shape and complete ridges of denticles. According to Orchard (2007a), *E. paracostatus* is a precursor of *E. costatus* that occurs in higher levels than *E. paracostatus* in Hubei. On the contrary, the stratigraphic position of *E. paracostatus*-like element occupies the higher level than that of typical *E. costatus* in the present Abrek Bay section. Koike (1982) pointed out that these features are intraspecific variation in his numerous specimens of *Platyvillosus costatus* from the Taho Limestone in Shikoku, Japan. *E. paracostatus* is probably conspecific with *E. costatus*.

Genus *Neogondolella* Bender and Stoppel, 1965

Type species: *Gondolella mombergensis* Tatge, 1956.

Neogondolella carinata (Clark, 1959)

Fig. 151.1–151.3

Gondolella carinata Clark, 1959, p. 308, pl. 44, figs. 15–19; Matsuda, 1984, p. 119, pl. 1, figs. 1–11, pl. 2, figs. 1, 3–5.

Neogondolella carinata (Clark). Sweet, 1970b, p. 240, pl. 3, figs. 1–17, 24, 26, 27; McTavish, 1973, p. 288, pl. 2, fig. 13; Wang and Wang, 1976, p. 409, pl. 5, figs. 6–9; Buryi, 1979, p. 66, pl. 9, fig. 5, pl. 17, fig. 2; Tian *et al.*, 1983, p. 368, pl. 80, figs. 8–9; Dagis, 1984, p. 5, pl. 1, fig.13; Cao and Wang, 1993, p. 256, pl. 54, figs. 7, 11, pl. 55, fig. 10; Orchard and Krystyn, 1998, p. 358, pl. 4, figs. 9, 11, 16, 17, 20.

Material examined: MPC6572, from AB1008-1b, MPC6573, from AB1010-P2, MPC6574, from AB1012-2.

Occurrence: Illustrated specimens range from AB1008 to AB1012 within the *Neogondolella carinata* Zone with the *Lytophiceras* sp. Zone (Early Induan＝Griesbachian), the *Gyronites subdharmus* Zone (late Early Induan＝late Griesbachian), and the *Ambitoides fuliginatus* Zone (early Late Induan＝early Dienerian) in the middle to upper part of the Lazurnaya Bay Formation, Abrek Bay area, South Primorye.

The range of this worldwide species is the Griesbachian to the lower part of Smithian (Orchard & Krystyn, 1998).

Remarks: Unfortunately, specimens identified are rare and poorly preserved. General outline and denticulation, however, are identical to those of many previously described specimens.

Genus *Neospathodus* Mosher, 1968

Type species: *Spathognathodus cristagalli* Huckriede, 1958.

Neospathodus concavus Zhao and Orchard, 2007

Fig. 154.13

Neospathodus concavus Zhao and Orchard, in Zhao *et al.*, 2007, p. 35, pl. 1, figs. 1A, B, C; Orchard and Krystyn, 2007, fig. 4.

Material examined: MPC6637, from AB1022-2.

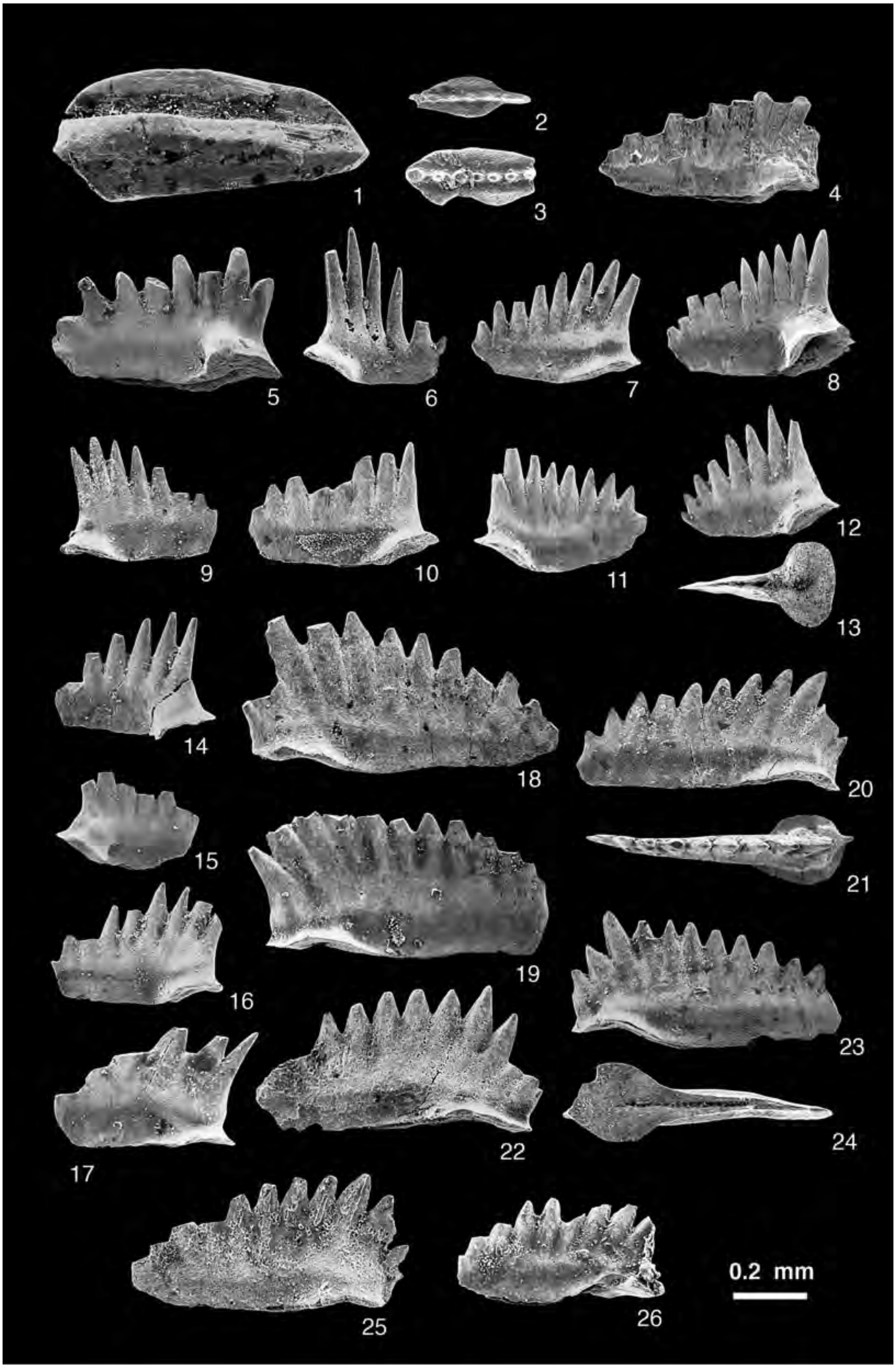
Occurrence: The specimen is recovered from AB1022 within the lower part of the *Neospathodus* ex gr. *waageni*-*N. novaehollandiae* Zone with the *Clypeoceras timorense* Zone (early Early Olenekian＝early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

The range of this species in the Pingdingshan Section is restricted to the *N. waaageni eowaageni* Subzone and the lowermost part of the *N. waageni waageni* Subzone (MO4-10＝lower part of the *Flemingites*-*Euflemingites* Zone). This implies the lowest Olenekian.

Remarks: The description and illustration of this species were originally given by Zhao and Orchard (in Zhao *et al.*, 2007). Orchard and

→

Fig. 151. 1–3. *Neogondolella carinata* (Clark, 1959). 1, MPC6672, from AB1008-1b. 2, MPC6573, from AB1010-P2. 3, MPC6574, from AB1012-2. 4–5, *Neospathodus* cf. *cristagalli* (Huckriede, 1958) from AB1014-1. 4, MPC6575. 5, MPC6576. 6–16, *Nospathodus dieneri* Sweet, 1970 from AB1014-1 (6–9), AB1014-P1 (10–16). 6, MPC6577. 7, MPC6578. 8, MPC6579. 9, MPC6580. 10, MPC6581. 11, MPC6582. 12–13, MPC6583. 14, MPC6584. 15, MPC6585. 16, MPC6586. 17, *Neospathodus* sp. A, MPC6587, from AB1014-P1. 18–26, *Neospathodus pakistanensis* Sweet, 1970 from AB1014-P1. 18, MPC6588. 19, MPC6589. 20–21, MPC6590. 22, MPC6591. 23–24, MPC6592. 25, MPC6593. 26, MPC6594.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
0.2 mm

Krystyn (2007), however, illustrated the other type of this species that bears 13 denticles on strongly arched blade. The present specimen resembles the Spiti specicmen in number of denticles.

Neospathodus cf. ***cristagalli*** (Huckriede, 1958)

Fig. 151.4–151.5

cf. *Spathognathodus cristagalli* Huckriede, 1958, p. 161, pl. 10, figs. 14, 15.
cf. *Neospathodus cristagalli* (Huckriede). Sweet, 1970a, p. 246, pl. 1, figs. 14, 15; Matsuda, 1982, p. 92, pl. 3, figs. 1–12.
cf. multielement apparatuses, *Neospathodus* cf. *cristagalli* (Sweet). Orchard, 2005, p. 88, text-fig. 14.
Many other synonyms of this species are eliminated herein.

Material examined: Two specimens, MPC6575, 6576, from AB1014-1.

Occurrence: Specimens from AB1014 within the lower part of the *Neospathodus dieneri-N. pakistanensis* Zone with the *Clypeoceras spitiense* bed (early Late Induan=early Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye.

This species and its morphotypes are known from the Dienerian and Smithian associated with *N. dieneri* Sweet elsewhere.

Remarks: Denticles are suberect and stought in the present specimens. Their tips are mostly lacking but probably discreted. Identification is reserved in the future research.

Neospathodus dieneri Sweet, 1970

Figs. 151.6–151.16, 152.8–152.9

Neospathodus dieneri Sweet, 1970a, p. 9, pl. 1, fig. 17; Sweet, 1970b, p. 249, pl. 1, figs. 1, 4; McTavish, 1973, p. 293, pl. 2, figs.3, 6; Buryi, 1979, p. 52, pl. 7, fig. 7; Wang and Cao, 1981, pl. 2, figs. 24, 25; Matsuda, 1982, p. 90, pl. 2, figs. 1–11; Koike, 1982, p. 37, pl. 6, figs. 15–21, 28, 29; Tian *et al.*, 1983, p. 376, fig. 3; Dagis, 1984, p. 27, pl. 6, figs. 4–7; Buryi, 1989, p. 26, pl. 1, fig.1; Beyers and Orchard, 1991, pl. 5, fig. 4; Wang and Zhong, 1994, p. 400, pl. 1, fig. 18; Buryi, 1997, pl. 1, fig. 9; Zhao and Orchard (in Zhao *et al.*, 2007), p. 35, pl. 1, figs. 12A, B, 9A, B, C, 11A, B, C; Orchard and Krystyn, 2007, figs. 3, 6, 7.

Material examined: Four specimens, MPC6577–6580, from AB1014-1, six specimens, MPC6581–6586, from AB1014-P1, two specimens, MPC6602, 6603, from AB1016-P1.

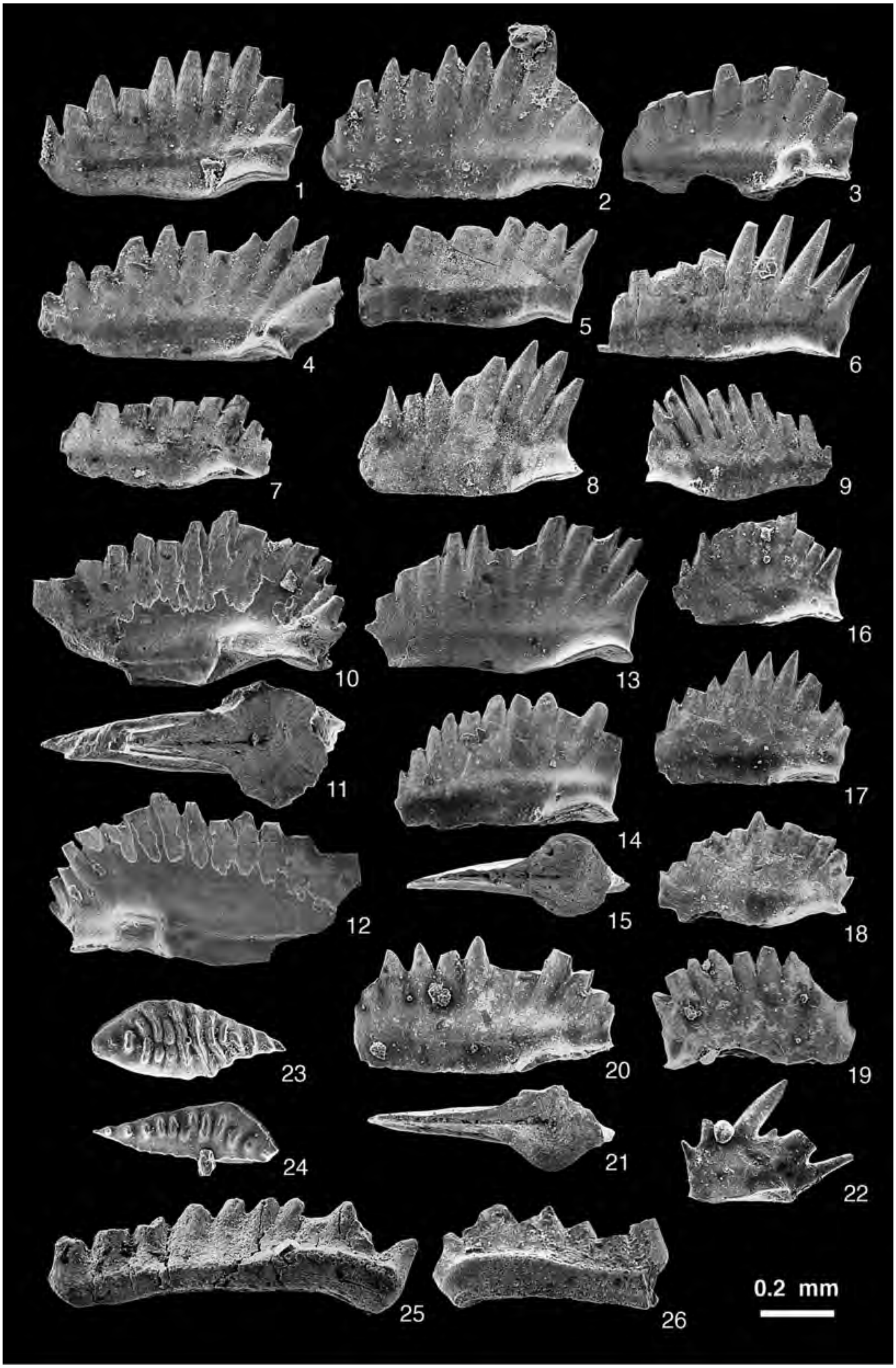
Description: Thin segminate elements, 0.35 to 0.50 mm long and 0.33 to 0.38 mm high, length to height ratio 0.9 to 1.5. Denticles 6 to 10 in number, average 8, discrete in upper half, pointed, reclined to erect, height gradually decreases toward anterior. Terminal cusp slightly higher or shorter than other denticles. Basal margin straight or slightly arched in anterior portion, upturned in posterior one-third of unit. Basal cavity large, subrounded or oval around deep pit.

Occurrence: Described specimens from AB1014 and AB1016 within the lower part of the *Neospathodus dieneri-N. pakistanensis* Zone with the *Clypeoceras spitiense* “bed” (early late Induan=early Dienerian) and the lower part of the *Paranorites varians* Zone (late Induan=Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye.

N. dieneri is a well-known species in the upper Dienerian to Smithian strata elsewhere.

→

Fig. 152. 1–7, 10–13, 20–21. *Neospathaodus pakistanensis* Sweet, 1970. 1–2, MPC6595, 6596, from AB1016-1. 3–6, MPC6597, 6598, 6599, 6600, from AB1016-P1. 7, MPC6601, from AB1021-P2. 10–12, MPC6604, fused elements, from AB1019-1. 13, MPC6605, from AB1019-1. 20–21, MPC 6611, from AB1021-P2. 8–9, *Neospathodus dieneri* Sweet, 1970 from AB1016-P1. 8, MPC6602. 9, MPC6603. 14–19, *Neospathodus* ex gr. *waageni* Sweet, 1970 from AB1021-P2. 14–15, MPC6606. 16, MPC6607. 17, MPC6608. 18, MPC6609. 19, MPC6610. 22, *Ellisonia*? cf. *peculiaris* (Sweet, 1970), MPC6612, from AB1021-P2. 23–24, *Eurygnathodus costatus* Staesche, 1964. 23, MPC6613, from AB1016-P1. 24, MPC6614, from AB1021-P2. 25–26, *Borinella* cf. *nepalensis* (Kozur and Mostle, 1976) from AB1016-P1. 25, MPC6615. 26, MPC6616.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
0.2 mm

The *N. dieneri* Zone corresponds to the stratigraphic interval including Bed 20 to Bed 24 of the Yinkeng Formation (uppermost Induan) at the West Pingdingshan Section in Chaohu, China (Zhao *et al.*, 2007). The occurrence of three morphotypes of *N. dieneri* is recorded also in Pakistan, Guryul Ravine Section in Kashmir, Lalung Section in Spiti, the Locker and Kockatea shale of Western Australia, South Primorye, and various localities in South China, Malaysia, and many others (e.g., Sweet, 1970; McTavish, 1973; Buryi, 1979; Matsuda, 1982; Koike, 1982; Tian *et al.*, 1983; Wang & Zhong, 1994; Orchard & Krystyn, 2007).

Remarks: Zhao and Orchard (in Zhao *et al.*, 2007) introduced three morphotypes in this *Neospathodus dieneri*. Specimens illustrated in Fig. 151.6–151.10, 151.12 in this paper are similar to their Morphotype 1 characterized by a higher and broader terminal cusp than other denticles. Specimens from AB1014 (MPC6580, 6584, 6585 in Fig. 151.9, 151.14, 151.15) are identical with their Morphotype 2 having posteriorly inclined and almost the same sized denticles. Two specimens from AB1016 (MPC6602, 6603 in Fig. 152.8, 152.9) exhibit a characteristic feature in a shorter and broader cusp compared with other denticles. These specimens resemble Morphotype 3 defined by Zhao and Orchard (op. cit.).

Neospathodus novaehollandiae McTavish, 1973

Figs. 153.8–153.14, 154.7–154.11, 155.1–155.11

Neospathodus novaehollandiae McTavish, 1973, p. 294, figs. 4, 5, 14, 16–23; Goel, 1977, p. 1091, pl. 1, figs. 1, 2; Tian *et al.*, 1983, p. 379, pl. 93, fig. 9; Duan, 1987, pl. 3, fig. 1; Beyers and Orchard, 1991, pl. 5, fig. 7; Orchard, 2007b, figs. 16–18.

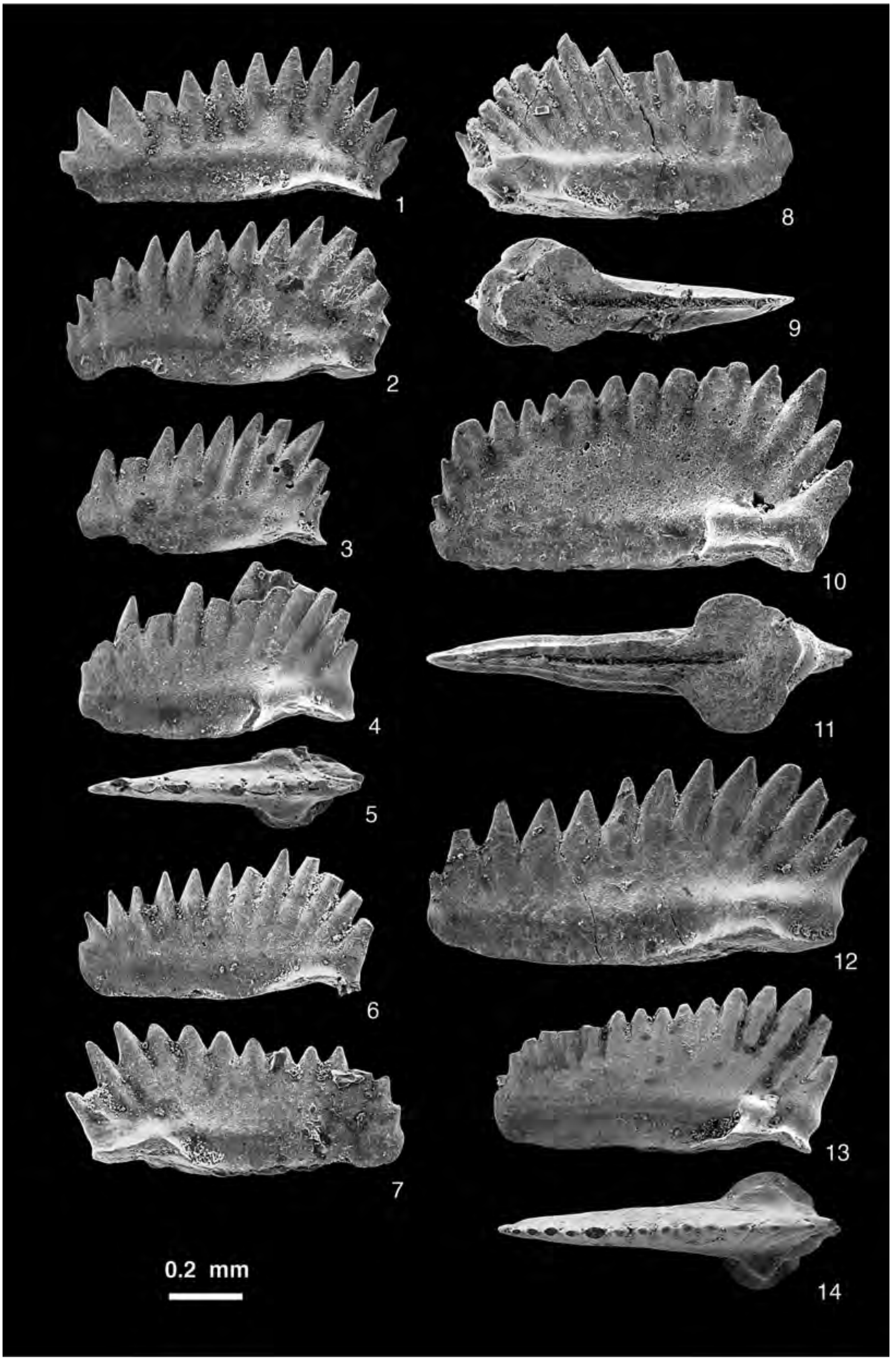
Material examined: Twelve specimens, MPC6623–6626, 6633–6635, 6638–6642, from AB1022-2, one specimen, MPC6645, from AB1024-1, two specimens, MPC6643, 6644, from AB1025-1.

Description: Blade-like large elements 0.73 to 1.30 mm, average 0.93 mm in length; 0.43 to 0.62 mm, average 0.53 in height; length to height ratio 1.6 to 2.3, average 1.7 in 15 specimens. Upper edge of elements arched to straight or more or less tapers anteriorly; base essentially straight. Denticles robust, high, erect to reclined posteriorly, sharply pointed, fused in a lower half, discrete in upper part, end at sharply pointed tip; numbers 10 to 17, average 14; 2 to 3 posterior and anterior denticles shorter than others. Cusp slightly longer than other denticles, situated above basal cavity. Lateral face of base bears straight rib becomes strong posteriorly in large specimens. Platform flange on flanks of element at posterior end conspicuously developed in some large specimens. Lateral process with fused denticles appears on lateral face near posterior end and surface of basal cup. In some aberrant or pathologic specimens, lateral process branched posterior-lateral and forms Y-shaped basal cavity in lower view. Basal cavity in most of specimens large, rounded to elliptical in lower view with deep pit. Deep furrow extended to anterior end of base.

Occurrence: Described specimens range from AB1022 to AB1025 within the *Neospathodus* ex gr. *waageni-N. novaehollandiae* Zone with the *Clypeoceras timorense*

→

Fig. 153. 1–7, *Neospathodus pakistanensis* Sweet, 1970 from AB1022-2. 1, MPC6617. 2, MPC6618. 3, MPC6619. 4–5, MPC6620. 6, MPC6621. 7, MPC6622. 8–14, *Neospathodus novaehollandiae* McTavish, 1973 from AB1022-2. 8–9, MPC6623. 10–11, MPC6624. 12, MPC6625. 13–14, MPC6626.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
0.2 mm

Zone and *Radioprionites abrekensis* "bed" (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

This species is originally described from the Locker shale (Smithian) of Western Austlaria (McTavish, 1973). Goel (1977) reported the abundant occurrence of this species associated with *N. dieneri* Sweet in the Khar Section of Spiti. Matsuda (1983) regarded this species with a synonym of *N. pakistanensis* Sweet from the Guryul Ravine in Kashmir. Beyers and Orchard (1991) reported this species from Fauna 6 (Smithian) contained in the Cache Creek Complex, south-central British Columbia. Orchard (2007b) and Orchard and Krystyn (2007) pointed out that *N. novaehollandiae* occurs in association with *N. pakistanensis* in Bed 13A-1 and Bed 13A-2 of IOB strata in Mud, Spiti.

Remarks: Many specimens identified to this species exhibit considerable variations as already pointed out by McTavish (1973) and other previous authors. General configuration of denticles, large and stout elements, and almost straight basal margin enable the author to distinguish from the similar species, such as *N. pakistanensis*. The author follows McTavish's oppinion that *N. pakistanensis* is the progenitor of *N. novaehollandiae*.

Several large specimens at hand show extreme development of lateral process and the surface of flare of basal cavity. There are possibilities that the specimens may belong to a new species, but the author tentatively assigned them with pathologic and/or aberrant ones of *N. novaehollandiae* in this study. Further consideration, however, is required to conclude.

Neospathodus pakistanensis Sweet, 1970

Figs. 151.18–151.26, 152.1–152.7, 152.10–152.13, 152.20–152.21, 153.1–153.7, 154.1–154.6

Neospathodus pakistanensis Sweet, 1970a, p. 254, pl. 1, figs. 16. 17; McTavish, 1973, p. 295, pl. 1, figs. 1, 2; Buryi, 1979, p. 57, pl. 9, fig. 2, pl. 18, fig. 5; Wang and Cao, 1981, p. 367, pl. 2, fig. 27; Dagis, 1982, p. 57, pl. 1, fig. 4; Matsuda, 1983, p. 87, pl. 1, figs. 1–5; Dagis, 1984, p. 26, pl. 5, figs. 9–11, pl. 12, fig. 6; Beyers and Orchard, 1991, pl. 5, fig. 2; Cao and Wang, 1993, p. 260, pl. 58, fig. 14; Wang and Zhong, 1994, p. 401, pl. 1, fig. 16, 24; Buryi, 1997, pl. 2, fig. 9; Orchard, 2007b, figs. 19, 20, 23–26. Orchard and Krystyn, 2007, figs. 19, 20.

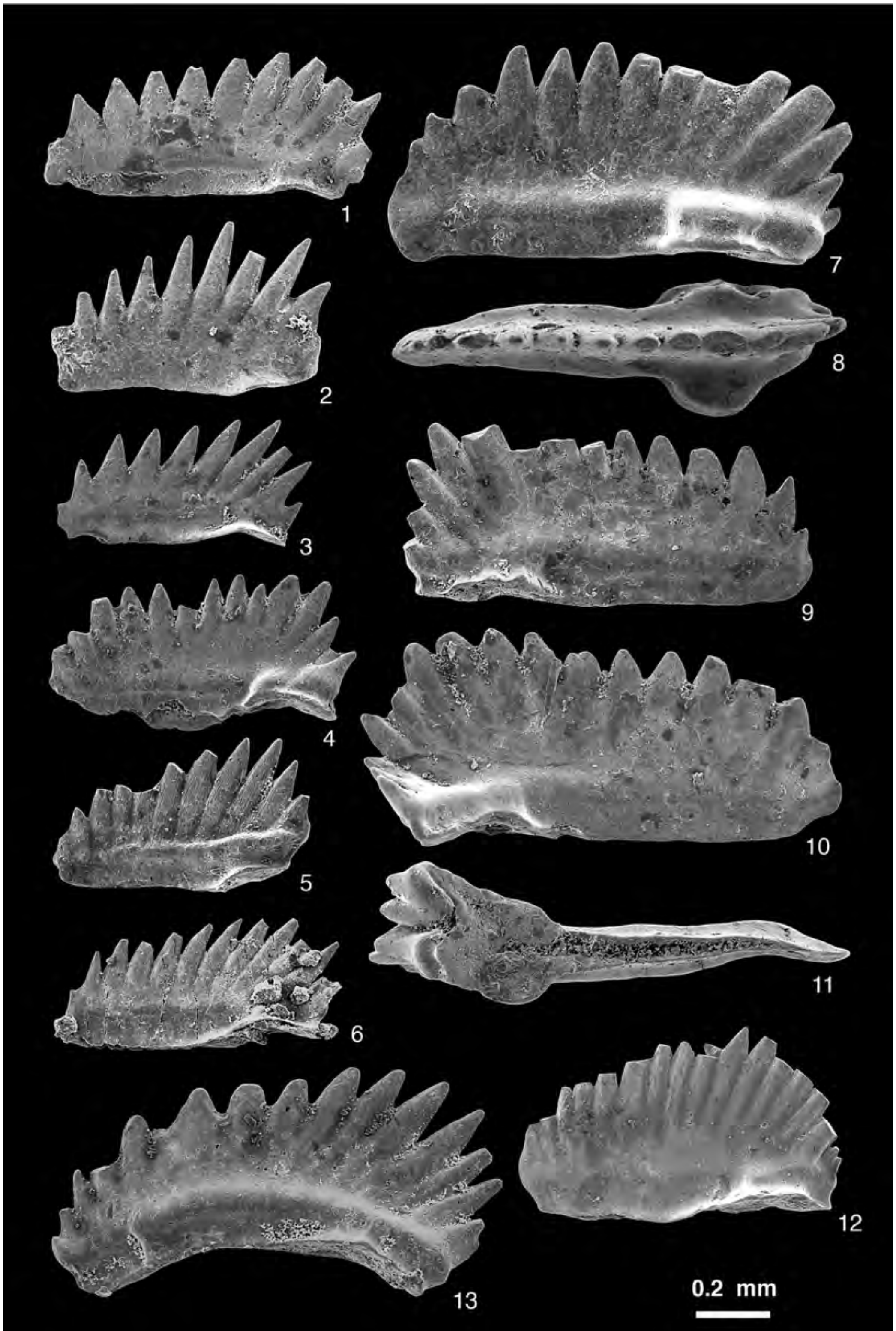
Neospathodus svalbardensis Trammer, in Birkenmajer, and Trammer, 1975, p. 306, pl. 1, figs. 5–7, pl. 2, figs. 1–7.

Material examined: Seven specimens, MPC6588–6594, from AB1014-P1, two specimens, MPC6595, 9596, from AB1016-1, four specimens, MPC6597–6600, from AB1016-P1, two specimens, MPC6604, 6605, from AB1019-1, two specimens, MPC6601, 6611 from AB1021-P2, eleven specimens, MPC6617–6622, 6627–6631, from AB1022-2, one specimen, MPC6632, from AB1022-3.

Description: Laterally compressed blade-shaped elements 0.55 mm to 0.83 mm long, average 0.71 mm; 0.31 mm to 0.49 mm high, average 0.41 mm in 20 samples. Ratio of length to height 1.5 to 2.3, average 1.73 in 20 individuals. Upper edge of element gently arched, highest point located posterior one-forth; lower edge generally straight or weakly curved upward in anterior most part; posterior part of lower margin downcurved or slightly deflected upward. Lateral rib prominent, par-

→

Fig. 154. 1–6, *Neospathodus pakistanensis* Sweet, 1970 from AB1022-2 (1–5), AB1022-3 (6). 1, MPC6627. 2, MPC6628. 3, MPC6629. 4, MPC6630. 5, MPC6631. 6, MPC6632. 7–11, *Neospathodus novaehollandiae* McTavish, 1973 from AB1022-2. 7–8, MPC6633. 9, MPC6634. 10–11, MPC6635, aberrant or pathologic element. 12, *Neospathodus* aff. *posterolongatus* Zhao and Orchard 2007, MPC6636, from AB1022-2. 13, *Neospathodus concavus* Zhao and Orchard, 2007 MPC6637, from AB1022-2.


1
2
3
4
5
6
7
8
9
10
11
12
13
0.2 mm

ticularly in posterior part. Denticles laterally flattend, triangular with sharp tip, slightly reclined posteriorly or erect, fused in lower base, discrete in upper half; number of denticles 12 to 14. Cusp slightly longer than other denticles, with 2 to 3 shorter denticles above posterior basal cup. Basal cavity subrounded, spatulate, with deep pit, and distinct furrow extended anteriorly.

Occurrence: Described specimens range from AB1014 to AB1022 within the *Neospathodus dieneri-N. pakistanensis* and the *Neospathodus* ex gr. *waageni-N. novaehollandiae* zones with the *Clypeoceras spitiense* "bed" (early late Induan=early Dienerian), the *Paranorites varians* Zone (late Induan=Dienerian), and the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) in the Zhitokov Formation, Abrek Bay area, South Primorye.

This species is originally described from West Pakistan and defines the *N. pakistanensis* Zone (Zone 6) in the Mittiwali Member of the Mianwali Formation (Sweet, 1970b). The zone overlies immediately above the *N. cristagalli* Zone and ends the base of the *N. waageni* Zone. The species is also known to occur in South Primorye (Buryi, 1979), Siberia (Dagis, 1982, 1984), Idaho (Paull, 1988), Cache Creek in British Columbia (Beyers & Orchard,1991), and other loclities in the North American Continent. Recent investigations by Orchard (2007a) and Orchard and Krystyn (2007), and Krystyn *et al.* (2007) clarified the range of this species starts from Bed 12 and ends at Bed 13A-2 in the *Flemingites* beds in Spiti. Thus the range of *N. pakistanensis* straddles the Dienerian-Smithian boundary (IOB); however, the species is one of the excellent indicators of latest Dienerian age.

Remarks: *N. pakistanensis* exhabits considerable morphological variations in size, general lateral profile, the shape of basal cavity, and numbers of denticles (e.g., Matsuda, 1983). The present specimens examined also exhabit similar broad variations mentioned above. The elements from AB1014 and AB1016 are slightly shorter in length, and denticles are fewer in number compared with those from AB1022.

Neospathodus aff. ***posterolongatus*** Zhao and Orchard, 2007

Fig. 154.12

aff. *Neospathodus posterolongatus* Zhao and Orchard, in Zhao *et al.*, 2007, p. 36, pl. 1, figs. 2A, B, C; Orchard, 2007b, figs. 1–6.

Material examined: MPC6636, from AB1022-2.

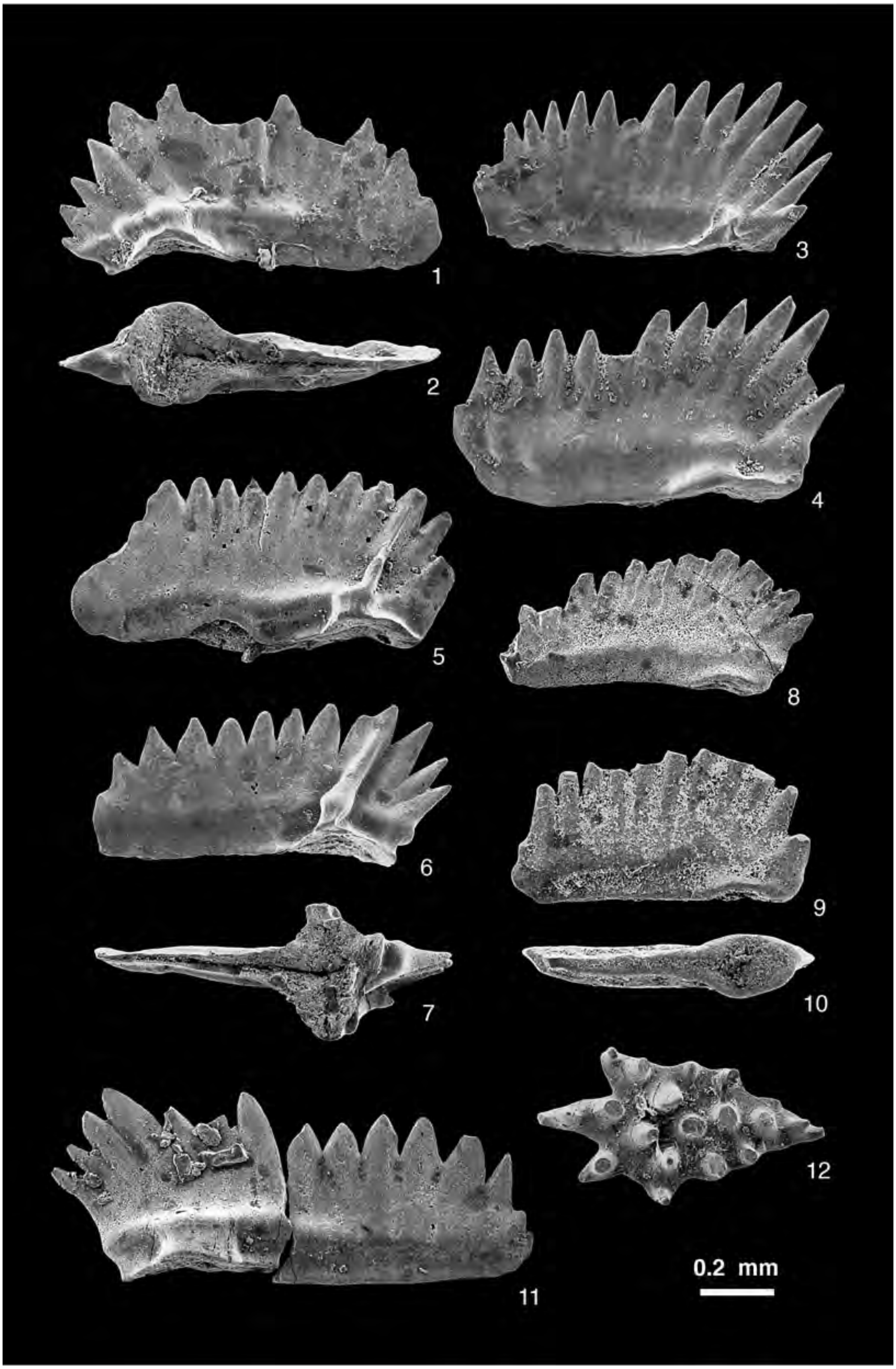
Occurrence: The specimen from AB1022 within the lower part of the *Neospathodus* ex gr. *waageni-N. novaehollandiae* Zone with the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

N. posterolongatus occurs in the *N. waageni waageni* Subzone of the Yinkeng Formation in Chaohu sections, and the species is one of the index species of the basal Olenekian (Zhao *et al.*, 2007).

Remarks: General profile of the present specimen is somewhat similar to this species that has recently been proposed as a new to science from the Yinkeng Formation in Chao-

→

Fig. 155. 1–11, *Neospathodus novaehollandiae* McTavish, 1971 from AB1022-2 (1–7), AB1025-1 (8–11). 1–2, MPC6638. 3, MPC6639. 4, MPC6640. 5, MPC6641. 6–7, MPC6642, aberrant or pathologic elements. 8, MPC6643. 9–10, MPC6644. 11, MPC6645. 12, *Foliella gardenae* (Staesche, 1964), MPC6646, from AB1025-1.


1
2
3
4
5
6
7
8
9
10
11
12
0.2 mm

hu. The present specimen, however, has more numbers of fused denticles than those of the latter. The author's present identification is tentative.

Neospathodus spitiensis Goel, 1977

Fig. 156.1–156.6, 156.21–156.22

Neospathodus spitiensis Goel, 1977, p. 1094, pl. 1, figs. 14–18; Tian *et al.*, 1983, p. 379, pl. 98, fig. 13.

Material examined: Seven specimens, MPC6647–6652, 6664, from AB1025-1.

Occurrence: Described specimens from AB1025 within the *Neospathodus* ex gr. *waageni-N. novaehollandiae* with the *Radioprionites abrekensis* "bed" (early Early Olenekian= early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

The holotype and illustrated paratypes of *N. spitiensis* came from the Smithian strata at Khar in Spiti (Goel, 1977). This species also occurs in Bed 15 at Muth in Spiti and Bed 26 of West Pingdingshan both of which include typical succession of the Induan-Olenekian Boundary strata (e.g., Orchard & Krystyn, 2007).

Remarks: The specimens examined are similar to the original specimens from Spiti. The present ones differ in number of denticles, more or less higher elements, and shorter posterior process than those of Spiti specimens.

Neospathodus ex gr. ***waageni*** Sweet, 1970

Figs. 152.14–152.19, 156.7–156.19

Neospathodus waageni Sweet, 1970b, p. 260, pl. 1, figs. 11, 12; McTavish, 1973, p. 300, pl. 2, figs. 11, 22, 25–28; Mosher, 1973, p. 172, pl. 20, fig.5; Wang and Wang, 1976, p. 411, pl. 3, figs. 4–7, 17; Goel, 1977, p. 1094, pl. 2, figs. 1–4; Solien, 1979, p. 304, pl. 3, fig. 9; Buryi, 1979, p. 56, pl. 7, figs. 8, 9; Wang and Cao, 1981, pl. 2, fig. 26; Koike, 1982, p. 39, pl. 6, figs. 26, 27; Matsuda, 1983, p. 88, pl. 1, figs. 6–10, pl. 2, figs. 1–7; Dagis, 1984, p. 24, pl. 7, figs. 1–10, pl. 8, figs. 1–7; Duan, 1987, pl. 2, fig. 7; Cao and Wang, 1993, p. 261, pl. 56, figs. 5, 11; Wang and Zhong, 1994, p. 402, pl. 1, figs. 12, 13; Buryi, 1997, pl. 1, fig. 7.

Neospathodus waageni waageni Sweet. Zhao and Orchard, in Zhao *et al.*, 2007, p. 36, pl. 1, figs. 10A, B.

Neospathodus waageni eowaageni Zhao and Orchard, in Zhao *et al.*, 2007, p. 36, pl. 1, figs. 5A, B.

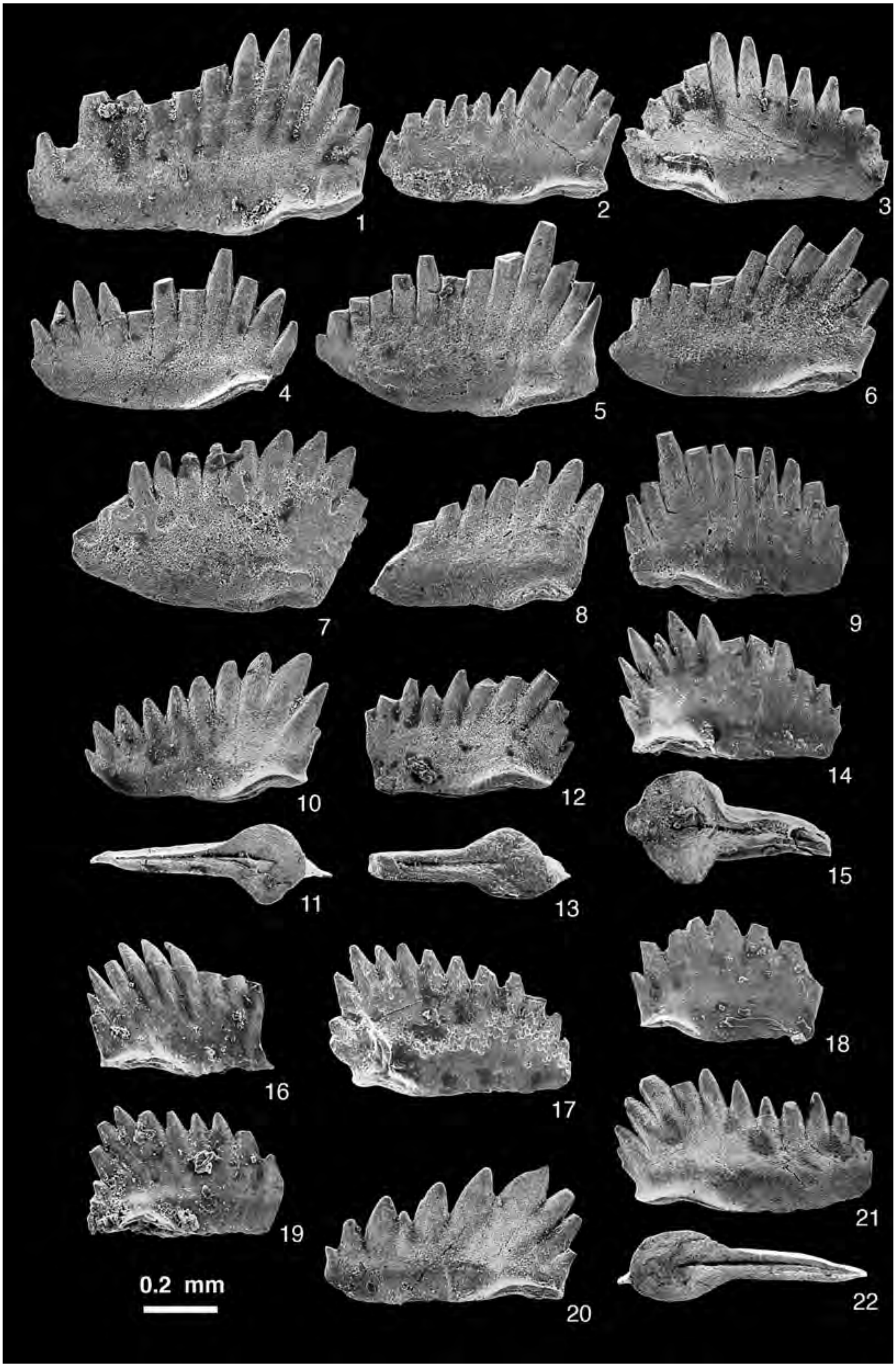
? *Neospathodus pingdingshanensis* Zhao and Orchard, in Zhao *et al.*, 2007, p. 36, pl. 1, figs. 4A, B, C.

Material examined: Five specimens, MPC6656, 6659–6662, from AB1024-1, five specimens, MPC6653–6655, 6657, 6658, from AB1025-1.

Description: Elements 0.43 mm to 0.85 mm, average 0.62 mm in length; 0.31 mm to 0.45 mm, average 0.37 mm in height; ratio of length to height 1.4–2.2, average 1.5 in 11 specimens. General profile of element arcuate, highest point situates at posterior half to near posterior margin. Lower margin of element almost straight to slightly undulated, posterior part upturned in some specimens. Denticles number 10 to 12, upturned, suberect to reclined posterioly, with pointed tip, discrete in upper part and fused in lower half. Cusp bears 2 small denticles at posterior end, slightly longer or shorter than other denticles. Lateral rib parallel to margin and more or less swollen. Platform flange developed on flanks

→

Fig. 156. 1–6, 21–22, *Neospathodus spitiensis* Goel, 1977 from AB1025-1. 1, MPC6647. 2, MPC6648. 3, MPC6649. 4, MPC6650. 5, MPC6651. 6, MPC6652. 21–22, MPC6664. 7–19, *Neospathodus* ex gr. *waageni* Sweet, 1970 from AB1025-1 (7–13), AB1024-1 (14–19). 7, MPC6653. 8, MPC6654. 9, MPC6655. 10–11, MPC6656. 12–13, MPC6657. 14–15, MPC6658. 16, MPC6659. 17, MPC6660. 18, MPC6661. 19, MPC6662. 20, *Neospathodus* sp. B, MPC6663, from AB1025-1.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
0.2 mm

of posterior end; cusp bears short lateral process in some specimens. Basal cavity large, rounded, and with deep pit.

Occurrence: Described specimens range from AB1021 to AB1025 within the *Neospathodus* ex gr. *waageni-N. novaehollandiae* Zone with the *Clypeoceras timorense* and *Radioprionites abrekensi*s "bed" (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

N. waageni is a well-known species throughout the world. This species is subdivided into *waageni eowaageni*, *waageni waageni*, and *posterolongatus* (Zhao & Orchard, in Zhao *et al.*, 2007) based on the rich materials from the Pingdingshan Section. Furthermore, Orchard and Krystyn (2007) distinguished six morphotypes of *N.* ex gr. *waageni* from material collected from the Muth Section in Spiti. These studies clarify that *N.* ex gr. *waageni* is a variable species, however, their morophotypes and several allied new species range the entire part of the Smithian (=lower division of Olenekian) elsewhere.

Remarks: The specimens exhibit broad variation as pointed out by previous authors. Matsuda (1983) separated this species into three types. Orchard and Krystyn (2007) proposed six morphotypes in Spiti specimens. In the present specimens, four morphotypes of *N. waageni* are present that correspond with their Morphotypes 1, 2, 3, and 4. Specimens numbered MPC6606 (Fig. 152.14) and MPC6660 (Fig. 156.17) have a similar flange observed in Morphotype 1. Specimens MPC6607-6610 (Fig. 152.16–152.19) have slightly reclined, subequal denticles forming an arcuate crest. This type of *N. waageni* corresponds with the holotype of this species, *N. waageni waageni*. The specimen MPS6655 (Fig. 156.9) has upright denticles, straight basal margin, and upturned at both ends. These features recognized in *N. waageni eowaageni* Zhao and Orchard. Specimens MPC6658 (Fig. 156.14, 156.15) and MPC6662 (Fig. 156.19) have two small lower posteriormost denticles that are abruptly smaller/lower than those to the anterior. This feature is diagnostic in Morphotype 4.

***Neospathodus* sp. A**

Fig. 151.17

Material examined: MPC6587, from AB1014-P1.

Occurrence: Figured specimen from AB1014 within the lower part of the *Neospathodus dieneri-N. pakistanensis* Zone with the *Clypeoceras spitiense* "bed" (early Late Induan=early Dienerian) in the lower part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Remarks: A fragmentary small segminate element with straight basal margin bears posteriorly curved 6 denticles. This unidentified species is similar to *Neospathodus waageni* Sweet (s.l.), but identification is postponed.

***Neospathodus* sp. B**

Fig. 156.20

Material examined: MPC6663, from AB1025-1.

Occurrence: This specimen from AB1025 within the *Neospathodus* ex gr. *waageni-N. novaehollandiae* Zone with the *Radioprionites abrekensi*s "bed" (early Early Olenekian= early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Remarks: A segminate element has 10 denticles, which are stout, posteriorly inclined, and uneven in size. This unidentified species may belong to the group of *Neospathodus waageni*.

Chondrichthyans (by H. Yamagishi)

Systematic descriptions basically follow Cappetta (1987) and Duffin and Ward (1995). Morphological terms follow Cappetta (1987) and Johns *et al.* (1997), and micromorphological terms follow Cuny and Benton (1999). All specimens described in this paper are reposited in the University Museum of the University of Tokyo (UMUT).

Class Chondrichthyes Huxley, 1880
Subclass Elasmobranchii Bonaparte, 1838
Cohort Euselachii Hay, 1902

Euselachii order, fam., gen., et sp. indet.
Fig. 157.5

Material obtained: Sixteen placoid scales, UMUT MV29694–29709, from AB1025–1, twenty-four placoid scales, UMUT MV29727–29750, from AB1024-1, thirteen placoid scales, UMUT MV29753–29765, from AB1022-3, five placoid scales, UMUT MV29771–29775, from AB1022-2, fourty-four placoid scales, UMUT MV29783–29826, from AB1021-P2, thirty-five placoid scales, UMUT MV29830–29864, from AB1019-1, sixty placoid scales, UMUT MV29880–29939, from AB1016-1, fourty placoid scales UMUT MV29943–29982, from AB1016-P1, nine placoid scales, UMUT MV29983–29991, from AB1014-P5, eight placoid scales, UMUT MV29996–30003, from AB1014-P1, and one placoid scale, UMUT MV30004, from AB1012-2.

Occurrence: Described specimens range from AB1012 within the *Ambitoides fuliginatus* Zone (early Late Induan=early Dienerian) in the uppermost part of the Lazurnaya Bay Formation to AB1025 within the *Radioprionites abrekensis* "bed" (early Early Olenekian=early Smithian) in the main part of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: A total of 255 placoid scales were recovered from the Abrek section. In the present study, these scales are not subjected to morphological description and taxonomical identification, but instead are treated as supplemental data to simply verify the presence of sharks.

Superfamily Hybodontoidea Owen, 1849
Family Acrodontidae Casier, 1959
Genus ***Acrodus*** Agassiz, 1837

Type species: *Acrodus gaillardoti* Agassiz, 1837.

Acrodus cf. ***cuneocostatus*** Cuny, Rieppel and Sander, 2001
Fig. 157.1–157.4

Material examined: Two teeth, UMUT MV29710–29711, from AB1024-1, a fragmented tooth, UMUT MV29751, from AB1022-3, one tooth, UMUT MV29766, from AB1022-2, one tooth, UMUT MV29776, from AB1021-P2, two fragmented teeth, UMUT MV29865–29866, from AB1016-1, two fragmented teeth, UMUT MV29940–29941, from AB1016-P1, and one tooth, UMUT MV29992, from AB1014-P1.

Description: Crown mesiodistally planar without obvious cusps. Crown has obvious occlusal crest and transverse ridges, with occlusal crest and longitudinal shoulder ridges at nearly same height. Root high and thin.

Occurrence: Described specimens range from AB1014 within the *Clypeoceras spitiense* "bed" (early Late Induan=early Dienerian) to AB1024 within the *Clypeoceras timorense* Zone (early Early Olenekian=early Smithian) of the Zhitkov Formation, Abrek Bay area, South Primorye.

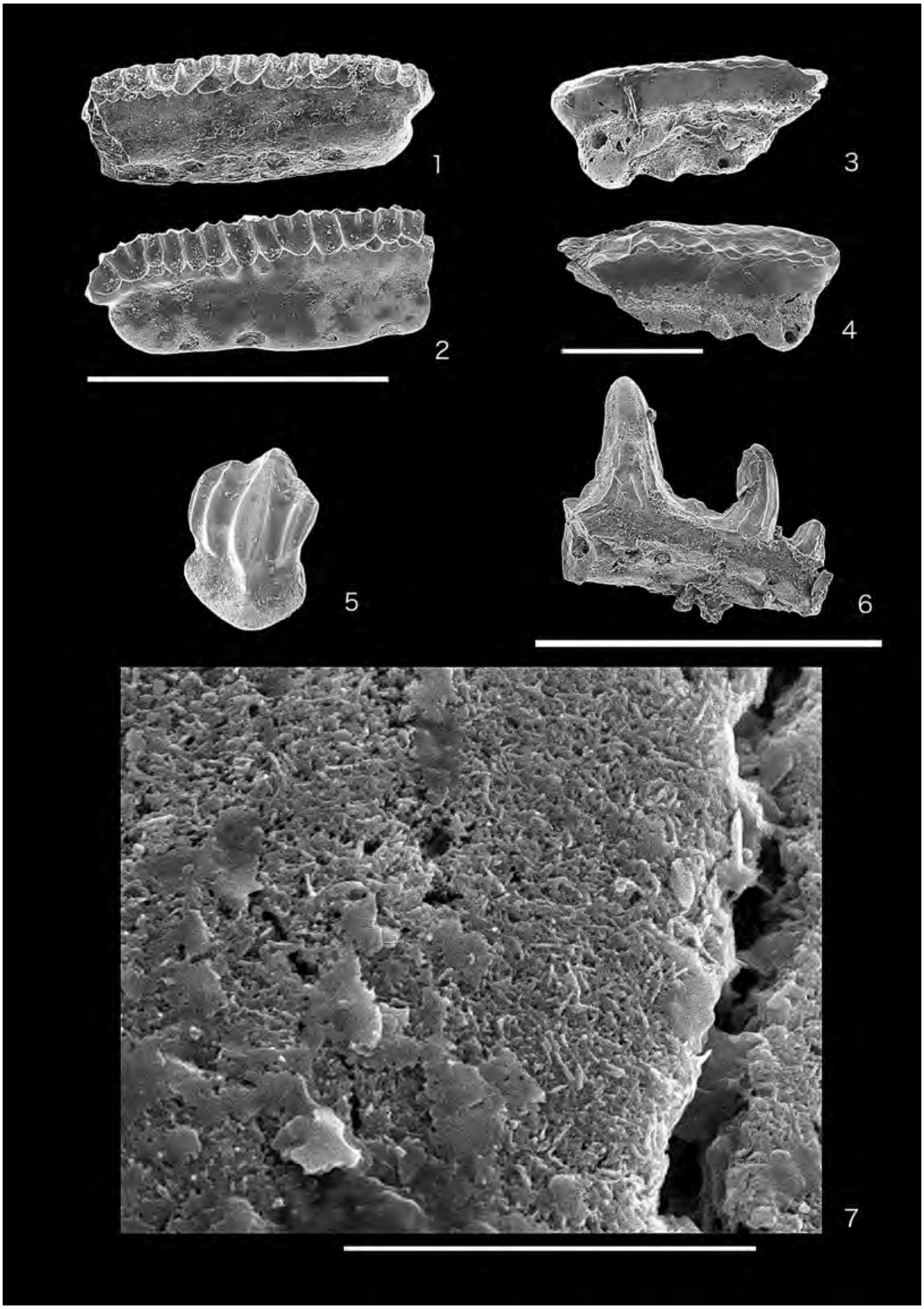
Discussion: Several specimens lack their roots and/or they have been abraded, but they do retain an obvious occlusal ridge on their crowns and part of the transverse lines on their shoulders. These teeth are similar to *Acrodus* cf. *cuneocostatus* Cuny, Rieppel and Sander (2001, Anisian, Fossil Hill Member, Favret Formation, Nevada) in terms of morphology, but their size range is quite different (holotype is 4.3 mm long mesio-distally and maximum labio-lingually width is 1.8 mm, whereas the Abrek specimens range only up to about

Table 2. List of shark teeth and scales obtained from the Lower Triassic Abrek Bay section.

Registered number	N	Sample	Species	Remarks
UMUT MV29692	1	AB1025-1	*Lissodus* cf. *cristatus* Delsate & Duffin	tooth
UMUT MV29693	1	AB1025-1	*Polyacrodus* sp. indet.	tooth
UMUT MV29694–29709	16	AB1025-1	Euselachii order, fam., gen., et sp. indet.	placoid scales
UMUT MV29710–29711	2	AB1024-1	*Acrodus* cf. *cuneocostatus* Cuny, Rieppel & Sander	teeth
UMUT MV29712–29714	3	AB1024-1	*Hybodus* sp. indet.	teeth
UMUT MV29715–29717	3	AB1024-1	*Lissodus* cf. *cristatus* Delsate & Duffin	teeth
UMUT MV29718–29726	9	AB1024-1	*Polyacrodus* sp. indet.	teeth
UMUT MV29727–29750	24	AB1024-1	Euselachii order, fam., gen., et sp. indet.	placoid scales
UMUT MV29751	1	AB1022-3	*Acrodus* cf. *cuneocostatus* Cuny, Rieppel & Sander	fragmented tooth
UMUT MV29752	1	AB1022-3	*Polyacrodus* sp. indet.	fragmented tooth
UMUT MV29753–29765	13	AB1022-3	Euselachii order, fam., gen., et sp. indet.	placoid scales
UMUT MV29766	1	AB1022-2	*Acrodus* cf. *cuneocostatus* Cuny, Rieppel & Sander	tooth
UMUT MV29767–29769	3	AB1022-2	*Lissodus* cf. *cristatus* Delsate & Duffin	teeth
UMUT MV29770	1	AB1022-2	Euselachii order, fam., gen., et sp. indet.	tooth
UMUT MV29771–29775	5	AB1022-2	Euselachii order, fam., gen., et sp. indet.	placoid scales
UMUT MV29776	1	AB1021-P2	*Acrodus* cf. *cuneocostatus* Cuny, Rieppel & Sander	tooth
UMUT MV29777	1	AB1021-P2	*Hybodus* sp. indet.	tooth
UMUT MV29778–29780	3	AB1021-P2	*Lissodus* cf. *cristatus* Delsate & Duffin	teeth
UMUT MV29781–29782	2	AB1021-P2	*Polyacrodus* sp. indet.	teeth
UMUT MV29783–29826	44	AB1021-P2	Euselachii order, fam., gen., et sp. indet.	placoid scales
UMUT MV29827–29828	2	AB1019-1	*Lissodus* cf. *cristatus* Delsate & Duffin	fragmented teeth
UMUT MV29829	1	AB1019-1	*Polyacrodus* sp. indet.	fragmented tooth
UMUT MV29830–29864	35	AB1019-1	Euselachii order, fam., gen., et sp. indet.	placoid scales
UMUT MV29865–29866	2	AB1016-1	*Acrodus* cf. *cuneocostatus* Cuny, Rieppel & Sander	fragmented teeth
UMUT MV29867	1	AB1016-1	*Hybodus* sp. indet.	fragmented tooth
UMUT MV29868–29879	12	AB1016-1	Euselachii order, fam., gen., et sp. indet.	fragmented teeth
UMUT MV29880–29939	60	AB1016-1	Euselachii order, fam., gen., et sp. indet.	placoid scales
UMUT MV29940–29941	2	AB1016-P1	*Acrodus* cf. *cuneocostatus* Cuny, Rieppel & Sander	fragmented teeth
UMUT MV29942	1	AB1016-P1	*Lissodus* cf. *cristatus* Delsate & Duffin	fragmented tooth
UMUT MV29943–29982	40	AB1016-P1	Euselachii order, fam., gen., et sp. indet.	placoid scales
UMUT MV29983–29991	9	AB1014-P5	Euselachii order, fam., gen., et sp. indet.	placoid scales
UMUT MV29992	1	AB1014-P1	*Acrodus* cf. *cuneocostatus* Cuny, Rieppel & Sander	tooth
UMUT MV29993–29995	3	AB1014-P1	*Hybodus* sp. indet.	fragmented teeth
UMUT MV29996–30003	8	AB1014-P1	Euselachii order, fam., gen., et sp. indet.	placoid scales
UMUT MV30004	1	AB1012-2	Euselachii order, fam., gen., et sp. indet.	placoid scale

→

Fig. 157. Elasmobranch remains from the Abrek Bay section. 1–4, Teeth of *Acrodus* cf. *cuneocostatus* Cuny, Rieppel and Sander, 2001. 1, 2, UMUT MV29766 from AB1022-2. 1, labial view. 2, lingual view. 3, 4, UMUT MV29940 from AB1016-P1. 3, labial view. 4, lingual view. 5, Placoid scale of Euselachii order, fam., gen., et sp. indet, UMUT MV29771 from AB1022-2. 6, 7, Tooth of *Hybodus* sp. indet. 6, UMUT MV29993 from AB1014-P1. Specimen etched with hydrochloric acid (1%) for 10 sec to observe microstructure of enameloid. 6, labial view. Scanning electolon micrograph of enameloid microstructure of the principal cusp. Scale bar=1 mm (1, 2, 5, 6), 0.5 mm (3, 4), 0.01 mm (7).


1
2
3
4
5
6
7

1 mm). They are also similar to *A.* cf. *spitzbergensis* Hulke (1873) from the Vardebukta Formation, Lower Triassic (Dienerian), Hornsund area, Hyrnefjellet Mt., South Spitzbergen as illustrated in Błażejowski (2004).

Family Hybodontidae Owen, 1846
Genus ***Hybodus*** Agassiz, 1837

Type species: *Hybodus reticulatus* (Agassiz), 1837.

Hybodus sp. indet.
Fig. 157.6–157.7

Material examined: Three teeth, UMUT MV29712–29714, from AB1024-1, one tooth, UMUT MV29777, from AB1021-P2, one fragmented tooth, UMUT MV29867, from AB1016-1, and three fragmented teeth, UMUT MV29993–29995, from AB1014-P1.

Description: Crown with cusps not well separated, notches between cusps fail to reach the level of root, cusps vertical or slightly lingually inclined and between one and five pairs of lateral cusps with cutting edges well developed. Crown bears relatively faint striae, which may bifurcate near base of labial crown shoulder. Anterolateral teeth with high, pointed cusps, presumed lateral teeth with distally inclined cusps and posterolateral teeth mesiodistally elongate with principal cusp and low lateral cusps. Root arcuate, root labial face shallow and flat perforated by regular row of foramina, and basal face flat to concave. Lingual face convex and lingually displaced, presenting some foramina. Root vascularisation anaulacorhize.

Occurrence: Described specimens range from AB1014 within the *Clypeoceras spitiense* “bed” (early Late Induan = early Dienerian) to AB1024 within the *Clypeoceras timorense* Zone (early Early Olenekian = early Smithian) of the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: Frequently, the teeth of the genus *Hybodus* and those of primitive neoselachians can not be easily divided based on their gross morphology (Reif, 1973, 1977; Maisey, 1982; Cuny & Benton, 1999). One of our specimens (UMUT MV29993) was examined for histology. Its enameloid consists only of SCE (single crystallized enameloid), a component of hybodont tooth enameloid, and no PFE (parallel fibred enameloid), which is considered to be one of the synapomorphic characters of neoselachians (Maisey, 1982). Therefore, these particular teeth are regarded as belonging to the genus *Hybodus*.

Family Polyacrodontidae Glikman, 1964
Genus ***Lissodus*** Brough, 1935

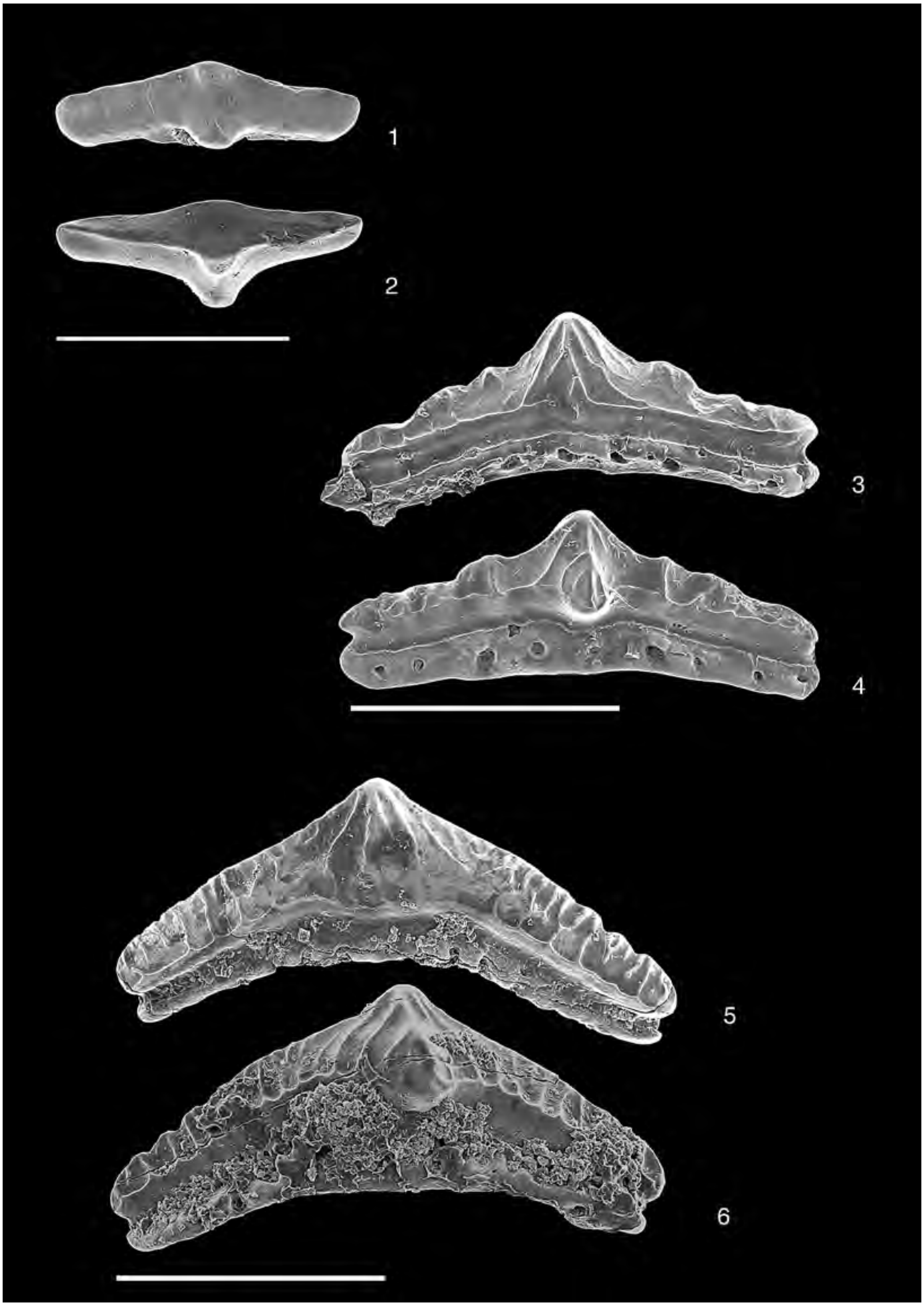
Type species: *Hybodus Africanus* (Broom), 1909.

Lissodus cf. ***cristatus*** Delsate and Duffin, 1999
Fig. 158.1–158.2

Material examined: One tooth, UMUT MV29692, from AB1025-1, two teeth, UMUT MV29715–29716, and fragmented tooth, UMUT MV29717, from AB1024-1, three teeth, UMUT MV29767–29769, from AB1022-2, three teeth, UMUT MV29778–29780, from AB1021-P2, two fragmented teeth, UMUT MV29827–29828, from AB1019-

→

Fig. 158. Elasmobranch remains from the Abrek Bay section. 1, 2, Tooth of *Lissodus* cf. *cristatus* Delsate and Duffin, 1999, UMUT MV29778 from AB1021-P2. 1, labial view. 2, occlusal view. 3–6, Teeth of *Polyacrodus* sp. indet. from AB1024-1. 3, 4, UMUT MV29718. 3, labial view. 4, lingual view. 5, 6, UMUT MV29719. 5, labial view. 6, lingual view. Scale bar = 1 mm.


1
2
3
4
5
6

1, and one fragmented tooth, UMUT MV29942, from AB1016-P1.

Description: Crown with obvious labial peg and low principal cusp, and smooth surface with almost no striae, due probably to the effects of abrasion. Most specimens lack their root because they were not preserved.

Occurrence: Described specimens range from AB1016 within the *Paranorites varians* Zone (Late Induan=Dienerian) to AB1025 within the *Radioprionites abrekensis* “bed” (early Early Olenekian=early Smithian) in the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: Most specimens lack their root and/or have been abraded, but they retain an obvious labial peg on their crowns. These teeth are similar to *Lissodus cristatus* Delsate and Duffin (1999, Middle Triassic, Upper Muschelkalk, Moersdorf, Grand Duchy of Luxembourg and the Upper Muschelkalk of Dalhenheim, Bas-Rhin, France), and to *L. angulatus* (Stensiö, 1921) from the Vardebukta Formation, Lower Triassic (Dienerian), Hornsund area, Hyrnefjellet Mt., South Spitzbergen as illustrated in Błażejowski (2004). The Abrek teeth are very similar to these specimens by way of their outline and by having a smooth, unornamented crown, but differ in lacking an accessory cusplet.

Genus ***Polyacrodus*** Jaekel, 1889

Type species: *Hybodus polycyphus* (Agassiz), 1837.

Polyacrodus sp. indet.

Fig. 158.3–158.6

Material examined: One tooth, UMUT MV29693, from AB1025-1, nine teeth, UMUT MV29718–29726, from AB1024-1, one fragmented tooth, UMUT MV29752, from AB1022-3, two teeth, UMUT MV29781–29782, from AB1021-P2, and one fragmented tooth, UMUT MV29829, from AB1019-1.

Description: Teeth strongly to slightly arcuate mesio-distally with rather high, pyramidal principal cusp, more than 4 pair of blunt lateral cusps or transverse ridges, and well-developed lingual peg. Ornamentation nearly the same in labial and lingual faces of crown, aside from having a lingual peg. Root shallow with pores in labial and lingual root face.

Occurrence: Described specimens range from AB1019 within the *Paranorites varians* Zone (Late Induan=Dienerian) to AB1025 within the *Radioprionites abrekensis* “bed” (early Early Olenekian=early Smithian) in the Zhitkov Formation, Abrek Bay area, South Primorye.

Discussion: *Polyacrodus* specimens from the Abrek section resemble *Polyacrodus contraries* Johns *et al.* (1997) from the Ladinian and Carnian of Canada and *P. bucheri* Cuny *et al.* (2001) from the Anisian of North-Western Nevada in their overall morphology. They share a developed lingual peg and an ornamented circumferential rim. Abrek specimens differ from *P. bucheri* in having a more pointed, higher main cusp, lateral cusplets and a clear occlusal ridge. *P. contraries* teeth have a more elongate shape and stronger ornamentation than the Abrek specimens.

Concluding remarks

(by. Y. Shigeta, Y. D. Zakharov, H. Maeda and A. M. Popov)

The Japanese-Russian Joint investigation of a Lower Triassic section in the Abrek Bay area has resulted in a detailed analysis of its stratigraphy as well as an extensive description of its various faunal successions. Even though the section was withdrawn from consideration as a GSSP candidate for the I/O boundary due to magnetostratigraphy problems (remagnetization), our studies not only have resulted in the establishment of a biostratigraphic framework, but they also have contributed to a better understanding of global environmental change and the dynamics of the biotic recovery following the Permian-Triassic mass extinction. Several modern disciplines, such as stable-isotope stratigraphy, radioisotopic analysis and sedimentary facies analysis, have been utilized to broaden the knowledge of the Triassic of South Primorye, but much work still remains to be done. Therefore, it is anticipated that future efforts by the joint research team will result in even further significant contributions.

Acknowledgements

We are very grateful to Academician A. I. Khanchuk, Director of Far Eastern Geological Institute, Vladivostok, for his supervision of this research program, and to all personnel of the Institute for their kind help and cooperation throughout the field survey. We also thank W. Weitschat (University of Hamburg), H. Bucher (University of Zürich), S. Z. Shen (Nanjing Institute of Geology and Palaeontology), Z. Q. Chen (West Australia University), A. Nützel (Bayerische Staatssammlung für Paläontologie und Geologie), T. Koike (Professor Emeritus, Yokohama National University), M. J. Orchard (Geological Survey of Canada), N. Goudemand (University of Zürich), T. Komatsu (Kumamoto University), K. Ichikawa (Professor Emeritus, Osaka City University), B. N. Shurygin (Institute of Oil and Gas Geology, Novosibirsk), M. Hautmann (University of Zürich), Y. Tominaga (Kanazawa University), W. Schatz (University of Luzern), and T. Engeser (Freie Universität Berlin) for their help during the course of this study in various ways. We also thank M. Shigeoka for her help with modal and chemical analyses and heavy mineral separations, and T. Watanabe (late Professor of Hokkaido University) for providing sand samples from the Amur River. Y. Shigeta are indebted to the Geological Survey of India (Kalkata), Nanjing Institute of Geology and Palaeontology (Nanjing), Institute and Museum of Paleontology, University of Zürich (Zürich), Far Eastern Geological Institute (Vladivostok), and Central Research Geological Prospecting Museum (St. Petersburg) for kindly providing him the opportunity to examine type and comparative specimens of Early Triassic ammonoids and nautiloids. Thanks are extended to J. F. Jenks (Utah) for his helpful suggestions and improvement of the English text.

This study was financially supported by JSPS Fellowships for research in NIS countries in 1998, Grant-in-Aid for Scientific Research from JSPS (nos. 13740302 and 17540447), Overseas Research Fellowship of the Ministry of Education, Culture, Sports, Science and Technology of Japan in 2003–2004, and grants of the National Museum of Nature and Science in 2006–2008 to Y. Shigeta, the Sasagawa Scientific Research Grant from the Japan Science Society (Project No. 20-720M) to T. Kumagae, and RFBR grant (No. 09-05-98524-R_vostok_a) to Y. D. Zakharov. A. Kaim's work is a part of a project carried out under the auspices of a Humboldt Fellowship and it is partially financed by the Institute of Paleobiology, Polish Academy of Sciences. This study is a contribution to the IGCP 572 project "Permian-Triassic Ecosystems".

References

Agassiz, L., 1833-1843. *Recherches sur les Poissons fossils. 5 vols.* 1420 pp., suppl. Imprimerie de Petitpierre, Neufchatel.

Ager, D. V. & D. L. Sun, 1988. Distribution of Mesozoic brachiopods on the northern and southern shores of Tethys. *Palaeontologia Cathayana*, **4**: 23–51.

Alberti, F. (ed.), 1864. *Überblick über die Trias mit Berücksichtigung ihres Vorkommens in den Alpen.* 352 pp. J. G. Cotta, Stuttgart.

Allasinaz, A., 1966. Il Trias in Lombardia (studi geologici e paleontologici). XVIII, La fauna a Lamellibranchi dello Julico (Carnico medio). *Rivista Italiana di Paleontologia e Stratigraphia*, **72** (3): 609–752.

Allasinaz, A., 1972. Revisione dei Pettinidi triassici. *Rivista Italiana di Paleontologia e Stratigraphia*, **78** (2): 189–428, pls. 24–48.

Ammon, L. von, 1878. Die Gastropoden des Hauptdolomites und Plattenkalkes der Alpen. *Abhandlungen des Zoologisch-Mineralogischen Vereins in Regensburg*, **11**: 1–72.

Ammon, L. von, 1893. Die Gastropodenfauna des Hochfellen-Kalkes und über Gastropoden-Reste aus Ablagerungen von Adnet, vom Monte Nota und Raibler Schichten. *Geognostische Jahreshefte*, **5**: 161–219.

Arnold, W. H., 1965. A glossary of a thousand-and-one terms used in conchology. *The Veliger, Supplement*, **7**: 1–50.

Arthaber, G., 1906. Die alpine Trias des Mediterran-Gebietes. *In* F. Frech (ed.), *Lethaea geognostica*. *Handbuch der Erdgeschichte mit Abbildung der für die Formationen bezeicherdsten Versteinerungen. II Teil, Das Mesozoicum, 1 Band Trias (3)*, 223–472, pls. 34. E. Schweizerbart'schen Verlagsbuchhandlung (E. Nägele), Stuttgart.

Assmann, P., 1915. Die Brachiopoden und Lamellibranchiaten der oberschlesischen Trias. *Jahrbuch der Königlich Preussischen Geologischen Landesanstalt*, **36** (1): 586–638.

Batten, R. L. & W. L. Stokes, 1986. Early Triassic gastropods from the Sinbad Member of the Moenkopi Formation, San Rafael Swell, Utah. *American Museum Novitates*, **2864**: 1–33.

Bando, Y., 1981. Lower Triassic ammonoids from Guryul Ravine and the Spur three kilometers north of Burus. *In* K. Nakazawa & H. M. Kapoor (eds.), *The Upper Permian and Lower Triassic fossils of Kashmir*, 137–171, pls. 14–20. Palaeontologia Indica, New Series 46.

Baumiller, T. K. & H. Hagdorn, 1995. Taphonomy as a guide to functional morphology of *Holocrinus*, the first post-Paleozoic crinoid. *Lethaia*, **28**: 221–228.

Bender, G., 1921. Die Homomyen und Pleuromyen des Muschelkalkes der Heidelberger Gegend. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften*, **73**: 24–112, pls. 1–5.

Bender. H., 1967. Zur Gliederung der Mediterranen Trias II. Die Conodontenchronologie der Mediterranen Trias. *Annales Géologiques des Pays Helléniques. Prèmiere Séri*e, **19**: 465–540, pls. 1–5.

Bender, H. & D. Stoppel, 1965. Permo-Conodonten. *Geologisches Jahrbuch*, **82**: 331–364, pls. 33–34.

Berry, R., C. Burrett & M. Bannes, 1984. New Triassic fauna from East Timor and their tectonic significanse. *Geologica et Palaeontologica*, **18**: 127–137, pl. 1.

Beyers, J. N. & M. J. Orchard, 1991. Upper Permian and Triasic conodont faunas from the type area of the Cache Creek Complex, south-central British Columbia, Canada. *Geological Survey of Canada Bulletin*, **417**: 269–297.

Bhattacharya, J. P., 2006. Deltas. *In* H. W. Posamentier & R. G. Walker (eds.), *Facies models revisited*, 237–292. SEPM Special Publication 84, SEPM, Tulsa.

Biernat, G. & C. C. Emig, 1993. Anatomical distinctions of Mesozoic lingulide brachiopods. *Acta Palaeontologica Polonica*, **38**: 1–20.

Birkenmajer, K. & J. Trammer, 1975. Lower Triassic conodonts from Hornsund, South Spitsbergen. *Acta Geologica Polonica*, **25** (2): 229–308, pls. 1–2.

Bittner, A., 1891. Triaspetrefacten von Balia in Kieinasien. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt*, **41**: 97–116.

Bittner, A., 1898. Beiträge zur Paläontologie, insbesondere der triadischen Ablagerungen centralasiatischer Hochgebirge. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt*, **48**: 689–718.

Bittner, A., 1899a. Trias Brachiopoda and Lamellibranchiata. *Memoirs of the Geological Survey of India, Palaeontologia Indica, Series 15* (*Himalayan Fossils*), **3** (2): 1–76, pls. 1–12.

Bittner, A., 1899b. Versteinerungen aus den Trias-Ablagerungen des Süd-Ussuri-Gebietes in der ostsibirischen Küstenprovinz. *Mémoires du Comité Géologique*, **7** (4): 1–35, pls. 1–4. (partially in Russian)

Bittner, A., 1901a. Üeber *Pseudomonotis Telleri* und verwandte Arten der unteren Trias. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt*, **50**: 559–593, pls. 22–24.

Bittner, A., 1901b. Lamellibranchiaten aus der Trias des Bakonyerwaldes. *Resultäte der Wissenschaftlichen Erforschung des Balatonsees, Paläontologischer Anhang*, **1** (1): 1–106, pls. 1–9.

Błażejowski, B., 2004. Shark teeth from the Lower Triassic of Spitzbergen and their histology. *Polish Polar Research*, **25** (2): 153–167.

Bouchet, P., J.-P. Rocroi, J. Frýda, B. Hausdorf, W. F. Ponder, Á.Valdés, & A. Warén, 2005. Classification and nomenclator of gastropod families. *Malacologia*, **47**: 1–368.

Brayard, A. & H. Bucher, 2008. Smithian (Early Triassic) ammonoid faunas from northwestern Guangxi (South China): taxonomy and biochronology. *Fossil and Strata*, **55**: 1–179.

Broglio Loriga, B., 1968. Alcune considerazioni su *Lingula tenuissima* Bronn del Werfiniano delle Dolomiti. *Annali dell'Universita di Ferrara, Sezione 9*, **4** (12): 189–202.

Broglio Loriga, B., C. Neri & R. Posenato, 1980. La "*Lingula*" Zone delle Scitico (Triassic Inferiore). *Stratigrafia e Paleoecologia. Annali dell'Universita di Ferrara, Sezione* 9, **6** (6): 91–130.

Broom, R., 1909. Fossil fishes of the Upper Karoo Beds of South Africa. *Annals of the South African Museum*, **7** (3): 251–269, pls. 12–13.

Bronn, H. G., 1850–1851. Trias-Periode. *In* H. G. Bronn & F. Roemer (eds.), *Lethaea geognostica von H. G. Bronn* (*3rd. edition*), 124 pp., E. Schweizer-bart'sche Verlagshandlung und Druckerei, Stuttgart.

Brough, J., 1935. On the structure and relationships of the hybodont sharks. *Memoirs and Proceedings of the Manchester Literary and Philosophical Society*, **79**: 35–49, pls. 1–3.

Bruguiere, J. G., 1797. Vers, Coquilles, Mollusques et Polypiers. *Tableau encyclopedique des trois regnes de la nature*, 2, Agasse, Paris: pls. 96–314.

Brühwiler, T., H. Bucher, N. Goudemand & A. Brayard, 2007. Smithian (Early Triassic) ammonoid successions of the Tethys: new preliminary results from Tibet, India, Pakistan and Oman. *In* S. G. Lucas & J. A. Spielmann (eds.), *The global Triassic*, 25–26. New Mexico Museum of Natural History and Science Bulletin, 41.

Brühwiler, T., A. Brayard, H. Bucher & K. Guodun, 2008. Griesbachian and Dienerian (Early Triassic) ammonoid faunas from northeastern Guangxi and southern Guizhou (South China). *Palaeontology*, **51** (5): 1151–1180.

Budurov, K. & S. Pantic, 1973. Conodonten aus den Capilller Schichten von Brassina (Westerbien). *Burgarian Academy of Sciences. Ministry of Heavy Industry Bulletin of the Geological Institute-Series of Paleontology*, **22** (4): 49–64, pls. 1–4.

Budurov, K. & M. N. Sudar, 1994. *Boriella* Budurov and Sudar nomen novum for the Triassic conodont genus *Kozurella* Budurov and Sudar, 1993. *Geologia Balcanica*, **24** (3): 30.

Burij, I. V., 1959. Stratigraphija triasovykh otlozhenij Yuzhnogo Primor'ya. *Trudy Dalnevostochnogo Politekhnicheskogo Instituta*, **1**: 3–34. [Stratigraphy of Triassic sediments of South Primorye.] (In Russian)

Burij, I. V., 1962. See Burij, I. V. & N. K. Zharnikova, 1962.

Burij, I. V. & N. K. Zharnikova, 1962. Novye vidy triasovykh cheratitov Dal'nego Vostoka. *In* N. A. Shvedova (ed.), *Sbornik statej po paleontologii i biostratigraphii 29*, 78–92, pl. 1–3. Nauchno-Issledovatel'skij Institut Geologii Arktiki (NIIGA), Leningrad. [New species of the Far Eastern Triassic ceratites. *In* N. A. Shvedova (ed.), *Miscellanea of papers on paleontology and stratigraphy 29*.] (In Russian)

Burij, I. V. & N. K. Zharnikova, 1981. Ammonoidei iz tirolitovoj zony Yuzhnogo Primor'ya. *Paleontologicheskij Zhurnal*, 1981 (3): 61–69. [Ammonoids from the *Tirolites* Zone of South Primorye.] (In Russian)

Buryi, G. I., 1979. *Nizhnetriasovye konodonty yuzhnogo Primorya*. 144 pp. Nauk, Moscow. [*Lower Triassic conodonts of the South Primorye.*] (In Russian)

Buryi, G. I., 1989. *Konodonty i stratigrafiya triasa Sikhote-alinya.* 136 pp. Akademiya Nauk SSSR, Dal'nevostochnoe otdelenie, Dal'nevostochnyj Geologicheskij Institut, Vladivostok. [*Triassic conodonts and stratigraphy of Sikhote-alin.*] (In Russian)

Buryi, G. I., 1997. Early Triassic conodont biofacies of Primorye. *Mémoires de Géologie* (*Lausanne*), **30**: 35–44.

Cao, Y. & Z. Wang, 1993. Triassic conodont biostratigraphy and lithofacies paleogeography. Triassic biostratigraphy sections bearing conodonts. Triasic conodont biostratigraphy. *In* C. Wang (ed.), *Conodonts of lower Yangtze Valley-an indexes to biostratigraphy and organic metamorphic maturity*, 103–117, pls. 54–64. Science Press, Beijing.

Cappetta, H., 1987. *Handbook of paleoichthyology, volume 3B, Chondrichthyes II, Mesozoic and Cenozoic Elasmobranchii.* 193 pp., 148 figs. Gustar Fischer Verlag, Stuttgart.

Catullo, T. A., 1848. Memoria geognostico-paleozoica sulle Alpi Venete. *Memorie della Società Italiana delle scienze residente in Modena*, **24**: 187–339.

Cecca, F., 1992. Ammonite habitats in the Early Tithonian of Western Tethys. *Lethaia*, **25**: 257–267.

Chao, K. K., 1959. Lower Triassic ammonoids from Western Kwangsi, China. *Palaeontologia Sinica, New Series B*, **9**: 1–355, pls. 1–45.

Chen, C. Z., 1976. See Editorial Group on Fossil Lamellibranchiata of China, Nanjing Institute of Geology and Palaeontology, Academia Sinica (ed.), 1976.

Chen, C. Z., Q. H. Ma & Z. M. Zhang, 1974. Triassic Lamellibranchiata. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica (ed.), *Handbook of stratigraphy and paleontology of the southwestern region*, 326–343, pls. 173–179, Science Press, Beijing. (In Chinese)

Chen, Y. M. 1983. New advance in the study of Triassic brachiopods in Tulong district of Naylam County, Tibet. *Contribution to the Geology of Qinghai-Xizang Plateau*, **11**: 145–156.

Chen Z. Q. & G. R. Shi, 1999. Revision of *Prelissorhynchia* Xu and Grant, 1994 (Brachiopoda) from the Upper Permian of South China. *Proceedings of Royal Society of Victoria*, **111**: 15–26.

Chen Z. Q. & G. R. Shi, 2002. See Chen, Z. Q., G. R. Shi & K. Kaiho, 2002.

Chen, Z. Q., G. R. Shi & K. Kaiho, 2002. A new genus of rhynchonellid brachiopod from the Lower Triassic of South China and implications for timing the recovery of Brachiopoda after the end-Permian mass extinction. *Palaeontology*, **45**: 149–164.

Chen, Z. Q., K. Kaiho & A. D. George, 2005. Early Triassic recovery of the brachiopod from the end-Permian mass extinction: A global review. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **224**: 270–290.

Ciriacks, K. W., 1963. Permian and Eotriassic bivalves of the Middle Rockies. *Bulletin of the American Museum of Natural History*, **125** (1): 1–100, pls. 1–16.

Clark, D. L., 1959. Conodonts from the Triassic of Nevada and Utah. *Journal of Paleontology*, **33** (2): 305–312, pls. 44–45.

Clark, D. L., W. C. Sweet, S. M. Bergström, G. Klapper, R. L. Austin, R., F. H. T. Rhodes, K. J. Müller, W. Ziegler, M. Lindström, J. F. Miller & A. G. Harris, 1981. *Treatise on invertebrate paleontology part W miscellanea, supplement 2, Conodonta*. 202 pp. Geological Society of America, Inc. & the University of Kansas Press, Lawrence.

Collignon, M., 1933. Paléontologie de Madagascar 20-Les céphalopodes du Trias infériur. *Annales de Paléontologie*, **22**: 151–180, pls. 14–20.

Conrad, T. A., 1835. Description of five new species of fossil shells in the collection presented by Mr. Edward Miller to the Geological Society. *Transactions of the Geological Society of Pennsylvania*, **1**: 267–270.

Cossmann M., 1888. Catalogue illustré des coquilles fossils de l'Éocène des environs de Paris. *Annales de la Société royale malacologique de Belgique*, **23**: 1–324, pls. 1, 12.

Cossmann, M., 1902. Rectification de nomenclature. *Revue critique de la nomenclature*, **6**: 223.

Cox, L. R., 1960. Gastropoda. General characteristics of Gastropoda. *In* J. B. Knight, L. R. Cox, A. M.Keen, A. G. Smith, R. L., Batten, E. L. Yochelson, N. H. Ludbrook, R. Robertson, C. M. Yonge & R. C. Moore (eds.), *Treatise on invertebrate paleontology. part I. Mollusca 1*, 84–169. Geological Society of America, Inc. & University of Kansas Press, Lawrence.

Cuny, G. & M. J. Benton, 1999. Early radiation of the Neoselachian sharks in Western Europe. *Geobios* **32** (2): 193–204.

Cuny, G., O. Rieppel & P. M. Sander, 2001. The shark fauna from the Middle Triassic (Anisian) of North-Western Nevada. *Zoological Journal of the Linnean Society*, **133** (3): 285–301.

Curioni, G., 1856. Sulla successione normale del diversi membri del terreno triasico nella Lombardia. *Memorie dell' I. R. Istituto Lombardo di Scienze e Lettere ed Arti*, **5**: 312–343, pls. 5–7.

Dagis, A. A. 1982. Drevnejshiye olenekskiye konodonty severa Sibiri. *Trudy Instituta Geologii i Geophiziki Sibirskogo otdeleniya Akademii Nauk SSSR*, **462**: 55–59. [The oldest Olenekian conodonts of Northern Siberia.] (In Russian)

Dagis. A. A., 1984. *Rannetriasovye konodonty severa srednej Sibiri*. 71 pp. Nauka, Moscow. [*Early Triassic conodonts of northern middle Siberia*] (In Russian)

Dagys, A. S., 1965. *Triasovye brakhiopody Sibiri*. 188 pp., 26 pls. Akademia Nauk SSSR, Sibirskoe Otdelenie, Izdatel'stvo "Nauka", Moscow. [Triassic brachiopods from Siberia.] (In Russian)

Dagys, A. S., 1974. Triasovye brakhiopody (Morfologiya, sistema, filogeniya, stratigraficheskoe znachenie i biogeografiya). *Trudy Instituta Geologii i Geofiziki, Sibirskoe Otdelenie, Akademiya Nauk SSSR*, **214**: 1–387, pls. 1–49. [Triassic brachiopods (Morphology, classification, phylogeny, stratigraphical significance and biogeography).] (In Russian)

Dagys, A. S., 1993. Geographic differentiation of Triassic brachiopods. *Palaegeography, Palaeoclimatology, Palaeoecology*, **100**: 79–87.

Dagys, A. S., A. A. Dagis, S. P. Ermakova, A. G. Konstantinov, N. I. Kurushin, E. S. Sobolev & A. M. Truschelev, 1996. *Triasovaya fauna Severo-Vostoka Azii*. 168 pp, 64 pls. Nauka, Novosibirisk. [*Triassic fauna of the North-Eastern Asia.*] (In Russian)

Dagys, A. S. & N. I. Kurushin, 1985. Triasovye brakhiopody i dvustvorchatye mollyuski severa Srednei Sibiri. *Trudy Instituta Geologiya i Geofizika*, **633**: 1–159, pls. 1–24. [The Triassic brachiopods and bivalves in the north of the Central Siberia.] (In Russian)

Davidson, Th., 1848. Mémoire sur les brachiopods du systéme Silurian supérieur de l'Angleterre. *Bulletin de la Société géologique de France* (*série 2*), **5**: 309–338, 370–374.

Delsate, D. & C. J. Duffin, 1999. A new fish fauna from the Middle Triassic (Upper Muschelkalk) of Moersdorf (Grand Duchy of Luxembourg). *Travaux Scientifiques du Musée National d'Histoire Naturelle de Luxembourg*, **32**: 5–53.

Deshayes G. P., 1825. Anatomie et monographie du genere Dentale. *Mémoires de la Société d'Histoire naturelle de Paris*, **2**: 321–378, pls. 15–18.

Diener, C., 1895. Triasdische Cephalopodenfaunen der otsibirischen küstenprovinz. *Mémoires du Comité Géologique St. Pétersbourg*, **14** (3): 1–59, pls. 1–5.

Diener, C., 1897. Himalayan fossils. The Cephalopoda of the Lower Trias. *Palaeontologia Indica, Series 15*, **2** (1): 1–181, pls. 1–23.

Diener, C., 1913. Triassic faunae of Kashmir. *Palaeontologia Indica, New Series*, **5** (1): 1–133, pls. 1–13.

Diener, C., 1916. Einige Bemerkungen zur Nomenklatur der Triascephalopoden. *Centralblatt für Mineralogie, Geologie und Palaeontologie*, 97–105.

Doguzhaeva, L. A. & H. Mutvei, 1996. Attachment of the body to the shell in ammonoids. *In* N. H. Landman, K. Tanabe & R. A. Davis (eds.), *Ammonoid paleobiology*, 43–63. Plenum Press, New York.

d'Orbigny, A., 1847. Considerations zoologiques et géologiques sur les Brachiopodes ou Palliobranches. *Comptes Rendus Hebdomadaires des Seances de l'Academie des Science*s, **25**: 193–195, 266–269.

Duan, J., 1987. Permian-Triassic conodonts from southern Jiangsu and adjacent areas, with indexes of their colour alteration. *Acta Micropalaeontologica Sinica*, **4** (4): 351–368. pls. 1–4.

Duffin, C. J. & D. J. Ward, 1995. The Early Jurassic Palaeospinacid sharks of Lyme Regis, southern England. *Belgian Geological Survey Professional Paper*, **264**: 53–102.

EGFLC, 1976. See Editorial Group on Fossil Lamellibranchiata of China, Nanjing Institute of Geology and Palaeontology, Academia Sinica (ed.), 1976.

Editorial Group on Fossil Lamellibranchiata of China, Nanjing Institute of Geology and Palaeontology, Academia Sinica (ed.), 1976. *Fossil Lamellibranchiata of China*. 255 pp., 150 pls. Science Press, Beijing. (In Chinese)

Egorov, A. N. & L. E. Popov, 1990. Novyj rod lingulid iz nizhnepermskikh otlozhenij Sibirskoj platformy. *Paleontologicheskii Zhurnal*, 1990 (4): 111–115. [A new genus of lingulid from the Early Permian deposits of the Siberian platform.] (In Russian)

Eichwald, E., 1851. Naturhistorische Bemerkungen, als Beitrag zu einer vergleichenden Geognosie, auf einer reise durch die Eifel, Tyrol, Italien, Sizilien und Algier. *Memoirs de la Societe Imperiale de Naturalistes d'Histoire de Moscou*, **9**: 1–464.

Emig, C. C., 2003. Proof that *Lingula* (Brachiopoda) is not a living-fossil, and emended diagnoses of the Family Lingulidae. *Carnets de Géologie/Notebooks on Geology*, Maintenon, Letter 2003/01: 9.

Evans, J. A., J. I. Chisholm & M. J. Leng, 2001. How U-Pb detrital monazite ages contribute to the interpretation of the Pennine Basin infill. *Journal of the Geological Society*, **158**: 741–744.

Farsan, N. M., 1972. Stratigraphische und Paläogeographische Stellung der Khenjan-serie und deren Pelecypoden (Trias, Afghanistan). *Paleontographica Abteilung A*, **140**: 131–191, pls. 38–46.

Fraiser, M. L. & D. J. Bottjer, 2004. The non-actualistic Early Triassic gastropod fauna: a case study of the Lower Triassic Sinbad Limestone Member. *Palaios*, **19**: 259–275.

Frebold, H., 1939. Das Festungsprofil auf Spitzbergen. V, Stratigraphie und Invertebraten-Fauna der älteren Eotrias, nebst Beschreibung anderer Vorkommen in Spitzbergen. *Skrifter om Svalbard og Ishavet*, **77**: 1–58, pls. 1–3.

Frech, F., 1904. Neue Zweischaler und Brachiopoden aus de Bakonyer Trias. *Resultäte der Wissenschaftlichen Erforschung des Balatonsees, Paläontologischer Anhang*, **1** (2): 1–138.

Frech, F., 1907. Die Leitfossilen der Werfener Schichten und Nachträge zur Fauna des Muschelkalkes, der Cassianer und Raibler Schichten, sowie des Rhaet unt des Dachsteinkalkes (Hauptdolomit). *Resultäte der Wissenschaftlichen Erforschung des Balatonsees, Paläontologischer Anhang*, **1** (1): 1–96, pls. 1–16.

Gan, X. M. & H. F. Yin, 1978. Phylum Mollusca. *In* Guizhou Working Team of Stratigraphy and Palaeontology (ed.), *Palaeontological atlas of southwest China, Carboniferous-Quaternary. Guizhou volum*e, 337–394, pls. 109–126. Geological Publishing House, Beijing. (In Chinese)

Garver, J. I., M. T. Brandon, M. Roden-Tice & P. J. J. Kamp, 1999. Exhumation history of orogenic highlands determined by detrital fission-track thermochronology. *In* U. Ring, M. T. Brandon, G. S. Lister & S. D. Willett (eds.), *Exhumation processes: normal faulting, ductile flow and erosion*, 283–304. Geological Society, London.

Giebel, C, 1855. Die Versteinerungen im Muschelkalk von Lieskau bei Halle. *Abhandlungen des Naturwissenschaftlichen Vereins für die Provinz Sachsen und Thüringen in Halle*, **1**: 54–126, 7 pls., Wiegandt, Berlin.

Girty, G. H., 1927. Descriptions of new species of Carboniferous and Triassic fossils. Appendix to G. R. Mansfield, Geology and mineral resources of part of southeastern Idaho. *United States Geological Survey Professional Paper*, **152**: 411–446.

Goel, R. J., 1977. Triassic conodonts from Spiti (Himachal Pradesh), India. *Journal of Paleontology*, **51**: 1085–1101, pls. 1–3.

Goldfuss, G. A., 1836. *Petrefacta Germaniae, part 2, lief 5*. pp. 69–140, pls. 97–121. Arnz, Düsseldorf.

Goldfuss, G. A., 1837–38. *Petrefacta Germaniae, part 2, lief 6*. pp. 141–224, pls. 122–146. Arnz, Düsseldorf.

Griesbach, C. L., 1880. Palaeontological notes on the Lower Trias of the Himalayas. *Records of the Geological Survey of India*, **13**: 94–113, pls. 1–4.

Gründel, J., 1997. Zur Kenntis einiger Gastropoden-Gattung aus dem französischen Jura und allgemaine Bemerkungen zur Gastropodenfauna aus dem Dogger Mittel- und Westeuropas. *Berliner Geowissenschaftliche Abhandlungen, Reihe E*, **25**: 69–

129.

Guex, J., 1978. Le Trias inférieur des Salt Ranges (Pakistan): problèmes biochronologiques. *Eclogae Geologica Helvetiae*, **71** (1): 105–141.

Guex, J., 2006. Reinitialization of evolutionary clocks during sublethal environmental stress in some invertebrates. *Earth and Planetary Science Letters*, **242**: 240–253.

Hada, S., 1966. Discovery of Early Triassic ammonoides from Gua Musang, Kelantan, Malaya. *Journal of Geosciences, Osaka City University*, **9**: 111–113.

Haggart, J. W., 1989. New and revised ammonites from the Upper Cretaceous Nanaimo Group of British Columbia and Washington state. *Geological Survey of Canada Bulletin*, **396**: 181–221.

Hall, J., 1858. Paleontology of Iowa. *Iowa Geological Survey*, **1**: 473–724.

Hauer, F., 1850. Über die von Herrn Bergrat W. Fuchs in den Venetianer Alpen gesammelten Fossilien. *Denkschriften der Kaiserlichen Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse*, **2**: 109–126.

Holmer, L. E. & L. E. Popov, 2000. Class Lingulata. *In* R. L. Kaesler (ed.), *Treatise on invertebrate paleontology part H Brachiopoda* (*revised*) *2*, 30–146. Geological Society of America, Inc. & the University of Kansas Press, Lawrence.

Hoover, P. R., 1979. Early Triassic terebratulid brachiopods from the Western Interior of the United States. *United States Geological Survey Professional Paper*, **1057**: 1–21. pls. 1–4.

Hsu, T. Y., 1936–37. Contribution to the marine Lower Triassic fauna of southern China. *Bulletin of the Geological Society of China*, **16**: 303–346, pls. 1–4.

Huckried, R., 1958. Die Conodonten der mediterranen Trias und ihr stratigraphischer Wert. *Paläontologische Zeitschrift*, **32**: 141–175, pls. 10–14.

Hulke, I. W., 1873. Memorandum on some fossil vertebrate remains coll. by the Swedish expeditions to Spitzbergen in 1864 and 1868, Stockholm. *Bihang till Kongliga Svenske Vetenskapsakademiens Handlingar*, **1**: 1–11.

Hyatt, A., 1879. See White, C. A., 1879.

Hyatt, A., 1883. Genera of fossil cephalopods. *Proceedings of the Boston Society of Natural History*, **22**: 253–272.

Hyatt, A., 1891. Carboniferous cephalopods. *Texas Geological Survey, Annual Report*, **2**: 327–356.

Hyatt, A., 1894. Phylogeny of an acquired characteristics. *Proceedings of the American Philosophical Society*, **32**: 349–647, pls. 1–14.

Hyatt, A., 1900. Cephalopoda. *In* K. A. Zittel (ed.), *Textbook of palaeontology*, 502–592. C. R. Eastman, London.

Hyatt, A. & J. P. Smith, 1905. The Triassic cephalopod genera of America. *United States Geological Survey Professional Pape*r, **40**: 1–394.

Ichikawa, K. & Y. Yabe, 1955. *Eumorphotis multiformis shionosawensis*, subsp. nov. from the Shionosawa Limestone at Shionosawa, north of the Sanchu Graben, Kwanto Mountainland, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, **17**: 5–12, pl. 2.

Ireland, T. R., 1991. Crustal evolution of New Zealand: Evidence from age distributions of detrital zircons in Western Province paragneisses and Torlesse greywacke. *Geochimica et Cosmochimica Acta*, **56**: 911–920.

Isaji, S., T. Kase, K. Tanabe & K. Uchiyama, 2002. Ultrastructure of the muscle-shell attachment in *Nautilus pompilius* Linnaeus (Mollusca: Cephalopoda). *The Veliger*, **45** (4): 316–330.

Ishiga, H. & S. Suzuki, 1984. Discovery of Permian radiolarians and conodonts from the Shimomidani Formation in the “Maizuru Belt”, Southwest Japan and its significance. *Earth Science*, **38**. 17–206.

Ishiwatari, A. & T. Tsujimori, 2003. Paleozoic ophiolites and blueschists in Japan and Russian Primorye in the tectonic framework of East Asia: A synthesis. *The Island Arc*, **12**: 190–206.

Jablonski, D. & R. A. Lutz, 1980. Molluscan larval shell morphology: Ecological and paleontological applications. *In* D. C. Rhoads & R. A. Lutz (eds.), *Skeletal growth of aquatic organisms*, 323–377. Plenum Press, New York.

Jablonski, D. & R. A. Lutz, 1983. Larval ecology of marine benthic invertebrates: paleobiological implications. *Biological Reviews of the Cambridge Philosophical Society*, **58**: 21–89.

Jaekel, O. 1889. Die Selachier aus dem oberen Muschelkalk Lothringens. *Abhandlungen zur Geologischen Specialkarte von Elsass-Lothringen*, **3**: 275–332.

Jia, D., R. Hu, Y. Lu & X. Qiu, 2004. Collision belt between the Khanka block and the North China block in the Yanbian region, northeast China. *Journal of Asian Earth Sciences*, **23**: 211–219.

Johns, M. J., C. R. Barnes & M. J. Orchard, 1997. Taxonomy and biostratigraphy of Middle and Late Triassic elasmobranch ichthyoliths from Northeastern British Columbia. *Geological Survey of Canada Bulletin*, **502**: 1–235.

Kaesler, R. L. (ed.), 2000. *Treatise on invertebrate paleontology part H Brachiopoda (revised) 2*. 423 pp. Geological Society of America, Inc. & the University of Kansas Press, Lawrence.

Kaesler, R. L. (ed.), 2002. *Treatise on invertebrate paleontology part H Brachiopoda (revised) 4*. 768 pp.

Geological Society of America, Inc. & the University of Kansas Press, Lawrence.

Kambe, N., 1963. On the boundary between the Permian and Triassic Systems in Japan, with the description of the Permo-Triassic formations at Takachiho-cho, Miyazaki Prefecture in Kyushu and the Skytic fossils contained. *Report of Geological Survey Japan*, **198**: 1–66, pls. 1–19.

Kashiyama, Y. & T. Oji, 2004. Low-diversity shallow marine benthic fauna from the Smithian of northeast Japan: paleoecologic and paleobiogeographic implications. *Paleontological Research*, **8** (3): 199–218.

Khanchuk, A. K., 2001. Pre-Neogene tectonics of the Sea-of-Japan regions: a view from the Russian side. *Earth Science* (*Chikyu Kagaku*), **55**: 275–291.

Khanchuk, A. K., V. V. Ratkin, M. D. Ryazantseva, V. V. Golozubov & N. G. Gonokhova, 1996. *Geology and mineral deposits of Primorsky krai* (*territory*). 61 pp. Dalnauka, Vladivostok.

King, W., 1848. *A catalogue of the organic remains of the Permian rocks of Northumberland and Durham*. 16 pp. Newcastle upon Tyne.

Kiparisova, L. D., 1938. Nizhnetriasovye plastinchatozhabernye Ussurijskogo kraya. *Trudy Geologicheskogo Instituta*, **7**: 197–311, pls. 1–6. [Lower Triassic bivalves of Ussuri region.] (In Russian with English descriptions for new species)

Kiparisova, L. D., 1947a. Klass Gastropoda. Briuhonogiye. *In* E. V. Voinova, L. D. Kiparisova & V. N. Robinson (eds.), *Atlas rukovodyashshikh form iskopaemykh faun SSSR, 7: triasovaya sistema*, 120–124. Gosgeoltekhizdat, Moscow. [Class Gastropoda. *In* E. V. Voinova, L. D. Kiparisova & V. N. Robinson (eds.), *Atlas of the guiding species of fossil fauna of USSR, 7: Triassic System*.] (In Russian)

Kiparisova, L. D. (ed.), 1947b. *Atras rukovodyashshikh form iskopaemykh faun SSSR, 7: triasovaya sistema*. 253 pp., 51 pls. Gosudarstvennoe Izdatel'stvo Geologicheskoj Literatury Ministerstva Geologii SSSR, Moscow. [*Atlas of the guide forms of the fossil faunas of the USSR, 7: Triassic.*] (In Russian)

Kiparisova, L. D., 1954. See Kiparisova, L. D. & A. N. Krishtofovich, 1954.

Kiparisova, L. D., 1956. Rod *Anaxenaspis* Kiparisova gen. nov. *In* L. D. Kiparisova, B. P. Markovskij & G. P. Radchenko (eds.), *Materialy po paleontologii*, 76–77, Vsyesoyuznyj Nauchno-issledovatyel'skij Geologichyeskij Instityt (VSEGEI), Novaya seriya 12, Leningrad. [*Anaxenaspis* Kiparisova gen. nov. *In* L. D. Kiparisova, B. P. Markovskii & G. P. Radchenko (eds.), *Materials on paleontology.*] (In Russian)

Kiparisova, L. D., 1960. Otryad Nautilida. *In* B. P. Markovsky (ed.), *Novye vidy drevnikh rastenij i bespozvonochnykh SSSR, 2*, 136–137, Gosgeoltekhizdat, Moscow. [Order Nautilida. *In* B. P. Markovsky (ed.), *New species of ancient plants and invertebrates of the USSR*.] (In Russian)

Kiparisova, L. D., 1961. Paleontologicheskoe obosnovanie stratigrafii triasovykh otlozhyenij primorskogo kraya. 1. Golovonogie mollyuski. *Trudy Vsyesoyuzhogo Nauchno-isslyedovatyel'skogo Geologichyeskogo Instityta (VSEGEI), Novaya seriya*, **48**: 1–278. [Paleontological fundamentals for the stratigraphy of Triaasic deposits of Primorye region. 1. Cephalopod Mollusca.] (In Russian)

Kiparisova, L. D., 1966. See Kiparisova, L. D., Y. M. Bychkov & I. V. Poludotko, 1966.

Kiparisova, L. D., 1972. Paleontologicheskoe obosnovanie stratigrafii Triasovykh otlozhenij Primorskogo kraya. *Vsyesoyuzhnyj Nauchno-issledovatelskij Geologicheskij Institut* (*VSEGEI*), *Novaya seriya*, **181**: 1–246, pls. 1–17. [Paleontological basis of Triassic stratigraphyof Primorye region.] (In Russian)

Kiparisova, L. D., Y. M. Bychkov & I. V. Poludotko, 1966. *Pozdnetriasovye dvustvorchatye mollyuski Severo-Vostoka SSSR*. 312 pp. Ministerstvo Geologii SSSR, Magadan. [*Upper Triassic bivalve molluscs from the Northeast USSR*.] (In Russian)

Kiparisova, L. D. & A. N. Krishtofovich, 1954. *Polevoj atlas kharakternykh kompleksov fauny i flory triasovykh otlozhenij primorskogo kraya*. 127 pp. Gosgeoltekhizdat, Moscow. [*Field atlas of typical complexes of fauna and flora of Triassic deposits in Primorye region*.] (In Russian)

Kittl, E., 1894. Die Gastropoden der Schichten von St. Cassian der südalpinen Trias. 3. Theil. *Annalen des kaiserlich-königlichen Naturhistorischen Hofmuseums*, **9**: 143–275.

Kittl, E., 1904 (1903). Geologie der Umgebung von Sarajevo. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt, Paläontologischer Anhang*, **53** (4): 665–738, pls. 21–23.

Klug, C. & A. Lehmkuhl, 2004. Soft-tissue attachment structures and taphonomy of the Middle Triassic nautiloid *Germanonautilus*. *Acta Palaeontologica Polonica*, **49** (2): 243–258.

Koike, T., 1982. Triassic conodont biostratigraphy in Kedah, West Malaysia. *In* T. Kobayashi, R. Toriyama & W. Hashimoto (eds.), *Geology and Palaeontology of Southeast Asia 23*, 9–51, pls. 4–10. University of Tokyo Press, Tokyo.

Koike, T., 1988. Lower Triassic conodonts *Platyvillosus* from the Taho Limestone in Japan. *Science Reports of the Yokohama National University, Section*

II, Biological and Geological Sciences, **35**: 61–79, pls.1–2.

Kojima, S., 1989. Mesozoic terrane accretion in Northeast China, Sikhote-Aline and Japan regions. *Palaeogeography Palaeoclimatology Palaeoecology*, **69**: 213–232.

Kojima, S., I. V. Kemkin, M. Kametaka & A. Ando, 2000. A correlation of accretionary complexes of Southern Sikhote Alin of Russia and the Inner zone of Southwest Japan. *Geosciences Journal*, **4** (3): 175–185.

Kolar-Jurkovsek, T. & B. Jurkovsek, 1996. Contribution to the knowledge of the Lower Triassic conodont faunas in Slovenia. *Razprave IV. Razreda SAZU*, **37**: 4–20, pls. 1–4.

Komatsu, T., T. H. Dan & J. H. Chen, 2008. Lower Triassic bivalve assemblages after the end-Permian mass extinction in South China and North Vietnam. *Paleontological Research*, **12** (2): 119–128.

Koninck, L. G. de, 1863. Descriptions of some fossils from India, discovered by Dr. A. Fleming, of Edinburgh. *The Quarterly Journal of the Geological Society of London*, **19**: 1–19, pls. 1–8.

Koninck, L. G. de, 1881. Faune du calcaire carbonifère de la Belgique. Troisiéme partie, Gastéropodes. *Annales du Musée royal d'Histoire naturelle de Belgique, série paléontologiqu*e, **6**: 1–170.

Koninck, L. G. de, 1883. Faune du calcaire carbonifc̆re de la Belgique. Quatrième partie, Gastéropodes (suite et fin). *Annales du Musée royal d'Histoire naturelle de Belgique, série paléontologiqu*e, **8**: 1–240.

Kozur, H. & H. Mostler, 1976. Neue Conodonten aus dem Jungpaläeozoikum und der Trias. *Geologisches-Paläeontologisches Mitteilungen, Innsbruck*, **6** (3): 1–33.

Krafft, A., 1909. See Krafft, A. & C. Diener, 1909.

Krafft, A. & C. Diener, 1909. Himalayan fossils. Lower Triassic cephalopoda from Spiti, Malla Johar, and Byans. *Palaeontologia Indica, Series 15*, **6** (1): 1–186, pls. 1–31.

Krystyn, L., M. Balini & A. Nicora, 2004. Lower and Middle Triassic stage and substage boundaries in Spiti. *Albertiana*, **30**: 40–53.

Krystyn, L., O. N. Bhargava & S. Richoz, 2007. A candidate GSSP for the base of the Olenekian stage: Mud at Pin Valley; district Lahul & Spiti, Himachal Pradesh (Western Himalaya), India. *Albertiana*, **35**: 5–29.

Krystyn, L., S. Richoz, A. Baud & R. J. Twitchett, 2003. A unique Permian-Triassic boundary section from the Neotethyan Hawasina basin, central Oman mountains. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **191**: 329–344.

Kummel, B., 1953a. American Triassic coiled nautilids. *United States Geological Survey Professional Paper*, **250**: 1–104, pls. 1–19.

Kummel, B., 1953b. Lower Triassic Salt Range nautiloids. *Breviora, Museum of Comparative Zoology*, **20**: 1–8, pls. 1–2.

Kummel, B., 1961. The Spitsbergen arctoceratids. *Bulletin of the Museum of Comparative Zoolog*y, **123** (9): 499–532, figs. 1–5, pls. 1–9.

Kummel, B., 1964. Nautiloidea–Nautilida. *In* R. C. Moore (ed.), *Treatise on invertebrate paleontology part K Mollusca 3*, 383–457. Geological Society of America, Inc. & the University of Kansas Press, Lawrence.

Kummel, B., 1969. Ammonoids of the late Scythian (Lower Triassic). *Bulletin of the Museum of Comparative Zoology*, **137** (3): 311–702.

Kummel, B. & H. K. Erben, 1968. Lower and Middle Triassic cephalopods from Afghanistan. *Palaeontographica Abteilung A*, **126**: 95–148, pls. 19–24.

Kummel, B. & G. Steele, 1962. Ammonites from the *Meekoceras gracilitatus* Zone at Crittenden Spring, Elko County, Nevada. *Journal of Paleontology*, **36** (4): 638–703, pls. 99–104.

Kurushin, N. I., 1992. *Triasovye paleogeterodontnye i geterodontnye dvustvorki Sibiri*. 86 pp., 14 pls. Nauka, Novosibirisk. [*Triassic palaeoheterodont and heterodont bivalves of Siberia.*] (In Russian)

Lamarck, J. B. de, 1799. Prodrome d'une nouvelle classification des coquilles, comprenant une rédaction appropriée des caractères génériques, et l'établissement d'un grand nombre de genres nouveaux. *Mémoires de la Société d'Histoire Naturelle de Paris*, **1** (7): 63–91.

Lamarck, J. B. de, 1801. *Système des Animaux sans Vertébrés, ou Tableau General des Classes, des Orders, et des Genres dwes ces Animaux*. 432 pp. Deterville. Paris.

Landman, N. H., K. Tanabe & Y. Shigeta, 1996. Ammonoid embryonic development. *In* N. H. Landman, K. Tanabe & R. A. Davis (eds.), *Ammonoid paleobiology*, 343–405. Plenum Press, New York.

Leonardi, P., 1935. Il Trias inferiore delle Venezie. *Memorie Dell'Instituto Geologico della R. Università di Padova*, **11**: 1–136, pls. 1–8.

Liao, Z. T., 1980. Brachiopod assemblages from the Upper Permian and Permian-Triassic boundary beds, South China. *Canadian Journal of Earth Sciences* (*Ottawa*), **17** (2): 289–295.

Linné, C., 1758. *Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Vol. 1: Regnum animale. Editio decima, reformata*. 824 pp. Laurentii Salvii, Stockholm.

Lu, Y. J. & C. Z. Chen, 1986. Triassic bivalves from Mt. Burhan Budai, Qinghai. *In* Qinghai Institute of Geological Sciences & Nanjing Institute of Geology and Palaeontology, Academia Sinica (eds.), *Carboniferous and Triassic strata and fossils from the souothern slope of Mt. Burhan Budai, Qinghai, China*, 141–169, pls. 1–6. Anhui Science and Technology Publishing House, Wuhu. (In Chinese with English summary)

Maeda, H., 1987. Taphonomy of ammonites from the Cretaceous Yezo Group in the Tappu area, northwestern Hokkaido, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, **148**: 285–305.

Maeda, H., 1999. Did ammonoid carcasses surface or sink? *Memoirs of the Geological Society of Japan*, **54**: 131–140. (In Japanese with English abstract)

Maeda, H. & A. Seilacher, 1996. Ammonoid Taphonomy. *In* N. H. Landman, K. Tanabe & R. A. Davis (eds.), *Ammonoid paleobiology*, 543–578. Plenum Press, New York.

Maisey, J. G., 1982. The Anatomy and Interrelationships of Mesozoic hybodont sharks. *American Museum Novitates*, **2724**: 1–48.

Markevich, P. V. & Y. D. Zakharov (eds.), 2004. *Trias i yura Sikhote-Alinya, Kniga 1: Terrigennyj kompleks.* 420 pp. Dalnauka, Vladivostok. [*Triassic and Jurassic of the Sikhote-Alin, Book 1: Terrigenous assemblage.*] (In Russian with English summary)

Marwick, J., 1953. Division and faunas of the Hokonui System (Triassic and Jurassic). *New Zealand Geological Survey, Paleontological Bulletin*, **21**: 1–141, pls. 1–17.

Matsuda, T., 1982. Early Triassic conodonts from Kashmir, India, part 2: *Neospathodus* 1. *Journal of Geosciences, Osaka City University*, **25** (6): 87–102, pls. 1–4.

Matsuda, T., 1983. Early Triassic conodonts from Kashmir, India, part 3: *Neospathodus* 2. *Journal of Geosciences*, *Osaka City University*, **26** (4): 87–110, pls. 1–5.

Matsuda, T., 1984. Early Triassic conodonts from Kashmir, India, part 4: *Gondolella* and *Platyvillosus*. *Journal of Geosciences*, *Osaka City University*, **27** (4): 119–141, pls. 1–6.

Matsushita, S., 1926. Lower Triassic fossils of Kurotaki, Tosa province. *Chikyu*, **5** (5): 420–429. (In Japanese)

Matsumoto, T., 1954. Selected Cretaceous leading ammonites in Hokkaido and Saghalien. *In* T. Matsumoto (ed.), *The Cretaceous System in the Japanese Islands*, 243–324, pls. 1–20. Japan Society for the Promotion of Science, Tokyo.

McTavish, B. R., 1973. Triassic conodont faunas from Western Ausralia. *Neues Jahrbuch für Geologie und Paläontologie. Abhandlungen*, **143**: 275–303, pls. 1–2.

Meek, F. B., 1865. Remark on the family Pteriidae (=Aviculidae), with descriptions of some new genera. *American Journal of Science*, *2nd series*, **37**: 212–220.

Moisseiev, A. S., 1947. Class Brachiopoda. *In* L. D. Kiparisova (ed.), *Atlas rukovodyashhikh form iskopaemykh faun SSSR. Vol. 7. Triassic*, 61–81. Gosgeoltekhizdat, Leningrad, Moscow. [Class Brachiopoda. *In* L.D. Kiparisova (ed.), *Atlas of the guide forms of the fossil faunas of the USSR*.] (In Russian)

Mojsisovics, E., 1882. Die Cephalopoden der mediterranen Triasprovinz. *Abhandlungen der geologischen Reichsanstalt Wien*, **10**: 1–322, pls. 1–94.

Mojsisovics, E., 1886. Arktische Triasfaunen. Beitrage zur palaeontologischen Charakteristik der Arktischen-Pacifischen Triasprovinz. *Mémoires de l'Academie Imperiale des Sciences de St. Pétersbourg, ser. 7*, **33** (6): i–iii, 1–159, pls. 1–20.

Mojsisovics, E., 1902. Das Gebirge um Hallstatt, Theil 1, Die Cephalopoden der Hallstätter Kalke. *Abhandlungen der geologischen Reichsanstalt Wien*, **6** (1) (Supplement): 177–356, pls. 1–23.

Montfort, de P., 1808. *Conchyliologie systématique, et classification métodique des coquilles; offrant leurs figures, leur arrangement générique, leurs descriptions caractéristiques, leur noms; ainsi que leur synonomie en plusieurs langues. 1. Coquilles univalves, non cloisonés*. 410 pp. Paris, F. Schoell.

Moore, R. C. (ed.), 1957. *Treatise on invertebrate paleontology part L Mollusca 4*. 490 pp. Geological Society of America, Inc. & the University of Kansas Press, Lawrence.

Moore, R. C. (ed.), 1964. *Treatise on invertebrate paleontology Part K Mollusca 3.* 519 pp. Geological Society of America, Inc. & the University of Kansas Press, Lawrence.

Moore, R. C. (ed.), 1969. *Treatise on invertebrate paleontology part N* (*1, 2*), *Mollusca 6*. 952 pp. Geological Society of America, Inc. & the University of Kansas Press, Lawrence.

Mosher, L. C., 1968. Triassic conodonts from western North America and Europe and their correlation. *Journal of Paleontology*, **42** (4): 895–946, pls. 113–118.

Mosher, L. C., 1973. Trissic conodonts from British Columbia and the northern Arctic Islands. *Geological Survey of Canada Bulletin*, **222**: 141–193, pls. 17–20.

Mu, L., Y. D. Zakharov, W. Z. Li & S. Z. Shen, 2007.

Early Induan (Early Triassic) cephalopods from the Daye Formation at Guiding, Gtizhou Province, South China. *Journal of Paleontology*, **81** (5): 858–872.

Müller, K. J., 1956. Triassic conodonts from Nevada. *Journal of Paleontology*, **30** (4): 818–830, pls. 95–96.

Münster, G. G. zu (ed.), 1841. *Beiträge zur Geognosie und Petrefacten-Kunde des Südöstlichen Tirols vorzüglich der Schichten von St. Cassian*. 152 pp., 16 pls. Commission der Buch'nerschen Buchhandlung, Beyreuth.

Mutvei, H., J. M. Arnold & N. H. Landman, 1993. Muscles and attachment of the body to the shell in embryos and adults of *Nautilus belauensis* (Cephalopoda). *American Museum Novitates*, **3059**: 1–15.

Mutvei, H. & L. A. Doguzhaeva, 1997. Shell ultrastructure and ontogenetic growth in *Nautilus pompilius* L. (Mollusca, Cephalopoda). *Palaeontographica Abteilung A*, **246**: 33–52.

Nakazawa, K., 1958. The Triassic System in the Maizuru Zone, Southwest Japan. *Memoirs of the College of Science, University of Kyoto, Series B*, **24** (4): 265–313.

Nakazawa, K., 1959. Permian and Eo-Triassic *Bakevellia*s from the Maizuru Zone, Southwest Japan. *Memoirs of the College of Science, University of Kyoto, Series B*, **26** (2): 193–213, pls. 3, 4.

Nakazawa, K., 1960. Permian and Eo-Triassic Myophoriidae from the Maizuru Zone, Southwest Japan. *Japanese Journal of Geology and Geography*, **31** (1): 49–61, pls. 6.

Nakazawa, K., 1961. Early and Middle Triassic pelecypod-fossils from the Maizuru Zone, Southwest Japan. *Memoirs of the College of Science, University of Kyoto, Series B*, **27** (3): 249–291.

Nakazawa, K., 1971. The Lower Triassic Kurotaki fauna in Shikoku and its allied faunas in Japan. *Memoirs of the Faculty of Science, Kyoto University, Series of Geology & Mineralogy*, **38** (1): 103–133, pls. 23–25.

Nakazawa, K., 1981. Permian and Lower Triassic bivalves from Kashmir. *In* K. Nakazawa & H. M. Kapoor (eds.), *The Upper Permian and Lower Triassic fossils of Kashmir*, 89–122, pls. 9–11. Palaeontologia Indica, New Series 46.

Nakazawa, K., 1991. Mutual relation of Tethys and Japan during Permian and Triassic time viewed from bivalve fossils. *In* T. Kotaka, J. M. Dickins, K. G. McKenzie, K. Mori, K. Ogasawara & G. D. Stanley Jr. (eds.), *Shallow Tethys 3*, 3–20. Saito Ho-on Kai Special publication 3, Sendai.

Nakazawa, K., 1996. Lower Triassic bivalves from the Salt Range Region, Paksitan. *In* Geological Survey of India (ed.), *Gondwana Nine*, Volume 1, *Ninth International Gondwana Symposium*, 207–229, Balkema Publishers, Brookfield.

Nakazawa, K., Y. Bando & F. Golshani, 1981. Lower Triassic bivalves from the Elika Valley, Central Alborz Range, Iran. *Geological Survey of Iran, Report*, **49**: 133–154.

Nakazawa, K. & J. M. Dickins (eds.), 1985. *The Tethys, her paleogeography and paleobiogeography from Paleozoic to Mesozoic*. 317 pp. Tokai University Press, Tokyo.

Nakazawa K., T. Ishibashi, T. Kimura, T. Koike, D. Shimizu & A. Yao, 1994. Triassic biostratigraphy of Japan based on various taxa. *In* J. Guex & A. Baud (eds.), *Recent developments on Triassic stratigraphy* (*Proceedings of the Triassic symposium, Lausanne, 20–25 Oct. 1991*), 83–103. Mémoires de Géologie (Lausanne), 22.

Neri, C. & R. Posenato, 1985. New biostratigraphical data on uppermost Werfen Formation of western Dolomites (Trento Italy). *Geologisch-Paläontologische Mitteilungen Innsbruck*, **14** (3): 83–107.

Newell, N. D. & D. W. Boyd, 1975. Parallel evolution in early trigoniacean bivalves. *Bulletin of the American Museum of Natural History*, **154** (2): 53–162.

Newell, N. D. & B. Kummel, 1942. Lower Eo-Triassic stratigraphy, western Wyoming and southeast Idaho. *Geological Society of America Bulletin*, **53** (6): 937–995.

Nicora, A., 1991. Conodonts from the Lower Triassic sequence of Central Dolpo, Nepal. *Rivista Italiana di Paleontologia e di Stratigrafia*, **97** (3–4): 239–268.

Noetling, F., 1905a. Untersuchungen über den Bau der Lobenlinie von *Pseudosageceras multilobatum* Noetling. *Palaeontographica*, **51**: 155–260, pls. 19–27.

Noetling, F., 1905b. Die asiatische Trias. *In* F. Frech (ed.), *Lethaea geognostica. Theil 2, Das Mesozoicum 1, Trias* (*2*), 107–221, pls. 9–33. Handbuch der Erdgeschichte mit Abbildungen der für die Formationen bezeichnendsten Versteinerungen. Schweizerbart, Stuttgart.

Nützel, A., 2005. A new Early Triassic gastropod genus and the recovery of gastropods from the Permian/Triassic extinction. *Acta Palaeontologica Polonica*, **50**: 19–24.

Nützel, A., J. Frýda, T. E. Yancey, & J. R. Anderson, 2007. Larval shells of Late Palaeozoic naticopsid gastropods (Neritopsoidea: Neritimorpha) with a discussion of the early neritimorph evolution. *Paläontologische Zeitschrift*, **81**: 213–228.

Ogilvie Gordon, M. M., 1927. Das Grödener-, Fassa- und Enneberggebiet in den Südtiroler Dolomiten.

Geologische Beschreibung mit besonderer Berücksichtigung der Überschiebungserscheinungen. 3, Paläontologie. *Abhandlungen der Geologischen Bundesanstalt*, **24** (2): 1–89, pls. 1–13.

Orchard, M. J., 2005. Multielement conodont apparatuses of Triassic Gondolelloidea. *Special Papers in Palaeontology*, **73**: 73–101.

Orchard, M. J., 2007a. Conodont diversity and evolution through the latest Permian and Early Triassic upheavals. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **252**: 91–117.

Orchard, M. J., 2007b. Report on 2007 conodont collections from Mud, Spiti. *Albertiana*, **36**: 46–48.

Orchard, M. J. & L. Krystyn, 1998. Conodonts of the lowermost Triassic of Spiti, and new zonation based on *Neogondolella* successions. *Rivista Italiana di Paleontologia e di Stratigrafia*, **104** (3): 341–368.

Orchard, M. J. & L. Krystyn, 2007. Conodonts from the Induan-Olenekian boundary interval at Mud, Spiti. *Albertiana*, **33**: 30–36.

Orchard, M. J. & E. T. Tozer, 1997. Triassic conodont biochronology and intercalibration with the Canadian ammonoid sequence. *Albertiana*, **20**: 33–44.

Ozaki, H. & T. Shikama, 1954. On three Skytic molluscs from Gunma Prefecture, Central Japan. *Bulletin of the National Science Museum, Tokyo, New Series*, **1** (2): 42–45, pls. 19.

Palmer, C. P., 1974. A supraspecific classification of the scaphopod mollusks. *The Veliger*, **17** (2): 115–123.

Pakistani-Japanese Research Group, 1985. Permian and Triassic Systems in the Salt Range and Surghar Range, Pakistan. *In* K. Nakazawa & J. M. Dickins (eds.), *The Tethys, her paleogeography and paleobiogeography from Paleozoic to Mesozoic*, 221–312. Tokai University Press, Tokyo.

Pan, H. Z., 1982. Triassic marine fossil gastropods from SW China. *Bulletin of Nanjing Institute of Geology and Palaeontology, Academia Sinica*, **4**: 153–188. (in Chinese)

Paull, R. K., 1988. Distribution pattern of Lower Triassic (Scythian) conodonts in the Western United States: Documentation of the Paskistan connection. *Palaios*, **3**: 598–605.

Péron, S., S. Bourquin, F. Fluteau & F. Guillocheau, 2005. Paleoenvironment reconstructions and climate simulations of the Early Triassic: impact of the water and sediment supply on the preservation of fluvial system. *Geodinamica Acta*, **18** (6): 431–446.

Philippi, E., 1903. Die kontinentale Trias. *In* F. Frech (ed.), *Lethaea geognostica. Handbuch der Erdgeschichte mit Abbildung der für die Formationen bezeichendsten Versteinerungen. II Teil, Das Mesozoicum, 1 Band Trias (1)*, 6–104, pls. 4–5. E. Schweizerbart'schen Verlagsbuchhandlung (E. Näge le), Stuttgart.

Picard, K. 1883. Über eine neue Crinoiden-Art aus dem Muschelkalk der Hainleite bei Sondershausen. *Zeitschrift der Deutschen Geologische Gesellshaft*, **35**: 199–202.

Popov, Y. N., 1961. Triasovye ammonoidei Sebero-Vostoka SSSR. *Trudy Nauchno-Issledovatel'skogo Instituta Geologii Arktiki* (*NIIGA*), **79**: 1–179. [Triassic ammonoids of northeast USSR.] (In Russian)

Posamentier, H. W. & R. G. Walker, 2006. Deep-water turbidites and submarine fans. *In* H. W. Posamentier & R. G. Walker (eds.), *Facies models revisited*, 399–520. SEPM Special Publication 84, SEPM, Tulsa.

Pruss, S. B. & D. J. Bottjer, 2004a. Late Early Triassic microbial reefs of the western United States: a description and model for their deposition in the aftermath of the end-Permian mass extinction. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **211**: 127–137.

Pruss, S. B. & D. J. Bottjer, 2004b. Early Triassic trace fossils of the Western United States and their implications for prolonged environmental stress from the end-Permian mass extinction. *Palaios*, **19**: 551–564.

Purnell, M. A., P. C. Donghue & R. J. Aldridge, 2000. Orientation and anatomical notation in conodonts. *Journal of Paleontology*, **74** (1): 113–122.

Rasmussen, H. W. 1978. Systematic description, Articulata. *In* R. C. Moore & C. Teichert (eds.), *Treatise on invertebrate paleontology, part T. Echinodermata 2, Crinoidea* (*3*), 813–928. Geological Society of America, Inc. & the University of Kansas Press, Lawrence.

Reif, W. E., 1973. Morphologie und Ultrastruktur des Hai-"Schmelzes". *Zoologica Scripta*, **2**: 231–250.

Reif, W. E., 1977. Tooth enameloid as a taxonomic criterion: 1: a new euselachian shark form the Raetic-Liassic boundary. *Neues Jahrbuch für Geologie unt Paläontologie, Monatshefte*: 565–576.

Rodland, D. L. & D. J. Bottjer, 2001. Biotic recovery from the end Permian mass extinction: behavior of the inarticulate brachiopod *Lingula* as a disaster taxon. *Palaios*, **16** (1), 95–101.

Rowell, A. J., 1970. *Lingula* from the basal Triassic Kathwai member, Mianwali Formation, Salt Range and Surghar Range, West Pakistan. *In* B. Kummel & K. Techert (eds.), *Stratigraphic boundary problems: Permian and Triassic of West Pakistan*, 111–116. Special Publication 4. University of Kansas, Department of Geology.

Rudwick, M. J. S., 1970. *Living and fossil Brachiopoda.* 199 pp. Hutchinson and Co. Ltd., London.

Salnikova, E. B., S. A. Sergeev, A. B. Kotov, S. Z. Yakovleva, R. H. Steiger, L. Z. Reznitskiy & E. P. Vasilev, 1998. U-Pb zircon dating of granulite metamorphism in the Sludyanskiy Complex, eastern Siberia. *Gondwana Research*, **1**: 195–205.

Santosh, M., T. Morimoto & Y. Tsutsumi, 2006. Geochronology of the khondalite belt of Trivandrum Block, Southern India: Electron probe ages and implications for Gondwana tectonics. *Gondwana Research*, **9**: 261–278.

Schastlivtceva, N. P., 1981. O sistematicheskom polozhenii triasovykh ortotseratoidej yuga SSSR. *Byulleten Moskovskogo Obschestva Ispytatelej Prirody, Otdeleniye Geologicheskoye*, **56** (4): 76–82. [On systematic position of Triassic Orthoceratoidea of the South USSR.] (In Russian)

Schastlivtceva, N. P., 1986. Nekotorye triasovye ortotseratidy i nautilidy Severo-Vostoka SSSR. *Byulleten Moskovskogo Obschestva Ispytatelej Prirody, Otdeleniye Geologicheskoye*, **61** (2): 122–129. [Some Triassic orthoceratids and nautilids of the Northeast Russia.] (In Russian)

Schastlivtceva, N. P., 1988. Triasovye ortotseratidy i nautilidy SSSR. *Trudy Paleontologicheskogo Instituta*, **299**: 1–104, pls. 1–8. [Triassic orthoceratids and nautilods of the USSR.] (In Russian)

Scheltema, R. S., 1971. Larval dispersal as a means of genetic exchange between geographically separated populations of shallow-water benthic marine gastropods. *Biological Bulletin of the Marine Biological Laboratory, Woods Hole*, **140**: 284–322.

Schubert, J. K. & D. J. Bottjer, 1995. Aftermath of the Permian-Triassic mass extinction event: palaeoecology of Lower Triassic carbonates in the western U.S. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **116**: 1–39.

Schubert, J. K., D. J. Bottjer, & M. J. Simms, 1992. Paleobiology of the oldest known articulate crinoid. *Lethaia*, **25**: 97–110.

Scopoli, J. A., 1777. *Introdvctio ad historiam natvralem sistens genera lapidvm, plantarvm, et animalivm hactenvs detecta, caracteribvs essentialibvs donata, in tribvs divisa, svbinde ad leges natvrae.* 506 pp. Apvd Wolfgangvm Gerle, Prague.

Scott, G., 1940. Paleoecological factors controlling the distribution and mode of life of Cretaceous ammonoids in the Texas area. *Journal of Paleontology*, **14** (4): 299–323.

Shevyrev, A. A., 1986. Triasobye ammonoidei. *Trudy Paleontologicheskogo Instituta, Akademiya Nauk SSSR*, **217**: 1–184. [Triassic Ammonoidea.] (In Russian)

Shevyrev, A. A., 1968. Triasovye ammonoidei yuga SSSR. *Trudy Paleontologicheskogo Instituta, Akademiya Nauk SSSR*, **119**: 1–272. [Triassic ammonoids of the southern USSR.] (In Russian)

Shevyrev, A. A., 1995. Triasovye ammonity Severo-Zapadnogo Kavkaza. *Trudy Paleontologicheskogo Instituta, Rossijskaya Akademiya Nauk*, **264**: 1–174. [Triassic ammonites of northwestern Caucasus.] (In Russian)

Shimansky, V. N., 1962. Order Nautilida. *In* Y. A. Orlov (ed.), *Osnovy paleontologii. Mollyusk-golovonogiye. 1*, 115–154. Izdatel'stvo Akademii Nauk SSSR, Moscow. [*Fundamentals of Paleontology. Mollusca-Cephalopoda. 1*.] (In Russian)

Skelton, P. W. & M. J. Benton, 1993. Mollusca: Rostrochonchia, Scaphopoda and Bivalvia. *In* M. J. Benton (ed.), *The fossil record 2*, 237–263. Chapman & Hall, London.

Smith, J. P., 1913. Ammonoidea. *In* K. A. Zittel (ed.), *Textbook of palaeontology*, *2nd English edition*, 617–677. C. R. Eastman, London.

Smith, J. P., 1932. Lower Triassic ammonoids of North America. *United States Geological Survey Professional Paper*, **167**: 1–199.

Sobolev, E. S., 1989. *Triasovye nautilidy severo-vostochnoi Azii.* 192 pp. Nauk, Novosibirisk. [*Triassic nautiloids of northeastern Asia.*] (In Russian)

Sobolev, E. S., 1994. Stratigraphic range of Triassic boreal Nautiloidea. *In* J. Guex & A. Baud (eds.), *Recent developments on Triassic stratigraphy* (*Proceedings of the Triassic symposium*, *Lausanne*, *20–25 Oct. 1991*), 127–138. Mémoires de Géologie (Lausanne), 22.

Solien, M. A., 1979. Conodont biostratigraphy of the Lower Triassic Thaynes Formation, Utah. *Journal of Paleontology*, **53**: 276–308, pls. 1–3.

Sowerby, J. de C., 1823–25. *The mineral conchology of Great Britain, or Coloured figures and descriptions of those remains of testaceous animals or shells, which have been preserved at various times and depths in the earth, vol. 5*, 168 pp., pls. 407–503. London.

Spath, L. F., 1929. Corrections of cephalopod nomenclature. *Naturalist*: 269–271.

Spath, L. F., 1930. The Eo-Triassic invertebrate fauna of East Greenland. *Meddelelser om Grønland*, **83** (1): 1–90, pls. 1–12.

Spath, L. F., 1934. *Catalogue of the fossil Cephalopoda in the British Museum (Natural History). part 4, the Ammonoidea of the Trias.* 521 pp., 18 pls. The Trustees of the British Museum, London.

Spath, L. F., 1935. Additions to the Eo-Triassic invertebrate fauna of East Greenland. *Meddelelser om Grønland*, **98** (2): 1–115, pls. 1–23.

Staesche, U., 1964. Conodonten aus dem Skyth von Sudtirol. *Neues Jahrbuch für Geologie und*

Paläontologie. Abhandlungen, **119** (3): 247–306, pls. 28–32.

Steiner, G. & A. R. Kabat, 2001. Catalogue of supraspecific taxa of Scaphopoda (Mollusca). *Zoosystema*, **23** (3): 434–460.

Stensiö, S., 1921. *Triassic fishes from Spitzbergen. part 1*. 307 pp. Adolf Holzhausen, Vienna.

Sun, D. l., Z. X. Hu & T. E. Chen, 1981. Discovery of Upper Permian strata in Lhasa, Xizang. *Journal of Stratigraphy*, **5** (2): 139–142.

Sutter, J. R., 2006. Clastic shelves. *In* H. W. Posamentier & R. G. Walker (eds.), *Facies models revisited*, 339–398. SEPM Special Publication 84, SEPM, Tulsa.

Suzuki, K., M. Adachi & T. Tanaka, 1991. Middle Precambrian provenance of Jurassic sandstone in the Mino Terrane, central Japan: Th-U-total Pb evidence from an electron microprobe monazite study. *Sedimentary Geology*, **75**: 141–147.

Sweet, W., 1964. Nautiloidea-Orthocerida. *In* R. C. Moore (ed.), *Treatise on invertebrate paleontology part K Mollusca 3*, 216–261. Geological Society of America, Inc. & the University of Kansas Press, Lawrence.

Sweet, W. C., 1970a. Permian and Triassic conodonts from Guryne Ravine, Vihi district, Kashmir. *University of Kansas Paleontological Contributions, Paper*, **49**: 1–10, pl. 1.

Sweet, W. C., 1970b. Uppermost Permian and Lower Triassic conodonts of the Salt Range and Trans-Indus Ranges, West Pakistan. *In* B. Kummel & C. Teichert (eds.), *Stratigraphic boundary problems: Permian and Triassic of West Pakistan*, 207–275. University of Kansas, Special Publication 4.

Sweet, W. C., 1988. *The conodont morphology, taxonomy, paleoecology, and evolutionary history of a long-extinct animal phyllum*. 212 pp. Oxford Monography on Geology and Geophysics 10, Clarendon Press, Oxford.

Tanabe, K., 1979. Palaeoecological analysis of ammonoid assemblages in the Turonian *Scaphites* facies of Hokkaido, Japan. *Paläeontology*, **22** (3): 609–630.

Tatge, U., 1956. Conodonten aus dem Germanischen Muschelkalk. *Paläontologische Zeitschrift*, **30**: 108–127, 129–147, pls. 5–6.

Tian, C., J. Dai & S. Tian, 1983. Triassic conodonts. *In* Chengdu Institute of Geology and Mineral Resources (ed.), *Paleontological atlas of Southwest* China, *volume of microfossils*, 345–398, pls. 79–100.

Tong, J. N., S. B. Wu, Z. M. Li, G. Guo & J. J. Zhang, 2006. Lower Triassic bivalves from Chaohu, Anhui province, China. *Albertiana*, **34**: 42–51.

Tong, J., Y. D. Zakharov, M. J. Orchard, H. Yin & H. J. Hansen, 2003. A candidate of the Induan-Olenekian boundary stratotype in the Tethyan region. *Science in China, Series D*, **46** (11): 1182–1200.

Tong, J., Y. D. Zakharov, M. J. Orchard, H. Yin & H. J. Hansen, 2004. Proposal of Chaohu section as the GSSP candidate of the Induan-Olenekian boundary. *Albertiana*, **29**: 13–28.

Tozer, E. T., 1961. Triassic stratigraphy and faunas, Queen Elizabeth Islands, Arctic archipelago. *Geological Survey of Canada Memoir*, **316**: 1–116.

Tozer, E. T., 1963. Lower Triassic ammonoids from Tuchodi Lake and Halfway River areas, northeastern British Columbia. *Geological Survey of Canada Bulletin*, **96**: 1–30, pls. 1–5.

Tozer, E. T., 1981. Triassic ammonoidea: classification, evolution and relationship with Permian and Jurassic forms. *In* M. R. House & J. R. Senior (eds.), *The ammonoidea*, 65–100. The Systematic Association Special volume 18, London.

Tozer, E. T., 1994. Canadian Triassic ammonoid faunas. *Geological Survey of Canada Bulletin*, **467**: 1–663.

Trechmann, C. T., 1918. The Trias of New-Zealand. *Quartery Journal of Geological Society*, **73** (1–4): 165–246.

Trümpy, R., 1969. Lower Triassic ammonites from Jameson Land (East Greenland). Meddelelser om Grønland, **168** (2): 77–116, pls. 1–2.

Tsutsumi, Y., K. Yokoyama, K. Terada & Y. Sano, 2003. SHRIMP U-Pb dating of detrital zircons in metamorphic rocks from northern Kyushu, western Japan. *Journal of Mineralogical and Petrological Sciences*, **98**: 220–230.

Twitchett, R. J., 1999. Palaeoenvironments and faunal recovery after the end-Permian mass extinction. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **154**: 27–37.

Twitchett, R. J., 2006. The palaeoclimatology, palaeoecology and palaeoenvironmental analysis of mass extinction events. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **232**: 190–213.

Twitchett, R. J. & C. G. Barras, 2004. Trace fossils in the aftermath of mass extinction events. *In* D. McIlroy (ed.), *The Application of ichnology to palaeoenvironmental and stratigraphic analysis*, 397–417. Geological Society, London, Special Publications 228.

Twitchett, R. J., L. Krystyn, A. Baud, J. R. Wheeley & S. Richoz, 2004. Rapid marine recovery after the end-Permian mass-extinction event in the absence of marine anoxia. *Geology*, **32** (9): 805–808.

Twitchett, R. J. & T. Oji, 2005. Early Triassic recovery of echinoderms. *Comptes rendus Palevol*, **4**: 463–

474.

Vavilov, M. N. & Y. D. Zakharov, 1976. Reviziya rannetriasovogo roda *Pachyproptychites*. *Trudy Biologo-Pochvennogo Instituta, Dalnevostochnogo Nauchnogo Tsentra, Akademii Nauk SSSR, Novaya seriya*, **42** (145): 60–67, pl. 24. [Revision of Early Triassic genus *Pachyproptychites*.] (In Russian with English abstract)

Vozin, V. F. & V. V. Tikhomirova, 1964. *Polevoj Atlas Dvustvorchatykh i Golovonogikh Mollyuskov Triasovych Otlozhenij Severo-Vostoka SSSR*. 94 pp., 50 pls. Izdatel'stvo Nauka, Moscow. [*Field atlas of bivalve and cephalopod Mollusca from the Triassic deposits of Northeast USSR.*] (In Russian)

Vu Khuc, C., A. S. Dagys, L. D. Kiparisova, Ngugen Ba Nguyen, Truong Cam Bao & I. N. Srebrodolskaia, 1965. *Les fossils Caractéristiques du Trias au Nord Viet Nam*. 117 pp. Direction générale de Géologie de la RDV, Hanoi. (In Vietnamese with French descriptions for new species)

Vu Khuc, C., Vu Chau, T. H. Dan & Trinh Tho, 1991. Class Bivalvia. *In* C. Vu Khuc (ed.), *Paleontological atlas of Vietnam 3*, *Mollusca*, 1–117, pls. 1–43. Science and Technics Publishing House, Hanoi.

Waagen, W., 1880. Salt-Range fossils. I, Productus-limestone fossils. 2, Pisces- Cephalopoda: supplement. Gasteropoda. *Memoirs of the Geological Survey of India. Palaeontologia Indica*, **13**: 73–183, pls. 7–16.

Waagen, W., 1895. Salt Range fossils. Vol. 2: Fossils from the ceratite formation. part 1. Pisces-Ammonoidea. *Palaeontologia Indica, Series 13*, **2**: 1–323, pls. 1–40.

Wachsmuth, C. & F. Springer, 1886. Revision of the Palaeocrinoidea, pt. 3, sec. 2. Discussion of the classification and relations of the brachiate crinoids, and conclusion of the generic descriptions. *Proceedings of the Academy of Natural Sciences of Philadelphia*: 64–226.

Wang, C. & Z. Wang, 1976. Triassic conodonts of the Qomolamgma region. In scientific report of the Qomolamgma region 1966–1968. *Paleontology*, **2**: 387–416, pls. 1–5. (In Chinese)

Wang, H. & Y. Xi, 1980. Late Permian and early Triassic gastropods of western Guizhou. *In* Nanjing Institute of Geology and Paleontology (eds), *Stratigraphy and paleontology of Upper Permian coal-bearing formation in Western Guizhou and Eastern Yunan, China*, 195–232. Beijing, Science Press.

Wang, Z., 1978. Permian-Lower Triassic conodonts of the Liangshan area, southern Shaanxi. *Acta Palaeontologica Sinica*, **17** (2): 213–229, pls. 1–2.

Wang, Z. & Y. Cao, 1981. Early Triassic conodonts from Lichuan, Western Hubei. *Acta Palaeontologica Sinica*, **20** (4): 363–375, pls. 1–3.

Wang, Z. & D. Zhong, 1994. Triassic conodonts from different facies in eastern Yunnan, western Guizhou and northern Guangxi. *Acta Micropalaeontologica Sinica*, **11** (4): 379–412, pls. 1–5.

Wanner, J., 1911. Triascephalopoden von Timor und Rotti. *Neues Jahrbuch für Mineralogie, Geologie und Paläeontologie*, **32**: 177–196, pls. 6, 7.

Waterhouse, J. B., 1994. The early and middle Triassic ammonoid succession of the Himalayas in western and central Nepal, part 1, stratigraphy, classification and Early Scythian ammonoid systematics. *Palaeontograpgica, Abteilung* A, **232**: 1–83, pls. 1–6.

Waterhouse, J. B., 1996a. The early and middle Triassic ammonoid succession of the Himalayas in western and central Nepal, part 2, systematic studies of the early Middle Scythian. *Palaeontograpgica, Abteilung A*, **241**: 27–100, pls. 1–12.

Waterhouse, J. B., 1996b. The early and middle Triassic ammonoid succession of the Himalayas in western and central Nepal, part 3, late middle Scythian ammonoids. *Palaeontograpgica, Abteilung A*, **241**: 101–167, pls. 1–11.

Waterhouse, J. B., 2002. The early and middle Triassic ammonoid succession of the Himalayas in western and central Nepal, part 7, late Anisian ammonoids from west Nepal, and world wide correlations for early and early middle Triassic ammonoid faunules. *Palaeontograpgica, Abteilung A*, **267**: 1–118, pls. 1–8.

Weitschat, W. & U. Lehmann, 1978. Biostratigraphy of the uppermost part of the Smithian stage (Lower Triassic) at the Botneheia, W.-Spitsbergen. *Mitteilungen aus dem Geologisch-Paläontologischen Institut, Universität Hamburg*, **48**: 85–100.

Welter, O. A., 1922. Die Ammoniten der Unteren Trias von Timor. *Paläontologie von Timor*, **11**: 83–154, pls. 155–171.

Westermann, G. E. G., 1996. Ammonoid life and habitat. *In* N. H. Landman, K. Tanabe & R. A. Davis (eds.), *Ammonoid paleobiology*, 607–707. Plenum Press, New York.

White, C. A., 1879. Paleontological paper no. 9: fossil from the Jura-Trias of south-eastern Idaho. *Bulletin of the United States Geological and Geographical Survey of the Territories*, **5**: 105–117.

Wignall, P. B. & R. J. Twitchett, 2002. Extend, duration, and nature of the Permian-Triassic superanoxic event. *In* C. Koeberl & K. G. MacLeod (eds.), *Catastrophic events and mass extinctions: Impacts and beyond*, 395–413. Geological Society of America Special Paper 356.

Wilde, S. A., X. Zhang & F. Wu, 2000. Extension of a newly identified 500 Ma metamorphic terrane in North East China: further U-Pb SHRIMP dating of the Mashan complex, Heilongjiang province, China. *Tectonophysics*, **328**: 115–130.

Wilde, S. A., F. Wu & X. Zhang, 2003. Late Pan-African magmatism in northeastern China: SHRIMP U-Pb zircon evidence from granitoids in the Jiamusi Massif. *Precambrian Research*, **122**: 311–327.

Wirth, E., 1936. Beiträge zur Kenntnis der Trias in Provinz Szechuan, West China. *Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie, Beilage-Band*, **75**: 412–446.

Wissmann, H. L., 1841. IV, Conchilien B. Monomyarier. *In* G. G. zu Münster (ed.), Beiträge zur Geognosie und Petrefacten-Kund des Südöstlichen Tirols vorzüglich der Schichten von St. Cassian, 69–125, 16 pls. Commission der Buch'nerschen Buchhandlung, Beyreuth.

Wittenburg, P. V., 1909. Einige Lamellibranchiata der Salt-Range, mit Berücksichtigung der Lamellibrachiata des Süd-Ussuri-Gebiets. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, **1**: 6–13, pls. 2–3.

Wöhrmann, S. & E. Koken, 1892. Die Fauna der Raibler Schichten vom Schlernplateau. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften*, **44** (2): 167–223, 11 pls.

Wyck, N. V. & M. Norman, 2004. Detrital zircon ages from Early Proterozoic quartzite, Wisconsin, support rapid weathering and deposition of mature quartz arenites. *Journal of Geology*, **112**: 305–315.

Xu, G. H., 1988. Early Triassic cephalopods from Lichuan, Western Hubei. *Acta Palaeontologica Sinica*, **27**: 437–456, pls. 1–4. (In Chinese with English summary)

Xu G. R. & J. H. Xie, 1985. *Lunoglossa*; a new genus of Inarticulata. *Geological Review* (*Beijing*), **31** (5): 469–473.

Yabe, Y., 1956. Early Triassic mollusca from Shionosawa in the Sanchu graben, Kwanto massif, Japan. *Science reports of the Tokyo Kyoiku Daigaku, Section C*, **4** (39): 283–292, pls. 16, 17.

Yang, Z. Y., H. F. Yin, G. R. Xu, S. B. Wu, Y. L. He, G. C. Liu & J. R. Yin, 1983. *Triassic of the South Qilian Mts*. 224 pp., 20 pls. Geological Publishing House, Peking. (In Chinese with English summary)

Yehara, S., 1928. The Lower Triassic cephalopod and bivalve fauna of Shikoku. *Japanese Journal of Geology and Geography*, **5** (4): 135–172.

Yochelson, E. L., 1960. Permian Gastropoda of the southwestern United States. 3. Bellerophontacea and Patellacea. *Bulletin of the American Museum of Natural History*, **119**: 205–294.

Yochelson, E. L. & Y. Hongfu, 1985. Redescription of *Bellerophon asiaticus* Wirth (early Triassic: Gastropoda) from China, and a survey of Triassic Bellerophontacea. *Journal of Paleontology*, **59**: 1305–1319.

Yokoyama, K., K. Amano, A. Taira & Y. Saito, 1990. Mineralogy of silts from Bengal Fan. *Proceedings of Ocean Drilling Project*, *Science Results*, **116**: 69–73.

Yokoyama, K. & Y. Saito, 1996. Petrological study of Pre-Tertairy sandstones in the South Kitakami Massif, Northeast Japan. *Memoirs of National Science Museum*, *Tokyo*, **29**; 9–24.

Yokoyama, K. & Y. Saito, 2001. Provenance study of Pre-Tertairy sandstones in the northern Kanto districts, Central Japan. *Memoirs of National Science Museum*, *Tokyo*, **37**; 7–20.

Yokoyama, K., Y. Tsutsumi, C. S. Lee, J. J. S. Shen, C. Y. Lam & L. Zhao, 2007. Provenance study of Tertiary sandstones from the Western Foothills and Hsuehshan Range, Taiwan. *Bulletin of National Museum of Nature and Science*, *Series C*, **33**: 7–26.

Yoo, E. K., 1988. Early Carboniferous Mollusca from Gundy, Upper Hunter, New South Wales. *Records of the Australian Museum*, **40**: 233–264.

Zakharov, Y. D., 1968. *Biostratigraphiya i ammonoidei nizhnego triasa Yuzhnogo Primorya*. 175 pp. Nauk, Moscow. [*Lower Triassic biostratigraphy and ammonoids of South Primorye.*] (In Russian)

Zakharov, Y. D., 1978. *Rannetriasovye ammonoidei Vostoka SSSR*. 224 pp. Nauka, Moscow. [*Lower Triassic ammonoids of East USSR.*] (In Russian)

Zakharov, Y. D., 1987. See Zakharov, Y. D. & S. V. Rybalka, 1987.

Zakharov, Y. D., 1994. Stratotip granitsy indskogo i olenekskogo yarusov nizhnego triasa. *Tikhookeanskaya* Geologiya, 1994 (4): 33–44. [Stratotype of the Induan-Olenekian boundary of the Lower Triassic.] (In Russian with English abstract)

Zakharov, Y. D., 1996. The Induan-Olenekian boundary in the Tethys and Boreal realm. *Supplemento agli Annali dei Musei civici di Roverto, Sezione: Archeologia*, *Storia*, *Scienze naturali*, **11**: 133–156.

Zakharov, Y. D., 1997a. Ammonoid evolution and the problem of the stage and substage division of the Lower Triassic. *Mémoires de Géologie* (*Lausanne*), **30**: 121–136.

Zakharov, Y. D., 1997b. Recent view on the Induan, Olenekian and Anisian ammonoid taxa and zonal assemblages of South Primorye. *Albertiana*, **19**: 25–35.

Zakharov, Y. D., 2004. The global stratigraphic section and point 2 (GSSP) of the base of the Olenekian stage (Lower Triassic). *Albertiana*, **29**: 38–40.

Zakharov, Y. D., 2006. Notes on the business meeting of the Induan/Olenekian boundary working group (16 august 2006, Longyearbyen, Svalbard) and the after meeting discussion. *Albertiana*, **34**: 20–27.

Zakharov, Y. D., G. V. Kotlyar, S. A. Shorokhova, E. B. Volynets, V. G. Zimina, M. P. Zimina, A. S. Biakov & A. M. Popov, 2008. Pozdnepaleozoiskie i rannemezozoiskie kolebaniya klimata na vostochnoj okraine Azii (rekonstruktsiya po paleontologicheskim i izotopnym dannym). *In* P. V. Markevich & Y. D. Zakharov (eds.), *Trias i yura Sikhote-Alinya. 2. Vulkanogenno-osadochnyj kompleks, paleobiogeographiya*, 212–239. Dalnauka, Vladivostok. [Late Paleozoic and Early-Middle Mesozoic climatic fluctuations on the East Asia margin: reconstructions upon paleontological and isotope data. *In* P. V. Markevich & Y. D. Zakharov (eds.), *Triassic and Jurassic of the Sikhote-Alin. 2. Volcanosedimentary assemblage, paleobiogeography.*] (In Russian)

Zakharov, Y. D. & A. M. Popov, 1999. New data on Induan/Olenekian boundary in South Primorye. *Albertiana*, **22**: 19.

Zakharov, Y. D., A. M. Popov, & G. I. Buryi, 2004a. Triassic ammonoid succession in South Primorye: 2 Middle Olenekian *Tirolotes–Amphistephanites* zones. *Albertiana*, **29**: 29–37.

Zakharov, Y. D., A. M. Popov, & G. I. Buryi, 2004b. Triassic ammonoid succession in South Primorye: 3 Late Olenekian—Early Anisian zones (*Neocolumbites insignis*, *Subcolumbites multiformis*, *Ussuriphyllites amurensis and Leiophyllites pradyumna*). *Albertiana*, **31**: 54–64.

Zakharov, Y. D., A. M. Popov, & G. I. Buryi, 2005a. Triassic ammonoid succession in South Primorye: 4 Late Olenekian–Early Anisian zones of the Atlasov Cape section. *Albertiana*, **32**: 36–39.

Zakharov, Y. D., A. M. Popov, & G. I. Buryi, 2005b. Unique marine Olenekian–Anisian boundary section from South Primorye, Russian Far East. *Journal of China University of Geosciences*, **16** (3): 219–230.

Zakharov, Y. D. & S. V. Rybalka, 1987. Etalony permi i triasa teticheskoj oblasti. *In* Y. D. Zakharov & Y. I. Onoprienko (eds.), *Problemy biostratigrafii permi i triasa Vostoka SSSR*, 6–48, pls. 1–4. Dalnevostochnyj Nauchnyj Tsentr Akademii Nauk SSSR, Biologo-Pochvennyj Institut, Vladivostok. [A standards for the Permian-Triassic in the Tethys. *In* Y. D. Zakharov & Y. I. Onoprienko (eds.), *Problems of the Permian and Triassic biostratigraphy of the East USSR.*] (In Russian with English abstract)

Zakharov, Y. D. & Y. Shigeta, 2000. *Gyronautilus*, a new genus of Triassic Nautilida from South Primorye, Russia. *Paleontological Research*, **4** (4): 231–234.

Zakharov, Y. D., Y. Shigeta, A. M. Popov, A. N. Sokarev, G. I. Buryi, V. V. Golozubov, E. S. Panasenko & E. A. Dorukhovskaya, 2000. The candidates of global stratotype of the boundary of the Induan and Olenekian stages of the Lower Triassic in southern Primorye. *Albertiana*, **24**: 12–26.

Zakharov, Y. D., Y. Shigeta, A. M. Popov, A. N. Sokarev, G. I. Buryi & V. V. Golozubov, 2002. Kandidaty v globalnye stratotipy granitsy indskogo i olenekskogo yarusov nizhnego triasa v Yuzhnom Primorye. *Stratigraphiya. Geologicheskaya korrelyatsiya*, **10** (6): 50–61. [Candidates for global stratotype of the Induan-Olenekian boundary in South Primorye.] (In Russian)

Zakharov, Y. D., Y. Shigeta, A. M. Popov, G. I. Buryi, A. V. Oleinikov, E. A. Dorukhovskaya & T. M. Mikhalik, 2002. Triassic ammonoid succession in South Primorye: 1 Lower Olenekian *Hedenstroemia bosphorensis* and *Anasibilites nevolini* zones. *Albertiana*, **27**: 42–64.

Zenker, J. 1834. *Lingula keuperea* Zenk. and *Lingula calcaria* Zenk., zwei fossile Muschelarten aus Thüringen. *Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde.* SS: 394–397, pl. 5.

Zhang, Z. M., 1979. See Zhang, Z. M., Y. J. Lu & S. X. Wen, 1979.

Zhang, Z. M., Y. J. Lu & S. X. Wen, 1979. Lamellibranchs. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica & Qinghai Institute of Geosciences (eds.), *Palaeontological atlas of Western China. Qinghai Volume*, 225–314, Geological Press, Beijing. (In Chinese)

Zhao, L. & M. J. Orchard, 2007. See Zhao, L., M. J. Orchard, J. Michael & J. Tong, 2004.

Zhao, L., M. J. Orchard, J. Michael & J. Tong, 2004. Lower Triassic conodont biostratigraphy and speciation of *Neospathodus waageni* around the Induan-Olenekian boundary of Chaohu, Anhui Province, China. *Albertiana*, **29**: 41–43.

Zhao, L., M. J. Orchard, J. Tong, Z. Sun, J. Zuo, S. Zhang & A. Yun, 2007. Lower Triassic conodont sequence in Chaohu, Anhui Province, China and its global correlation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **252**: 24–38.

Zharnikova, N. K., 1962. See Burij, I. V. & N. K. Zharnikova, 1962.

Ziethen, C. H. (ed.), 1830–33. *Die Versteinerungen Württembergs.* 108 pp., 72 pls. Verlag & Lithographie der Expedition des Werkes Unsere Zeit, Stuttgart.