Late Ordovician brachiopods from the Selety river basin, north Central Kazakhstan

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A medium-diversity fauna of late Ordovician rhynchonelliformean brachiopods occurs in the Tauken Formation (upper Caradoc–lowermost Ashgill) of north Central Kazakhstan. It demonstrates close similarity to the approximately contemporaneous faunas characteristic of shallow clastic shelves (BA 2–3) of the Chingiz and Chu-Ili ranges (both in Kazakhstan) and South China, but is characterized by a high proportion of endemic new species, including *Tetraphalerella bestiubensis* sp. nov., *Glyptomena kaskolica* sp. nov., *Dinorthis taukensis* sp. nov., *Rhynchotrema seletensis* sp. nov., and *Nalivkinia* (*Pronalivkinia*) *zvontsovi* sp. nov. The abundance of *Rhynchotrema* is somewhat unusual by comparison with faunas from other Kazakhstanian terranes, where rhynchonellides of the family Ancistrorhynchidae are usually dominant in near-shore biofacies. The occurrence of the atrypides *Sulcatospira* and early *Nalivkinia* demonstrates a clear biogeographical linkage with approximately contemporaneous faunas of South China.

Key words: Brachiopoda, Upper Ordovician, taxonomy, biogeography, Kazakhstan.

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Introduction

The Selety Basin in north Central Kazakhstan comprises an outcrop area of Middle and Upper Ordovician siliciclastic and volcaniclastic deposits to the north-east of the city of Astana (Fig. 1; formerly Akmolinsk), along the Selety river basin towards the northern Kazakhstan-Russia border. Farther to the north the Ordovician deposits are concealed below a Mesozoic–Cenozoic cover. The fossil localities described below are on the north-western sector of the Selety Basin, where the Ordovician succession crops out in the Selety river canyon and in the valleys of its western tributaries. A detailed outline of the Ordovician geology and stratigraphy of the Selety Basin was given by Nikitin (1972). The region forms the northern segment of the Selety-Shugaty structural subzone (IIIa) as defined by Nikitin et al. (1991: fig. 1; see also Apollonov 2000: fig. 1).

Rich brachiopod faunas of mid and late Ordovician age were sampled in northern Central Kazakhstan during phases of extensive geological mapping from 1947 to 1959. However, the collections were not analysed in detail for a long period, and most of the brachiopod taxa are recorded only from tentative identifications (Nikitin 1972). The late Ordovician was a critical period in the understanding of geological history in Kazakhstan, when amalgamation of the major Kazakhstanian crustal terranes had occurred. This study of brachiopod faunas adds significant information to our interpretation of the palaeogeographical position of these terranes in the late Ordovician, and helps in the recognition of affinities and migration routes of Ordovician benthic faunas.

Geological and geographical setting

The faunas analysed here are from the Tauken Formation, which corresponds with the upper Anderken and Dulankara regional stages, of late Caradoc to earliest Ashgill age (*Climacograptus clingani–Pleurograptus linearis* biozones equivalent). In the north-western region of the Selety Basin the Tauken Formation sits unconformably on strongly dislocated chert sequences of the Lower to Middle Ordovician Akdym Group (Figs. 1 and 2). Farther to the east, in the central part of the basin it conformably succeeds graded siliciclastic and volcaniclastic deposits of the Bestiube Formation, which contains graptolites of the *Diplograptus multidens* Biozone (Nikitin 1972; Tsai 1976).

In the central part of the Selety Basin the Tauken Formation comprises mostly graded siliciclastic deposits with several olistostrome horizons. This basinal sequence is replaced by shallow-water deposits along the north-western margin of the basin, where the Tauken Formation consists of alternating sandstones and siltstones with some interbeds of andesitic tuff. Up to three beds of argillaceous limestone with a maximum thickness of 50–60 metres are present in the lower part of the formation (Fig. 2), comprising a unit known as the Kaskol Beds. All brachiopods described and discussed here were sampled from five localities along the north-western margin within the *in situ* units of the lower Tauken Formation (upper Caradoc), unless noted otherwise.

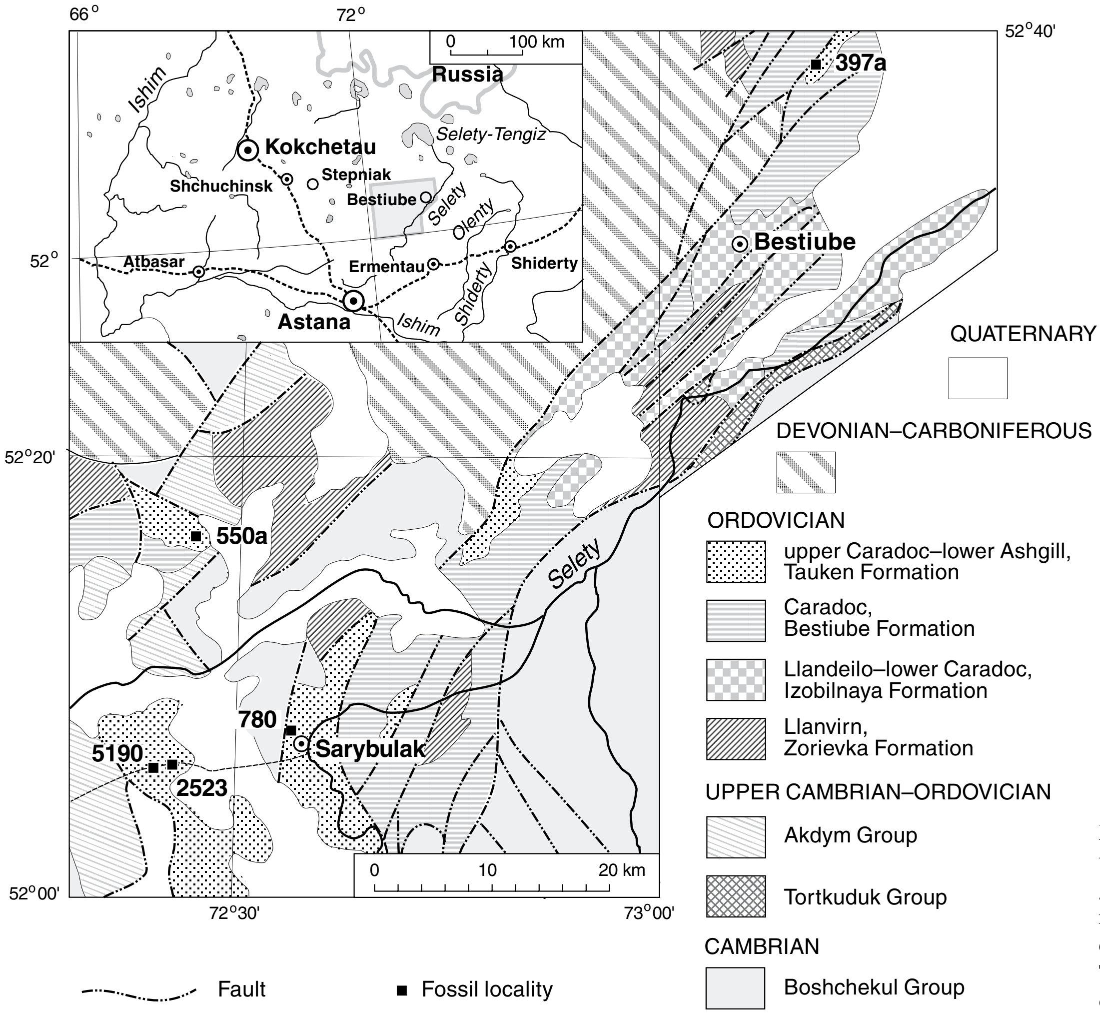


Fig 1. Outline map of north Central Kazakhstan and simplified geological map of the Selety river basin showing outcrop areas of the Upper Ordovician Tauken Formation and position of the brachiopod localities.

Locality 397a.—North of the town of Bestiube (Fig. 1; 73º11'44" E, 52º38'15" N). The brachiopods *Dinorthis taukensis* sp. nov. (7 ventral valves, 8 dorsal valves), *Rhynchotrema seletensis* sp. nov. (8 complete shells) and *Nalivkinia* (*Pronalivkinia*) *zvontsovi* sp. nov. (1 complete shell) were sampled by I.F. Nikitin in 1947 from a bed of calcareous volcanomict sandstone in a unit of alternating volcanomict sandstone, andesitic tuff and tuffite (Fig. 2).

Locality 550a.—East of Bolshoi Kaskol lake (Figs. 1, 2; 72º26'35" E, 52º16'33" N). Brachiopods occur in beds and lenses of bioclastic limestone (content of bioclasts on average 40–50%), within a 60 metre thick unit of argillaceous limestone (Fig. 2). Assemblages sampled by I.F. Nikitin in 1954 include *Dinorthis taukensis* sp. nov. (5 complete shells, 8 ventral valves, 5 dorsal valves), *Sowerbyella sinensis* Wang (>200 complete shells), *Skenidioides* sp. (6, 0, 0), *Triplesia* sp. (1, 0, 0), *Tetraphalerella bestiubensis* sp. nov. (1, 56, 55), *Glyptomena kaskolica* sp. nov. (1, 10, 7), *Rhynchotrema seletensis* sp. nov. (263, 11, 9), *Sulcatospira prima* Popov, Nikitin and Sokiran (1, 0, 1), and *Nalivkinia* (*Pronalivkinia*) *zvontsovi* sp. nov. (0, 4, 0). The tabulate corals *Khangalites koskolensis* (Kovalevsky) and *Rhabdotetradium cribriforme* (Ethridge) are also characteristic of the fauna.

Locality 780.—North-east of the village of Sarybulak, formerly Gogolevka (Figs. 1, 2; 72º34'04" E, 52º08'25" N). Brachiopods collected are *Dinorthis taukensis* sp. nov. (3, 7, 11), *Glyptomena kaskolica* sp. nov. (0, 3, 0), *Anoptambonites* sp. (1, 1, 0), *Rhynchotrema seletensis* sp. nov. (0, 1, 1), and *Nalivkinia* (*Pronalivkinia*) *zvontsovi* sp. nov. (0, 1, 2), all sampled by S.M. Bandaletov in 1948 from a calcarenite bed rich in fragments of echinoderms, bryozoans and brachiopods. Associated fossils include the trilobites *Stenopareia oviformis* (Warburg), *S. linnarssoni* (Holm), *Isotelus*? *aktchokensis* Weber, *Amphilichas* cf. *whalenbergi* Warburg, and *Eocosovopeltis romanovskyi* (Weber), all identified by the late M.K. Apollonov, together with the tabulate coral *Amsassia* sp.

Locality 2523.—This locality comprises a bed of argillaceous limestone exposed along the Shollakkarasu river (Figs. 1, 2; 72º25'53" E, 52º06'12" N), sampled by V.S. Zvontsov in 1954. Brachiopod assemblages include *Dinorthis taukensis* sp. nov. (180, 11, 19), *Mabella* sp. (2, 0, 0), *Sowerbyella sinensis* Wang (0, 1, 0), *Tetraphalerella bestiubensis* sp. nov. (5, 4, 1), *Glyptomena kaskolica* sp. nov. (0, 1, 1), *Rhynchotrema seletensis* sp. nov. (102, 0, 0), *Sulcatospira prima* Popov, Nikitin, and Sokiran (2, 0, 0), and *Nalivkinia* (*Pronalivkinia*) *zvontsovi* sp.

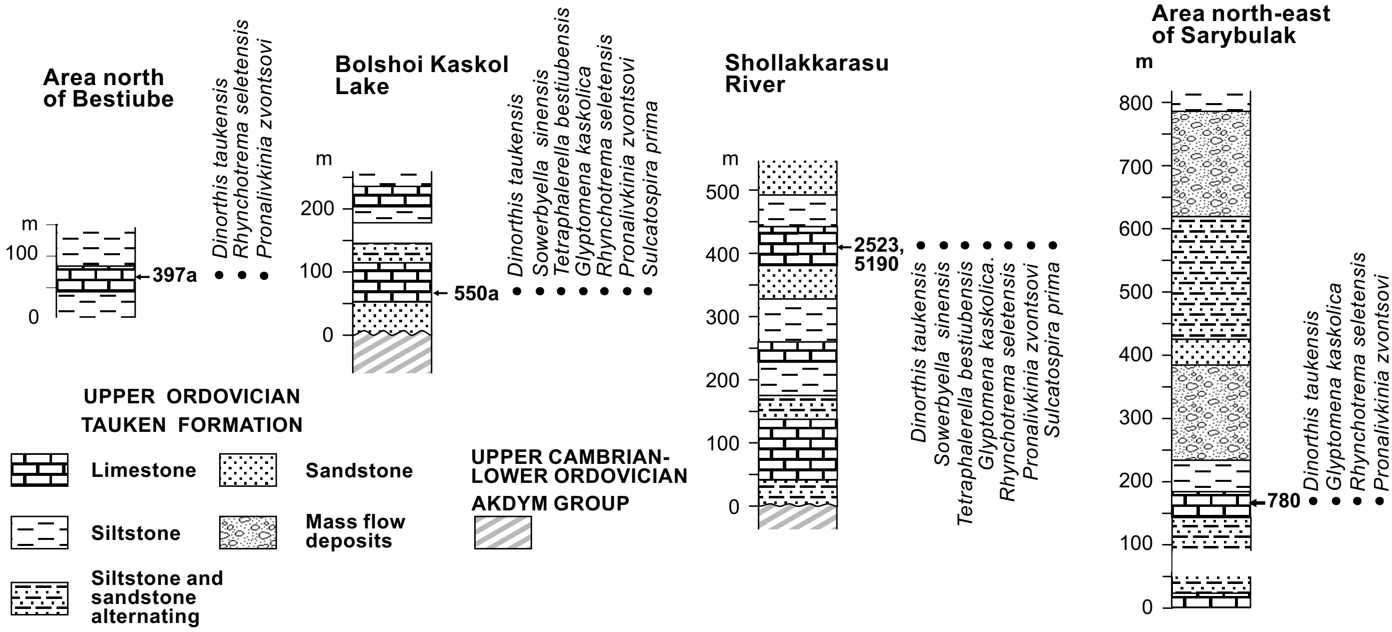


Fig. 2. Generalised successions in selected sections of the Tauken Formation showing stratigraphic position of the Kaskol beds and brachiopod samples.

nov. (198, 0, 0). Tabulate corals present are *Propora* sp. and *Steliporella zvontsovi* Kovalevsky.

Locality 5190.—On the Shollakkarasu river west of locality 2523 (Figs. 1, 2; 72º24'20" E, 52º06'25" N), in the same unnamed limestone unit. Brachiopods present are *Dinorthis taukensis* sp. nov. (75, 12, 19), *Rhynchotrema seletensis* sp. nov. (101, 0, 0), *Sulcatospira prima* Popov, Nikitin and Sokiran (0, 0, 1), and *Nalivkinia* (*Pronalivkinia*) *zvontsovi* sp. nov. (135, 0, 0), sampled by M.K. Apollonov in 1954. Associated trilobites include *Cheirurus kasachstanicus* Tschugaeva, *Birmanites* sp., *Eokosovopeltis* sp., and *Pliomerina unda* Koroleva.

Biogeographical affinities

Of the eleven brachiopod species described here from the Tauken Formation, five are new and are apparently endemic to the region. They are mostly from skeletal limestone beds with a high content of fine clastics within a predominantly siliciclastic sequence. This fauna differs markedly from contemporaneous assemblages characteristic of the carbonate mud-mound assemblages that are widespread in Kazakhstan in late Caradoc–early Ashgill deposits, both in taxonomic composition and diversity (Nikitin and Popov 1986; Nikitin et al. 1996). In particular, brachiopods from carbonate units of the Tauken Formation lack the archaic athyridides *Kellerella* and *Nikolaispira*, and distinctive strophomenide genera such as *Bandaleta*, *Sortanella*, *Bellimurina*, and *Limbimurina*, whereas *Strophomena, Tetraphalerella, Glyptomena*, *Pronalivkinia*, and *Dinorthis* disappear completely in the diverse assemblages of the carbonate mud-mounds but are characteristic of the biofacies of the shallow clastic shelves.

General aspects of the biogeography of late Ordovician brachiopod faunas of Central and South-East Asia have been discussed in a number of recent publications (e.g., Jin 1996; Nikitin et al. 1996; Xu 1996; Popov et al. 1997; Cocks and Zhan 1998; Zhan and Cocks 1998), so there is no reason to repeat these discussions here. Therefore we concentrate instead on comments that identify some distinctive characters of the Kazakhstanian fauna. Notwithstanding the similar generic composition, the Tauken assemblage has some distinctive individual features, that distinguish it from some other approximately contemporaneous late Ordovician (late Caradoc to early Ashgill) faunas characteristic of shallow clastic shelves in the Chu-Ili Range (Rukavishnikova 1956; Popov et al. 2000), the Dzhebagly Mountains (Misius 1986), and the Chingiz Range (Klenina 1984). The occurrence of *Rhynchotrema* in the Tauken faunas is somewhat unusual, because in other parts of Kazakhstan, Caradoc and early Ashgill rhynchonellides are represented mostly by the ancistrorhynchids *Ancistrorhyncha*, *Altaethyrella* and *Dorytreta* (Nikitin and Popov 1984; Popov et al. 2000). The abundance of *Dinorthis* and *Pronalivkinia* at localities1523 and 5190 makes them comparable with the *Dinorthis* association of Popov et al. (2000) from the Otar beds in the lower Dulankara Formation of the Chu-Ili Range, but there are no common species with the exception of *Sulcatospira prima*. The assemblage from locality 550a is somewhat different in its abundance of the strophomenides *Sowerbyella sinensis*, *Tetraphalerella bestiubensis*, and *Glyptomena kaskolica*, whereas *Dinorthis* and *Pronalivkinia* together represent only about 3% of the total number of individuals in the assemblage.

There is also a close similarity with mid Ashgill faunas of South China and, in particular, with brachiopod assemblages of the Shiyanhe Formation in the Qingling region, emphasised by the co-occurrence of *Sowerbyella sinensis*, *Dinorthis,* and *Pronalivkinia*.

More precise assessment of the biogeographical relationships of Kazakhstanian terranes in the Ordovician requires detailed analysis of further, as yet undescribed faunas that we are studying. Currently conflicting tectonic reconstructions of the terrane collage of Central Asia further compound the interpretation of biogeographical linkages (cf. Şengör et al. 1993 and Holmer et al. 2001: fig. 19C), which again can only be resolved via the study of further faunas.

Systematic palaeontology

All figured specimens are deposited in the National Museum of Wales, Cardiff (NMW), together with a small sample of non-figured material. The remainder of the collections forming the basis for Tables 1–12, including paratype material, is in the Institute of Geological Sciences, Almaty. Abbreviations in tables of measurements and in the text are: Lv, Ld, maximum sagittal ventral and dorsal valve length; W, maximum width; T, maximum shell thickness; Ml, Mw, length and width of the muscle field; Sw, St, width and height of tongue in the ventral valve; LPl, length of lophophore platform; X, mean; S, standard deviation from the mean; MIN, minimum value; MAX, maximum value; N, number of measured or counted specimens. Morphological terminology and taxonomic classification follow Williams et al. (1997, 2000) in the revised volumes of the *Treatise on Invertebrate Paleontology.*

Order Strophomenida Öpik, 1934
Superfamily Strophomenoidea King, 1846
Family Strophomenidae King, 1846
Subfamily Strophomeninae King, 1846
Genus *Tetraphalerella* Wang, 1949
Tetraphalerella bestiubensis sp. nov.

Figs. 3A–H, 4A, B; Tables 1, 2.

Derivation of name: After the town of Bestiube near the type locality.

Holotype: NMW 98.30G.5, dorsal internal mould.

Type locality: Sample 550a, Bolshoi Kaskol lake, Selety river basin, Kazakhstan.

Type horizon: Ordovician, Tauken Formation.

Table 1. Dimensions of ventral valves of *Tetraphalerella bestiubensis* sp. nov. (sample 550a).

	Lv	W	Ml	Mw	L/W	Ml/Lv	Ml/Mw
N	56	56	8	8	56	8	8
X	9.9	13.0	3.9	3.9	77.3%	40.7%	101.8%
S	2.39	3.17	0.89	0.88	12.1	8.6	7.2
MIN	3.6	5.5	2.5	2.6	56.7%	33.0%	92.1%
MAX	16.2	18.0	5.5	5.3	118.9%	58.5%	111.8%

Table 2. Dimensions of dorsal valves of *Tetraphalerella bestiubensis* sp. nov. (sample 550a).

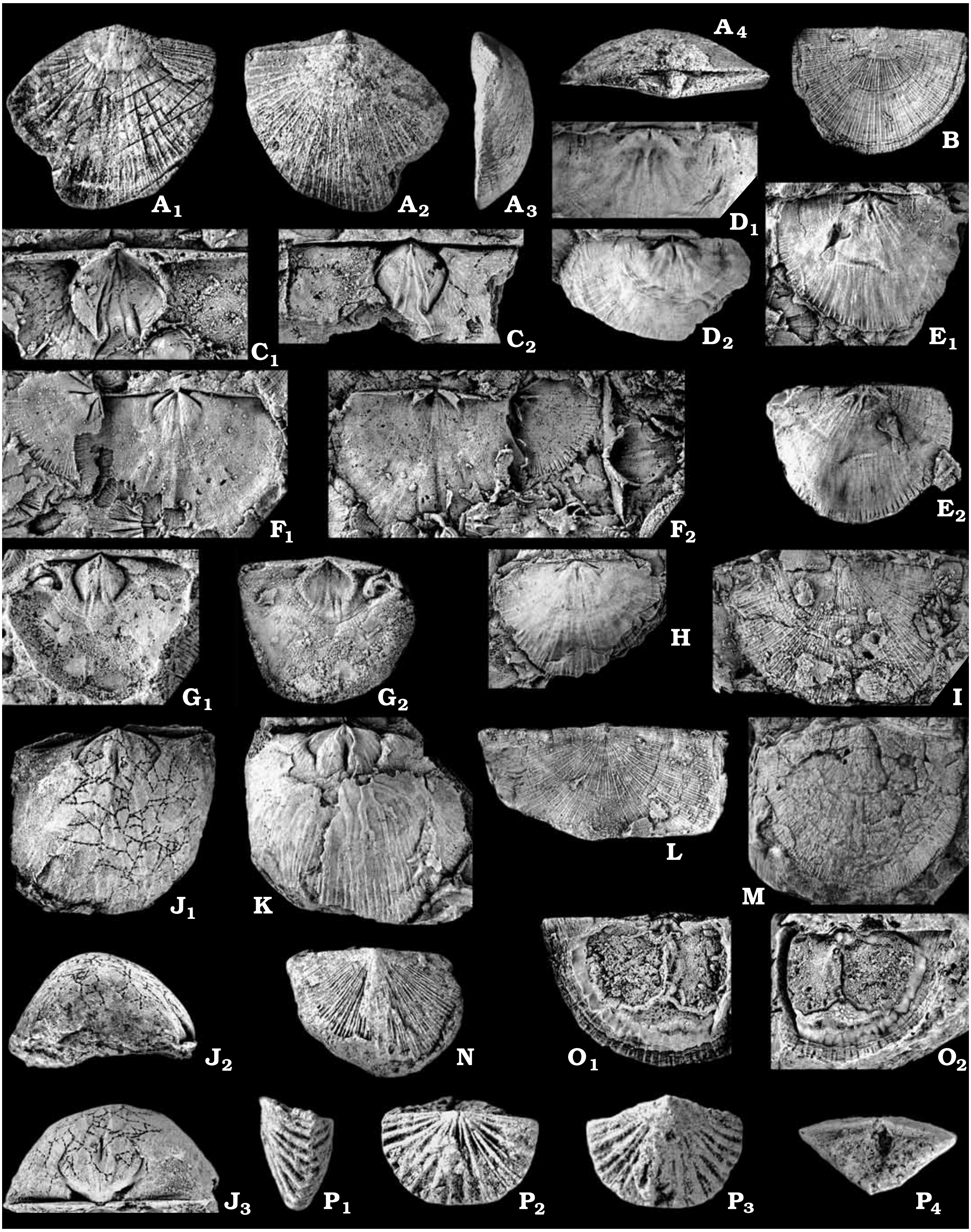
	Ld	W	T	Ld/W	T/Ld
N	26	26	26	26	26
X	9.7	13.3	2.0	73.8%	20.7%
S	2.44	3.45	0.98	9.5	8.3
MIN	6.0	8.4	0.5	55.7%	5.3%
MAX	14.2	20.2	4.0	103.3%	42.7%

Paratypes.—Six conjoined valves, 60 ventral and 56 dorsal valves.

Diagnosis.—Convexiconcave to convexiplane, transverse, suboval shell about 75% as long as wide with flattened lateral ventral profile; dorsal valve moderately and evenly convex, about 20% as high as long with very weak umbonal sulcus fading anteriorly; radial ornament unequally parvicostellate with 13–15 ribs per 3 mm along the anterior margin of mature specimens and with up to 5 parvicostellae in interspaces between accentuated ribs.

Description.—Shell slightly convexiconcave to convexiplane, transverse, suboval in outline with maximum width at the hinge line. Cardinal extremities slightly acute to right angled. Anterior commissure rectimarginate. Ventral valve flattened with lateral profile slightly convex in the umbonal area, very gently and evenly concave anteriorly. Ventral interarea plane, apsacline with broad, convex pseudodeltidium perforated apically by a minute, rounded foramen. Dorsal valve moderately and evenly convex in lateral profile. Dorsal interarea apsacline with a convex chilidium. Dorsal umbonal area with a very shallow, weakly defined sulcus in some specimens. Radial ornament unequally parvicostellate with accentuated costellae of three or four generations originating in the umbonal area, at about mid-valve length, and near the anterior and lateral margins in adult specimens. Number of costellae varying from 13 to 15 per 3 mm along the anterior margin of mature specimens.

Fig. 3. **A–H**. *Tetraphalerella bestiubensis* sp. nov.; sample 550a. **A**. NMW 98.30G.1, conjoined valves in ventral (A_1), dorsal (A_2), lateral (A_3), and posterior (A_4) views, × 2.25. **B**. NMW 98.30G.2, ventral valve exterior, latex cast, × 2.25. **C**. NMW 98.30G.3, ventral valve interior latex cast, × 3 (C_1), and internal mould, × 2.25 (C_2). **D**. NMW 98.30G.4, latex cast of dorsal valve interior showing cardinal process and socket ridges, × 3.6 (D_1), internal mould, × 2.8 (D_2). **E**. NMW 98.30G.5, holotype, dorsal internal mould (E_1) and latex cast of dorsal interior (E_2) showing cardinal process and socket ridges, × 2.25. **F**. NMW 98.30G.7, ventral internal mould (F_1) and latex cast of interior (F_2), × 2.25. **G**. NMW 98.30G.6, ventral valve internal mould (G_1) and latex cast (G_2), × 2.25. **H**. NMW 98.30G.8, dorsal internal mould, × 2.25. **I–M**. *Glyptomena kaskolica* sp. nov.; sample 550a. **I**. NMW 98.30G.11, latex cast of ventral exterior, × 2.25. **J**. NMW 98.30G.12, holotype, ventral (J_1), lateral (J_2), and posterior (J_3) views of ventral internal mould, × 1.6. **K**. NMW 98.30G.15, ventral internal mould, × 1.5. **L**. NMW 98.30G.14, latex cast of dorsal exterior, × 1.6. **M**. NMW 98.30G.13, ventral valve exterior, × 1. **N, O**. *Anoptambonites* sp.; sample 550a. **N**. NMW 98.30G.18, ventral valve exterior, × 2. **O**. NMW 98.30G.17, latex cast of dorsal interior (O_1) and dorsal internal mould (O_2), × 1.8. **P**. *Skenidioides* sp.; sample 550a; NMW 98.30G.28, lateral (P_1), dorsal (P_2), ventral (P_3), and posterior (P_4) views of conjoined valves, × 5.8. ➛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Ventral valve interior with strong oblique teeth; short, widely diverging dental plates continue anteriorly into ridge-like extensions that laterally bound a large, rounded sub-pentagonal muscle field about 40% as long as the valve. Ventral adductor muscle scars narrow, strongly elongated, sub-oval, occupying the median part of the muscle field, somewhat shorter than large, rounded, subtriangular diductor scars. Dorsal interior with small, bilobed cardinal process; a low ridge bisects the area between the lobes. Socket ridges widely divergent, slightly recurved towards the hinge line. A low, broad median ridge divides the entire dorsal adductor muscle field.

Discussion.—This is the first record of *Tetraphalerella* in Kazakhstan. It resembles *Tetraphalerella cooperi* Wang (1949: 29, pl. 8: 1–6) from the Maquoketa Shale (Ashgill) of Iowa in its semioval shell outline and lateral profile of both valves, but it is distinguished in having shells that are about half the size of the American species, a flattened ventral valve, and an evenly convex dorsal valve which is not flattened in the umbonal area. The radial ornament in *T. bestiubensis* is characterized by the presence of 2 to 5 finer ribs in the wide interspaces between accentuated costellae, whereas in *T. cooperi* these interspaces contain usually not more then 1 to 2 finer ribs.

Among Kazakhstanian strophomenids *T. bestiubensis* can be compared only with *Strophomena dzhumgalica* Misius (1988: 160, pl.18: 1–18, pl.19: 1–6) from the Tabylgaty Formation (upper Caradoc) of North Kyrgyzstan, but differs in having a much smaller average shell size, a strongly convex dorsal lateral profile, more clearly differentiated radial ornament, and in the absence of dorsal side ridges and a sub-peripheral rim in the ventral valve.

Occurrence.—Localities 550a and 2523.

Family Glyptomenidae Cooper, 1956
Subfamily Glyptomeninae Cooper, 1956
Genus *Glyptomena* Cooper, 1956
Glyptomena kaskolica sp. nov.

Figs. 3I–M, 5H; Tables 3, 4.

Derivation of name: After lake Kaskol near the type locality.

Holotype: NMW 98.30G.12, ventral internal mould.

Type locality: Sample 550a, Bolshoi Kaskol lake, Selety river basin, Kazakhstan.

Type horizon: Ordovician, Tauken Formation.

Paratypes.—17 ventral and 11 dorsal valves.

Table 3. Dimensions of ventral valves of *Glyptomena kaskolica* sp. nov. (sample 550a).

	Lv	W	T	Lv/W	T/Lv
N	10	10	10	10	10
X	22.8	27.1	9.3	86.9%	41.0%
S	2.70	5.11	1.97	18.9	8.1
MIN	19.1	18.0	7.5	72.7%	29.3%
MAX	27.3	34.0	13.0	133.3%	51.4%

Table 4. Dimensions of dorsal valves of *Glyptomena kaskolica* sp. nov. (sample 550a).

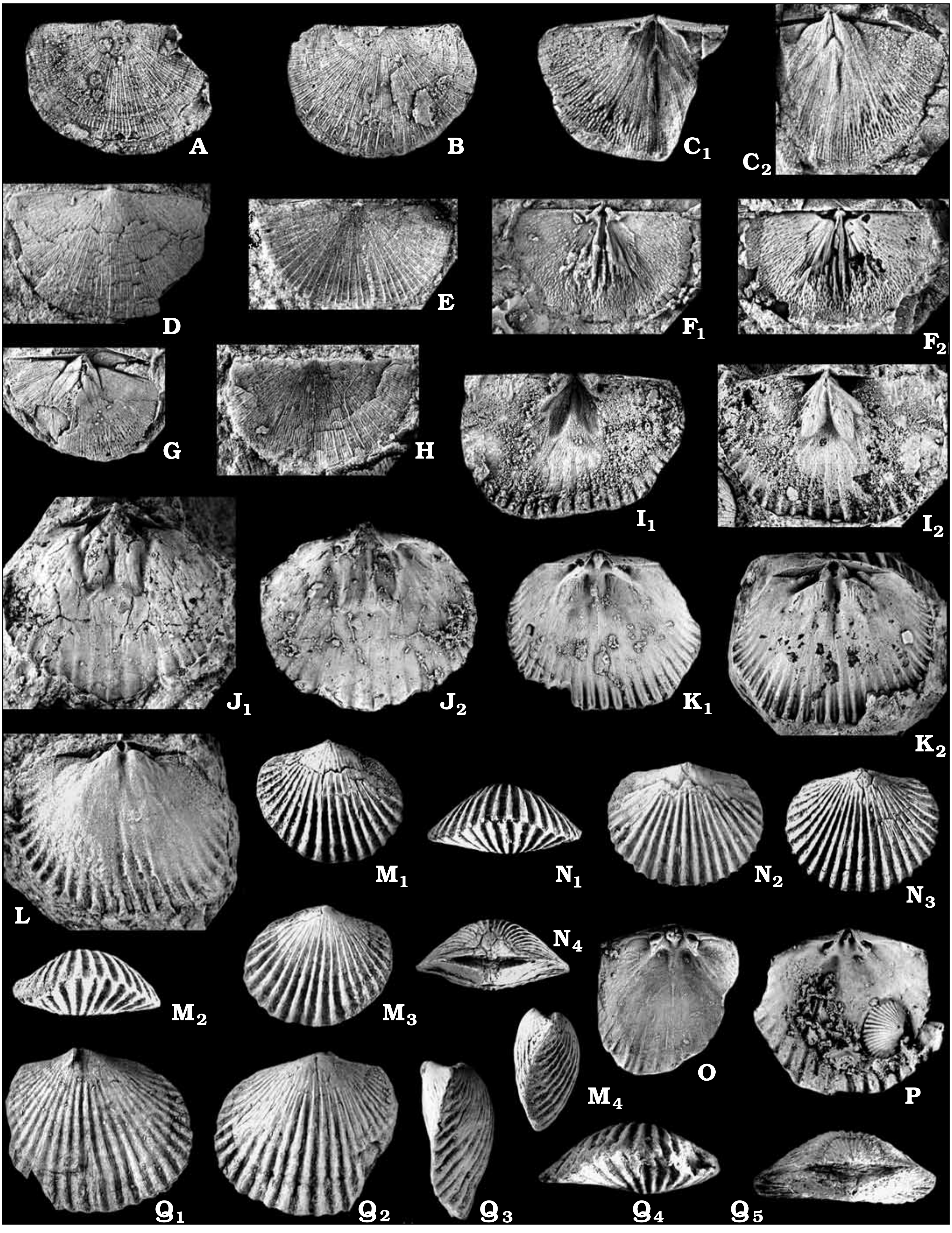
	Lv	W	Lv/W
N	4	4	4
X	15.5	23.0	67.3%
S	3.11	2.45	10.2
MIN	13.0	20.0	56.5%
MAX	20.0	26.0	76.9%

Diagnosis.—Shell strongly concavoconvex, about 85% as long as wide; ventral valve strongly and evenly convex, about 40% as thick as long with low apsacline interarea; dorsal valve evenly concave, rarely slightly geniculated in large specimens; radial ornament inequally parvicostellate with 3 to 4 parvicostellae between accentuated ribs and 10 to 12 ribs per 3 mm along the anterior margin of adult specimens; weak, oblique rugellae developed along the posterior margin.

Description.—Shell strongly concavoconvex, transversely semioval in outline with maximum width along the hinge line. Cardinal extremities slightly alate, acute to right angled. Ventral valve strongly and evenly convex in lateral profile. Interarea low triangular, plane, apsacline with a broad, triangular delthyrium which has an apical convex pseudodeltidium. Dorsal valve evenly concave in lateral profile, or slightly geniculated anteriorly. Dorsal interarea linear, plane, anacline. Notothyrium broad, triangular, with discrete lateral chilidial plates. Radial ornament finely and unequally parvicostellate with accentuated ribs separated by 3 to 4 finer parvicostellae and with 5 to 6 ribs per 1 mm along the anterior margin of adult specimens about 15 mm long. Fine, evenly spaced concentric fila cross the costellae. Weak, obliquely concentric rugellae are developed along the posterior margin.

Ventral interior with strong, obliquely directed teeth bearing 5 to 6 crenulations on the postero-dorsal surface (see also

Fig. 4. **A**, **B**. *Tetraphalerella bestiubensis* sp. nov.; sample 550a. **A**. NMW 98.30G.8, latex cast of ventral exterior. **B**. NMW 98.30G.23, latex cast of dorsal exterior; both × 2.25. **C**–**H**. *Sowerbyella sinensis* Wang, sample 550a; **C**. NMW 98.30G.21, latex cast of ventral internal mould (C_1) and internal mould (C_2), × 3. **D**. NMW 98.30G.22, ventral valve exterior, × 3. **E**. NMW 98.30G.20, dorsal valve exterior, × 3. **F**. NMW 98.30G.24, latex cast of dorsal interior (F_1) and dorsal internal mould (F_2), × 3. **G**. NMW 98.30G.19, ventral internal mould, × 3. **H**. NMW 98.30G.23, dorsal valve exterior, × 3. **I**–**Q**. *Dinorthis taukensis* sp. nov. **I**. NMW 98.30G.29, sample 2523; latex cast of ventral interior (I_1) and ventral internal mould (I_2), × 2.5. **J**. NMW 98.30G.30, sample 5190; ventral internal mould (J_1) and latex cast (J_2), × 2. **K**. NMW 98.30G.32, sample 2523; latex cast of dorsal interior (K_1) and dorsal internal mould (K_2), × 2.25. **L**. NMW 98.30G.33, sample 2523; dorsal internal mould, × 2. **M**. NMW 98.30G.38, sample 2523; ventral (M_1), anterior (M_2), dorsal (M_3), and lateral (M_4) views of conjoined valves, × 2.25. **N**. NMW 98.30G.31, sample 2523; anterior (N_1), dorsal (N_2), ventral (N_3), and posterior (N_4) views of conjoined valves, × 2.25. **O**. NMW 98.30G.34, sample 2523; latex cast of dorsal interior, × 2.25. **P**. NMW 98.30G.35, sample 5190; latex cast of dorsal interior, × 2.25. **Q**. NMW 98.30G.36, sample 5190; ventral (Q_1), dorsal (Q_2), lateral (Q_3), anterior (Q_4), and posterior (Q_5) views of conjoined valves, × 2.25. →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Rong and Cocks 1994: fig. 8). Dental plates short, divergent, strongly thickened, with ridge-like extensions laterally bounding a subcircular muscle field, about 25% as long as the valve. Adductor scars linear, slightly raised, separating large subcircular diductor scars. Mantle canals with thin, divergent *vascula media*. Dorsal interior observed only in a single poorly preserved specimen. It has a double cardinal process and straight, widely divergent socket plates.

Discussion.—*Glyptomena kaskolica* differs from the type species *Glyptomena sculpturata* Cooper, 1956 from the Chatham Hill Formation (Caradoc) of Virginia in having a strongly convex ventral lateral profile with the maximum thickness at mid-valve length, and in the weakly developed to absent geniculation of the dorsal valve. The number of fine intercostal parvicostellae in the Kazakhstanian species does not exceed 4, whilst in the type species the interspaces between accentuated ribs are somewhat wider and include up to 7 parvicostellae. In convexity and lateral shell profile *G. koskolica* resembles *Glyptomena parvula* Cooper, 1956, from the Effna and Rich Valley formations (Caradoc) of Virginia, but differs in its pattern of more closely spaced accentuated costellae, the relatively small ventral muscle field which occupies no more than one quarter of the maximum valve length, and in having oblique concentric rugellae along the cardinal margin.

This new species also somewhat resembles *Glyptomena subcraignsis* Severgina (in Kulkov and Severgina, 1989: figs. p.132, pl. 17: 6–10), but differs in having a larger shell of semioval outline with maximum width at the hinge line, maximum height at about mid-length, slightly alate ventral cardinal extremities and weakly developed to absent geniculation in the dorsal valve, which occurs rarely and only in gerontic specimens, plus finer radial ornament with weak oblique rugellae along the hinge line.

Occurrence.—Localities 550a, 780 and 2523.

Superfamily Plectambonitoidea Jones, 1928
Family Leptellinidae Ulrich and Cooper, 1936
Genus *Mabella* Klenina, 1984
Mabella? sp.

(not figured)

Material.—Two ventral valves.

Remarks.—These specimens are characterised by a strongly and evenly convex ventral valve with a transversely, semioval outline, maximum width at the hinge line, a rectimarginate anterior commissure, and very finely parvicostellate radial ornament. The ventral and dorsal interiors are unknown. Both specimens closely resemble the type species *Mabella semiovalis* (Klenina 1984: 69) from the Taldyboi Formation (upper Caradoc to lower Ashgill; Chingiz Range, Kazakhstan) in their external shell shape and radial ornament, but there is insufficient detail to make further definitive comparisons.

Occurrence.—Locality 2523.

Family Hesperonomiidae Cooper, 1956
Genus *Anoptambonites* Williams, 1962
Anoptambonites sp.

Fig. 3N, O.

Material.—One complete specimen and one ventral valve.

Measurements.—NMW 98.30G.17, conjoined valves, Ld: 15.8, LPl: 10.8; NMW 98.30G.18, ventral valve, Lv: 12.2, W: 16.4, T: 4.9.

Remarks.—These specimens are comparable with *Anoptambonites orientalis* Popov, 1980 from the Anderken Formation (Caradoc) of the Chu-Ili Range in having equally parvicostellate radial ornament, an open delthyrium and an undercut, striated cardinal process, but differ in having an only slightly carinate ventral valve and an uneven lateral profile with its highest point at about one quarter of the shell length from the anterior margin. The equally parvicostellate radial ornament, unevenly convex ventral lateral profile and open delthyrium in the Tauken Formation specimens also distinguish them from *Anoptambonites kovalevskii* Popov, Nikitin, and Cocks, 2000 from the Dulankara Formation (upper Caradoc) of the Chu-Ili Range in Kazakhstan.

Occurrence.—Locality 780.

Family Sowerbyellidae Öpik, 1930
Subfamily Sowerbyellinae Öpik, 1930
Genus *Sowerbyella* Jones, 1928
Sowerbyella sinensis Wang in Wang and Jin, 1964

Fig. 4C–H; Tables 5, 6.

Sowerbyella sinensis Wang in Wang and Jin, 1964: 46, pl. 13: 9–11.
Sowerbyella (*Sowerbyella*) *sinensis* Wang; Xu 1996: 554, pl. 2: 5–13, pl. 4: 8.
Sowerbyella (*Sowerbyella*) *sinensis* Wang; Zhan and Cocks 1998: 40, pl. 5: 8–13.

Material.—More then 200 dorsal and ventral valves.

Description.—Shell concavoconvex, outline semioval, about 65% as long as wide and about 145% as thick as long. Cardinal extremities slightly acute to near right angled. Anterior margin broadly and evenly rounded, commissure rectimarginate. Ventral valve moderately and evenly convex in lateral profile, slightly carinate posteriorly in some specimens. Ventral interarea low, apsacline with a convex, apical pseudodeltidium. Dorsal valve gently and evenly concave, about 60% as long as wide. Dorsal interarea linear, anacline with discrete chilidial plates united apically. Radial ornament finely and unequally parvicostellate, with accentuated costellae of three generations separated by 2 to 3 parvicostellae in the interspaces and with up to 14 to 16 costellae per 3 mm at the anterior margin of mature specimens.

Ventral valve interior with teeth supported by short, low dental plates extending basally into divergent muscle-bounding ridges flanking a flabellate muscle field. Diductor scars large, rhomboidal, divided posteriorly by small, lanceolate adductor scars which are bisected by a short median ridge. Mantle canals lemniscate with straight, divergent *vas-*

Table 5. Dimensions of ventral valves of *Sowerbyella sinensis* Wang (sample 550a).

	Lv	W	T	Ml	Mw	Sl	Lv/W	T/Lv	Ml/Lv	Ml/Mw
N	52	51	50	7	7	7	51	50	7	7
X	5.2	8.3	0.7	1.6	2.6	0.8	63.9%	13.6%	28.6%	59.5%
S	1.20	1.97	0.29	0.66	0.88	0.24	9.3	4.9	9.0	10.6
MIN	3.0	4.0	0.2	1.0	1.8	0.5	47.4%	6.0%	15.9%	41.2%
MAX	8.2	14.0	1.8	3.0	4.2	1.1	93.2%	31.0%	42.9%	71.4%

Table 6. Dimensions of dorsal valves of *Sowerbyella sinensis* Wang (sample 550a).

	Ld	W	Ld/W
N	51	51	51
X	5.1	8.4	61.4%
S	1.08	1.96	7.5
MIN	3.3	5.5	47.6%
MAX	7.5	14.0	80.0%

cula media. Dorsal interior with a trifid, undercut cardinal process, which is ankylosed to low, short socket plates. Bema low, subcircular, distinguished only in adult specimens, about 60 to 70% as long and 40% as wide as the valve. Inner side septa prominent, forming the inner edges of the bema in adult specimens. A short median septum and a second pair of widely divergent outer side septa are developed in some adult shells, but are not characteristic of most specimens.

Discussion.—We follow Zhan and Cocks (1998) in our interpretation of this species, described originally from the Ashgill of South China (see also Xu 1996). Our specimens differ only very slightly in their somewhat smaller size, and the poorly defined bema which is developed with certainty only in gerontic specimens.

Another similar species is *Sowerbyella insueta* Klenina (1984: 84, pl. 8: 8–10) from the Taldyboi Formation (upper Caradoc) of the Chingiz Range, east Central Kazakhstan, but our specimens of *S. sinensis* can be distinguished easily by their evenly convex ventral lateral profile, more closely spaced accentuated costellae, and in the absence of oblique rugellae along the cardinal margin.

Occurrence.—Localities 550a and 1523.

Order Orthotetida Waagen, 1884
Suborder Triplesiidina Moore, 1952
Superfamily Triplesioidea Schuchert, 1913
Family Triplesiidae Schuchert, 1913
Genus *Triplesia* Hall, 1859
Triplesia? sp.

(not figured)

Material.—One steinkern.

Remarks.—This unnamed species is present in the collection as a single juvenile specimen, characterised by a slightly dorsibiconvex, subcircular shell with a slightly uniplicate anterior commissure. A forked cardinal process on a short shaft is recognisable in the dorsal valve.

Occurrence.—Locality 550a.

Order Protorthida Schuchert and Cooper, 1931
Superfamily Protorthoidea Schuchert and Cooper, 1931
Family Skenidiidae Kozłowski, 1929
Genus *Skenidioides* Schuchert and Cooper, 1931
Skenidioides sp.

Fig. 3P.

Material.—Six conjoined valves.

Description.—Shell ventribiconvex, transverse, semioval in outline with maximum width at the hinge line. Cardinal extremities acute. Anterior margin rounded, commissure weakly sulcate. Ventral valve subpyramidal with maximum height at the umbo. Ventral interarea high, triangular, anacline to near catacline with a narrow, triangular, open delthyrium. Dorsal valve gently convex in lateral profile with a shallow, narrow sulcus originating at the umbo. Radial ornament coarsely costate with 12 to 13 rounded ribs. Interior of both valves unknown.

Measurements.—NMW 98.30G.28, complete shell, Lv: 3.8, Ld: 3.4, W: 5.5, T: 2.9.

Remarks.—This unnamed species is somewhat similar to *Skenidioides paucicostatus* Wright (1964: 212, pl. 7: 14–20, 22, 25, 27) from the mid Ashgill Portrane Limestone, of eastern Ireland, in having a coarsely ribbed ornament, but differs in its somewhat less transverse shell outline, acute but not alate cardinal extremities, and in the absence of a ventral median fold.

Occurrence.—Locality 550a.

Order Orthida Schuchert and Cooper, 1932
Superfamily Orthoidea Woodward, 1852
Family Plaesiomyidae Schuchert, 1913
Genus *Dinorthis* Hall and Clarke, 1892
Dinorthis taukensis sp. nov.

Figs. 4I–Q, 5G; Tables 7, 8.

Derivation name: After the Tauken Mountains near the type locality.

Table 7. Dimensions of complete shells of *Dinorthis taukensis* sp. nov. (sample 2523).

	Lv	Ld	W	T	Iw	Lv/W	Ld/W	T/Lv	Iw/W
N	65	65	65	65	65	65	65	65	65
X	11.6	11.6	14.4	6.5	9.9	80.9%	80.8%	55.5%	69.1%
S	2.16	2.18	2.47	1.66	2.35	7.2	7.8	8.1	10.4
MIN	6.2	6.0	7.8	2.8	6.0	61.5%	62.9%	35.4%	42.0%
MAX	17.0	17.3	20.1	10.5	16.0	96.5%	100.0%	77.0%	94.3%

Table 8. Dimensions of complete shells of *Dinorthis taukensis* sp. nov. (sample 5190).

	Lv	Ld	W	T	Iw	Lv/W	Ld/W	T/Lv	Iw/W
N	52	52	52	52	52	52	52	52	52
X	11.6	11.6	14.6	6.7	10.0	79.8%	79.3%	57.1%	68.5%
S	2.20	2.18	2.45	1.62	2.46	5.7	5.5	6.7	9.1
MIN	6.5	6.5	8.3	3.2	6.0	65.7%	65.7%	44.4%	49.2%
MAX	15.6	15.4	18.6	10.5	17.0	91.3%	89.4%	72.9%	92.4%

Holotype: NMW 98.30G.37, complete shell.

Type locality: Sample 2523, Shollakkarasu river, Selety river basin, Kazakhstan.

Type horizon: Ordovician, Tauken Formation.

Paratypes.—265 complete shells, 42 ventral and 63 dorsal valves.

Diagnosis.—Dorsibiconvex, about 80% as long as wide and 55% as high as long; evenly convex dorsal lateral profile with a shallow ventral sulcus originating near mid-length; radial ornament costellate with 20 to 30 rounded ribs.

Description.—Shell dorsibiconvex in mature specimens, transversely suboval in outline with maximum width at the mid-length. Cardinal extremities rounded. Anterior commissure broadly uniplicate. Ventral valve moderately convex with maximum height slightly anterior to the umbo at or about a mid-point between the umbo and mid-valve. Interarea subtriangular, apsacline, weakly concave. Delthyrium open, triangular. Beak pointed and slightly erect posteriorly. Sulcus broad and shallow, originating somewhat posterior to mid-valve. Dorsal valve about 80% as long as wide, moderately convex in lateral profile with maximum thickness at about mid-length. Dorsal interarea low, planar, anacline. An indistinct dorsal median fold occurs near the anterior margin in some specimens. Radial ornament costate with 20 to 30 rounded ribs separated by interspaces of about equal width. Concentric ornament of fine, evenly spaced and slightly elevated growth lines.

Ventral interior with strong teeth and short divergent dental plates. Muscle field large, slightly elongated, rounded subpentagonal in outline, about 45% as long as the valve. Large diductor scars completely surround small elongate adductor scar in the posterior half of the ventral muscle field. A low median ridge bisects the ventral muscle field longitudinally anterior to the diductor scars. Mantle canals saccate with short, straight, slightly divergent *vascula media*. Dorsal interior with ridge-like cardinal process crenulated posteriorly. Brachiophores blade-like with widely divergent bases. Adductor scars weakly impressed, bisected longitudinally by a low median ridge.

Variability.—There is fairly considerable variation in the relative convexity and transverse profile of both valves in the available samples. Dorsibiconvex shells are predominant, but subequally biconvex and slightly ventribiconvex shells comprise about 20% of specimens in sample 2523 and up to 30% in sample 5190. Shells with 22 to 26 ribs are the most abundant and represent 83% of the total number of specimens in both samples.

Discussion.—This species is similar to *Dinorthis ortonurensis* Misius (in Andreeva and Misius 1977: 106, pl. 25: 12–16; Misius 1986) from the Ichkebash Formation (upper Caradoc) of North Kyrgyzstan and to *Dinorthis kassini* Rukavishnikova (1956: 126, pl. 1: 12–16) from the Dulankara Formation (upper Caradoc) of the southern Chu-Ili Range, but differs from both these species in having a less convex dorsal lateral profile and in the absence of an umbonal dorsal sulcus. *D. taukensis* sp. nov. is about twice as small and has not more than 30 ribs by comparison with the 40 to 48 ribs in the Kyrgyzstanian species.

D. taukensis is also somewhat comparable with *Dinorthis westfieldensis* Laurie (1991: 34, fig. 30A) from the Benjamin Limestone (upper Caradoc) of Tasmania in its general shape and radial ornament, but differs in having an evenly convex dorsal lateral profile and a shallow, but well-defined sulcus in the anterior half of the ventral valve.

Occurrence.—Localities 397a, 550a, 780, 2523, 5190.

Order Rhynchonellida Kuhn, 1949
Superfamily Rhynchonelloidea Gray, 1848
Family Rhynchotrematidae Schuchert, 1913
Subfamily Rhynchotrematinae Schuchert, 1913
Genus *Rhynchotrema* Hall, 1860
Rhynchotrema seletensis sp. nov.

Figs. 5A–F, 6; Table 9.

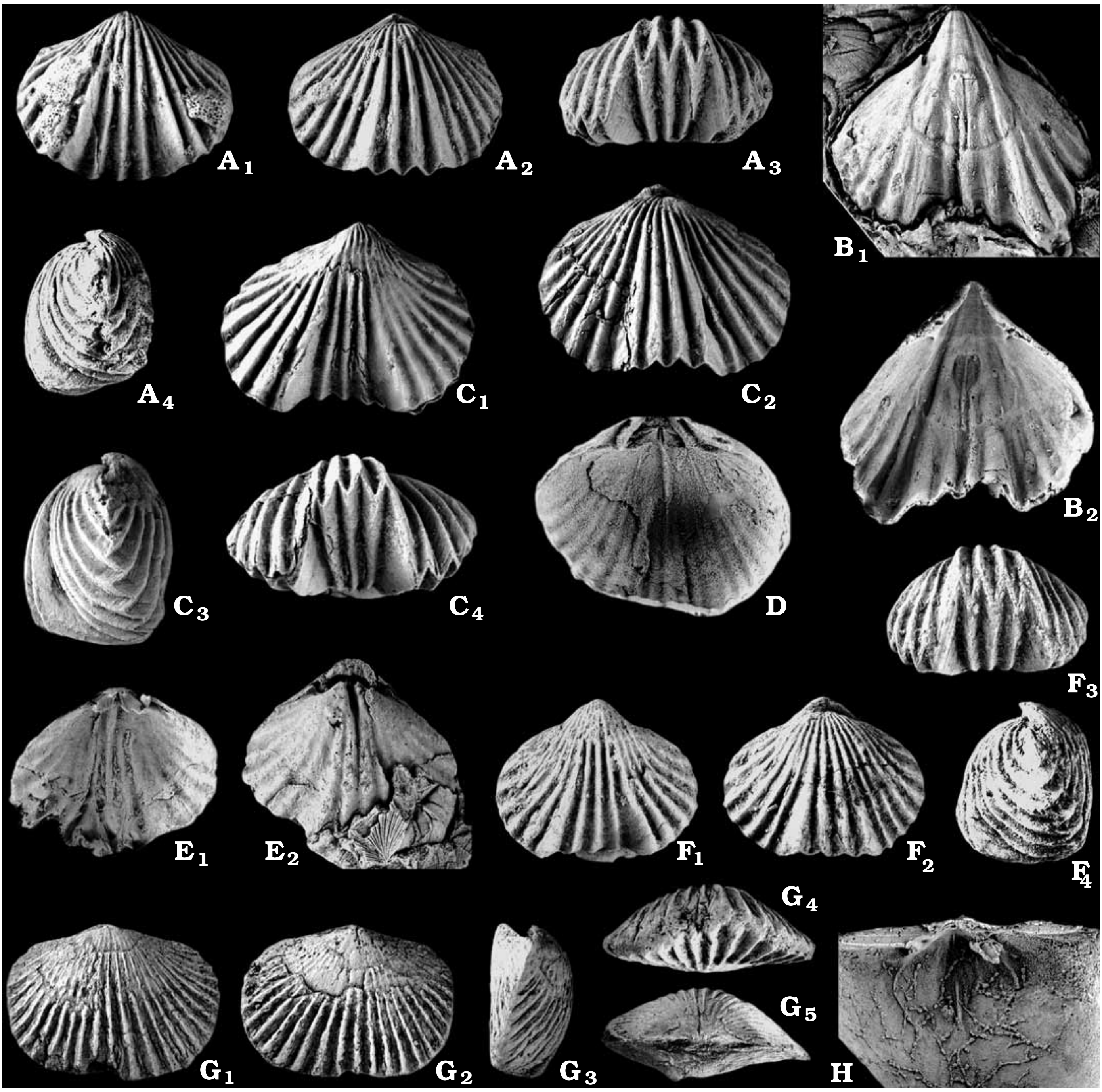

Fig. 5. **A**–**F**. *Rhynchotrema seletensis* sp. nov. **A**, **C**, **F**, sample 2523; **B**, **D**, **E**, sample 550a. **A**. NMW 98.30G.40, ventral (A_1), dorsal (A_2), anterior (A_3), and lateral (A_4) views of conjoined valves, × 2.25. **B**. NMW 98.30G.43, ventral internal mould (B_1) and latex cast (B_2), × 3. **C**. NMW 98.30G.41, holotype, ventral (C_1), dorsal (C_2), lateral (C_3), and anterior (C_4) views of conjoined valves, × 2.25. **D**. NMW 98.30G.45, latex cast of dorsal interior, × 2.5. **E**. NMW 98.30G.42, latex cast of dorsal valve interior (E_1) and dorsal internal mould (E_2), × 2.25. **F**. NMW 98.30G.44, anterior (F_1), ventral (F_2), dorsal (F_3), and lateral (F_4) views of conjoined valves, × 3. **G**. *Dinorthis taukensis* sp. nov.; NMW 98.30G.37, holotype, sample 2523; dorsal (G_1), ventral (G_2), lateral (G_3), anterior (G_4), and posterior (G_5) views of conjoined valves, × 2.25. **H**. *Glyptomena kaskolica* sp. nov.; NMW 98.30G.12, holotype, sample 550a; latex cast of ventral interior showing muscle field, × 2.25.

Derivation of name: After the Selety river near the type locality.

Holotype: NMGW 98.30G.41, complete shell.

Type locality: Sample 2523, Shollakkarasu river, Selety river basin, Kazakhstan.

Type horizon: Ordovician, Tauken Formation.

Paratypes.—486 conjoined valves, 12 ventral and 10 dorsal valves.

Diagnosis.—Shell dorsibiconvex, about 80% as long as wide and 80% as thick as long; ventral valve with weakly developed deltidial plates and sulcus originating slightly posterior

Fig. 6. Transverse serial sections of conjoined valves of *Rhynchotrema seletensis* sp. nov. Distance in mm is measured from the posterior tip of the ventral beak. Dorsal valve uppermost.

Table 9. Dimensions of complete shells of *Rhynchotrema seletensis* sp. nov. (sample 5190).

	Lv	Ld	W	T	St	Sw	Lv/W	Ld/W	T/Lv	Sw/W
N	52	52	52	52	52	52	52	52	52	52
X	13.5	12.8	16.8	10.9	10.0	5.0	80.8%	76.4%	80.9%	37.3%
S	1.26	1.33	1.94	1.75	1.31	1.16	6.3	6.5	11.3	8.1
MIN	11.6	11.0	12.5	7.5	7.0	3.0	68.9%	64.6%	58.6%	24.0%
MAX	16.4	17.0	20.6	14.6	13.5	7.5	97.3%	93.3%	121.2%	59.3%

to mid-valve length; dorsal valve strongly and slightly unevenly convex in lateral profile with moderately high median fold, trapezoidal in cross section; radial ornament of 11 to 20 ribs with 3 ribs on ventral sulcus and 4 ribs on median fold; ventral muscle field large, extending anterior to mid-length; dorsal median septum slender, about one half as long as the valve.

Description.—Shell dorsibiconvex, slightly transversely suboval with maximum width at the mid-length. Anterior commissure strongly uniplicate. Ventral valve moderately convex in transverse profile with maximum thickness near the mid-valve length. Beak slightly incurved, acuminate. Deltidial plates weakly developed. Sulcus originates about 4 to 6 mm from the beak, with steep flattened lateral slopes, deepening anteriorly and forming a trapezoidal tongue that occupies about 60% of maximum valve width and is about 37% as high as the shell. Lateral slopes flattened slightly in posterior view. Dorsal valve strongly convex with the maximum thickness slightly anterior to the mid-valve length, about 75% as long as wide with an obtuse, incurved beak. A median fold complementary to the sulcus originates at about 4 to 6 mm from the umbo, trapezoidal in cross section with steep, smooth lateral slopes. Radial ornament costate with 11 to 20 angular ribs, mostly with 3 ribs in the sulcus and 4 ribs on the median fold and 6 to 8 ribs on the flanks. Specimens with 15 to16 ribs in total are predominant. Concentric ornament comprises fine, evenly spaced fila at about 8 to 10 per 1 mm, developed occasionally as slightly stronger growth lamellae.

Ventral interior with strong teeth supported by short, dental plates. The floor of the delthyrial chamber is occupied by a pedicle callist. Muscle field large, extending anterior to mid-valve length. A small, elongate central suboval adductor muscle track is bounded laterally and anteriorly by large, subflabellate diductor scars. Dorsal valve with a disjunct hinge plate and a small, narrow cruralium supported by a low, thin median septum extending anterior to the mid-valve length. Cardinal process high, blade-like. Crura long, radulifer.

Discussion.—By comparison with North American species of *Rhynchotrema*, *R. seletensis* somewhat resembles *Rhynchotrema nutrix* (Billings, 1866) as revised by Jin (1989), but can be distinguished in having a slightly more transverse shell outline, a dorsal median fold originating at some distance from the umbo, usually exceeding the 3 mm characteristic of the American species, and in the absence of a distinctive median furrow in the umbonal area of the dorsal valve. It differs from *Rhynchotrema iowense* Wang (1949) from the Maquoketa Formation (Ashgill) of Iowa, as well as from specimens identified as the same species described by Laurie (1991: 92, fig. 48A) from the lower Benjamin Limestone (Caradoc) of Tasmania in being generally larger and in having a strongly dorsibiconvex shell and well defined dental plates. The Kazakhstanian shells also differ from another Tasmanian species, *Rhynchotrema ponderosa* Laurie (1991: 90, fig. 46B), in having a strongly dorsibiconvex lateral shell profile, a well defined dorsal median fold which is prominent in posterior view, well developed dental plates, and a long dorsal median septum extending anteriorly to the centre of the valve.

R. seletensis and *Rhynchotrema oepiki* Percival (1991: 159, fig. 18) from the Eastonian (middle Caradoc) of New South Wales, Australia are similar in having a strongly dorsibiconvex lateral shell profile in mature specimens, an open delthyrium with very short deltidial plates, and well defined dental plates, but the Kazakhstanian species differs in the consistent absence of rib bifurcation on the median fold, as

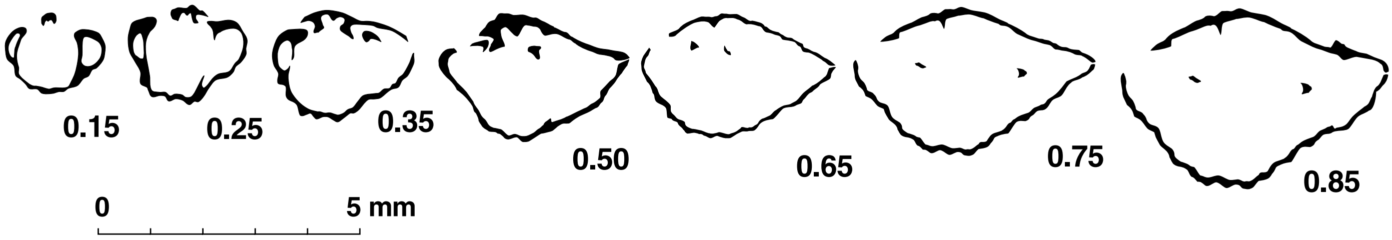

Fig. 7. Transverse serial sections of conjoined valves of *Sulcatospira prima* Popov, Nikitin, and Sokiran. Distance in mm is measured from the posterior tip of the ventral beak. Dorsal valve uppermost.

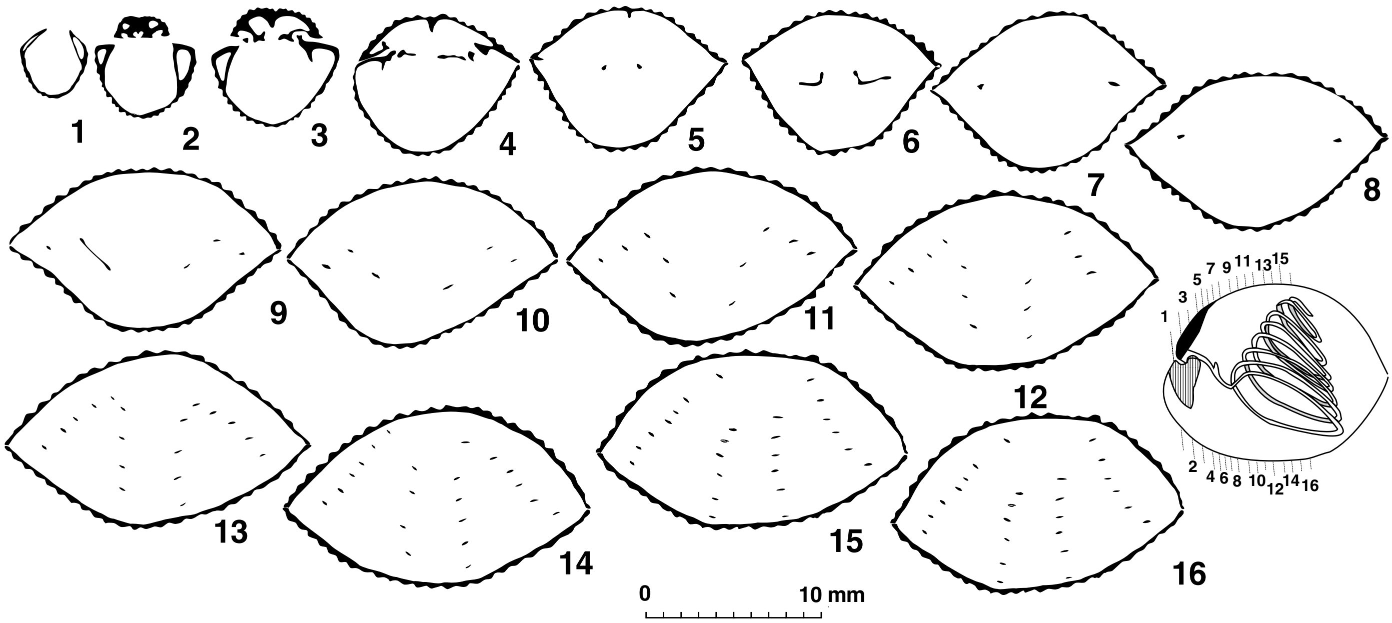

Fig. 8. Transverse serial sections of conjoined valves and reconstruction of brachial supports of *Nalivkinia* (*Pronalivkinia*) *zvontsovi* sp. nov. Dorsal valve uppermost.

well as having a ventral sulcus and dorsal median fold that originate at a considerable distance from the umbo.

Occurrence.—Localities 397a, 550a, 780, 2523 and 5190.

Order Atrypida Rzhonsnitskaya, 1960
Suborder Atrypidina Rzhonsnitskaya, 1960
Superfamily Atrypoidea Gill, 1871
Family Atrypinidae McEwan, 1939
Genus *Sulcatospira* Xu, 1979
Sulcatospira prima Popov, Nikitin, and Sokiran, 1999

Figs. 7, 9G.

Sulcatospira prima Popov, Nikitin, and Sokiran, 1999: 642, pl. 2: 15–16; pl. 3: 11–8; fig. 8.

Holotype: CNIGR Museum (St Petersburg) 17/12986, complete shell.

Type locality: Koskarasu valley, north-central Kazakhstan.

Type horizon: Upper Ordovician, upper Caradoc–lower Ashgill, Angrensor Formation, Koskarasu beds.

Material.—Three conjoined valves, one ventral and two dorsal valves.

Diagnosis.—See Popov, Nikitin, and Solkiran 1999: 642.

Remarks.—Specimens from the Tauken Formation are identical in size, general shell shape, radial ornament, and nature of the ventral sulcus and dorsal median fold with the types of *Sulcatospira prima* described and illustrated by Popov et al. (1999).

Occurrence.—Localities 550a, 2523 and 5190.

Family Clintonellidae Poulsen, 1943
Genus *Nalivkinia* Bublichenko, 1928
Subgenus *Pronalivkinia* Rukavishnikova, 1977
Nalivkinia (*Pronalivkinia*) *zvontsovi* sp. nov.

Figs. 8, 9A–F; Tables 10, 11.

Derivation of name: After V.S. Zvontsov, Kazakhstanian geologist.

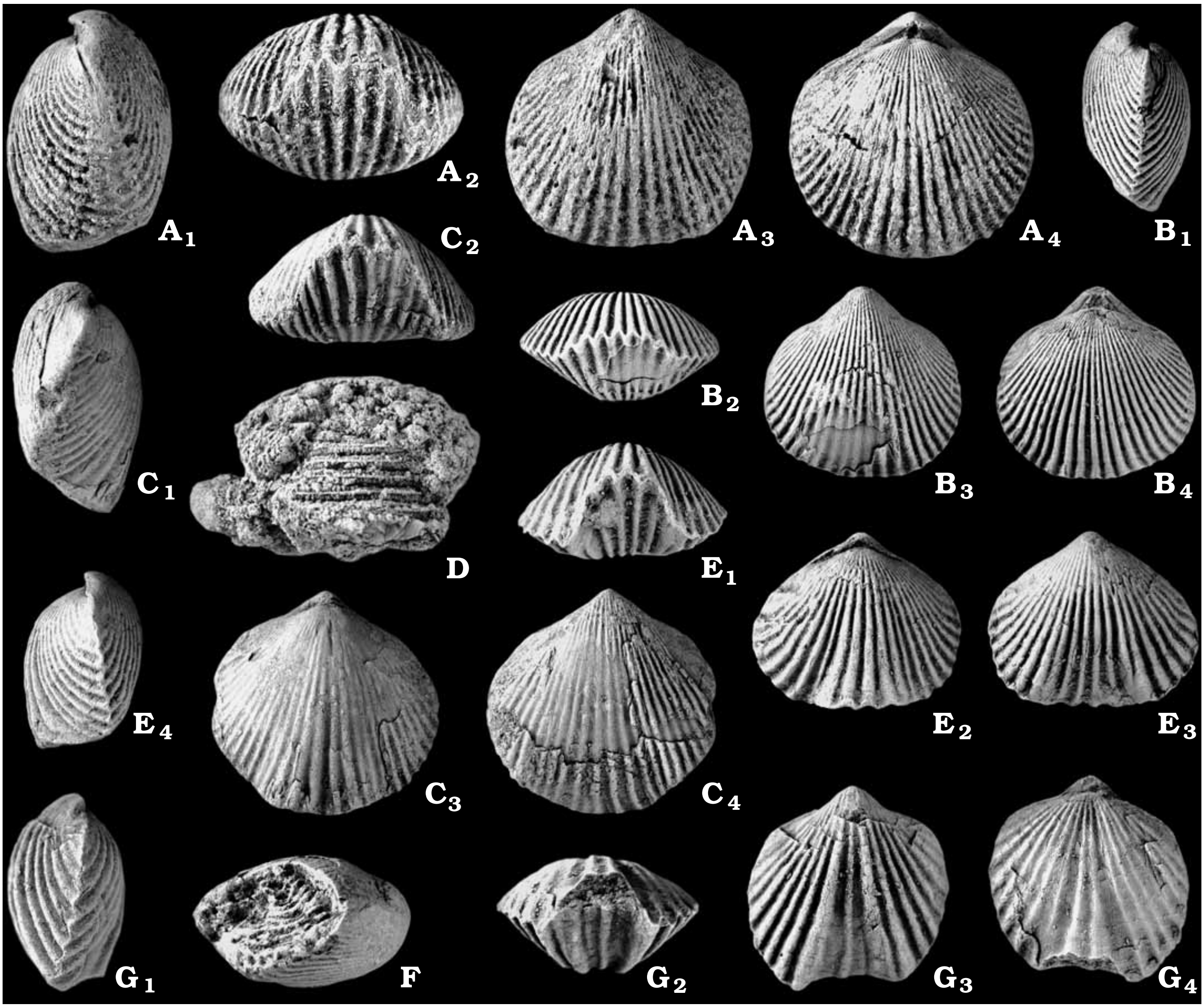

Fig. 9. **A**–**F**. *Nalivkinia* (*Pronalivkinia*) *zvontsovi* sp. nov.; **A**–**E**, from sample 5190, **F**, from sample 2523. **A**. NMW 98.30G.54, holotype, lateral (A_1), anterior (A_2), ventral (A_3), and dorsal (A_4) views of conjoined valves, × 3. **B**. NMW 98.30G.53, lateral (B_1), anterior (B_2), ventral (B_3), and dorsal (B_4) views of conjoined valves, × 2.5. **C**. NMW 98.30G.55, lateral (C_1), anterior (C_2), dorsal (C_3), and ventral (C_4) views of conjoined valves, × 2. **D**. NMW 98.30G.57, lateral view of incomplete shell showing spiralia, × 3.7. **E**. NMW 98.30G.56, anterior (E_1), dorsal (E_2), ventral (E_3), and lateral (E_4) views of conjoined valves, × 1.7. **F**. NMW 98.30G.58, lateral view of incomplete shell showing spiralia, × 2.25. **G**. *Sulcatospira prima* Popov, Nikitin, and Sokiran; sample 5190; NMW 98.30G.49, lateral (G_1), anterior (G_2), ventral (G_3), and dorsal (G_4) views of conjoined valves, × 4.

Holotype: NMW 98.30G.54, conjoined valves.

Type locality: Sample 5190, Shollakkarasu river, Selety river basin, Kazakhstan.

Type horizon: Ordovician, Tauken Formation.

Paratypes.—333 conjoined valves, six ventral and two dorsal valves.

Diagnosis.—Slightly dorsibiconvex shell about 90% as long as wide and 65% as thick as long, with a strongly uniplicate anterior commissure; dorsal median fold and ventral sulcus broad, occupying about 60% of maximum valve width; radial ornament of 24 to 30 rounded ribs with 4 to 8 ribs in the sulcus, 5 to 9 ribs on the fold.

Description.—Biconvex to slightly dorsibiconvex in mature specimens, subcircular to slightly transverse in outline. Anterior commissure uniplicate. Ventral valve moderately convex in transverse profile with maximum thickness between the umbo and mid-valve length. Beak slightly incurved. Delthyrium open, triangular. Sulcus originates at about mid way between the umbo and mid valve length, deepening gradually anteriorly. Dorsal valve on average 84% as long as wide with a swollen umbonal region. Median fold originates between about 4 to 5 mm from the umbo, produced anteriorly as a high, semioval tongue. Radial ornament costate with 24 to 30 rounded ribs, including 4 to 8 ribs in the sulcus and 5 to 9 on the fold.

Table 10. Dimensions of complete shells of *Nalivkinia* (*Pronalivkinia*) *zvontsovi* sp. nov. (sample 2523).

	Lv	Ld	W	T	Sw	St	Sw/W	St/Sw
N	121	121	121	121	121	121	121	121
X	11.5	10.7	12.7	7.3	7.6	2.8	59.7%	36.6%
S	1.64	1.55	2.12	1.64	1.75	1.28	8.3	17.8
MIN	7.1	6.5	7.4	4	3.5	0.5	26.8%	10.6%
MAX	15	13.8	17.8	12.5	11	8	82.1%	181.1%

Table 11. Dimensions of complete shells of *Nalivkinia* (*Pronalivkinia*) *zvontsovi* sp. nov. (sample 5190).

	Lv	Ls	W	T	Sw	St	Lv/W	Ld/W	T/Lv
N	89	89	89	89	89	89	89	89	89
X	11.3	10.3	12.6	7.6	7.3	2.9	90.2%	82.6%	66.6%
S	1.96	1.90	2.64	2.12	1.82	1.48	7.2	6.0	11.9
MIN	6.7	6	7.2	3.1	3	0.2	71.2%	67.5%	43.7%
MAX	17	16	18.6	12.5	12	7.5	113.0%	99.1%	117.9%

Ventral interior with strong teeth supported by thin dental plates, and a strong pedicle callist confined to the base of the delthyrial cavity. Ventral muscle field large, extending anteriorly to the mid valve length with narrow, lanceolate adductor scars, completely enclosed by larger diductor scars. Dorsal valve with a narrow cruralium supported by a high median septum. Cardinal process simple, ridge-like. Crura divergent and directed anteriorly. Spiralial cones of up to 9 whorls, with dorso-medially directed apices and very short, posteriorly located and separated jugal processes.

Discussion.—This species differs from *Nalivkinia* (*Pronalivkinia*) *rudis* (Rukavishnikova 1956) from the Upper Ordovician Dulankara Formation of the Chu-Ili Range, South Kazakhstan in having coarser radial ornament, a stronger dorsal median fold and ventral sulcus, and a thick shell which is usually about 60 to 70% as thick as long. In *N.* (*P.*) *rudis* the shell thickness is about half the sagittal length (Popov et al. 2000). The number of ribs in *N.* (*P.*) *rudis* varies considerably, but is usually from 7 to 12, which is well above the range observed in *N.* (*P.*) *zvontsovi*.

Our new species differs from *Nalivkinia* (*Pronalivkinia*?) *xichuanensis* Xu, 1996 from the Upper Ordovician Shiyanhe Formation (Ashgill) of the Qinling Region, China in having coarser radial ornament with only up to 30 ribs, whereas in the Chinese species the number varies from 36 up to 48.

Occurrence.—Localities 397a, 550a, 780, 2523 and 5190.

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