

## Earliest Silurian articulate brachiopods from central Kazakhstan

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An abundant early Silurian brachiopod assemblage of 14 species, with strong affinities to the early Rhuddanian faunas of Britain and Baltoscandia, was recovered from the Akkerme Peninsula, on the western side of Lake Balkhash, southern Central Kazakhstan. The occurrence of *Stricklandia lens mullochensis*, which is the earliest member of the *Stricklandia-Costistricklandia* lineage, dates this brachiopod assemblage as early Rhuddanian, within a stratigraphic interval from the *Akidograptus acuminatus* to the lower part of the *Monograptus cyphus* graptolite biozones. This is the first well documented record of early Rhuddanian brachiopods in Kazakhstan. The assemblage also includes *Meifodtia tulkulensis* sp. nov. and *Eospirifer cinghizicus* with well preserved spiralia. The co-occurrence of *Stricklandia lens mullochensis* and *Eospirifer cinghizicus* has not been recorded previously and is regarded here as the most significant difference between the early Rhuddanian brachiopod faunas of the Baltic (East-European) Plate and Britain; in contrast *Eospirifer* first appears in the two latter areas in the late Llandovery.

**Key words:** Brachiopoda, taxonomy, palaeogeography, Silurian, Rhuddanian, Kazakhstan.

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### Introduction

In Kazakhstan early Silurian brachiopods are previously known only from the Alpeis Formation (early to middle Llandovery) of the Chingiz Range (Borissjak 1955). Descriptions of several atrypide and pentameride species were published later by Rukavishnikova (1977) and Rukavishnikova & Sapelnikov (1975), but there was no record of early to middle Llandovery brachiopods in southern Central Kazakhstan.

An abundant early Rhuddanian brachiopod fauna was recovered recently from basal Silurian strata exposed along the northeastern coast of the Akkerme Peninsula on the western side of Lake Balkhash (Fig. 1).

The geology and stratigraphy of the Akkerme Peninsula was described in detail by Keller (1958) and by Nikitin, Apollonov *et al.* (1980).

Late Ordovician and early Silurian strata have not been formally subdivided in this area. Ashgill and Llandovery deposits are exposed in several tectonic blocks in the western part of the Akkerme Peninsula (Fig. 1), and the best exposures are situated on a cliff along the northeastern coast (Fig. 2). Late Ordovician and Rhuddanian strata usually have faulted contacts with either a limestone of the Ludlow age Akkan Formation, or with graded, fine-grained clastic rocks bearing Silurian graptolites. A diverse brachiopod fauna from the Akkan Formation was described by Nikiforova (1938), Sapelnikov & Rukavishnikova (1975) and Olenicheva (1983), but Rhuddanian brachiopods have never been recorded from this area.

## Stratigraphic setting

Four informal units may be distinguished in the Ordovician-Silurian boundary section of the Akkerme Peninsula (Fig. 3). They are: (1) about 30 m of massive, micritic limestone, succeeded by a bedded detrital limestone at the top; (2) about 15–20 m of intercalating fine to medium grained sandstone and siltstone; (3) more than 15 m of fine-grained sandstone and siltstone with nodules and nodular interlayers of a calcareous mudstone and argillaceous limestone.

The upper part of the lower unit contains a diverse late Ordovician fauna of tabulatormorph corals, brachiopods, ostracods, trilobites and echinoderms (Figs 1–3: locality 9301). According to Melnikova (1986) ostracods from this unit are closely similar to the assemblage of the Dulankara Regional Stage (latest Caradoc–early Ashgill) from the Chu-Ili Range. Most species (e.g. *Laccochilina (L.) indigena*, *Rectella kemphi*, *Reversocypris angularis*), which are unknown outside Kazakhstan. Only *Bairdocypris indeterminatus* is known from the Rakvere to Porkuni regional stages in the East Baltic. An articulate brachiopod assemblage from this unit includes *Ptychopleurella* sp., *Dolerorthis* sp., *Parastrophina* sp., *Christiania* sp., and *Eospirigerina* sp.

The early Silurian brachiopod assemblage is preserved in nodules and nodular interlayers of a calcareous mudstone and argillaceous limestone of Unit 3, which rests on the unfossiliferous sandstone of Unit 2. The presence of *Dolerorthis sowerbyana* (14.9% of the total number of individuals), *Isorthis (Protocortezorthis) prima* (8.9%), *Eopholidostrophia sefinensis ellisae* (3.7%), *Stricklandia lens mullochensis* (7.2%) and *Eospirigerina porkuniana* (16.8%) indicates a Rhuddanian age for this fauna. *Giraldiella* sp. (1%), *Leangella scissa* (4.3%), *Eostropheodonta* sp. (1%), *Saughina* sp. (1%), *Zygospiraella duboisi* (15.3%), *Meifodia tulkulensis* sp. n. (23.4%),

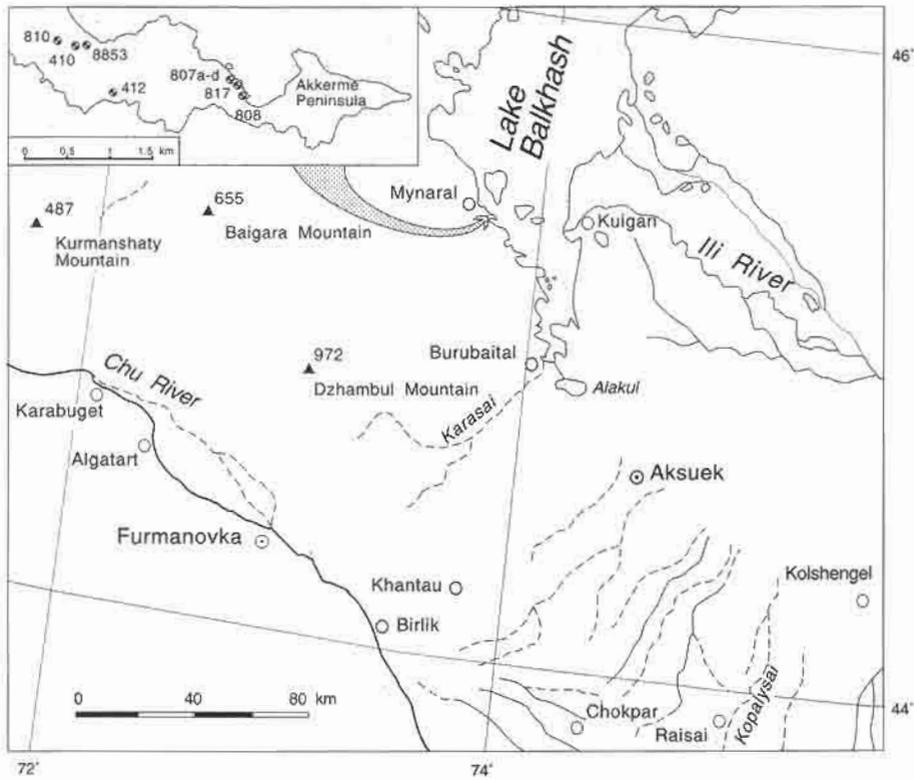


Fig. 1. Map of a southern part of Kazakhstan showing location of the Akkermé Peninsula and the position of the main fossil localities containing early Rhuddanian brachiopods (Department of stratigraphy and palaeontology, VSEGEI, locality numbers).

and *Eospirifer cinghizicus* (2.7%) also occur. Associated faunal assemblage includes rare trilobites, numerous tabulate and rugose corals. Algae *Dimorphosiphon* and *Palaeoporella* also present in most localities.

*Stricklandia lens mullochensis*, which is the earliest member of the *Stricklandia-Costistricklandia* lineage (Baarli & Johnson 1988), is the most stratigraphically significant. There are no records of stratigraphically useful species of graptolites or conodonts, but according to Baarli (1986) in Norway this brachiopod subspecies in Norway has a stratigraphic range from the *Akidograptus acuminatus* to the lower part of *Monograptus cyphus* graptolite biozone (early Rhuddanian).

It is possible that the underlying unfossiliferous unit of clastic rocks was deposited during the Hirnantian regressive event.

## Brachiopod faunal affinities

The latest Ordovician and earliest Silurian brachiopod assemblages and palaeozoogeography were discussed in detail in several recent publications

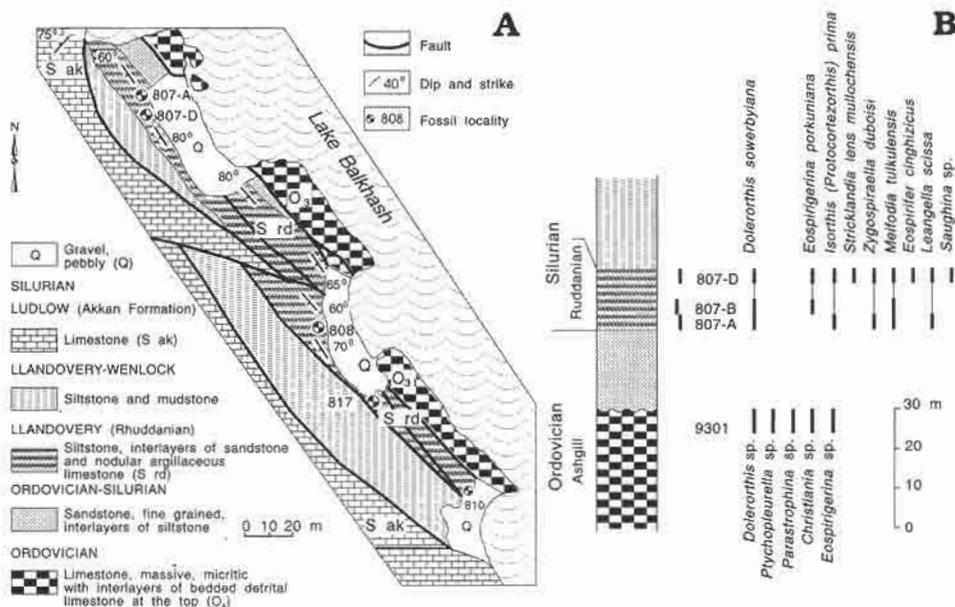


Fig. 2. □A. Geological map of the northeastern part of Akkerme Peninsula showing the position of fossil localities. □B. A composite stratigraphic section of late Ordovician and early Silurian rocks in Akkerme Peninsula with associated ranges of selected brachiopods.

(Cocks 1988; Sheehan & Coorough 1990; Owen, Harper, & Rong 1992; Harper & Rong 1995). Records of early Rhuddanian brachiopods are usually very sparse. In Kazakhstan the most complete sequence of Ordovician–Silurian boundary beds exposed in the southern Chu-Ili Range about 200 km south of the Akkerme Peninsula (Apollonov *et al.* 1988). The late Ashgill brachiopods in the Chu-Ili Range are represented by a diverse assemblage with *Holorhynchus* (upper part of the *Climacograptus super-nus* Zone) and by the *Hirnantia* fauna, which appears first in the *Norma-lograptus extraordinarius* Zone (Nikitin *et al.* 1980), but deposits with the *Hirnantia* assemblage are replaced by graptolite shales lacking a diagnostic shelly fauna in all the known sections from this area. The early Palaeozoic accretionary history of southern central Kazakhstan is inadequately known, but it is likely, that the assemblage with *Stricklandia lens mullochenensis* and *Eospirifer cinghizicus* succeeds *Holorhynchus* and *Hirnantia* faunas across the southern Kazakhstani terranes. The majority of genera in the early Ruddanian brachiopod assemblage from the Akkerme Peninsula are newcomers, and their relations to the late Ordovician brachiopod assemblages are uncertain. The only exception is *Eostropheodonta*, which is characteristic for the Hirnantian brachiopod assemblages, as well as two Lazarus genera (*Dolerorthis* and *Eospirigera*). The latter two taxa occur in Kazakhstan within the late Ordovician brachiopod assemblages associated with carbonate mounds, but they disappear in the Hirnantian.

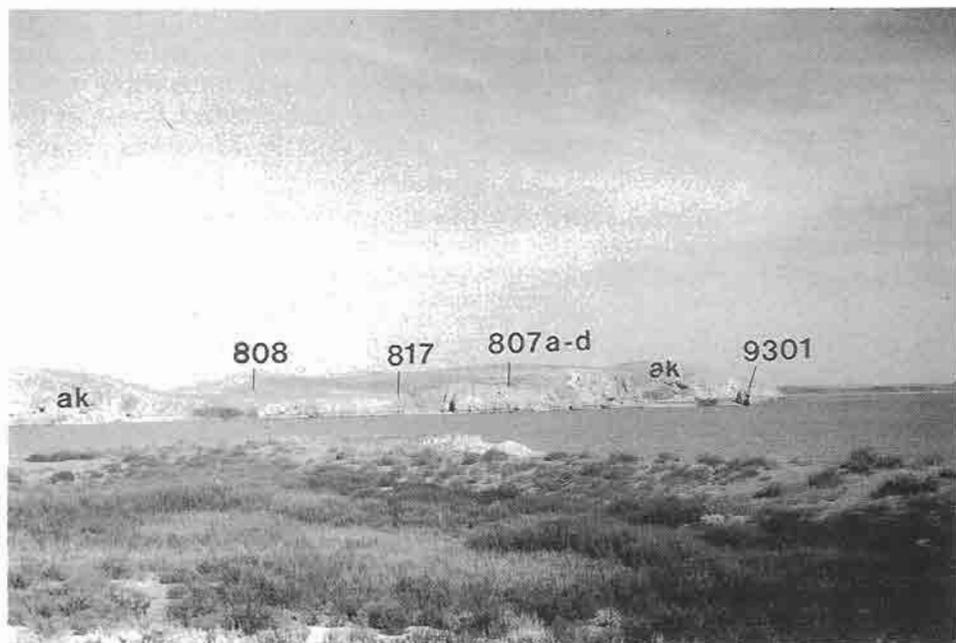


Fig. 3. Northern view of the exposures of Silurian rocks on a cliff along the northeastern coast of the Akkerme Peninsula.

The early Rhuddanian brachiopod assemblage from the Akkerme Peninsula has some remarkable differences from early to middle Llandovery brachiopod faunas recovered from the Alpeis Formation in the Chingiz Range. Such genera as *Eopholidostrophia*, *Saughina*, and *Meifodia* have never been recorded from Kazakhstan, but early stricklandiids occur in the late Ashgill *Holorhynchus giganteus* beds of the Chu-Ili Range (Sapelnikov & Rukavishnikova 1975). *Holorhynchus cinghizicus* is relatively abundant in the lower part of the Alpeis Formation but is absent in contemporaneous strata of southern Central Kazakhstan. *Stricklandia* appears first in the Chingiz Range only in the upper part of the Alpeis Formation together with *Pentamerus longiseptatus* (Sapelnikov & Rukavishnikova 1975).

The affinity of the early Rhuddanian brachiopod assemblage from the Akkerme Peninsula is closest to contemporaneous faunas from Britain (the Bronydd Formation, and upper Haverford Mudstone Formation, both in Wales). Four species (*Dolerorthis sowerbyiana*, *Leangella scissa*, *Eopholidostrophia sefinensis ellisae*, *Stricklandia lens mullochensis*) and the genera *Giraldiella*, *Saughina*, *Eospirigerina*, and *Meifodia* are common to both areas (Cocks 1988; Cocks *et al.* 1984; Cocks & Price 1975).

Baltoscandian affinities may be illustrated by the number of Kazakh taxa which also occur in the early Rhuddanian strata in Norway and Estonia: *Stricklandia lens mullochensis*, *Zygospiraella duboisi*, and *Eospi-*

*rigerina porkuniana* (Rubel 1970, 1977) are recorded from the Juuru Regional Stage of Estonia. The genera *Leangella* and *Meifodia* are also common, but represented by different species. *Isorthis* (*Protocortezorthis*) *prima*, *Leangella scissa*, and *Stricklandia lens mullochensis* occur in the Langyene and Langra formations (Cocks 1988) and Myren Member (Baarli & Harper 1986) in the Oslo Region, southern Norway.

The relative abundance of *Stricklandia lens mullochensis*, *Isorthis* (*Protocortezorthis*) *prima*, as well as the co-occurrence of the atrypides *Zygospiraella* and *Eospirigerina*, in the early Ruddanian assemblage from Akkerme peninsula suggest that this assemblage may have affinity with the stricklandiid paleocommunities and in particular with the *Stricklandia lens* community from the early Rhuddanian of Estonia (Rubel 1970b); however, *Meifodia* is more characteristic for *Clorinda* community in the early Silurian brachiopod fauna of the East Baltic.

The *Stricklandia*/coral association from Solvik Formation of Norway (Baarli 1987) is also somewhat similar, but the atrypid genera are relatively rare in the Norwegian assemblage, and *Eospirigerina* and *Zygospirella* are missing.

The co-occurrence of *Stricklandia lens mullochensis* and *Eospirifer cingizicus* in the assemblage from the Akkerme Peninsula is the most important difference from early Ruddanian brachiopod assemblages of the East-European Platform and Britain, because *Eospirifer* appeared in the two latter areas only in the late Llandovery. However, *Eospirifer* is recorded from approximately contemporaneous strata in Australia (Sheehan & Baillie 1981) and from the middle Ashgill of western Zhejiang, China (Rong *et al.* 1994). The late Rhuddanian and early Aeronian *eospiriferines* are known mostly from southwestern and northern China and Kazakhstan.

## Systematic palaeontology

Abbreviations appearing in the tables of measurements and text are as follows:

L	sagittal length.
W	maximum width.
T	thickness.
MI	length of the muscle field.
Mw	width of the muscle field.
SI	length of the median septum.
LP	width of the dorsal platform.
Fw	width of the fold along the anterior margin.
X	mean.
S	standard deviation from the mean.
OR	observed range.
N	number of specimens.
MAX	maximum value.
MIN	minimum value.

Table 1. *Dolerorthis sowerbyiana* (Davidson), average dimensions of 6 ventral valves.

	L	W	lw	MI	Mw	L/W	lw/W	MI/L	MI/Mw
N	6	6	4	3	3	6	4	3	3
X	10.8	13.6	11.1	2.9	3.4	78%	88%	28%	84%
S	3.01	3.00	3.5	0.85	0.59	6.6	6.3	5.7	9.6
MIN	6.2	8.0	6.6	2.3	3.0	70%	82.5%	22.5%	77%
MAX	14.2	16.2	14.7	3.9	4.1	88%	96%	34%	95%

All illustrated specimens are housed in the CNIGR Museum, St. Petersburg under collection 12889. Museum collections abbreviations refer to British Geological Survey in Nottingham (BGS), Natural History Museum in London (NHM), Smithsonian Institution in Washington, D.C. (USNM), Geological Institute in Tallinn, Estonia (GIT).

Order Orthida Schuchert & Cooper 1932  
 Superfamily Orthoidea Woodward 1852  
 Family Dolerorthidae Öpik 1934  
 Subfamily Dolerorthinae Öpik 1934  
 Genus *Dolerorthis* Schuchert & Cooper 1931

### *Dolerorthis sowerbyiana* (Davidson 1869)

Fig. 4A–J; Table 1.

*Dolerorthis sowerbyiana* (Davidson 1869); Temple 1987: p. 30, pl. 1: 11–18 (full synonymy).

Lectotype: Selected by Whittard & Barker (1950: p. 564), BGS 11605 and 11606.

Type locality: Gasworks, Haverfordwest, Dyfed, Wales.

Type horizon: Gasworks Mudstone. Silurian, Rhuddanian.

**Diagnosis.** — See Temple (1970: p. 13).

**Description of the specimens from Kazakhstan.** — Shell dorsibiconvex, transverse subrectangular in outline on average 88% as long as wide with the maximum width at a mid-length, and 23–33% as thick as long. Posterior margin about 79–95% of the maximum valve width. Cardinal extremities slightly obtuse to near perpendicular. Anterior commissure rectimarginate. Ventral valve gently convex, flattening peripherally. Interarea moderately high, apsacline with an open delthyrium. Dorsal valve moderately convex, weakly sulcate posteriorly, with a low, planar anacline interarea. Ornamentation costellate with 15–23 costae in the umbonal area and about 37–51 costellae along the posterior margin of mature specimens. New costellae originate by bifurcation in the umbonal region, and at the distance of 8 to 12 mm from the umbo. Concentric ornamentation represented by fine evenly spaced filae.

Ventral interior with strong teeth supported by short, slightly divergent dental plates. Muscle field occupies about one third of a sagittal valve length, slightly raised anteriorly with narrow lanceolate adductor scars bisected medianly by a fine ridge, and broadly subtriangular diductor scars. Dorsal interior with a simple, ridge-like cardinal process on the

small notothyrial platform and short, divergent brachiophores. Adductor scars divided by a low and broad median ridge extending anteriorly to the mid-valve. Posterior adductors slightly larger than anterior ones and separated from the latter by fine transverse ridges.

**Remarks.** — Specimens of *Dolerorthis sowerbyiana* from the Rhuddanian of Kazakhstan are closely comparable with specimens of this species described and illustrated by Temple (1970: pl. 2: 1–11) from the Rhuddanian of Meifod, Wales as well as with specimens described by Williams (1951) under the name *D. plicata*. As suggested by Temple (1970, 1987) in his revision of the Rhuddanian brachiopods from Meifod, the lectotype of *D. plicata* (J. de C. Sowerby 1839) is poorly preserved, and it is safer to regard this name as a *nomen dubium* until this species is redescribed on the basis of a representative topotype collection. However, Temple questionably included this species in the synonymy of *D. sowerbyiana* (Davidson 1869). The lectotype of *D. plicata* illustrated by Temple (1987: pl. 1: 16) differs from Kazakhstani specimens of *Dolerorthis* in having a strongly alate and transversely semi-elliptical dorsal valve.

**Material.** — Figured: dorsal internal mould 10/12889 (L = 12.1, W = 17.3), ventral internal mould 11/12889 (L = 11.5, W = 15), dorsal external mould 12/12889 (L = 10.5, W = 14.8), ventral internal mould 13/12889 (L = 10, W = 13.5), dorsal internal mould 14/12889. Unfigured: complete shell 2/12889 (L = 15.2, W = 19.8, T = 5.3), complete shell 9/12889 (L = 6.2, W = 8.0, T = 2.4, lw = 6.6). Total of 29 complete shells, 43 ventral and 36 dorsal valves.

**Occurrence.** — Akkerme Peninsula, localities 412, 807-A, 807-B, 807-D, 808, 817, and 8853.

Family Plectorthidae Schuchert 1929

Subfamily Plectorthinae Schuchert 1929

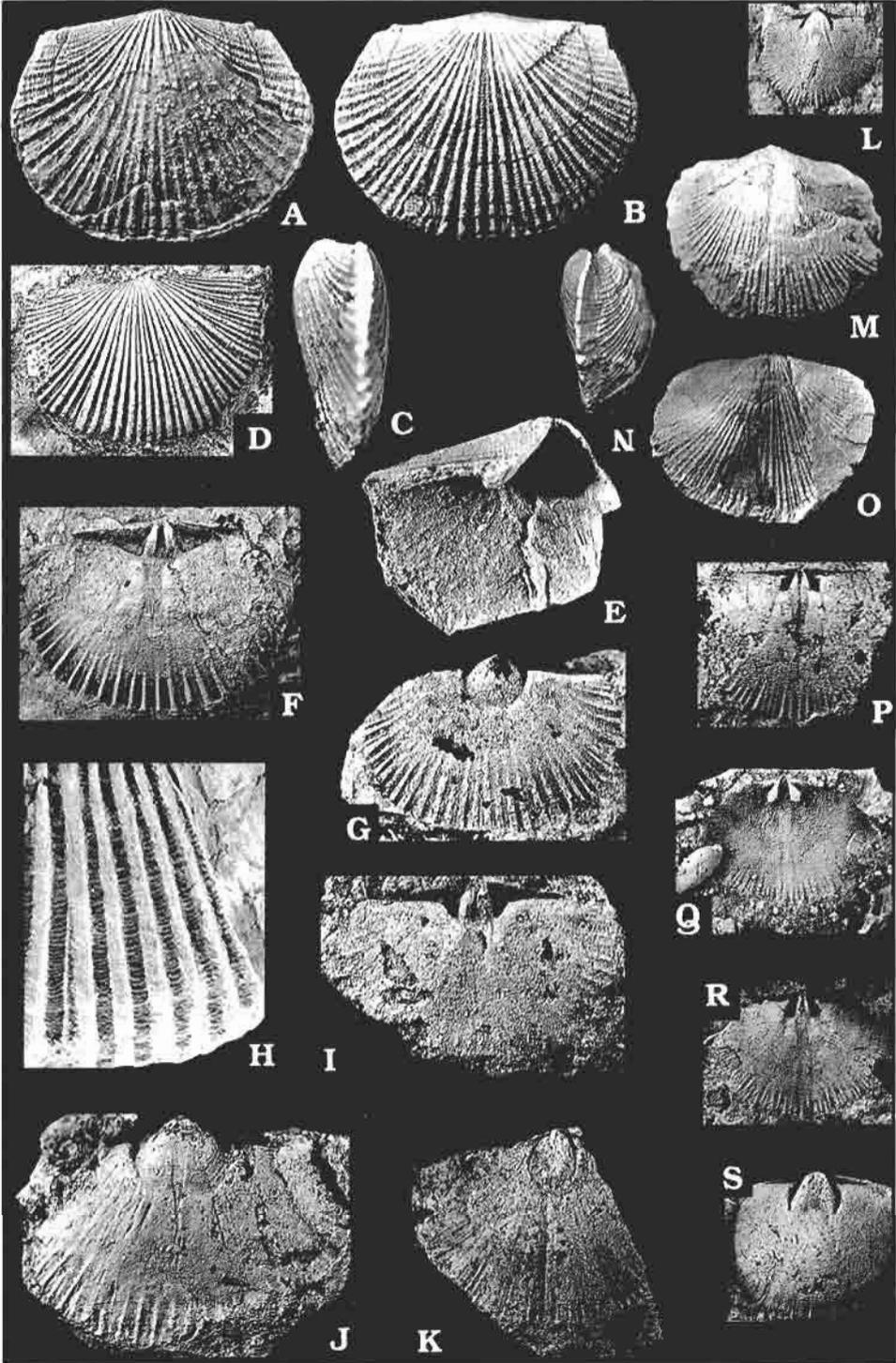
Genus *Giraldiella* Bancroft 1949

### *Giraldiella* sp.

Fig. 4K.

**Description.** — Shell transverse, subrectangular in outline with a maximum width at the hinge line. Cardinal extremities near perpendicular.

Fig. 4. □A–J. *Dolerorthis sowerbyiana* (Davidson 1869). A–C. Conjoined valves 1/12889; ventral (A), dorsal (B), and side (C) views; locality no. 8853; × 3. D. Dorsal exterior 12/12889, latex cast; locality no. 817; × 3. E. Ventral valve interior 6/12889; locality no. 808; × 3. F. Dorsal internal mould 10/12889; locality no. 817; × 2. G. Ventral internal mould 13/12889; locality no. 817; × 2. H. Ornamentation of the ventral valve 4/12889; locality no. 8853; × 5. I. Dorsal internal mould 14/12889; locality no. 817; × 3. J. Ventral internal mould 11/12889; locality no. 817; × 3. □K. *Giraldiella* sp., ventral internal mould 15/12889; locality no. 808; × 2. □L–S. *Isorthis (Protocortezorthis) prima* Walmsley & Boucot 1975. L. Ventral internal mould 18/12889; locality no. 817; × 3. M–O. Conjoined valves 16/12889; dorsal (M), side (N), and ventral (O) views; locality no. 808; × 3. P. Dorsal internal mould, 21/12889; locality no. 817; × 3. Q–R. Dorsal valve interior 20/12889; latex cast (Q), dorsal internal mould (R); locality no. 817; × 3. S. Ventral internal mould 17/12889; locality no. 817; × 3.



Anterior commissure rectimarginate. Ventral valve gently convex, flattened peripherally. Interarea aplanate with an open triangular delthyrium. Radial ornamentation fascicostellate. Ventral interior with small teeth supported by short, slightly divergent dental plates. Muscle field small, restricted mainly to the delthyrial cavity and occupying about 30% of the sagittal valve length. Dorsal valve unknown.

**Discussion.** — It is impossible to make a precise assignment of this species on the basis of the fragmentary material represented by this single ventral internal mould. It is somewhat similar to *Giraldiella giraldi* Williams (1951: p. 93) in the size and shape of the ventral valve, as well as in having a strongly fascicostellate ornamentation impressed on the internal mould.

**Material.** — Figured: internal mould of a ventral valve 15/12889 (L = 12.8, Ml = 3.8, Mw = 3.4).

**Occurrence.** — Akkerme Peninsula, locality 808.

Superfamily Dalmanelloidea Schuchert 1913

Family Rhipidomellidae Schuchert 1913

Subfamily Isorthinae Schuchert & Cooper 1931

Genus *Isorthis* Kozłowski 1929

Subgenus *Protocortezorthis* Walmsley & Boucot 1975

### *Isorthis (Protocortezorthis) prima* Walmsley & Boucot 1975

Fig. 4L–S.

*Isorthis (Protocortezorthis) prima* sp. nov.: Walmsley & Boucot 1975: p. 63, pl. 3: 1–3.

*Isorthis prima* Walmsley & Boucot 1975: Cocks 1978: p. 69.

*Mendacella mullochensis* (Davidson 1869) (*pars*): Temple 1987: p. 39.

Holotype: By original designation; USNM 204883; a ventral valve.

Type locality: Rough Neuk Quarry, Craighead Inlier, Girvan, Scotland.

Type horizon: Mulloch Hill Formation, Silurian, Rhuddanian.

**Diagnosis.** — See Walmsley & Boucot (1975).

**Description of the specimens from Kazakhstan.** — Shell ventribiconvex, subcircular to slightly transverse oval in outline, about 91% (S 4.3, OR 84.0–98.9%, N 13) as long as wide, with a maximum width at the mid-length and 45% (S 6.9, OR 30.3–55.6%, N 13) as thick as long. Posterior margin is straight, about 80% (S 7.2, OR 66.3–93.5%, N 13) of the maximum valve width. Cardinal extremities are rounded. Anterior commissure gently sulcate. Ventral valve moderately and evenly convex with a concave, aplanate interarea and narrowly triangular open delthyrium. Dorsal valve gently convex with a shallow sulcus originating near the umbo. Dorsal interarea low, planar, anaplanate. Radial ornament multi-costellate with 11–14 costellae per 3 mm along the anterior margin in adult specimens.

Ventral interior with strong teeth supported by well developed, divergent dental plates. Muscle field bilobed about 29% a valve length, with narrow, centrally placed adductor scars slightly raised anteriorly, and subtriangular, strongly impressed diductor scars extending slightly anterior to the adductor scar. *Vascula media* straight and divergent. Dorsal

interior with high, short blade-like brachiophores. The posterior part of the notothyrial platform is occupied mainly by a broad sessile cardinal process with a thin, simple myophore. Adductor muscle field elongate subrectangular in outline, extending anteriorly beyond the mid-length and divided by a broad median ridge. Anterior adductor scars longitudinally ovate, separated from the posterior adductor scars by narrow transverse ridges.

**Discussion.** — Temple (1987: p. 39) synonymised *Isorthis* (*Protocortezorthis*) *prima* with *Mendacella mullochensis* (Davidson 1869). This wide concept of the latter species is rejected here. *I.* (*Protocortezorthis*) *prima* may be distinguished from the other early Llandovery dalmanelloid brachiopods by the morphology of the cardinalia possessing a simple sessile cardinal process with a thin, simple myophore, as well as in the configuration of the ventral and dorsal muscle fields.

**Material.** — Figured: complete shell 16/12889 (L = 8.4, W = 10, T = 4.3, Iw = 7.8), ventral internal mould 17/12889 (L = 8.2, W = 9.0, Ml = 2.7, Mw = 2.4), ventral internal mould 18/12889 (L = 6.6, W = 7.2), dorsal internal mould 20/12889 (L = 7.3, W = 8.5), dorsal internal mould 21/12889 (L = 9.6, W = 8.8). Unfigured: internal mould 19/12889 (L = 10.6, W = 11.8; T = 4.4), internal mould 22/12889 (L = 8.5, W = 9.2; T = 3.2). Total of 15 complete shells, 28 ventral and 9 dorsal valves.

**Occurrence.** — Akkerme Peninsula, localities 412, 805, 807-A, 807-D, 808, 817, and 8853.

Order Strophomenida Öpik 1934

Superfamily Plectambonitoidea Jones 1928

Family Leptestiidae Öpik 1933

Genus *Leangella* Öpik 1933

### *Leangella scissa* (Davidson 1871)

Fig. 51–M.

*Leangella scissa* (Davidson 1871); Cocks 1978: p. 96 (selected synonymy); Temple 1987: p. 55, pl. 3: 16.

Lectotype: Selected by Cocks (1970: p. 160); an internal mould of the ventral valve BGS I1364.

Type locality: Haverfordwest, Dyfed, Wales.

Type horizon: The upper Haverford Mudstone Formation, Silurian, Rhuddanian.

**Diagnosis.** — See Temple (1970: p. 36).

**Remarks.** — Specimens from Kazakhstan are indistinguishable in ornamentation and general shell shape from the British specimens described and illustrated by Temple (1970). They differ from the latter only in the lesser convexity of the ventral valve and a larger maximum size.

**Material.** — Figured; 25/12889, damaged complete shell (L = 5.0, W = 7.4); 26/11889, ventral valve (L = 7.3, W = 15.1); 14/12 ventral internal mould; 27/12889, ventral internal mould; 28/12889, dorsal internal mould (L = 6.8, W = 9.0, LPl = 4.8, LPw = 6.3 Bl = 1.7, Bw = 3.5). Total of 2 complete shells 19 ventral and 7 dorsal valves.

**Occurrence.** — Akkerme Peninsula, localities 805, 807-A, 807-D, 808, 810, 817, and 8853.

Family Leptostrophiidae Caster 1939

Genus *Eostropheodonta* Bancroft 1949

*Eostropheodonta* sp.

Fig. 5A, C-D.

**Description.** — Shell planoconvex, transverse semi-elliptical in outline, about 63% as long as wide with a maximum width along the hinge line. Cardinal extremities acute and alate. Ventral valve gently convex with a low planar, apsacline interarea. Delthyrium covered apically by a small, convex pseudodeltidium. Dorsal valve flat with a low, planar interarea. Chilidium broadly convex. Radial ornamentation inequally parvicostellate with about 11–12 costellae per 2 mm in a number. Strong oblique rugae appear along the hinge line.

Ventral interior with short divergent dental plates. Other structures not easily discernable. Dorsal interior has widely divergent socket plates with a crenulate posterior surface, a low median ridge extending to the mid-length and cardinal process with lobes divergent anteriorly.

**Remarks.** — According to Harper & Boucot (1978) the genera *Eostropheodonta* and *Aphanomena* may be distinguished mainly on the basis radial ornament, which is parvicostellate in *Aphanomena* and fascicostellate in *Eostropheodonta*. In fact the radial ornament of *E. hirnantensis*, the type species of *Eostropheodonta*, is strongly variable; specimens with fascicostellate, parvicostellate and multicostellate ornament occur within toptype populations of this species. Therefore Rong & Cocks (1994) regarded *Eostropheodonta* as a senior objective synonym of *Aphanomena*. This revised concept of *Eostropheodonta* is accepted here.

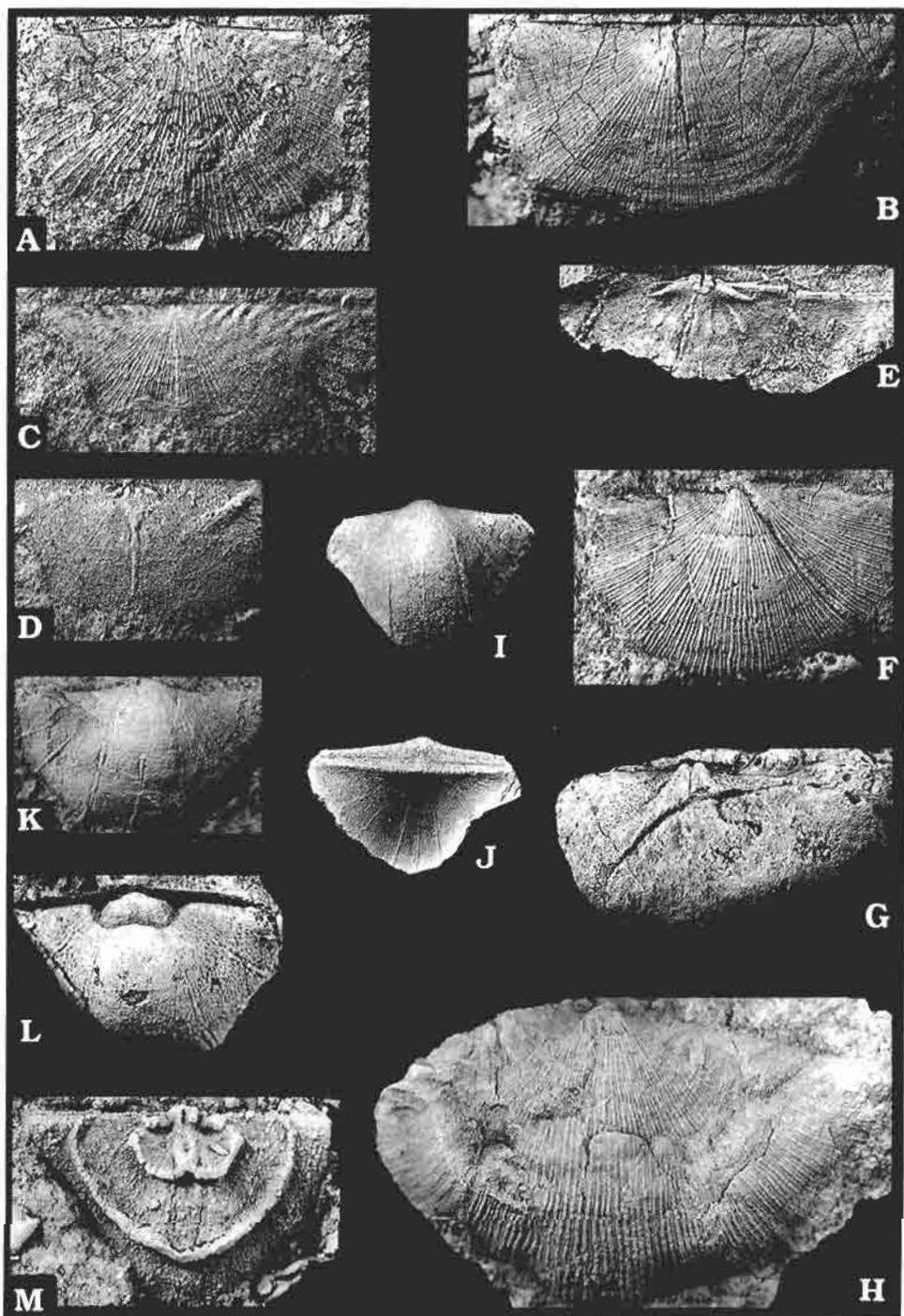
The distinctive feature of Kazakhstani specimens is the presence of rather strong oblique small rugae along the hinge line. In this feature, as well as in the internal morphology of the dorsal valve they are closely comparable and possibly conspecific with the specimen of *Aphanomena* sp. from the early Llandoverý of Sweden illustrated by Harper & Boucot (1978: pl. 1: 10).

**Material.** — Figured: ventral internal mould 30/12889 (L = 15, W = 20.7), dorsal internal and external moulds 31/12889 (L = 9.2+, W = 22.5). Total of 1 ventral and 4 dorsal external and internal moulds.

**Occurrence.** — Akkerme Peninsula, locality 817.

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Fig. 5. □A, C-D. *Eostropheodonta* sp. A. Ventral internal mould 30/12889; locality no. 817; × 2. C. Dorsal external mould, 29/12889; locality no. 817; × 2. D. Dorsal exterior 29/12889, latex cast; locality no. 817; × 2. □B, E-H. *Eopholidostrophia sefinensis ellisae* Hurst 1974. B. Dorsal external mould 34/12889; locality no. 817; × 2. E. Dorsal interior 37/12889, latex cast; locality no. 817; × 3. F. Ventral exterior 32/12889, latex cast; locality no. 817; × 2. G. Ventral internal mould 32/12889; locality no. 810; × 2. H. Ventral exterior 33/12889; locality no. 817; × 2. □I-M. *Leangella scitssa* (Davidson 1871). I, J. Conjoined valves 25/12889; ventral (I) and dorsal (J) views; locality no. 808; × 4. K. Ventral valve exterior 26/12889;



locality no. 817;  $\times 3$ . L. Ventral internal mould 27/12889; locality no. 810;  $\times 3$ . M. Dorsal valve interior 28/12889, latex cast; locality no. 817;  $\times 4$ .

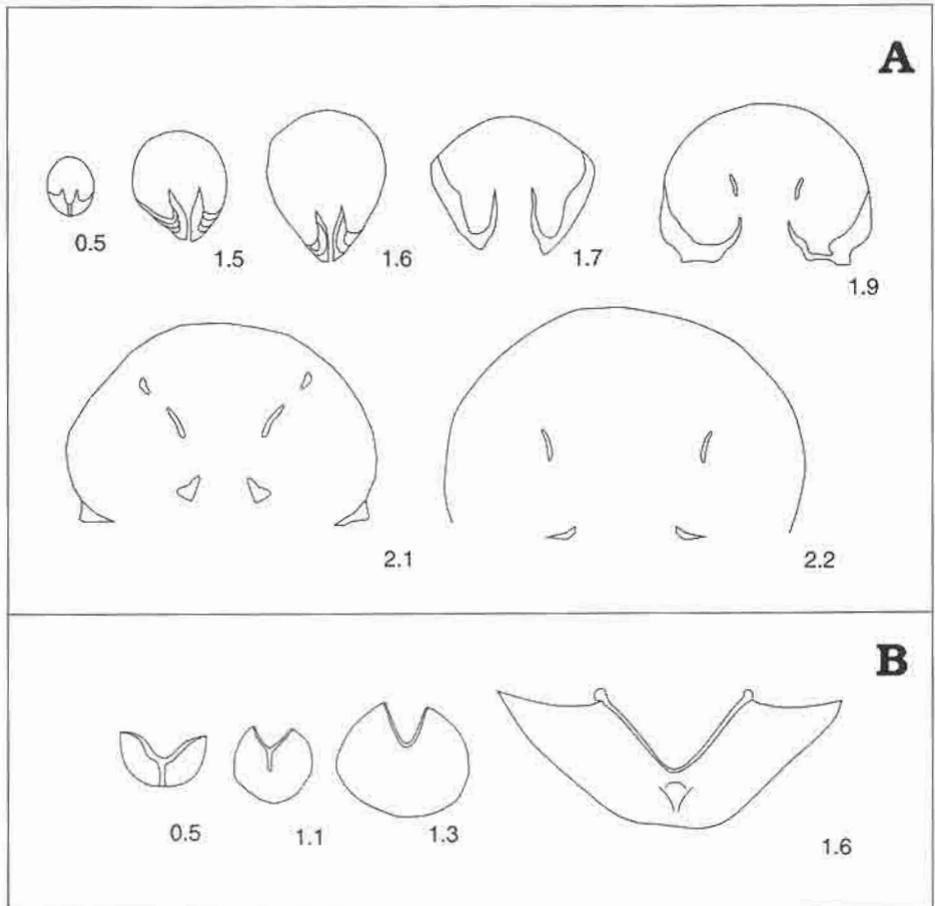


Fig. 6. *Stricklandia lens mullochensis* Reed. A. Serial sections of the ventral valve 52/12889. B. Serial sections of the dorsal valve 53/12889.

Family *Eopholidostrophiidae* Rong & Cocks 1994

*Eopholidostrophia sefinensis ellisae* Hurst 1974

Fig. 5B, E–H.

*Eopholidostrophia sefinensis ellisae* Hurst 1974; Temple 1987: p. 83, pl. 9: 13–16 (full synonymy).

Holotype: Internal and external moulds of the ventral valve NHM 68742a. b.

Type locality: Haverfordwest, Dyfed, Wales.

Type horizon: Haverford Mudstone Formation, Silurian, Rhuddanian.

**Diagnosis.** — Shell concavoconvex with ventral geniculation, transversely subtriangular to semielliptical in outline, about 63–65% as long as wide with a maximum width along the hinge line; cardinal extremities acute and slightly alate; ventral pseudointerarea apsacline to orthocline with a small apical pseudodeltidium; ribbing unequally parvicostellate without accentuated sagittal costa in the ventral valve; weakly defined concentric rugae

along the posterior margin of both valves, concentric filae variably developed; ventral interior with small composite plates bearing up to 10 denticles, and weakly impressed muscle field divided medianly by a fine ridge; dorsal interior with widely divergent dental plates and a short median ridge.

**Remarks.** — Shells from Kazakhstan are closely comparable with specimens of *Eopholidostrophia sefinensis ellisae* from Mathrafal and Haverfordwest, Wales (Hurst 1974; Temple 1970, 1987) in size, outline and transverse profile. They differ from the latter in having a finer radial ornamentation with 14–16 costellae per 2 mm in the number along the anterior margin of adult specimens, and fine evenly spaced concentric filae covering the shell surface. In the latter character they are similar to *E. sefinensis sefinensis* (Williams 1951: p. 124); however there is no accentuated sagittal costa on the ventral valve of the specimens from Kazakhstan.

**Material.** — Figured: ventral valve 32/12889 (L = 10.4, W = 15.6), ventral valve 33/12889 (L = 10.6, W = 19.9), dorsal external mould 35/12889 (L = 10.0, W = 15.4), ventral internal mould 36/12889 (L = 14.5, W = 22.9); 37/12899, dorsal internal mould. Total of 18 ventral and 2 dorsal valves.

**Occurrence.** — Akkerme Peninsula, localities 810 and 817.

Superfamily Fardenioidea Williams 1965

Family Fardeniidae Williams 1965

Genus *Saughina* Bancroft 1949

*Saughina* sp.

Fig. 7G–I.

**Description.** — Ventral valve unknown. Dorsal valve flat to gently convex, transverse, and suboval in outline about 58% as long as wide. Interarea low, planar, anacline with a broadly convex chilidium. Radial ornamentation unequally parvicostellate with 8 costellae per 2 mm along the anterior margin and with 2–4 finer costellae in the interspaces between accentuated costellae. Fine concentric filae about 14 per 1 mm in number cover all the shell surface. Dorsal interior has a small bilobed cardinal process fused with widely divergent, slightly curved socket plates.

**Remarks.** — These specimens recall in ornamentation and internal morphology of the dorsal valve specimens of *Saughina pertinax* (Reed 1917) described by Temple (1987: p. 90) and Modzalevskaya (1985), but an absence of information on the ventral valve makes the precise specific assignment of Kazakhstani shells impossible.

**Material.** — Figured: dorsal external mould 38/12889 (L = 15.7, W = 21.7), dorsal exterior 39/12889 (L = 13.4), dorsal internal mould 41/12889 (L = 10.3, W = 12.3), dorsal internal mould 42/12889 (L = 14, W = 17.3). Total of 5 dorsal valves.

**Occurrence.** — Akkerme Peninsula, localities 807-D and 817.

Order Pentamerida Schuchert & Cooper 1931

Superfamily Stricklandioidea Billings 1859

Family Stricklandiidae Billings 1859

Genus *Stricklandia* Billings 1859

*Stricklandia lens mullochensis* Reed 1917

Figs 6; 7R–U.

*Stricklandia mullochensis* sp. nov.; Reed 1917: p. 932, pl. 23: 5–8.

*Stricklandia lens prima* subsp. nov.; Williams 1951: p. 99, figs 19–20; Amsden 1966:

p. 1013, pl. 116: 1–7; Rubel 1977: p. 204, pl. 1: 8–16, pl. 2, pl. 5: 16–17; Cocks 1978: p. 141; Baarli & Johnson 1982: pl. 1: 1–3; Baarli 1986: pl. 21: 1–2.

*Stricklandia lens* (Sowerby, 1839) forma *a*; Rubel 1970a: p. 13, pl. 2: 1–12.

*Stricklandia lens mullochensis* Reed 1917; Temple 1987: p. 98, pl. 11: 1–4, pl. 12: 10–12.

Lectotype: Designated by Cocks 1978: p. 141; internal mould of dorsal valve NHM B72463.

Type locality: Mulloch Hill Quarry, Girvan, Scotland.

Type horizon: Mulloch Hill Formation, Silurian, Rhuddanian.

**Discussion.** — According to Temple (1987), *Stricklandia lens prima* Williams 1951 is indistinguishable from *S. mullochensis* Reed (1917) from Girvan District and he regarded *S. mullochensis* as a senior synonym of the former subspecies. This proposal is also accepted here.

Specimens of *Stricklandia* are common in the Rhuddanian of the Akkerme Peninsula; however it is impossible to collect a large number of well preserved internal moulds and casts for a detailed study of variations in the internal shell morphology for comparison with the observations of Baarli (1986) on Norwegian and Estonian *Stricklandia*. A few internal moulds and thin sections show a delicate cardinalia in the dorsal valve with long outer plates extended anteriorly beyond their fusion with the brachial processes and acutely triangular inner plates, which converge dorsally. Externally the specimens from Kazakhstan are characterised by a smooth shell of transversely suboval outline with a well defined ventral sulcus and dorsal fold. In these features they are closely comparable to specimens of *S. lens mullochensis* described by Rubel (1970, 1977) from the Juuru Stage of Estonia as *S. lens prima*.

**Material.** — Figured: complete shell 44/12889 (L = 9.4, T = 5.7), dorsal valve 45/12889 (L = 6.9, W = 14.5). Total of 5 complete shells, 34 ventral and 31 dorsal valves.

Fig. 7. □A–F. *Zygospiraella duboisi* (de Verneuil 1845). A Dorsal valve 56/12889 exterior; locality no. 817; × 3. B. Ventral internal mould 55/12889; locality no. 817; × 2. C–E. Conjoined valves 54/12889; ventral (C), dorsal (D), and side (E) views; locality no. 807-A; × 2. F. Ventral internal mould 58/12889; locality no. 817; × 3. □G–I. *Saughina* sp. G. Dorsal valve exterior 40/12889, latex cast; locality no. 817; × 2. H. Dorsal valve exterior 38/12889, latex cast; locality no. 817; × 2. I. Dorsal internal mould 41/12889; locality no. 817; × 2. □K–Q. *Meifodia tulkulensis* sp. n. J. Ventral internal mould 77/12889; locality no. 807-D; × 2. K. Dorsal internal mould 74/12889; locality no. 817; × 2. L–N. Conjoined valves 71/12889, holotype; side (L), dorsal (M), and ventral (N) views; locality no. 808; × 2. O–Q. Conjoined valves 72/12889; side (O), ventral (P), and dorsal (Q) views; locality no. 810; × 2. □R–U. *Stricklandia lens mullochensis* Reed 1917. R–T. Conjoined valves 44/12889; ventral (R), posterior (S), and dorsal (T) views; locality no. 8853; × 3. U. Dorsal valve exterior 5/12889; locality no. 817; × 2.

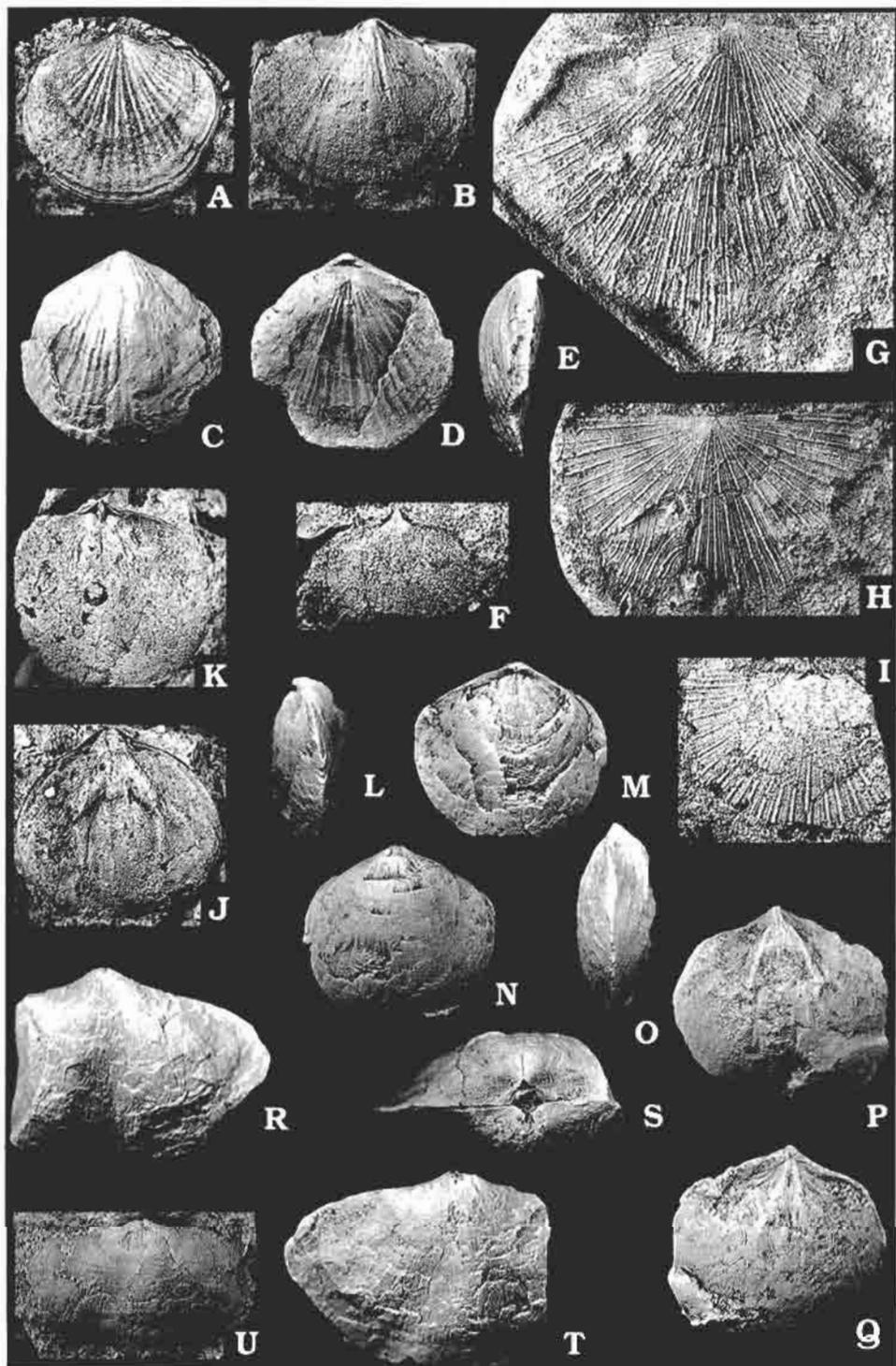


Table 2. *Zygospiraella duboisi* (de Verneuil 1845), average dimensions of 14 ventral and 8 dorsal valves.

	Ventral valves			Dorsal valves		
	L	W	L/W	Ld	W	Ld/w
X	8.8	9.4	84%	8.75	10.0	88%
S	2.00	2.31	6.4	2.25	2.47	9.6
MIN	5.4	5.6	82%	6.6	6.8	76%
MAX	12.5	13	106%	12.6	14.2	100%

Table 3. *Eospirigrina porkuniana* (Jaanusson 1970), average dimensions of 9 complete shells.

	L	W	T	Sw	L/W	T/L	Sw/W
X	9.6	9.1	4.4	4.7	109%	46%	53%
S	3.06	4.01	1.85	1.70	1.09	5.4	10.5
MIN	6.6	5.7	2.7	2.9	87%	38%	35%
MAX	16.2	18.6	8.4	8.2	122%	51%	67%

**Occurrence.** — Akkerme Peninsula, localities 412, 807-D, 808, 810, 817, and 8853.

Order Atrypida Rzhonsnitskaya 1960

Suborder Atrypidina Rzhonsnitskaya 1960

Superfamily Atrypoidea Gill 1871

Family Atrypidae Gill 1871

Genus *Zygospiraella* Nikiforova 1961

### *Zygospiraella duboisi* (de Verneuil 1845)

Fig. 7A–F; Table 2.

*Zygospiraella duboisi* (de Verneuil 1845); Rubel 1970a: p. 28, pl. 13: 1–15 (full synonymy);

Lopushinskaya 1976: p. 64, pl. 11: 7; Modzalevskaya 1985: p. 67, pl. 4, 1978.

*Zygospiraella scotica* (Salter 1851); Cocks 1978: p. 159 (full synonymy).

**Diagnosis.** — Shell planoconvex, subcircular in outline; anterior commissure rectimarginate to weakly sulcate; ventral valve moderately and evenly convex, weakly subcarinate, with a small acute, slightly incurved beak and delthyrium covered laterally by plates; dorsal valve flat with a shallow sulcus originating at the umbonal part of the valve; shell surface costellate with rounded costellae; lamellose distally; spiralia with 4–5 whorls, dorsally directed; disjunct jugal processes subcentrally placed, turned dorsally.

**Remarks.** — In the outline and convexity of the shell, as well as in the ornamentation, specimens from central Kazakhstan fit well within the wide range of variability of *Zygospiraella duboisi* (Nikifirova & Andreeva 1961; Rubel 1970a). However, they possess a somewhat coarser radial ornamentation (of 21–23 costellae in the mature specimens), show few rib bifurcations, and are invariably characterized by a planoconvex shell. Cocks (1978: p. 159) emphasised the similarity and possible conspecific nature of *Z. duboisi* and *Z. scotica*. Our study of specimens of *Z. scotica*

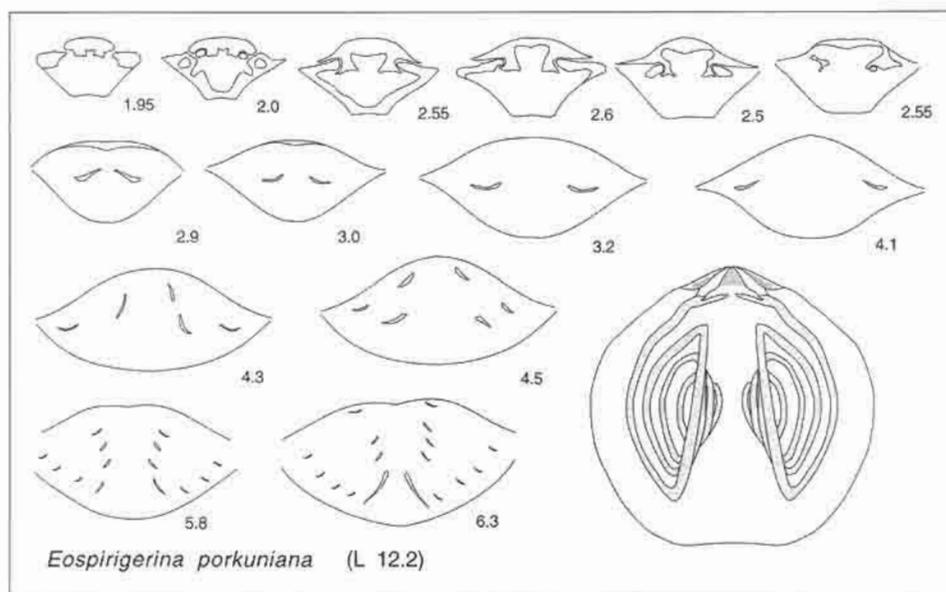


Fig. 8. Serial sections and reconstruction of the spiralia and jugal processes of *Eospirigerina porkuniana* (Jaanusson 1970) based on specimen 70/12889.

deposited at the Natural History Museum, London, shows that in the outline of valves and rib structure there are no significant differences between these two species. Thus the British specimens are regarded here as conspecific with *Z. duboisi*. *Z. duboisi* is also closely comparable with *Z. planoconvexa* (Hall). According to Copper (1982), there are only minor differences between these two species, which are difficult to identify on specimens from Kazakhstan in a view of the different preservation. It is probable that *Z. planoconvexa* is a geographic variant within *Z. duboisi*.

**Material.** — Figured: complete shell 54/12889 (L = 12.7, W = 12.7, T = 3.6), ventral internal mould 55/12889 (L = 12, W = 13.5), dorsal external mould 56/12889 (L = 11.2, W = 12.9), dorsal internal mould 58/12889 (L = 12.2, W = 13.5). Total of 21 complete shell, 53 ventral and 29 dorsal valves.

**Occurrence.** — Akkerme Peninsula, localities 807-A, 807-D, 808, 817, and 8853.

Genus *Eospirigerina* Boucot & Johnson 1967

*Eospirigerina porkuniana* (Jaanusson in Rubel 1970)

Figs 8; 10A–J; Table 3.

*Spirigerina* (*Eospirigerina*) *porkuniana* Jaanusson, in coll.; Rubel 1970a: p. 30; pl. 14: 16–27; pl. 15: 11–17, 21, 22.

*Eospirigerina* cf. *porkuniana* (Jaanusson); Modzalevskaya 1985: p. 68; pl. 4: 6–8, 12.

Holotype: By original designation, complete shell GIT Br664.

Type locality: Porkuni village, Estonia.

Type horizon: Juuru Stage, Silurian, Rhuddanian.

Table 4. *Meifodia tulikulensis* sp. n., average dimensions of 16 complete shells.

	L	W	T	L/W	T/L
X	8.8	9.0	4.3	99%	49%
S	1.72	1.83	0.86	7.1	6.8
MIN	6.4	5.7	2.8	86%	37%
MAX	12	12.2	5.6	112%	64%

**Diagnosis.** — Shell slightly dorsibiconvex, subcircular in outline, with an anacline ventral beak, well developed ventral sulcus forming a semielliptical tongue, and dorsal fold; radial ornamentation costellate with 8 costellae per 5 mm along the anterior margin, total about 30–40 costellae in adults; concentric ornamentation of evenly spaced filae and numerous growth lamellae.

**Description.** — Shell slightly dorsibiconvex, subcircular in outline, on average 108% as long as wide and 53% as thick as long. Anterior commissure uniplicate in adults. Ventral valve moderately convex with a slightly anacline beak. Delthyrium widely triangular, covered laterally by deltidial plates fusing at their base. Sulcus originates near the beak as a plication between two accentuated ribs, deepening anterior to the mid-length and forming a moderately high semielliptical tongue. Dorsal valve moderately convex with a sharply edged fold on average 53% as wide as a maximum valve width. Ornamentation costellate with 30–37 costellae in adult shells. Concentric ornamentation of fine, evenly spaced filae and numerous growth lamellae.

Ventral interior with small teeth supported by short, thin dental plates. Muscle field large, bilobate with strongly elongated diductor scars extending to the center of the valve. Dorsal interior with disjunct hinge plates. Crura laterally directed, circular in a cross section. Spiralia dorsally directed, with about five whorls.

**Remarks on the ontogeny.** — Young shells of *Eospirigerina porkuntiana* tend to be elongately subtriangular in outline. They differ from larger shells in having a deeper ventral valve and intraplicate anterior commissure. The dorsal fold originates as a single rib that bifurcates distally. About 5 mm from the beak the fold is raised above two accentuated primary costae that flank it laterally. A single rib (rarely two) originates by intercalation in the sulcus near the ventral beak. Three or four primary costae are present on the flanks of both valves. Gerontic specimens are almost as long as wide, or slightly wider than long and usually dorsibiconvex.

**Remarks.** — *Eospirigerina porkuntiana* differs from the contemporaneous species *E. parksi* (Williams 1919) and *E. tripartita* (Sowerby 1839) in having a subcircular to slightly elongate shell outline, coarser radial ornamentation and more strongly developed concentric ornamentation. Internally there are up to five dorsally directed spiralia whorls.

**Material.** — Figured: complete shell 60/12889 (L = 15.8, W = 15.6, T = 7.8, Sw = 7.6), complete shell 61/12889 (L = 6.8, W = 6.2, T = 8.7), ventral

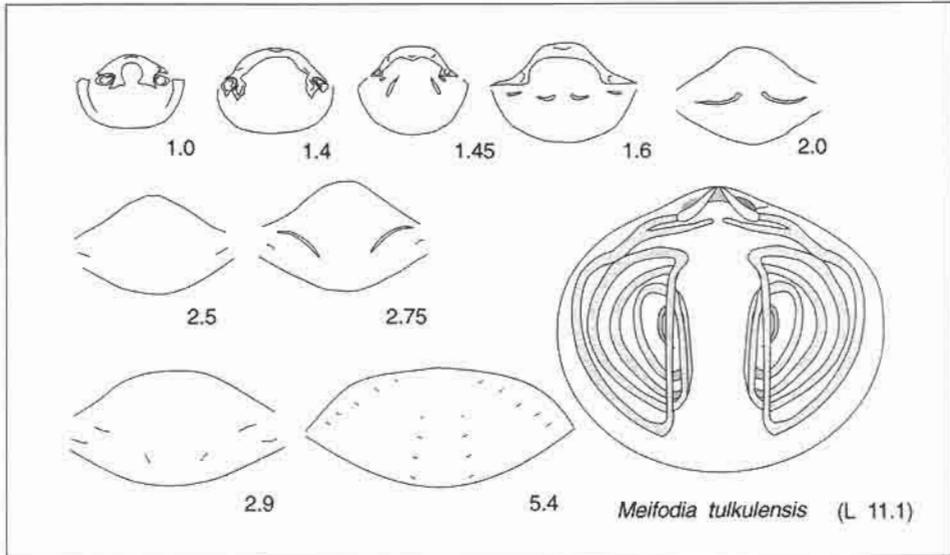


Fig. 9. Serial sections and reconstruction of the spiralia and jugal processes of *Meifodia tulkulensis* sp. n. based on specimen no. 76/12889.

internal mould 62/12889 (L = 16, W = 16.4), complete shell 63/12889 (L = 11.0, W = 10), damaged complete shell 64/12889. Unfigured: complete shell 65/12889 (L = 10, W = 9, T = 5.3), complete shell 69/12889 (L = 11.1, W = 11.3, T = 4.4). Total of 68 complete shells, 13 ventral and 5 dorsal valves.

**Occurrence.** — In Kazakhstan *E. porkuniana* is relatively abundant in the early Rhuddanian of the Akkerme Peninsula, localities 412, 807-B, 807-D, 808, 810, and 8853.

Superfamily Lissatryoidea Twenhofel 1914

Family Lissatrypidae Twenhofel 1914

Subfamily Lissatrypinae Twenhofel 1914

Genus *Meifodia* Williams 1951

*Meifodia tulkulensis* sp. n.

Figs 7L-Q, 9; Table 4.

Ethymology: After Tulkuli Ridge on the Akkerme Peninsula.

Holotype: Complete shell 71/12889 (L = 11.3, W = 12.2, T = 5.2).

Type locality: 817. Akkerme Peninsula, western coast of Lake Balkhash, Kazakhstan.

Type horizon: Silurian, Rhuddanian.

**Diagnosis.** — Shell, ventribiconvex, subcircular in outline about as long as wide with rectimarginate or weakly uniplicate anterior commissure, lack of fold and sulcus, internally with fine dorsal median ridge not extending to mid-valve and dorsally directed spiralia with about 4–5 whorls.

**Description.** — Shell smooth, slightly ventribiconvex, subcircular in outline, on average 99% as long as wide and 49% as deep as long. Anterior commissure rectimarginate to weakly uniplicate. Ventral valve moderately and evenly convex with an orthocline to slightly anacline beak, a submesothryrid pedicle opening and lacking delthyrial plates. Dorsal valve moderately and evenly convex with a small, strongly incurved beak.

Ventral interior with small teeth and rudimentary dental plates masked by secretion of a secondary shell in adults. Muscle field large, subtriangular in outline, bounded laterally by ridges. Mantle canal system pinnate. Dorsal interior with a split hinge plate, well defined, widely divergent sockets and a fine median ridge not extending to the mid-valve. Spiralia have 4–5 whorls, dorsally directed. Jugal processes disjunct.

**Discussion.** — This species differs from *Meifodia subundata* (M'Coy) (Williams 1951: p. 107) and *M. ovalis* Williams (1951: p. 109) in the subcircular outline of the shell, which completely lacks a fold and sulcus. *M. tulkulensis* sp. nov. is similar to the juvenile specimens of *M. recta alia* (Nikiforova 1968: pl. 23: 13) in the external morphology and convexity of the shell and the rectimarginate anterior commissure, but a shallow ventral sulcus originates near the anterior margin of the adult shells in the latter species.

**Paratypes.** — Figured: complete shell 72/12889 (L = 2.7, W = 13.8, T = 5.0), dorsal internal mould 74/12889, ventral internal mould 77/12889. Unfigured: complete shell 73/12889 (L = 8.0, W = 8.4, T = 3.4), complete shell no 75/12889 (L = 8.0, W = 6.9). Total of 93 complete shells, 20 ventral and 7 dorsal valves.

**Occurrence.** — *M. tulkulensis* is abundant in the early Rhuddanian of the Akkerme Peninsula, Kazakhstan, localities 412, 807-A, 807-B, 807-D, 808, 810, 817, and 8853.

Subfamily Cyclospirinae Schuchert 1913

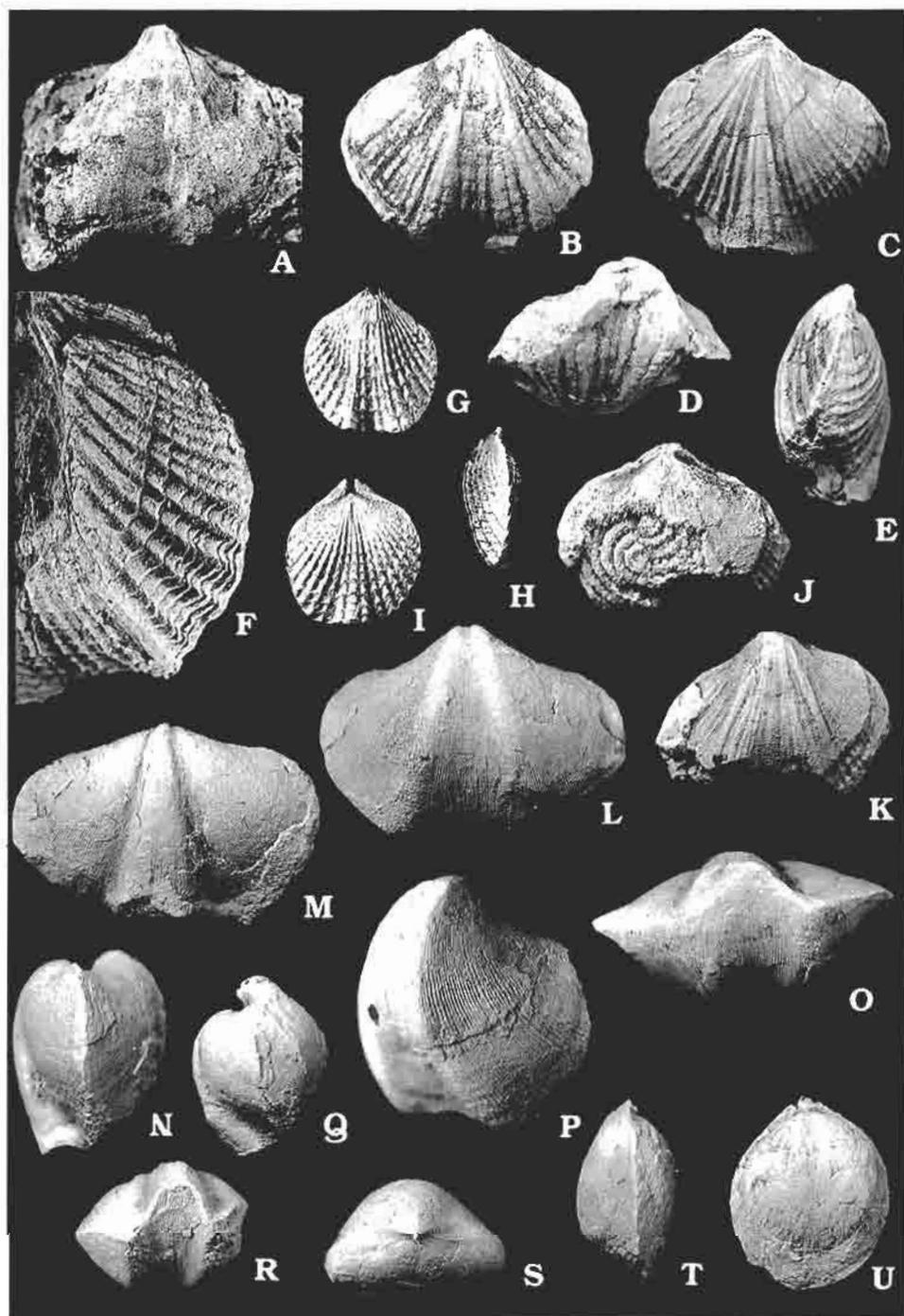
Cyclospirinae gen. et sp. indet.

Figs 8S–U, 11.

**Description.** — Shell slightly ventribiconvex, elongate, subelliptical in outline, about 118% as long as wide and 55% as deep as long. Anterior commissure rectimarginate. Ventral valve strongly and evenly convex,

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Fig. 10. □A–K. *Eospirigertina porkuniana* (Jaanusson 1970). A. Ventral internal mould 62/12889; × 2; locality no. 807-D. B–E. Conjoined valves 60/12889; ventral valve (B), dorsal exterior (C), anterior view (D), side view (E); locality no. 808; × 2. F. Ornamentation of the ventral valve 64/12889; locality 808; × 5. G–I. Conjoined valves 61/12889; ventral (G), side (H), and dorsal (I) views; locality no. 8853; × 3. J–K. Conjoined valves 63/12889; dorsal view showing spiralia (J), ventral view (K); locality 808; × 2. □L–R. *Eospirifer cinghizicus* M. Borissiak 1955. L–O. Conjoined valves 80/12889; ventral (L), dorsal (M) N, side (N), and anterior (O) views, locality no. 8853, × 3. P. Ventral valve 82/12889, oblique lateral view, locality no. 807-D, × 5. Q, R. Conjoined valves 81/12889; side (Q), and anterior (R) views; locality no. 808; × 2. □S–U. Cyclospirinae gen. et sp. indet., conjoined valves 79/12889; posterior (S), side (T), dorsal (U) views; locality no. 8853; × 3.



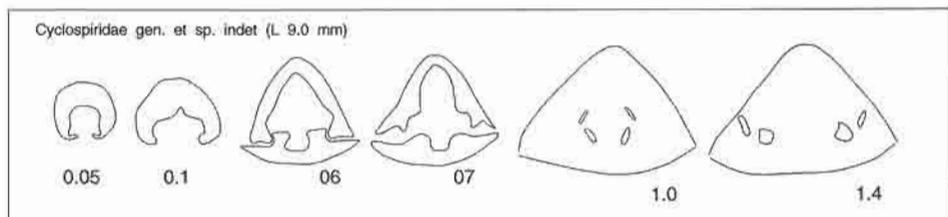


Fig. 11. Serial sections of *Cyclospirinae* gen. et sp. indet. based on specimen 79/12889.

subcarinate with erect beak. Dorsal valve moderately convex with maximum height at the posterior third of the valve. A shallow sulcus originates near the beak and disappears at the mid-length. Ventral interior with small teeth and rudimentary dental plates masked by secretion of a secondary shell in adults. Dorsal interior with a split hinge plate. Spiralia are unknown.

**Remarks.** — The external characters and the internal morphology of the ventral valves of these specimens suggest a close affinity with *Cyclospira*. In general shell shape and the presence of a shallow dorsal sulcus lacking a median fold they are comparable to *Cyclospira sulcata* Cooper 1956 (Cooper 1956: p. 696). However, the specimens from the Rhuddanian of Kazakhstan may be distinguished from *C. sulcata* in having a rectimarginate anterior commissure of adult specimens, more strongly convex dorsal valve with a sulcus becoming indistinct anteriorly and in attaining twice the size. They also differ from all other species of *Cyclospira* in the absence of a dorsal median septum.

**Material.** — Figured: complete shell 72/12889 (L = 11.2, W = 12.2, T = 4.6); 75/212889, ventral internal mould. Unfigured: complete shell 73/12889 (L = 8, W = 8.4, T = 3.4). Total of 3 complete shells.

**Occurrence.** — Akkerme Peninsula, locality no. 8853.

Order Spiriferida Waage 1883

Superfamily Cyrtioidea Frederiks 1919

Family Cyrtiidae Fredericks 1919

Subfamily Eospiriferinae Schuchert 1929

Genus *Eospirifer* Schuchert 1913

*Eospirifer cinghizicus* M. Borissiak 1955

Figs 10L–R, 12.

*Eospirifer cinghizicus* sp. nov.: Borissiak 1955: p. 68, pl. 12: 6–9 (not fig. 6a).

Lectotype: Selected here, complete shell CNIGR 6/7304 (figured by Borissiak 1955: pl. 12: 6b–f [not 6a]).

Type locality: Akdombak mountain, Chingiz Range, Kazakhstan.

Type horizon: Alpeis Formation, Silurian, Rhuddanian.

**Diagnosis.** — Shell ventribiconvex, transversely subpentagonal in outline; ventral interarea strongly curved with an open delthyrium; delthyrium covered laterally by small deltidial plates; ventral sulcus and dorsal fold

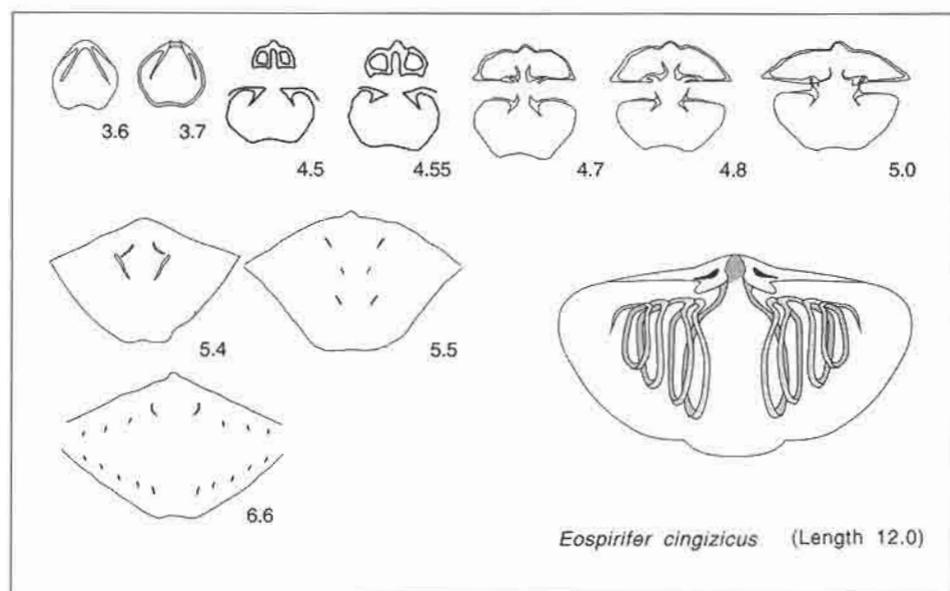


Fig. 12. Serial sections and reconstruction of the spiralia of *Eospirifer cinghizicus* M. Borisiak 1955 based on specimen 83/12889.

well defined laterally, with an U-shaped cross-sectional profile; ornamented by fine striae about 11 per 1 mm along the anterior margin of adult specimens; dental plates short, divergent, ventral muscle field weakly impressed; spiralia with about five whorls directed posterolaterally.

**Description.** — Shell ventribiconvex about 73–97% as long as wide with the maximum width slightly posterior to mid-length, and 66–73% as deep as long, transversely subpentagonal in outline. Hinge line is about 73–74% of the maximum width of the shell. Cardinal extremities rounded. Anterior commissure strongly uniplicate. Ventral valve strongly and evenly convex with an apsacline interarea strongly curved in cross section. Sulcus originates near the umbo forming a high semielliptical tongue. Dorsal valve moderately convex with a short, incurved interarea and strong steep-sided fold originating near the umbo. Shell ornamented by fine radial striae about 11 per 1 mm along the anterior margins of adult specimens.

Ventral interior with small teeth supported by short dental plates divergent slightly toward the anterior margin and a weakly impressed muscle field. Dorsal interior with a split hinge plate supported by long crural plates with bases divergent anteriorly. Crura originate from crural plates near their junction with the hinge plate. Spiralia have about five whorls and are directed posterolaterally.

**Discussion.** — Specimens of *Eospirifer cinghizicus* from the lower Rhudanian of the Akkerme Peninsula are closely comparable in the shell shape and size with topotypes described by Borisiak (1955) from the lower part of the Alpeis Formation, Chingiz Range. Our specimens differ only in

having finer radial ornamentation. This species is distinguished from *E. kassini* Borissiak 1955 (Borissiak 1955: p. 69), recorded from the upper part of the Alpeis Formation of Chingiz Range, in having a more strongly developed fold and sulcus and finer radial ornamentation. However, the original description of the latter species is based on a small number of poorly preserved specimens and information on the interior of both valves is inadequate. Another species of *Eospirifer* from the early Llandovery of Kazakhstan is *E. olgae* Borissiak 1955 (Borissiak 1955: p. 66). The type material of this species is represented by a few poorly preserved internal and external moulds, which makes exact comparison with any other species of *Eospirifer* impossible. *E. olgae* is regarded here as *nomen dubium*. *E. cinghizicus* is closely similar to *E. radiatus* (Sowerby 1834) (Rubel 1970a: p. 59) in the convexity and outline of the shell, and a fine radial ornament. It may be distinguished from the latter in having an U-shaped cross-sectional profile of the fold and sulcus, fine radial ornamentation and in being of smaller size.

*E. cinghizicus* differs from the approximately contemporaneous Australian species *E. tasmanensis* Sheehan & Baillie (1981) in having a finer, radial ornament, U-shaped cross-sectional profile of the fold and sulcus, discrete deltidial plates and shorter dental plates.

Rong *et al.* (1994) have provided a comprehensive discussion on Rhudanian and early Aeronian eospiriferines.

**Material.** — Figured: complete shell 80/12889 (L = 9.8, W = 14.1, T = 7.4); 81/12889 (L = 12.1, T = 8.7), ventral valve 82/12889 (L = 7, W = 9.8). Total of 7 complete shells, 6 ventral and 3 dorsal valves.

**Occurrence.** — Akkerme Peninsula, localities 807-D, 808, 817, and 8853.

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## Streszczenie

Opisano obfitą faunę ramienionogową pochodzącą z wczesno-sylurskich warstw odsłoniętych wzdłuż północno-wschodniego wybrzeża półwyspu Akkerme (jez. Bałkasz, Kazachstan). Obecność w zespole *Stricklandia lens mullochensis*, która jest najwcześniejszym przedstawicielem linii *Stricklandia-Costistricklandia*, pozwala datować badany zespół na wczesny ruddanian, tj. interwał obejmujący poziomy od *Akidograptus acuminatus* do *Monograptus cyphus*. Jest to pierwsze tak dobrze udokumentowane występowanie ramienionogów tego wieku w Kazachstanie. Po raz pierwszy stwierdzono współwystępowanie *Stricklandia lens mullochensis* i *Eospirifer cinghizicus*, które zdaniem autorów, stanowi najistotniejszą różnicę między opisywaną fauną a zespołami tego wieku z Platformy Wschodnio-Europejskiej i Wielkiej Brytanii.