FAUNAL CHANGE NEAR THE END-PERMIAN EXTINCTION: THE BRACHIOPODS OF THE ALI BASHI MOUNTAINS, NW IRAN

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Abstract. The Julfa Formation in the Ali Bash Moun tens, northwest Iran, is very rich in brachiopods, particularly in its lower part, which has been dated by fusulinids and conodonts as Wuchiapingian in age. The brachiopod fauna described herein has been collected along the Main Valley section of the Ali Bash Mountains, several hundred metres away from the historical sections described in the 1960's and 1970's. It comprises 39 species of the orders Productida, Orthotetida, Orthida, Rhychnonellida, Athyridida, Spirellida, and Terebratulida, most of which are known in the coeval successions of Transcaucasia, Alborz Mountains in north Iran and in South China, confirming the Wuchiapingian age indicated by other proxies. A new of the brachiopod taxa range up into the Changhsiangian Parasimilites Limestone.

The shale and marly limestone at the base of the formation are dominated by semi-infaunal productids, that are progressively succeeded near the top of the lower part of the formation by a more diverse range of pedicle attached and cemented taxa, suggesting a sloping upward trend and a shift to higher nutrient-substrates in more turbulent waters. The successive deepening trend recorded in the upper part of the Julfa Formation and in the overlying Ali Bash Formation is very unfavourable for the brachiopods and only a few species survive, represented by small sized pediculate taxa that thrive on hardgrounds.

Introduction

The Upper Permian sections of Iran and Transcaucasia have been known for a long time to be among the most fossiliferous in the Neotethys, especially those of the Ali Bash Mountains (= Kuh-e-Ali Bash), Julfa, Iran, and those of the Araxes (Aras) Gorge, near Dorasham, Azerbaijan (Abich 1878; Frech & Athaber 1900; Stoyanow 1910, 1915; Bonnet 1912; Rieben 1934; Bonnet & Bonnet 1947; Ruzhentsev & Sarytcheva 1965; Stepanov et al. 1969; Teichert et al. 1973; Rozovtsev & Azaryan 1973; Kozur et al. 1980; Kozur 2005, 2007; Kotlyar et al. 1983; Ghaderi et al. 2013; Leda et al. 2013). They are among the best localities to study the dramatic faunal change of marine organisms at the end of the Palaeozoic and unravel the debated causes of the end Permian mass extinction (e.g. Sepkoski 1984; Hallam & Wignall 1997; Erwin 2006; Knoll et al. 2007; Shen et al. 2011; Clapham & Payne 2011; Brand et al. 2012).

The marine sections in Transcaucasia, North and Central Iran provide a unique opportunity to study uninterrupted, highly fossiliferous successions in carbonate with claystone-dominated facies and represent an important link to the well-investigated Chinese Permian-Triassic boundary sections (e.g. Jin et al. 2006; Shen & Shi 2007; Shen et al. 2011).

Here, we describe the systematics and the faunal change of the brachiopods, one of the groups of benthic animals that suffered most significantly during the end Permian crisis (Clapham & Payne 2011), along a Permian-Triassic section in the Ali Bash Mountains, northwest Iran (Figs 1-2). These outcrops were discovered in the 1850’s by Abich and described by many authors (e.g. Frech & Athaber 1900; Stoyanow 1910, 1915; Rieben 1934; Stepanov et al. 1969; Teichert et al. 1973; Baud et al. 1974; Altiner et al. 1982; Kozur 2004, 2005, 2007; Richoz 2006; Richoz et al. 2010; Ghaderi et al. 2013;
Leda et al. 2013). The outcrops closely resemble those of Dorasham in Transcaucasia, which is located only nine kilometres northwestward. The brachiopods described in this paper have been collected bed-by-bed by some of us in the Upper Permian Julfa and Ali Bashi formations along the Main Valley section of the Ali Bashi Mountains, northwest Iran (Figs 1-3).

This study considerably extends the knowledge of Lopingian brachiopods from North Iran and Transcaucasia, previously documented in the works of Stoyanov (1910, 1915, 1942), Bonnet & Bonnet (1947), Rushtonsev & Sarytcheva (1965), Stepanov et al. (1969), Teichert et al. (1973), Angiolini & Carabelli (2010), and Angiolini et al. (2010). In fact, only few of these papers pro-
vide systematic descriptions of the brachiopods from these regions and none in particular describes the systems and faunal change of the brachiopods from the Ali Bashi Mountains, Julfa.

This paper provides a sound taxonomic account of the brachiopod fauna tied in to a detailed stratigraphic section, clarifies the position of data from older literature, and provides insights for understanding the biotic change near the end Permian mass extinction.

**Geological setting**

North and Central Iran have long been considered part of the Cimmerian blocks of Gondwana ancestry (Sengor 1979; Stampfli et al. 1991; Stampfli & Borel 2002; Angiolini et al. 2007; Gaetani et al. 2009), that rifted from Gondwana in the Early Permian to reach a palaeoequatorial latitude in the Late Permian (Muttoni et al. 2009). Collision with the Eurasian active margin happened in the Late Triassic (Zanchi et al. 2009).

The Permian-Triassic sedimentary succession of northwest Iran is 1120 m thick, and it is well exposed in the Ali Bashi Mountains, west of the town of Julfa, Iran (Figs 1-2). The base of the Permian succession corresponds to an unconformity above Devonian? Carboniferous volcano-sedimentary rocks. Permian deposits begin with 110 m of red siliciclastics, possibly equivalent to the Dorud Group (Gaetani et al. 2009) of the Alborz Mountains, North Iran. This succession is unconformably covered by marine carbonates ranging from the Middle Permian to the Triassic, which were first described by Stepanov et al. (1969) (Tab. 1). These authors recognized eight rock units (A-H) in a thickness of about 1000 meters. Units A (Gnishik beds) and B (Khachik beds) of Middle Permian age; units C (Lower Julfa beds), D (Upper Julfa beds), and lower part of unit E (Transitional beds) of Late Permian age; unit F (Paratirolites Limestone) of Early Triassic age; and units G and H, considered as equivalent to the Elkah Formation (Glaus 1964) of the Alborz Range. Later, Teichert et al. (1973) described four sections at Localities 1 to 4, located about 500 m apart, and introduced the name Ali Bashi Formation for units E and F of Stepanov et al. (1969), which were considered to be latest Permian in age (Tab. 1). According to Teichert et al. (1973), the Ali Bashi 1 section may serve as a standard for all lithostratigraphic PTB sections in northwest Iran (Fig. 3). There has been a long standing debate (e.g. Sweet & Mei 1999a, b; Kozur 2004, 2005, 2007; Henderson et al. 2008; Baud 2008, Shen & Mei 2010; Leda et al. 2013) on the problem of correlation of Locality 4 of Teichert et al. (1973) with the other localities. However, very recently Ghaderi et al. (2013) and Leda et al. (2013) have shown that Locality 4 has the same succession as the other Ali Bashi sections, as already suggested by Henderson et al. (2008) and Baud (2008). The latter author found that the microfacies of the upper part of Locality 4 in the section of Teichert et al. (1973) is the same of that of the base of Locality 1 (section of Teichert et al. 1973). Whereas the microfacies of the Paratirolites bed is very different, being "...a nodular lime mudstone with intraclasts and with microammonoid and bivalve shells" (Baud 2008, p. 8). In addition, Leda et al. (2013) described in detail the distinctive fabric of the Paratirolites Limestone that is nodular with abundant intraclasts of red limestone.

Thus Teichert et al. (1973) correlated the top of the Julfa Formation of Locality 4, which is formed by red marly limestones, with the Paratirolites Limestone of Locality 1 (Leda et al. 2013). According to Henderson et al. (2008, p. 9), Teichert et al. (1973) "...apparently did not finish the section at Locality 4..."
In this research, we will focus on the brachiopods from the Julfa and Ali Bashi formations of the Ali Bashi Mountains Main Valley section, which is located 8 km west of Julfa at 38°56’06” N, 45°31’21” E (Figs 1-3). This section comprises, from base to top, the following rock units (Fig. 4, Tab. 1):

**Tab. 1** - Comparison among the stratigraphic classifications of the Permian-Triassic succession of the Ali Bashi Mountains of Stepanov et al. (1969), Teichert et al. (1973) and the one followed in the present paper.

**Julfa Formation**: 34.99 m thick, Wuchiapingian in age based on conodonts (e.g. Sweet & Mei 1999a, b; Shen 2007; Henderson et al. 2008). It conformably overlies a dark grey bioclastic packstone, named *Codonofusiella* Limestone, that is the uppermost member of the underlying Khachik Formation. According to the for-
Fig. 4 - Stratigraphic log of the Main Valley Section (38°56'06" N, 45°31'21" E) showing the range of the studied brachiopods.
Fig. 5 - Foraminifers from the Julfa and Al Bashi formations. Scale bar is 200 micron.
1, 6) *Froudinia* ex gr. *permica*; 1 - subaxial section, Sample G119; 6 - subaxial section, Sample G125. 2) *Froudinia* sp.; Sample G120. 3) *Climacammina* sp.; subaxial section, Sample G120. 4) *Palaeotextularia* sp.; subaxial section, Sample G125. 5) *Codonofusiella* cf. *kwaniana*; equatorial section, Sample G124. 7) *Globorotalia* cf. *vonderschmittii*; subequatorial section, Sample G118. 8) *Pseudobovina* sp.; subequatorial section, Sample G111. 9) *Agathammina* sp.; longitudinal sections, Sample G124. 10) *Hemigordius* sp.; longitudinal sections, Sample G120. 11) *Neoendothrya* sp.; axial section, Sample G264. 12) *Glomomidiella nestellonii*; oblique section, Sample G106B. 13) *Nankinella* sp.; subequatorial section, Sample G106. 14) *Paragloborotalia gracilis*; subequatorial section, Sample G110. 15) *Rectostipulina quadrata*; transverse section, Sample G247.
aminiferal content (i.e. Agathammina sp., Codonofusiella sp., Codonofusinella kwangasiana, Climacamina sp., Frondina ex gr. permica, Frondina sp., Globorotalina cf. vonderschmitti, Glomomodiella nestellorum, Hemi-gordius spp., Nankinella sp., Palaeotextulina sp., Paradongohalia gracilis, Pseudobasilina sp.), which we illustrate for the first time in Fig. 5, the Codonofusinella Limestone is Wuchiapingian and not Guadalupian as previously suggested by Stepanov et al. (1969) and Teichert et al. (1973) (Tab. 1). Altiner et al. (1980) previously reported foraminifers from the upper member of the Ali Bashi Formation (Locality 3, including Sher-vyrevites and Paratirolites beds). These authors recorded a foraminiferal assemblage referred to as Capitanian-Wuchiapingian in age, pointing out the lack of genera and species markers of the latest part of the Late Permian.

The Julfa Formation consists of grey to red shale with nodular limestone (bioclastic wackestone and oolite-cemented lime mudstone) and marlstone intercalations. The macrofauna comprises brachiopods (particularly common at the base of the formation), ammonoids (Araxoceras in the lower part, Vedioceras in the upper part), nautiloids, and rugose and tabulate corals.

The Julfa Formation records an overall deepening trend reaching outer ramp conditions, punctuated by several cycles.

**Ali Bashi Formation**: 15.94 m thick, Changhsingian in age based on conodonts (e.g. Sweet & Mei 1999a, b; Shen 2007; Henderson et al. 2008). It comprises two units:

a) Unnamed shaly unit at the base, 11.08 m thick, with red to purple shale with several horizons of redish, nodular mudstone and peloidal mudstone with brachiopods, ammonoids, corals, ostracods, conodonts, fish remains and echinoderms.

b) Paratirolites Limestone, 4.86 m thick, a conspicuous unit composed of thin-bedded, red nodular limestone and marlstone with intercalation of red shale. The limestone consists of burrowed bioclastic wackestone with ammonoids, ostracods, conodonts, fish remains, echinoderms, radiolarians, and foraminifers deposited in an oxygenated deep shelf environment below the storm wave base (Leda et al. 2013). Towards the top of the unit there is evidence for a decrease in the carbonate fraction; the unit shows evidence of condensation with an increasing number of hardgrounds, and bored and encrusted bioclasts and lithoclasts.

A noticeable accumulation of Lithistida sponge remains occurs in the uppermost 2 cm of the Paratirolites Limestone, named "Sponge Spike" by Leda et al. (2013) and considered to possibly mark the extinction horizon in the section. The microfacies consists of a sponge packstone with partially articulated skeletons of siliceous sponges, which are embedded in a thick micritic matrix.

**Elkah Formation**: latest Permian-Early Triassic in age. Its basal part is composed of two different units:

a) 'Boundary Clay' (0.65 m thick in the Main Valley section); latest Changhsingian in age. The 'Boundary Clay' is composed of red and green shale with a few intercalations of marly nodules, consisting of sponge wackestone and burrowed ostracod mudstone. According to Leda et al. (2013) they have been deposited on a deep shelf in suboxic conditions.

b) Carbonate unit, more than 7 m thick in the Main Valley section, but mostly covered. This unit contains the P-T boundary at 0.6 m from its base, as indicated by the first appearance of the conodont *Hindeodus parvus* (Ghaderi in progress). The lower part of this unit (from 1.18 to 2.05 m above the extinction horizon) comprises yellow-grey, marly, thin-bedded, platy limestone intercalated with green and red marly shale. Light-grey, thick-bedded limestone beds intercalated with grey shale overlie these. The most common fossils are ostracods, gastropods, conodonts and bivalves. The microfacies consist of a densely laminated bindstone, a wackestone with calcite sparry spines, and an ooid floatstone. The lower part of this unit seems to have been deposited in a deep environment similar to that of the Paratirolites Limestone (Leda et al. 2013).

**The brachiopod fauna**

The studied brachiopod fauna comprises 39 species of the orders Productida, Orthothetida, Orthida, Rhynchonellida, Athyridida, Spiriferida, and Terebratulida.

The brachiopod fauna mostly occurs in the lower Julfa Formation (lower Julfa beds), with sixteen species occurring in the upper Julfa Formation and only two (*Transcaucusathyris lata* and *Dielasma* sp. ind.) ranging to the top of the Paratirolites Limestone (Fig. 4).

Stepanov et al. (1969) reported a few more brachiopod species from the Ali Bashi Formation (both from the unnamed shaly unit and from the Paratirolites Limestone). However, abundance and diversification of brachiopods in the Julfa Formation are higher than the Ali Bashi Formation, which has a rich ammonoid content. A decline of brachiopod diversity and abundance over the two formations may be linked to a gradual facies change caused by deepening. However, Angiolini et al. (2010) have shown that the stratigraphic abundance of brachiopod species (calculated as the percentage of samples in which each brachiopod species occurs) is low in the upper Lopingian sections of Iran when compared to other taxa or other regions such as
South China, and this may explain why they seem to disappear earlier (Signor-Lipps effect).

**Palaeoecology.** The brachiopod fauna under study mainly comprises articulate specimens indicating that they are in life assemblages, with no or minor transport. The majority of the genera are pediculate (*Cleiothyridina, Transaucachybinia, Juxathybinia, Anaxathybinia, Permothyiodothybinia, Acoarima, Rhpidomella, Unanammellina, Wellerellina, Prelissorhynchina, Cartorhbinia, Rostraterina, Dietasma*), which, numbered following the method of Angiolini (2007), are represented by 129 individuals and are thus 46% of the total association. A similar life-style is shown by the orthotetids with koskinoid perforation allowing the formation of pedicle threads that are further stabilized by penetration of the elongate umbo (i.e. *Orthothetina, Perigeyerella*, and *Paraorthbotetina*). These numerically represent 5% of the total fauna.

A different settling preference is shown by free-living concavo-convex spiny semi-infaunal productids (*Cathaysia, Spinosargemisera, Haydenella, Tichernyschevia*, and *Sarytchevina*) and large concavo-convex shells with stout helteroid spines (*Araxilevis*). Even if subordinate in number of taxa, they are very numerous in terms of individuals; they are 134 and thus represent 48% of the total association. A few Lyttomines have been found cemented on other brachiopod taxa, suggesting they were exploiting limited hard substrates offered by larger coexisting shells.

Semi-infaunal productids mostly occur in soft bottom, low energy, environments such as those recorded by the shale and marly limestone of the lower-middle part of the lower Julfa Formation (Fig. 6). However, except for some species of *Spinosargemisera*, they tend to disappear from bed G147 upward where the bioclastic limestone at the top of the lower Julfa Formation records a shallowing trend and thus higher energy that requires firm attachment to the substrate. Pediculate species are more favoured for this strategy.

Pediculate taxa seem to be ubiquitous; even if they are more abundant in the more limy facies, they occur also in the shale and marly limestone where they are probably able to subsist on small hard substrate, as for instance provided by shell debris or local cementation (Fig. 6).

The association that characterizes the upper Julfa Formation is overwhelmingly dominated by pediculate taxa of smaller size than the fauna in the lower beds; the two species that occur at the top of the *Paratrotites* Limestone are pediculate with a comparatively large foramen, and they probably thrived on hardgrounds in settings characterized by low nutrient supply.

**Correlations.** Stepanov et al. (1969) correlated the fauna of the Julfa beds (Tab. 1) with the faunal succes-

![Fig. 6](image-url) - Change of brachiopod life-style through the Julfa Formation, from a dominance of free living concavo-convex spiny semi-infaunal productids and and large concavo-convex shells with stout helteroid spines in the lower part of the formation to a dominance of pediculate taxa with a few cemented brachiopods toward the top. Orthotetids with pedicle threads further stabilized by penetration of the elongate umbo mainly occur in the lower part of the Julfa Formation.
tion of Dorasham, Transcaucasia described by Ruzhentsev & Sarytcheva (1965) and gave it a Dzhulfian age. More specifically they correlated their Araxilevis-Orthotetina (sic) zone with the Araxilevis beds of Dorasham, their Pseudogastrioceras-Permophrictothyris zone to the Araxoceras-Oldhamina beds of Dorasham and the Haydenella-Pseudowellerrara zone to the Ve- 
dioceras-Haydenella beds of Dorasham. The systematic study here presented supports this correlation, even if we prefer to name the biozones of Julfa as Araxilevis intermedius biozone, Permorphrictothyris ovata bio-
zone, and Haydenella kiangiensis biozone respectively, based on the taxonomic revision of the fauna (Fig. 4). The recorded species of the genus Orthotetina in fact occurs at the very top of the Araxilevis intermedius biozone and extend into the Permorphrictothyris ovata biozone; we could not find any species of Pseudowellerra, but of Wellerrina, which however occur in just one sample (G182B) in the Haydenella kiangiensis bio-
zone.

More complex is the correlation between the suc-
cession of the Ali Bashi Mountains and the Alborz Mountains (Gaetani et al. 2009; Angiolini & Carabelli 2010). As shown by Angiolini & Carabelli (2010), the biozones of the lower member of the Nesen Formation can be correlated to the brachiopod biozones of Trans-
caucasia – and thus NW Iran – and so for instance, the Araxilevis intermedius biozone of the Alborz Moun-
tains is correlative to the Araxilevis zone of Transcaucasia and of Ali Bashi. However, the overlying Per-
morphrictothyris ovata biozone shares some taxa with the Oldhamina beds of Transcaucasia and with the Per-
morphrictothyris zone of NW Iran, but its age is Changhsingian, based on associated fusulinids and conodonts. The authors explained the fact that in Transcaucasia – and in NW Iran - P. ovata is restricted to the Wuchapingian because of the shift to deep water depositional environments, which are less favourable for large sized reticuloidids that need high nutrient supply in high hydrodynamic energy settings. Upward, the Enteteles lateroplicatus biozone of the Alborz Mountains has been roughly correlated to the Changhsingian “Come-
llicania” (= Groenallina) beds of Transcaucasia, but it is characterized by a greater abundance and biodiversity of brachiopods.

Conclusions

We describe for the first time the systematics of Lopingian brachiopods from an area of historical value for the stratigraphic studies of the Upper Permian Tethy
yan successions and for the development of the Tethyan Scale.

We show that also in northwest Iran the stratigraphic abundance of brachiopods is low in the upper Lopingian, when compared to other taxa or other re-
gions such as South China. In this particular case, a reduction in brachiopod abundance and diversity over the upper part of the Julfa Formation and the Ali Bashi Formation may be linked to a gradual facies change caused by deepening.

We record a shift from the shale and marly lime-
stone at the base of the Julfa Formation, which are dominated by semi-infaunal productids, to the bioclas-
tic limestone above. Here, more diversified pedicle at-
tached and cemented taxa suggest a shallowing upward trend and a shift to higher nutrient-substrates in more turbulent waters. The successive deepening trend and possibly a reduced nutrient supply recorded up to the top of the Ali Bashi Formation causes a dramatic reduction of brachiopods. Only a few small species of pedi-
culate taxa do occur, attaching to syndepositional hard substrates by their pedicle.

Systematic Palaeontology (C. Garbelli and L. Angiolini)

All the described specimens are housed in the Palaeontological Museum of the Department of Earth Sciences “A. Dino,” University of Milan, Italy. Specimens are registered with a prefix MPUM fol-
lowed by a four to five digit number. The systematic study follows the classifications of Brunton et al. in Williams et al. (2000) for the producticides and stropholaidids, Williams & Brunton in Williams et al. (2000) for the orthotetidines, Williams & Harper in Williams et al. (2000) for the orthis, Savage et al. in Williams et al. (2002) for the rhychonellids, Alvarez & Rong in Williams et al. (2002), Alvarez in Williams et al. (2007) for the eothyrids, Johnson et al. in Williams et al. (2006) for the ambocelidids, Carter & Gourvenec in Williams et al. (2006) for the reticuloidids and Jin et al. in Williams et al. (2006) for the denticelids.

Class Strophomenata Williams, Carlson, Brunton, Holmer & Popov, 1996

Order Productida Sarytcheva & Sokolskaya, 1959

Suborder Productidina Wågen, 1883

Superfamily Productoidea Gray, 1840

Family Productellidae Schuchert, 1929

Subfamily Productiniae Muir-Wood & Cooper, 1960

Tribe Chonetellini Licharew in Licharew et al., 1960

Genus Haydenella Reed, 1944

Type species: Productus kiangiensis Kayser, 1883 from the Lopingian of South China

Haydenella kiangiensis (Kayser, 1883)

Pl. 1, figs 1-2

1883 Productus kiangiensis Kayser, p. 185, pl. 26, figs 6-11.
1911 Productus kiangiensis - Frech, p. 129, 168, 172, pl. 2, fig. 2, pl. 21, figs 3, 4.
1927 Aonia kiangiensis - Chao, p. 125, pl. 14, figs 14-16.
1928 *Thomasia kiangensis* - Chao, p. 50, pl. 6, fig. 18.
1932 *Linxiproducina kiangensis* - Huang, p. 46, pl. 3, figs 13-19.
1944 *Producina (Haydenella) kiangensis* - Reed, p. 78.
1948 *Paramarginafera kiangensis* - Banson, p. 44.
1964 *Haydenella kiangensis* - Yang, p. 8, text-fig. 3, pl. 2, fig. 1, pl. 3, fig. 4.
1965 *Haydenella kiangensis* - Ruzhentsiev & Sarytcheva, pl. 38, figs 6-8.
1978 *Haydenella kiangensis* - Jing & Hu, p. 113, pl. 2, fig. 25.
1979 *Haydenella kiangensis* - Zhan, p. 81, pl. 5, figs 3, 4.
1984 *Haydenella kiangensis* - Yang, p. 218, pl. 33, fig. 9.
1995 *Haydenella kiangensis* - Zeng, et al., p. 5, fig. 8.
2005 *Haydenella kiangensis* - Campi et al., p. 111, pl. 1, figs Z, bb, cc, ee.
2008 *Haydenella kiangensis* - Li & Shen, p. 311, fig. 4 (?).
2009 *Haydenella kiangensis* - Shen & Clapham, p. 721, pl. 1, fig. 28, pl. 2, fig. 1.
2012 *Haydenella kiangensis* - Crippa & Angiolini, p. 138, figs 11c-j.

**Material:** One figured ventral valve: MPUM11214 (G147-1).

**Description.** Small sized shell; ventral valve strongly convex and globose, with a sub-rectangular outline; ears large, forming the maximum width of the shell. Ornamentation of fine costellae numbering 10-12 per 5 mm. Rugae on ears and possibly a row of fine spines between the ears and the visceral disk.

**Occurrence.** Julfa Formation, G162, G206.

**Distribution.** Changhsingian *Lyttonia* Bed of South China (Kayser 1883); Upper Guadalupian -Wuchiapingian Wargal Formation of Salt Range, Pakistan (Reed 1944); Wuchiapingian of Transcaucasia (Ruzhentsiev & Sarytcheva 1965); Guadalupian of Malaysia (Campi et al. 2005); Lopingian of South China (Li & Shen 2008); Wuchiapingian of Greece (Shen & Clapham 2009); Guadalupian of North Iran (Crippa & Angiolini 2012).

*Haydenella minuta* Sarytcheva in Ruzhentsiev & Sarytcheva, 1965

Pl. 1, figs 3-4

1965 *Haydenella minuta* Sarytcheva in Ruzhentsiev & Sarytcheva, p. 228, pl. 38, figs 10-11.
1994 *Haydenella minuta* - Leman, pl. 1, figs 7-8.

**Material:** One figured ventral valve: MPUM11213 (G182B-1).

**Description.** Small shell; maximum width: 5.2 mm, corresponding length: 4.3 mm. Ventral valve slightly convex with enrolled umbo projecting over the cardinal margin. Hinge line straight with large ears. Radial ornamentation of costellae numbering 2-3 in 1 mm.

**Occurrences.** Julfa Formation, G182B

**Distribution.** Wuchiapingian and Changhsingian of Transcaucasia (Ruzhentsiev & Sarytcheva 1965); Upper Permian of northwest Pahang, Malaysia (Leman 1994).

**Tribe Paramarginiferini** Lazarev, 1986

**Genus Cathaysia** Jin in Wang, Jin & Fang, 1966

**Type species:** *Producina chonetoides* Chao, 1927 from the Lopingian of China

**Cathaysia** sp. ind.

Pl. 1, figs 5-6

**Material:** One figured ventral valve: MPUM11214 (G147-1).

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**PLATE 1**

Figs 1-2 - *Haydenella kiangensis*, MPUM11211 (G206), ventral valve, ventral and dorsal views respectively, x2.
Figs 3-4 - *Haydenella minuta*, MPUM11213 (G182B-1), ventral valve, ventral and dorsal views respectively, x2.
Figs 5-6 - *Cathaysia* sp. ind., MPUM11214 (G147-1), ventral valve, ventral and anterior views respectively, x2.
Figs 7-8 - *Spiromarginifera ciliata*, MPUM11215 (G151-4), articulated shell, ventral and dorsal views respectively, x2.
Figs 9-12 - *Spiromarginifera helia*, MPUM11219 (G138-5), articulated shell, ventral and dorsal views respectively, x2; MPUM11218 (G136-5), articulated shell, ventral and dorsal views respectively, x2.
Figs 13-16 - *Spiromarginifera transica*, MPUM11221 (G136-9), articulated shell, ventral and dorsal views respectively, x2; MPUM11222 (G138-7), articulated shell, ventral and dorsal views respectively, x2.
Figs 17-22 - *Spiromarginifera spinosostachys*, MPUM11224 (G136-3), articulated shell, ventral and dorsal views respectively, x2; MPUM11225 (G141C-5), articulated shell, ventral and dorsal views respectively, x2; MPUM11226 (G142B-15), articulated shell, ventral and dorsal views respectively, x2.
Figs 23-26 - *Spiromarginifera sulata*, MPUM11229 (G137-19), articulated shell, ventral and dorsal views respectively, x2; MPUM11228 (G137-18), articulated shell, ventral and dorsal views respectively, x2.
Figs 27-28 - *Araxis crumica*, MPUM11232 (G138-15), articulated shell, ventral and dorsal views respectively, x1.
Figs 29-32 - *Sarytchevinaella dyuiformis*, MPUM11234 (G142B-22), articulated shell, ventral and dorsal views respectively, x2; MPUM11235 (G143B-7), articulated shell, ventral and dorsal views respectively, x1.
Figs 33-39 - *Tibemyschewsia typica*, MPUM11238 (G140-2), articulated shell, ventral, dorsal and anterior views respectively, x1; MPUM11237 (G135-1), articulated shell, ventral, dorsal, anterior and lateral views respectively, x1.
Figs 40 - *Lyttoninae* gen. et sp. ind., MPUM11305 (G148-2bis), x2.
Remarks. This single specimen shows a weakly nasute anterior margin. It has coarse and few ribs on the trail and rugae on the ears, but no row of spines between ears and flanks.


Subfamily Marginiferinae Stehli, 1954

Tribe Marginiferini Stehli, 1954

Genus Spinomarginifera Huang, 1932

Type species: Spinomarginifera kwaxihowensi Huang, 1932 from the Lopingian of South China

Spinomarginifera ciliata (Arthatber, 1900)

Pl. 1, figs 7-8

1920 Marginifera spinocostata var. ciliata Arthatber, p. 264, pl. 20, figs 9a-c.

1965 Spinomarginifera ciliata - Sarycheva & Sokol'skaya in Ruzhentsev & Sarycheva, pl. 37, figs 12a-c.

1966 Spinomarginifera ciliata - Fantini Sestini & Glaub, p. 903, pl. 64, fig. 7.

1969 Spinomarginifera helica - Stepanov et al., pl. 7, figs 3a-c.

2010 Spinomarginifera ciliata - Angiolini & Carabelli, p. 52, pl. 1, figs 7-9.

Material: One figured articulated shell: MPUM11215 (G151-4), two articulated shells: MPUM11216 (G138B-3, G149-13), one ventral valve: MPUM11217 (G149-3).

Description. Small to medium sized, concavo-convex shell, with deep corpus cavity and sub-trapezoidal outline. Maximum width anterior to the cardinal margin ranging from 14.8 to 18.8 mm; corresponding length ranging from 12.5 to 15.5 mm. Shell slightly wider than long with a W/L ratio comprised between 1.0 and 1.2. Anterior commissure rectimarginate. Ventral valve convex with strong geniculation. Umbo pointed and projecting over the cardinal margin. Median sulcus absent. Dorsal valve concave, with subelliptical outline. Ornamentation of ventral valve with irregular rugae, more prominent in the umbonal region. Spines are dense and uniformly distributed, spaced about 1 mm from each other. Spines are fine and longer towards the anterior margin. Spine base diameter is 0.3 mm, but reaches 0.6 mm on the ears. Along the trail spine bases form thin and short ridges ranging in length from 1 mm to 4 mm. Dorsal valve with irregular, densely spaced, prominent rugae. The spines are denser than in the ventral valve and spaced about 0.5–0.8 mm. The spine bases are smaller, having a diameter of about 0.1 mm.


Distribution. Wuchiapingian Oldbamina and Haydenella beds of Transcaucasia (Ruzhentsev & Sarycheva 1965); Wuchiapingian-Changhsingian of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010).

Spinomarginifera helica (Abich, 1878)

Pl. 1, figs 9-12

1878 Productus intermedius helicus Abich, p. 44, pl. 5, fig. 7; pl. 10, figs 5, 12-13, 17, 19-20.

1878 Productus aculeatus Abich, p. 50, pl. 5, fig. 12; pl. 10, fig. 21.

1878 Productus spinulosus Abich, pl. 51, pl. 5, fig. 9.

1878 Productus indeterminatus Abich, pl. 47, pl. 10, fig. 16, pl. 48, pl. 10, figs 6, 18.

1902 Marginifera intermedia helica - Arthatber, p. 265, pl. 20, figs 10–12.

1935 Marginifera helica - Diener, p. 74, pl. 3, fig. 9.

1935 Marginifera intermedia helica - Simic, p. 42, pl. 3, figs 1-4.

1937 Productus (Marginifera) intermedius-helicus var. multispira - Licharev, p. 69, pl. 10, figs 7-10.

1937 Productus (Marginifera) intermedius-helicus var. mutabilis - Licharev, p. 70, pl. 10, figs 11-20.

1939 Productus (Marginifera) intermedius-helicus - Licharev, p. 95, pl. 22, fig. 9.

1958 Marginifera helica helica - Ramovs, p. 501, pl. 2, fig. 8.

1962 Spinomarginifera intermedia-helica - Sarycheva et al., pl. 228, pl. 38, fig. 14.

1963 Spinomarginifera intermedia-helica - Schröter, p. 118, pl. 5, figs 3-11.

1965b Spinomarginifera helica - Fantini Sestini, p. 47, pl. 5, figs 6-7.

1965 Spinomarginifera helica - Sarycheva & Sokol'skaya in Ruzhentsev & Sarycheva, pl. 226, pl. 37, figs 9-11.

1966 Spinomarginifera helica - Fantini Sestini & Glaub, p. 904, pl. 64, fig. 6.

1969 Spinomarginifera helica - Stepanov et al., pl. 5, fig. 3a-b.


2011 Spinomarginifera helica - Verna & Angiolini in Verna et al., pl. 78, pl. 3, figs 1-7, pl. 6, figs 5-6.

Material: Two figured articulated shell: MPUM11218 (G136-5), MPUM11219 (G138-5); 27 articulated shells: MPUM11220 (G134-2-4-5-6, G137-1-7-9, G138-8, G138B-1, G139-2, G140-8, G140B-3-4, G141-5, G141C-1, G142B-7, G143B-9-12-24, G145B-1-9, G147-3, G148-10-16, G149-6, G149B-2-5).

Description. Small to medium sized, concavo-convex shell with deep corpus cavity and transverse sub-trapezoidal outline. Maximum width ranging from 8.6 to 22.7 mm, corresponding length ranging from 6.9 to 21.2 mm. Shell slightly wider than long with a W/L ratio from 1.2 to 1.4 mm. Ventral valve geniculated, with broad umbo, moderately projecting over the cardinal margin. Ears triangular and slightly enrolled. Dorsal valve slightly concave with transversely sub-rectangular outline; trail anteriorly geniculated; ears flat and triangular. Ornamentation of the ventral valve of fine, prominent and regular rugae on the umbonal region. Spines dense on the ventral visceral disk and on lateral ears, becoming more spaced anteriorly on the ventral valve. Spine bases rounded on the visceral disc, forming scat-
tered elongated ridges anteriorly on the trail; spine bases become longer towards the anterior commissure. Spine base diameter 0.3 mm on visceral disk, 0.5 mm on the anterior trail and 0.7 mm laterally, close to the lateral commissure. Ornamentation of dorsal valve with concentric, slightly irregular rugae, closer but less prominent on the ears; spines widely and regularly spaced with rounded base about 0.2 mm in diameter; deep dimples anteriorly on the visceral disk.

Intraspecific variability is high for the outline, which is generally transverse, but can be nearly equidimensional and for the elongation of the spine bases on the trail, which may form prominent ridges in some specimens.

Remarks. Spinomarginifera helica (Abich, 1878) is a very variable species as already suggested by Sar- ytcheva & Sokolskaya in Ruzhentsev & Sarytcheva (1965) and Angiolini & Carabelli (2010). Some of its less transverse and prominent ridge ornamented morphotypes may be rather close to Spinomarginifera spinoso-costata (Abich, 1878). We refer to the discussion of Angiolini & Carabelli (2010, p. 53) for the differences with other species belonging to the genus Spinomarginifera.


Distribution. Wuchiapingian Araxislepis, Oldah- mina and Haydenella beds of Transcaucasia (Ruzhent- sev & Sarytcheva 1965); Guadalupian Ruth Formation of North Iran (Fanti Sestini 1965b); Changhsingian of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010); Lopingian of Himalayas (Dienner 1903), North Caucasus (Licharew 1937, 1939) and SE Europe (Simic 1933; Ramovs 1958); Guadalupian-Lopingian of Turkey (Angiolini et al. 2007; Verna & Angiolini in Verna et al. 2011).

Spinomarginifera iranica Fantini Sestini, 1965a

1965a Spinomarginifera iranica Fantini Sestini, p. 992, pl. 94, figs 2-5.
2012 Spinomarginifera iranica - Angiolini & Carabelli, p. 56, pl. 1, figs 12-18
2011 Spinomarginifera iranica - Verna et al., p. 65, pl. 1, fig. 23

Material: Two figured articulated shells: MPUM11221 (G136-9), MPUM11222 (G138-7); three articulated shells: MPUM11223 (G136-10, G137-3, G141-6).

Description. Small to medium sized, concavo-convex shell with deep corpus cavity and longitudinally sub-rectangular to transversely sub-keeled outline. Maximum width ranging from 14.4 to 16.9 mm, corresponding length ranging from 11.2 to 14.9 mm. Ventral valve convex, with geniculation at about one-third of the valve length. Umbo small, acute, weakly projecting over the cardinal margin, which is shorter than the greatest width of the valve. Median sulcus absent. Dorsal valve slightly concave with a sub-elliptical outline. Ornamentation of ventral valve with closely spaced spines, very dense on the visceral disk and on the ears; spine bases with constant diameter of about 0.4 mm on the ventral valve and not forming ridges; low, fine rugae are occasionally present on the visceral disk. Dorsal valve ornamented by dense spines, about 0.2 mm in diameter.


Spinomarginifera spinoso-costa (Abich, 1878)

Pl. 1, figs 17-22

1878 Productus spinoso-costatus Abich, p. 41, pl. 10, figs 6-7, 10.
1878 Productus spinoso-costatus var. spinifera Abich, p. 41, pl. 10, fig. 8.
1878 Productus spinoso-costatus var. eximius Abich, p. 42, pl. 5, figs 8, 11.
1902 Marginifera spinosa-costa - Artiham, p. 262, pl. 20, figs 5-8.
1911 Productus (Marginifera) spinoso-costatus - Frech, p. 175, pl. 27, figs 1-2.
1937 Productus (Marginifera) spinoso-costatus - Lichereuw, p. 71, pl. 10, fig. 37.
1965b Marginifera spinosa-costa - Fantini Sestini, p. 43, pl. 5, figs 2-3.
1965 Spinomarginifera spinosa-costa - Sarytcheva & Sokolskaya in Ruzhentsev & Sarytcheva, p. 225, pl. 37, figs 6-8.
1966 Spinomarginifera spinosa-costa - Fantini Sestini & Glau, p. 925, pl. 64, fig. 5.
2010 Spinomarginifera spinoso-costata - Angiolini & Carabelli, p. 56, pl. 1, figs 21-22.
2011 Spinomarginifera spinoso-costata - Verna & Angiolini in Verna et al., p. 65, pl. 1, figs 31-33.

Material: Three figured articulated shells: MPUM11224 (G136-3), MPUM11225 (G141C-5), MPUM11226 (G142B-13); thirty articulated valves: MPUM11227 (G134-13, G136-7-11, G137-2-8-11, G138-4, G138B-4-7-8, G140B-5, G141-4, G141C-3-4-6, G142B-16, G143B-18-19-20-23, G144-1, G145B-4, G147-2, G148-3-5, G149-2, G154B-3-4, G157-1).

Description. Small to medium sized, concavo-convex shell with deep corpus cavity and longitudinally sub-rectangular to sub-trapezoidal outline. Maximum width at mid-length or slightly anteriorly, ranging from 8.5 to 19.7 mm, corresponding length ranging from 7.4 to 14.0 mm. Ventral valve convex with strong geniculation and long trail; umbo broad and strongly projecting on the cardinal margin; ears elongated and enrolled.
Median sulcus usually very weak or absent, more evident on the trail in some specimens. Dorsal valve concave, with transversally sub-rectangular outline. Ornamentation of ventral valve with fine, irregular ruguæ closely spaced in the umbalonal region; spine bases form coarse ridges, more prominent and more densely spaced anteriorly. Ridge is slightly larger than the spine base. Spines are closely spaced on the visceral disk; with spine base 0.2 mm in diameter; spines become widely spaced on the anterior trail and wider at base (diameter 0.5 mm). Largest specimens have spine ridges about 1 mm in width towards the anterior commissure. The coarseness of the ridges forming the spine bases is quite variable intraspecifically.

Dorsal valve with very fine and irregular ruguæ, dimples and traces of attachment of capillary spines. The spine bases are 0.1 mm in diameter on the dorsal valve.

**Remarks.** We agree with Sarytcheva and Sokolskaya in Ruzhentsev & Sarytcheva (1965) and Angiolini & Carabelli (2010), in considering that *S. belica* and *S. spinosocostata* are two end members of a morphological continuum. In the specimens under examination, the persistence of spine base ridges in *S. spinosocostata* is the most important character to discriminate between the two species.

**Occurrence.** Julfa Formation, beds G137, G147.

**Distribution.** Changhsingian of South China (Shen et al. 1992); Wuchiapingian-Changhsingian of North Iran (Angiolini & Carabelli 2010).

**Spinomarginifera** sp. ind.

**Material:** Seven articulated shells: MPUM11231 (G137-12, G138B-6, G145B-5-7-10, G148-1, G149-1).

**Remarks.** The overall state of preservation of this material and the juvenile stage of some shells do not allow any specific assignment.


**Family Productidae Gray, 1840**

**Subfamily Leio productinae Muir-Wood & Cooper, 1960**

**Tribe Tylopectini Termier & Termier, 1970**

**Genus Araxilevis** Sarytcheva & Sokolskaya in Ruzhentsev & Sarytcheva, 1965

Type species: *Productus intermedius* Abich, 1878 from the Lopingian of Transcaucasia

**Araxilevis intermedius** (Abich, 1878)

**Pl. 1, figs 27-28**

1878 *Productus intermedius* Abich, p. 27, pl. 4, figs 10-12; pl.7, fig. 1; pl. 10, figs A-B.

1878 *Productus intermedius* var. plano-convexus Abich, p. 31, pl. 4, fig. 13; pl. 9, fig. 6.

1902 *Productus intermedius* var. plano-convexus Abich, p. 32, pl. 5, fig. 1; pl. 9, fig. 4.

1902 *Productus intermedius* Abich, p. 254, pl. 19, figs 7-8.

1939 *Productus intermedius* - Licharew, p. 93, pl. 21, fig. 1.

1960 *Plicatopera intermedius* - Sarytcheva et al., p. 227, pl. 35, fig. 3.

1965 *Araxilevis intermedius* - Sarytcheva & Sokolskaya in Ruzhentsev & Sarytcheva, p. 222, pl. 35, fig. 4; pl. 36, figs 1-4.

1969 *Araxilevis intermedius* - Stepanov et al., p. 3, figs 1a-c.

2010 *Araxilevis intermedius* - Angiolini & Carabelli, p. 60, pl. 2, fig. 8.

**Spinomarginifera sulcata** Shen, He & Zhu, 1992

**Pl. 1, figs 23-26**


2010 *Spinomarginifera sulcata* - Angiolini & Carabelli, p. 57, pl. 1, fig. 23-24.

**Material:** Two figured articulated shells: MPUM11228 (G137-18), MPUM11229 (G137-19); one articulated shell: MPUM11230 (G147-5).

**Description.** Small sized, concavo-convex shell with sub-rectangular outline. The maximum width is at the cardinal margin, ranging from 10.2 to 11.3 mm; corresponding length ranging from 7.3 to 10.8 mm. W/L ratio ranging from 1.0 to 1.4. Ventral valve strongly convex and geniculated. Umbo incurred and strongly projecting over the cardinal margin; ears very distinct, flat and quadrate in outline. Median sulcus very deep on the trail. Dorsal valve concave with transversally sub-rectangular outline. Ornamentation of ventral valve with very weak ruguæ on the visceral disk near the umbo; spines widely and equally spaced on the shell: spine base diameter about 0.3 mm. Dorsal valve with fine and indistinct ruguæ on the visceral disk. Dorsal spine bases about 0.1 mm in diameter.

**Remarks.** *Spinomarginifera sulcata* Shen, He & Zhu, 1992 is characterized by a deep and very distinct sulcus, not present in other species of the genus. The specimens under examination resemble those figured by Shen et al. (1992).
Material: One figured articulated shell: MPUM11232 (G139-15); 15 articulated shells: MPUM11233 (G125-1, G134-8, G137-17, G138-14-16, G138B-2, G139-1-3, G140-4-10-11-12, G141C, G70-float).

Description. Medium to large sized shell, concavo-convex with maximum width ranging from 39 to 68.8 mm, corresponding length from 33.6 to 59.5 mm. Shell slightly wider than long, with W/L ratio from 1.0 to 1.3. Ventral valve strongly geniculated with umbo projecting well beyond the cardinal margin. Sulcus weakly developed, but broad in the umbonal region. Anterior trail long and lamellose. Ears well defined with sub-quadrangle outline. Dorsal valve slightly concave and geniculated. Ears triangular delimiting a depressed pentagonal field in the dorsal disk. Ventral valve distinctly lamellose on the trail; lamellae 2 mm thick along mid-valve; spines numerous on the visceral disk and on ears, reduced in number anteriorly along the trail; spine bases from 1.0 to 1.2 mm in diameter. Dorsal valve lamellose, with one mm-thick lamellae; no spines are present; thin longitudinal striae number 5 per 1 mm.

Remarks. Araxilevis intermedius (Abich, 1878) is very similar in shape and size to Tyloplecta yangtzeensis (Chao, 1927), from which it differs because of its long lamellose trail.


Distribution. Lower Wuchiapingian Araxilevis beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965); Wuchiapingian and early Changhsingian of North Iran (Angiolini & Carabelli 2010).

Superfamily Linoproductoidea Stehli, 1954
Family Monticuliferidae Muir-Wood & Cooper, 1960
Subfamily Compressoproductinae Jin & Hu, 1978
Genus Sarytchevina Waterhouse, 1983
Type species: Productus djulfensis Stoyanow, 1915 from the Capitanian of Armenia

Remarks. Waterhouse (1983) erected the genus Sarytchevina for those species similar to Compressoproductus Sarytcheva in Sarytcheva et al., 1960, but having a straight hinge. Sarytchevina is characteristic of the Late Permian palaeoequatorial regions.

Sarytchevina djulfensis (Stoyanov, 1910)

Pl. 1, figs 29-32

1915 Productus djulfensis - Stoyanow, p. 42, pl. 4, fig. 5, pl. 5, fig. 1-6, pl. 6, figs 1-5.
1965 Compressoproductus djulfensis - Sarytcheva & Sokolskaya in Ruzhentsev & Sarytcheva, pl. 38, figs 4-5.
1969 Compressoproductus djulfensis - Stepanov et al., pl. 4, figs 6a-b, 7; pl. 7, figs 2a-b.

Material: Two figured articulate shells: MPUM11234 (G142B-22, MPUM11235 (G145B-7); 26 articulate shells: MPUM11236 (G141B, G142-3, G142B-5-6-8-11-12-13-17-18-20-23, G143-2-3, G143B-0-2-3-8-10-13-14-22-26, G146-2-3, G148-6).

Description. Medium sized concavo-convex shell, with maximum width anterior to the hinge ranging from 20.2 to 34.6 mm, maximum length ranging from 28.2 to 42.8 mm. Corpus cavity shallow. Ventral valve geniculated, long anterior trail and umbo slightly projecting over the cardinal margin; ears sub-quadrangle strongly enrolled downward. Dorsal valve concave. Both valves ornamented with persistent irregular wrinkles (about 1 mm thick) and with 5-6 ribs in 2 mm. In the ventral valve a row of spines occurs along the hinge close to the ears.


Distribution. Wuchiapingian Araxilevis beds and Oldhamina beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965); Wuchiapingian lower Julfa beds of North Iran (Stepanov et al. 1969).

Suborder Strophalosoidea Schuchert, 1913
Superfamily Aulostegioidea Muir-Wood & Cooper, 1960
Family Scacchinellidae Licharev, 1928
Subfamily Tschernyschewiinae Muir-Wood & Cooper, 1960
Genus Tschernyschewia Stoyanow, 1910
Type species: Tschernyschewia typica Stoyanow, 1910 from the Lopingian of Armenia

Tschernyschewia typica Stoyanow, 1910
Pl. 1, figs 33-39

1878 Productus scabriulus Abich (non Martin, 1809), p. 33, pl. 5, fig. 3.
1900 Productus abicki - Arthaber, p. 252, pl. 20, fig. 1.
1910 Tschernyschewia typica - Stoyanow, p. 853.
1915 Tschernyschewia typica - Stoyanow, p. 77, pl. 1, figs 1-5; pl. 2, figs 1-12; pl. 4, fig. 1.
1933 Tschernyschewia typica - Simic, p. 95, pl. 1, figs 15-18.
1944 Productus (Tschernyschewia) typica - Reed, p. 83, pl. 12, fig. 13; pl. 15, fig. 7; pl. 18, fig. 6.
1958 Tschernyschewia typica - Ramovs, p. 524, pl. 9, figs 3-4.
1963 Tschernyschewia typica typica - Schréter, p. 109, pl. 3, figs 9-17; pl. 4, figs 1-2.
1965 Tschernyschewia typica typica - Amiot et al., p. 176, pl. 21, figs 22-26.
1965 Tschernyschewia typica typica - Sarytcheva & Sokolskaya in Ruzhentsev & Sarytcheva, p. 33, figs 8-9.
2010 Tschernyschewia typica typica - Angiolini & Carabelli, p. 63, pl. 2, fig. 12; pl. 3, fig. 1.
Material. Two figured articulated shells: MPUM11237 (G135-1), MPUM11238 (G140-2), six articulated shells: MPUM11239 (G134-8, G135-2, G136-4, G140-1-3-5).

Description. Medium to large sized with plano-convex shell. Maximum width anterior to the cardinal margin ranging from 39.3 to 43 mm, corresponding length ranging from 27.7 to 38.7 mm. Ventral valve slightly transverse with weak sulcus. Umbo enrolled projecting beyond the cardinal margin. Dorsal valve flat to slightly convex, geniculated anteriorly. Ventral valve ornamented with regularly and closely set spines (about 1 mm apart). Anteriorly on the ventral valve, the spine base diameter is 0.4-0.5 mm and the basal part of the spines runs sub-parallel to the valve surface. Dorsal valve with spines regularly spaced, but more closely set than on the ventral one (about 0.5 mm apart); spine bases slightly smaller, 0.2-0.3 mm in diameter.

Interior of ventral valve with robust and high median septum, umbonally inserted between the two lobes of the cardinal process.


Distribution. Wuchiapianian *Araxilevis* and *Oldhamina* beds of Transcaucasia (Ruzhentsev & Sarycheva 1965); Changhsingsian Nesen Formation of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010); Lopingian of southeastern Europe (Simic 1933; Ramovs 1958; Schräter 1963); Lopingian of Salt Range (Reed 1944); Changhsingsian of Sichuan, China (Shen et al. 1992).

Order Orthotetida Waagen, 1884

Suborder Orthotetidina Waagen, 1884

Superfamily Orthotetoidea Waagen, 1884

Family Meekellidae Stehli, 1954

Subfamily Meekellinae Stehli, 1954

Genus *Orthothetina* Schellwien, 1900

Type species: *Orthothetes persicus* Schellwien, 1900 from the Guadalupian of Iran

*Orthothetina persica* (Schellwien, 1900)

Pl. 2, figs 1-4

1900 *Orthothetes* (*Orthothetina*) *persicus* Schellwien, p. 8, pl. 1, fig. 2.

1911 *Orthothetes* (*Orthothetina*) *persicus* Schellwien; Frech, p. 123, pl. 28, fig. 3.

1965 *Orthothetina persica* (Schellwien) - Sokolskaya in Ruzhentsev & Sarycheva, p. 206, pl. 30, figs 4-5.

2010 *Orthothetina persica* - Angiolini & Carabelli, p. 65, pl. 4, figs 4-5.

Material: One figured articulated shell: MPUM11240 (G143B-1).

Description. Shell large, dorsi-biconvex. Shell approximately transversely sub-oval in outline, with a maximum width of 48.3 mm, and length of 42.7 mm. Hinge wide; anterior commissure slightly unisulcate. Ventral valve slightly convex with pointed umbo. Apsidal ventral interarea with pseudodeltidium and strong monitculus. Branchial valve with shallow median sulcus starting from the umbo. Ornamentation of ventral valve with coarse costellae (10-11 in 5 mm) interspersed with fine costellae; both sets of costellae are acute and arise by branching, and the interspaces between costellae are wider than the costellae themselves and finely ornamented by growth lines. On the dorsal valve the two orders of costellae are more evident.

Occurrence. Julfa Formation, beds G143B.

Distribution. Wuchiapianian *Oldhamina* beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965), Wuchiapianian-Changhsingsian of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010).

*Orthothetina eusarkos* (Abich, 1878)

Pl. 2, figs 5-11

1878 *Streptorhynchus crenistria* var. *eusarkos* Abich, p. 73, pl. 6, fig. 4.

1878 *Streptorhynchus crenistria* var. *incursus* Abich, p. 73, pl. 5, fig. 5.


1965 *Orthothetina eusarkos* - Sokoloskaja in Ruzhentsev & Sarycheva, p. 208, pl. 31, figs 3-5.

1969 *Orthothetina eusarkos* - Stepanov et al., p. 3, figs 2a-d.

1981 *Schelldostenella* sp. - Shimizu, p. 69, fig. 8, fig. 11.

2007 *Orthothetina eusarkos* - Shen & Shi, p. 21, pl. 6, figs 25-28.

Material. Two figured articulated shells: MPUM11241 (G142B-9), MPUM11242 (G143-1), one articulated shell: MPUM11243 (G140-7).

Description. Medium to large sized, moderately biconvex shell, wider than long; maximum width ranging from 32 to 55.7 mm, length from 27.6 to 52.6 mm. Hinge line about 4/5 of the maximum width; lateral sides meeting hinge line at about 120°. Anterior commissure slightly sulcate. Ventral valve convex in the umbal region, become flat anteriorly. Widely apsidal interarea with a triangular pseudodeltidium and a convex monitculus. Dorsal valve convex with large, gentle median sulcus starting at the umbo. Both valves ornamented by costellae numbering 9-10 per 5 mm; in the largest specimens thick concentric growth lines are evident anteriorly.


Distribution. Dzhulfian beds of the lower Julfa Formation, North Iran (Stepanov et al. 1969); Wuchiapianian.
pingian Khachik Formation of Armenia (Kotylar et al. 1983); Lopingian of South China (Shen & Shi 2007).

**Orthothetina** cf. O. ruber Frech, 1911
Pl. 2, figs 12-14

**Material.** One figured articulated shell: MPUM11244 (G206B-2), one articulated shell MPUM11245 (G206-1).

**Description.** Small to medium size, rounded to sub-elliptical in outline, with maximum width at the straight cardinal margin. Ventral valve slightly convex. Dorsal valve slightly convex to planar. Both valves ornamented with fine but prominent costellae numbering 10-12 per 5 mm. Interior of ventral valve with parallel dental plates.

**Occurrence.** Julfa Formation, beds 200, 206B.

**Distribution.** Orthothetina ruber occurs in Lopingian of South China (Shen & Shi 2007).

**Orthothetina** sp. ind.

**Material.** One articulated shell: MPUM11246 (G140-9).

**Remarks.** Large biconvex shell with transverse outline. The ornamentation and the features of the interior allow this specimen to be assigned to the genus Orthothetina, but the shell preservation and the strong distortion do not allow specific assignment.

**Occurrences.** Julfa Formation, G140.

**Genus Paraorthothetina** He & Zhu, 1985

**Type species.** Orthothetina propecta Liao, 1980 from the Lopingian of South China

**Paraorthothetina glauca** (Fantini Sestini & Glaus, 1966)
Pl. 2, figs 15-16

1966 *Orthothetina sp.* - Glaus, p. 71.
1966 *Orthothetina glauca* Fantini Sestini & Glaus, p. 90G, pl. 63, figs 6-7.
2010 *Paraorthothetina glauca* - Angiolini & Carabelli, p. 66, pl. 4, figs 6-9.

**Material.** One figured articulated shell MPUM11247 (G142-5).

**Description.** Medium size, biconvex shell, with dorsal valve more convex than the ventral one; outline sub-rectangular; cardinal extremities mucronate; maximum width: 43.1 mm and length: 41.2 mm. Anterior commissure unisulcate. Ventral valve more convex in the umbonal region, becoming flat anteriorly, with a gentle fold, broadening toward the anterior commissure. Dorsal valve sulcate, with sulcus broadening anteriorly. Ornamentation of costellae, numbering 10 per 5 mm in the umbonal region, and 14-16 per 5 mm at the anterior margin. In the anterior region, at about 2/3 of the valves length, evident growth lines also occur.

**Occurrence.** Julfa Formation, bed G142.

**Distribution.** Changhsingian of the the Alborz Mountains, North Iran (Angiolini & Carabelli 2010).

**Genus Perigeyerella** Wang, 1955

**Type species.** Perigeyerella costellata Wang, 1955 from the Lopingian of South China

**Perigeyerella** aff. P. miriae Verna et al., 2011
Pl. 2, figs 17-21

**Material.** Two figured articulated shells: MPUM11248 (G133-1), MPUM11249 (G140-13), MPUM11306 (G142B-3).

**Description.** Medium size, convexo-plane to slightly convexo-concave shell with maximum width anterior to the hinge line ranging from 28.1 to 45 mm; maximum length from 22.6 to 37.9 mm. Anterior commissure slightly unisulcate. Ventral valve weakly concave in the umbonal region, becoming flat anteriorly. Umbo elongated, pointed and slightly erect with koskinoid perforations. Interarea wide, apsacrine to ortholine, transversally striated, with long, triangular and narrow pseudodeltidium. Dorsal valve with sub-elliptical outline, strongly convex with a shallow dorsal sulcus, originating anterior to the umbonal region and widening anteriorly. Ventral valve ornamented with fine costellae numbering about 8-10 per 5 mm; concentric delicate rugae. Ornamentation of dorsal valve similar to the ventral one, but with two orders of ribs: 1) first order costellae numbering 4-5 per 5 mm; 2) second order costellae numbering 1-2 between two costellae of the first order. Concentric rugae present, but less evident than in the ventral valve.

**Remarks.** The specimens are considered similar to P. miriae for their outline, size, and the very wide and considerably high interarea that tend to be ortholine. The number and pattern of costellae are similar to P. miriae for the dorsal valve only; the ventral valve does not show two orders of costellae.

**Occurrence.** Julfa Formation, beds G133, G140, G142B.

**Distribution.** P. miriae occurs in the Guadalupian of Western Taurus, Turkey (Verna et al. 2011).

**Order Orthida** Schuchert & Cooper, 1932

**Superfamily Rhipidomelloidea** Schuchert, 1913

**Family Rhipidomellidae** Schuchert, 1913

**Genus Rhipidomella** Oeheleht, 1890

**Type species.** Terebratula michelini Léveillé, 1835 from the Visean of Belgium
Rhipidomella sp. ind.
Pl. 2, figs 22-23

Material: One figured articulated shell MPUM11250 (G141-3).

Description. Equally biconvex shell, slightly longer than wide; maximum width: 15.7 mm, corresponding length: 16.5 mm. Outline sub-triangular, with maximum width anterior to mid-length; anterior commissure slightly unisulcate. Ventral valve with apsacline recurved interarea. Both valves ornamented by concentric rugae and tubular costellae numbering 19-20 per 5 mm in the anterior margin. Dental plates absent.

Remarks. An equally biconvex shape and the absence of internal plates that allows it to be assigned to the genus *Rhipidomella* characterize this specimen. Based on its size, outline and ornamentation, the specimen is very similar to *Rhipidomella subcircularis* Shen & He, 1994, but it is more inflated and it has a narrow hinge. In these features, it also resembles *Rhipidomella bessensis* King, 1931. However, the latter species is very variable.

Occurrence. Julfa Formation, bed G141.

Superfamily Enteletoidea Waagen, 1884
Family Schizophoridiidae Schuchert & Lavene, 1929
Genus Acoarina Cooper & Grant, 1969
Type species: Acoarina donskoikia Cooper & Grant, 1969 from the Guadalupian of West Texas

Acoarina minuta (Abich, 1878)
Pl. 3, figs 7-9

1878 *Streptorhynchus peregirus var. minuta* Abich, p. 78, pl. 9, fig. 1a.
1965 *Orthobitha minuta* - Sokoloskaja in Ruzhentsev & Sarycheva, p. 200, pl. 29, figs 4-5.
2007 *Acoarina minuta* - Shen & Shi, p. 39, pl. 14, figs 27-38; pl. 15, figs 1-21.

Material: One figured articulated shell MPUM11251 (G136-2), two articulated shells: MPUM11252 (G137-5, G148-7).

Description. Subequally biconvex shell, slightly wider than long. Anterior commissure gently sulcate. Ventral valve less convex than the dorsal one. Ventral interarea slightly recurved. Dorsal valve with a gentle sulcus. ornamentation of tubular costellae irregularly developed in one valve only. Interior of ventral valve with median septum ending before middle.

Remarks. These small sized specimens have been included in *Acoarina minuta* because of their size, outline and ornamentation. They are different from the species of *Koitala* Grant, 1993 because they have a rather short ventral septum.


Distribution. Lopingian of South China (Shen & Shi, 2007); Wuchiapian *Oldhamina* beds of Transcaucasia (Ruzhentsev & Sarycheva 1965).

Order Rhynchonellida Moore, 1952
Superfamily Wellerelloidea Licharew, 1956
Family Wellerellidae Licharew, 1956
Subfamily Uncinunellinae Savage, 1996
Genus Uncinunellina Grabau, 1932
Type species: *Uncinunellina theobaldi* Waagen, 1883 from the Lopingian of Pakistan

Uncinunellina timorensis (Beyrich, 1864)
Pl. 3, figs 1-6

1864 *Rhynchonella timorensis* Beyrich, 1864, p. 72, pl. 1, fig. 10.
1883 *Uncinunellina theobaldi* - Waagen, p. 425, pl. 34, fig. 1.
1892 *Rhynchonella timorensis* - Rothpletz, p. 70, pl. 10, fig. 6.
1897 *Uncinunellina timorensis* - Diener, p. 69, pl. 10, figs 7-10.
1931 *Uncinunellina theobaldi* - Grabau, p. 72.
1933 *Uncinunellina timorensis* - Huang, p. 61, pl. 10, figs 30-32.
1964 *Uncinunellina timorensis* - Wang et al., p. 394, pl. 66, figs 9-10.
1965 *Uncinunellina timorensis* - Sokoloskaja in Ruzhentsev & Sarycheva, pl. 40, figs 1a-b.
1977 *Uncinunellina theobaldi* - Yang et al., p. 378, pl. 150, fig. 5.
1978 *Uncinunellina timorensis* - Tong, p. 240, pl. 85, fig. 5.
1979 *Uncinunellina timorensis* - Zhan in Hou et al., p. 95, pl. 10, fig. 4.

PLATE 2

Figs 1-4 - *Orthobithina persica*, MPUM11240 (G143B-1), articulated shell, ventral, dorsal, anterior and lateral views respectively, x1.
Figs 5-11 - *Orthobithina euarkos*, MPUM11241 (G142B-9), articulated shell, ventral, dorsal, anterior and lateral views respectively, x1; MPUM11242 (G143-1), articulated shell, dorsal and lateral views respectively, x1.
Figs 12-14 - *Orthobithina ci* *O. ribei*, MPUM11244 (G256B-2), articulated shell, ventral, dorsal and anterior views respectively, x1.
Figs 15-16 - *Paraorthobithina glauca*, MPUM11247 (G142-5), articulated shell, ventral and dorsal views respectively, x1.
Figs 17-21 - *Perigaricella all. B minae*, MPUM11248 (G133-1), articulated shell, ventral, dorsal and anterior views respectively, x1; MPUM11249 (G140-3), articulated shell, ventral and dorsal views respectively, x1.
Figs 22-23 - *Rhiodomoma sp. ind.*, MPUM11250 (G141-3), articulated shell, ventral and dorsal views respectively, x2.
1982 *Uncinuncella timorensis* - Wang et al., p. 235, pl. 84, fig. 3; pl. 93, fig. 5.
1982 *Uncinuncella timorensis* - Liu et al., p. 192, pl. 138, figs 11a-d.
1984 *Uncinuncella timorensis* - Yang, p. 227, pl. 36, fig. 6.
2007 *Uncinuncella timorensis* - Shen & Shi, p. 46, pl. 17, figs 31-42.

**Material.** Two figured articulated shells: MPUM11253 (G141-7), MPUM11254 (G152-4), two articulated shells: MPUM11255 (G140B-1, G141-1).

**Description.** Small to medium sized, dorsi-biconvex shell. Outline transversally sub-pentagonal with maximum width ranging from 9 to 16.6 mm, length from 7.4 to 12.9 mm. Hinge line about 1/3 of the maximum width; anterior commissure uniplicate. Ventral valve flat with a fairly wide and shallow sulcus beginning mid-valve length. Dorsal valve strongly convex with a shallow but broad fold. Both valves ornamented with prominent costae beginning at or slightly anterior to mid-length, resulting in a smooth umbonal region. Costae numbering 8-9 in the sulcus, 11-12 on each flank.

**Remarks.** *Uncinuncella timorensis* differs from *Uncinuncella jahensis* Waagen, 1883 in having a larger number of costae both in the sulcus and on the flanks; from *Uncinuncella exulis* Shen & Shi, 2007, it differs because of its more convex valves.

**Occurrence.** Julfa Formation, beds G140, G141, G152.

**Distribution.** Lopingian of South China (Shen & Shi 2007); Wuchiapingian *Oldhamina* beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965).

Family Pontisidae Cooper & Grant, 1976b
Genus *Prelissorbychis* Xu & Grant, 1994
Type species: *Pugnax pseudodah* Huang, 1933 from the Lopingian of southwest China

**Prelissorbychis dorashamensis** (Sokoloskaia in Ruzhentsev & Sarytcheva, 1965)
Pl. 3, figs 10-16
1965 *Wellerella dorashamensis* Sokoloskaia in Ruzhentsev & Sarytcheva, p. 233, text-fig. 37, pl. 40, fig. 7.

**Material.** Two figured articulated shells: MPUM11256 (G145B-21), MPUM11257 (G146-1), three articulated shell: MPUM11258 (G149-8, G161-2, G162-2).

**Description.** Small sized shell, unequally biconvex with maximum width slightly anterior to mid-length, ranging from 5.3 to 10.9 mm; corresponding length: 5.4-12 mm. Anterior commissure uniplicate. Ventral valve sub-circular to sub-triangular in outline, more convex in the umbonal region. Ventral umbo erect; sulcus broadening and deepening in the anterior half of the shell. Dorsal valve more evenly convex with fold anteriorly more evident. Both valves ornamented by ribs, numbering 3-4 in the sulcus, 4-5 on the fold and 4-6 on each flank.

**Remarks.** *P. dorashamensis* differs from the other species of the same genus by its more numerous ribs on fold and sulcus.

**Occurrence.** Julfa Formation, G143, G149, G160, G161, G162.

**Distribution.** Wuchiapingian *Haydenella* beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965).
Genus Wellerellina
Type species: Wellerellina chongqingensis Shen, He & Zhu, 1992 from the Changanian of South China

Wellerellina sp. ind.
Pl. 3, figs 17-20

Material: One figured articulated shell: MPUM11259 (G182B-2).

Remarks. This specimen belongs to Wellerellina because of its rather angular costae, starting from the umbo and the occurrence of dental plates, but the absence of a medium septum. The angular ribs are a distinctive character that allows the species of Wellerellina to be separated from those of Prellisorhynchia. The occurrence of dental plates differentiates it from species of Pseudowellerella Licharew, 1956.

Occurrence. Julfa Formation, bed G182B.

Distribution. The genus Wellerellina is known from the Lopingian of South China (Shen & Shi 2007).

Order Athryridida Boucot, Johnson & Staton, 1964
Suborder Athryridina Boucot, Johnson & Staton, 1964
Superfamily Athryridioidea Davidson, 1881
Family Athryrididae Davidson, 1881
Subfamily Cleiothyridininae Alvarez, Rong & Boucot, 1998
Genus Cleiothyridina Buckman, 1906
Type species: Atrypa pentina Sowerby, 1840 from the Permian of Kazan.

Cleiothyridina sp. ind.
Pl. 3, figs 21-22

Material: One figured articulated shell: MPUM11260 (G125-3).

Remarks. Very small sized, slightly biconvex shell ornamented by growth lines possibly bearing flat spines. The features seem to suggest the presence of a species of Cleiothyridina; however, the state of preservation prevents any specific assignment.

Occurrence. Julfa Formation, bed G125

Distribution. The genus Cleiothyridina is cosmopolitan from the upper Devonian to the Upper Permian (Alvarez & Rong in Williams et al. 2002).

Subfamily Transcaucasathyrinae Angiolini & Carabelli, 2010

Genus Transcaucasathyris Shen, Grunt & Jin, 2004
Type species: Araxathys araxensis Grunt in Ruzhentsev & Sarytcheva, 1965 from the Lopingian of Transcaucasia

Transcaucasathyris araxensis (Grunt in Ruzhentsev & Sarytcheva, 1965)
Pl. 3, figs 21-29; Fig. 7

1878 Spigera protea var. globularis - Abich, p. 58, pl. 7, fig. 9; pl. 10, fig. 9.
1965 Araxathys araxensis araxensis Grunt in Ruzhentsev & Sarytcheva, p. 247, pl. 43, fig. 6.
1986 Araxathys araxensis araxensis - Grunt, pl. 28, figs 1-2.
2004 Transcaucasathyris araxensis - Shen et al., p. 893, figs 7:30-7:43.

Material: Five figured articulated shells: MPUM11261 (G168-2), MPUM11262 (G172-2), MPUM11290 (G169-0), MPUM11291 (G179), MPUM11292 (G179-3), 10 articulated shells: MPUM11263 (G162-2, G164, G165, G169-2, G177, G183-1, G185-1, G188-1, G191-4).

Description. Small sized, biconvex shell with maximum width ranging from 7.5 to 13 mm; corresponding length: 6.4-11.4 mm. Anterior commissure uniplicate to weakly parasulate. Ventral valve sub-pentagonal in outline with sulcus broadening anteriorly; umbo with small foramen. Dorsal valve less convex than the ventral one, sub-rectangular to sub-elliptical in outline and flat. Interior of ventral valve with two short dental plates that are divergent and adherent to the valve wall.

Remarks. T. araxensis is quite a variable species. It shows great variability in the outline of the shell, which may vary from slightly transverse to longitudinal, and in the development of the ventral sulcus, starting from the umbo or even anteriorly to mid-length.


Distribution. Wuchiapingian Araxilevis and Haydennella beds of Transcaucasia (Ruzhentsev & Sar-
T. lata differs from T. araxensis by being generally larger, having a more transverse outline, a strongly para-sulcate anterior commissure, a more developed sulcal tongue and by the occurrence of a dorsal sulcus.


**Distribution.** Wuchiapingian *Oldhamina* beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965); Changhsingian Nesen Formation of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010).

**Transcaucasythis minor** (Grun in Ruzhentsev & Sarytcheva, 1965)

Pl. 3, figs 39-42

1965 *Transcaucasythis minor* Grunt in Ruzhentsev & Sarytcheva, p. 249, pl. 43, fig. 7.

1986 *Transcaucasythis minor* - Grunt, pl. 15, figs 4-5.

2004 *Transcaucasythis minor* - Shen et al., p. 895, figs 8.1-8.10, 12

**Material:** One figured articulated shell: MPUM11269 (G172-1), two articulated shells: MPUM11268 (G172-1, G193-1).

**Description.** Very small sized, subequally biconvex shell, maximum width ranging from 5.3 to 7 mm, corresponding length from 5.1 to 6.5 mm. Anterior commissure weakly uniplicate. Ventral valve slightly more convex than the dorsal one; sulcus widening and deepening anteriorly, umbo incurved and perforated by a small foramen. Dorsal valve sub-circular in outline. Both valves ornamented by growth lines.

**Remarks.** *Transcaucasythis minor* differs from the other species of this genus by its very small size and the mostly uniplicate anterior commissure.

**Occurrence.** Julfa Formation, beds G172, G179, G193.

**Distribution.** Wuchiapingian *Haydenella* beds and Changhsingian of Transcaucasia (Ruzhentsev & Sarytcheva 1965; Shen et al. 2004).

**Genus Juxathyris** Liang, 1990

*Type species:* *Juxathyris apicuwula* Liang, 1990 from the Capitanian of South China

**Juxathyris** sp. ind.

Pl. 3, figs 43-48

**Material:** Two figured articulated shells MPUM11270 (G126-2), MPUM11271 (G136-8), eight articulated shells MPUM11272 (G126-1, G134-7, G134-6, G137-6, G138-1-2-3, G138B-9).

**Description.** Biconvex shell with equidimensional outline; width and length ranging from 7.3 mm to 14.9 mm. Maximum width at mid-length; anterior commis-
1969 *Araxathysis protea* - Stepanov et al., pl. 5, fig. 4a-d.
1986 *Araxathysis protea* - Grunt, pl. 15, fig. 9; pl. 16, fig. 1; pl. 27, figs 2-3.
2010 *Araxathysis protea* - Angiolini & Carabelli, pl. 5, figs 16-18.

**Material:** Three figured articulated shells: MPUM11273 (G143B-17), MPUM11274 (G148-13), MPUM11294 (142-2), 6 articulated shells: MPUM11275 (G142-1, G143B-11, G148-15, G152-3, G155-1, G156).

**Description.** Medium sized shell, quite strongly inflated, with approximately equally convex valve; maximum width: 25.2-34.9 mm, length: 23.9-32.4 mm; outline sub-triangular to sub-pentagonal, slightly longer than wide. Hinge line about 2/3 of the maximum width; anterior commissure paratypes with squared to slightly rounded fold. Ventral valve triangular in outline; sulcus shallow and narrow at the umbo becoming broader anteriorly to mid-length. Dorsal valve sub-rectangular to sub-oval, with a narrow and shallow sulcus widening anteriorly, flanked by two gentle folds. Growth lamellae evident at the anterior margin.

**Remarks.** *Araxathysis protea* is very similar in size, shape and outline to *Araxathysis quadrilobata* (Abich, 1878); however *A. protea* shows a less transverse outline, with a width/length ratio of 1.05-1.10, whereas *A. quadrilobata* has a width/length ratio of 1.07-1.20. Furthermore, *A. protea* shows a stronger sulcal tongue than *A. quadrilobata* and it has a dorsal sulcus that widens anteriorly.

**Occurrence.** Julia Formation, beds G142, G142B, G143B, G148, G152, G155, G156.

**Distribution.** Wuchiapingian Oldhamina beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965); Wuchiapingian-Changhsingian of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010).

**Araxathysis abichi** (Arthaber, 1900)

Pl. 3, figs 56-62

1878 *Springera nysii* - Abich, p. 62, pl. 7, fig. 8.
1878 *Springera protea var. ambigua* - Abich, p. 62, pl. 6, fig. 9.
1878 *Springera protea var. subdita* - Abich, p. 65, pl. 6, figs 11-12.
1878 *Springera plano sulcata* - Abich, p. 65, pl. 8, figs 4.
1878 *Springera plano sulcata var. rugosa* - Abich, p. 64, pl. 8, figs 3.
1902 *Springera abichi* - Arthaber, p. 280, pl. 22, figs 10-12.
1965 *Araxathysis abichi* - Grunt in Ruzhentsev & Sarytcheva, p. 244, pl. 43, figs 2-3.
1986 *Araxathysis abichi* - Grunt, p. 113, figs 58, pl. 15, fig. 7; pl. 27, fig. 1.

**Material:** Two figured articulated shells: MPUM11276 (G142B-4), MPUM11277 (G148-11), five articulated shells: MPUM11278 (G142-4, G143B-15, G148-4, G149-3-10).
Description. Small to medium sized shells, with transverse outline; maximum width: 23.4-11.3 mm, corresponding length: 8.8-21.0 mm; anterior commissure uniplicate. Ventral valve more convex in the umbonal region, with a narrow and shallow sulcus starting at the umbo and expanding anteriorly, forming a very shallow tongue. Dorsal valve slightly and evenly convex with a median shallow sulcus delimited by gentle folds.

Remarks. A. abichi is easily distinguishable from the other species of the same genus because of its smaller size, its ventral and dorsal sulci which are very narrow and linear and because the ventral sulcus expands, but gently so, only in the most anterior part of the valve.


Distribution. Wuchiapigian Oldhamina beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965).

Axanathysis felina (Arthaber, 1900)

Pl. 3, figs 63-65

1878 Spirgera protea var. globulans Abich, p. 58, pl. 7, fig. 7; pl. 8, fig. 12.
1878 Spirgera protea var. subtila Abich, p. 59, pl. 8, figs 10-11.
1909 Spirgera protea var. data Arthaber, p. 275, pl. 22, fig. 2.
1909 Spirgera protea var. americanus Arthaber, p. 277, pl. 22, figs 6-7.
1950 Spirgera felina Arthaber, p. 279, pl. 22, figs 8-9.
1968 Axanathysis felina - Grunt in Ruzhentsev & Sarytcheva, p. 244, pl. 43, fig. 6; text-fig. 42.
1966 Axanathysis felina - Sestini & Glaus, p. 911, pl. 65, fig. 3.
1986 Axanathysis felina - Grunt, p. 112, fig. 57.
2010 Axanathysis felina - Angiolini & Carabelli, p. 80, pl. 5, figs 8-11.

Material: One figured articulated shell: MPUM11279 (G145B-6), three articulated shells: MPUM11280 (G142-6, G145B-4, G148-14).

Description. Medium sized biconvex shell, with sub-pentagonal outline; shell longer than wide with maximum width ranging from 22.1 to 35.5 mm; corresponding length: 24.3 to 36.0 mm. Anterior commissure parasulate with height-width ratio of fold of 0.4-0.6. Ventral valve more convex in the umbonal region becoming flat anteriorly; median sulcus starting from the umbo, broadening and deepening towards the anterior margin. The sulcus is flanked by two gently rounded ridges; sulcal tongue high. Dorsal valve fairly convex, with sub-oval outline, slightly longer than wide; median fold very low starting from the umbo. Ornamentation of growth lamellae at the anterior margin.

Remarks. A. felina differs from the congeneric species of the same size mainly because of its more elongated shell outline.


Distribution. Wuchiapigian Oldhamina beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965); Wuchiapigian-Changsningian of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010).

Axanathysis quadrilobata (Abich, 1878)

Pl. 4, figs 1-4

1878 Spirgera protea var. quadrilobata Abich, p. 53, pl. 7, fig. 6; pl. 9, figs 8-9.
1939 Atshyris (Composita) protea var. quadrilobata - Licharew, p. 117, pl. 24, fig. 3.
1965 Axanathysis quadrilobata - Grunt in Ruzhentsev & Sarytcheva, p. 101, pl. 43, figs 1a-c, 2a-c.
1976 Axanathysis quadrilobata - Stepanov, pl. 4, figs 8a-d.
1986 Axanathysis quadrilobata - Grunt, pl. 15, figs 8, 10.

Material: Two figured articulated shell: MPUM11281 (G143B-6), MPUM11285 (G157-1), 16 articulated shells: MPUM11282 (G140-6, G141C-2, G142B-1-2-10-19, G144-12, G149-12, G152-1, G154-1, G155B-1, G155C-2-4, G156B-1, G157-2).

Description. Large sized shell, elliptical in outline and slightly wider than long, with maximum width ranging from 22.8 mm to 34.3 mm, corresponding length: 19.7-32.5 mm; both valves equally convex; anterior commissure parasulate. Ventral valve more convex in the umbonal region; median sulcus expressed by a narrow small furrow which starts from the umbo, significantly expands in the middle part and passes into a broad flat depression at the anterior margin; sulcal tongue medium to very high, with fold deep-width ratio of 0.4-0.7. Dorsal valve elliptical in outline, with a thin median furrow bordered by folds.

Remarks. A. quadrilobata shows a great variability in the height of the sulcal tongue which can vary from moderately low to very high; also the ventral sulcus can be bordered anteriorly by folds differently evident. It differs from A. protea for the more transverse outline and the higher tongue.


Distribution. Wuchiapigian Oldhamina Beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965); Wuchiapigian Julfa beds of North Iran (Stepanov et al. 1969).

Order Spiriferida Waagen, 1883
Superfamily Ambocoelioidae George, 1931
Family Ambocoeliidae George, 1931
Subfamily Ambocoeliinae George, 1931
Genus Atshyris George, 1931
Type species: Spirifer wesi Fleming, 1828 from the Mississippian of Great Britain.
PLATE 4

Figs 1-4 - Araxathrys quadriobata, MPUM11281 (G143B-6), articulated shell, ventral, dorsal, lateral and anterior views respectively, x1.
Figs 5-6 - Cryptobrysm sp. ind., MPUM11283 (G142B-21), articulated shell, ventral and dorsal views respectively, x2.
Figs 7-10 - Cartorhium sp. ind., MPUM11284 (G206B-1), articulated shell, ventral, dorsal, lateral and anterior views respectively, x2.
Figs 11-18 - Permphirocondobrysm ovata, MPUM11285 (G149-4), articulated shell, ventral, dorsal, posterior and anterior views respectively, x1; MPUM11286 (G151-1), articulated shell, ventral, dorsal, lateral and anterior views respectively, x1.
Figs 19-23 - Rostranteria sp. ind., MPUM11288 (G159-1), articulated shell, lateral, ventral, dorsal, anterior and posterior views respectively, x2.
Figs 24-28 - Diploma sp. ind., MPUM11289 (G271), articulated shell, lateral, ventral, dorsal, posterior and anterior views respectively, x2.
Crurithyris sp. ind.
Pl. 4, figs 5-6

Material: One figured articulated shell: MPUM11283 (G142B-21).

Remarks. The specimen shows the typical characters of the genus, such as the ventri-biconvex shape, the weak sulci and possibly a microramation of spines, but the poor state of preservation does not allow a specific assignment.

Occurrence. Julfa Formation, bed G142B.

Distribution. The genus Crurithyris is cosmopolitan and ranges from the upper Devonian to the Permian (Johnson et al. in Williams et al. 2006).

Superfamily Spiriferoidae King, 1846
Family Trigonotretiidae Schuchert, 1893
Subfamily Neospiriferinace Waterhouse, 1968
Genus Cartothrium Cooper & Grant, 1976
Type species: Cartothrium twistrice Grant & Grant, 1976 from the Guadalupian of Texas

Cartothrium sp. ind.
Pl. 4, figs 7-10

Material: One figured articulated shell: MPUM11284 (G206B-1).

Remarks. The small spiriferid specimen under examination shows an equidimensional outline, an ornamentation of asymmetrically bifurcating ribs forming fascicles and an umbonally recurved interarea. These characters, besides the size, are typical of Cartothrium twistrice Xu & Grant, 1994.

Occurrence. Julfa Formation, bed G206B.

Distribution. Changhsingian of South China (Xu & Grant 1994).

Superfamily Reticolaroidea Waagen, 1883
Family Reticulariidae Waagen, 1883
Subfamily Reticulariinae Waagen, 1883
Genus Permophricodothyris Pavlova, 1965
Type species: Permophricodothyris ovata Pavlova, 1965 from the Lopingian of Transcaucasus

Permophricodothyris ovata Pavlova, 1965
Pl. 4, figs 11-18

1939 Neophricodothyris indica - Licharew, p. 114, pl. 27, fig. 5.
1965 Neophricodothyris indica - Ivanova in Rushentsev & Sarytcheva, pl. 40, fig. 12d-c.
1965 Permophricodothyris ovata Pavlova, p. 135, figs 1-4.
1965 Permophricodothyris ovata - Fantini Sestini and Glauss, p. 919, pl. 65, fig. 7; pl. 66, fig. 2a-b.
1969 Permophricodothyris ovata - Stepanov et al., pl. 6, fig. 3a-c; pl. 7, fig. 1a-c.

Material: Three figured articulated shells: MPUM11285 (G149-4), MPUM11286 (G151-1), MPUM11304 (G152-5), 16 articulated shells: MPUM11287 (G141-2, G142B-14, G145B-2, G148-2, G149-14, G151-3, G151B-1-2, G152-1-2, G154B-6, G155-3, G156B-1, G157-4-5-6).

Description. Medium to large sized biconvex shell with sub-pentagonal to longitudinally sub-elliptical outline; length-width ratio ranging from 1.08 to 1.34; maximum width slightly anterior to midlength; anterior commissure uniplicate. Ventral valve more convex in the umbonal region, flattening anteriorly; interarea high, short and gently incurved, with horizontal striation; sulcus narrow and shallow posteriorly, widening and deepening anteriorly. Dorsal valve more evenly convex than the ventral one. Ornamentation of concentric bands, 1-2 mm-thick, carrying a row of biramous spines.

Remarks. As outlined by Angiolini & Carabelli (2010), this species is quite variable in its outline which may be either sub-oval and longer than wide or equidimensional and roughly sub-pentagonal.


Distribution. Guadalupian Gnischik Formation and Wuchiapingian Oldhamina beds of Transcaucasus (Rushentsev & Sarytcheva 1965); Wuchiapingian-Changhsingian of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010).

Order Terebratulida Waagen, 1883
Superfamily Cryptonelloidea Thomson, 1926
Family Notothyrididae Licharew, 1960
Genus Rostranteris Gemellaro, 1899
Type species: Dielasma advenus Gemellaro, 1894 from the Guadalupian of Sicily

Rostranteris sp. ind.
Pl. 4, figs 19-23

Material: One figured articulated shell: MPUM11288 (G159-1).

Remarks. This specimen has been placed in Rostranteris, as revised by Smirnova (2007), because of its
Figs 1-3 - Serial sections of *Truncocarathys arxensis* MPUM11290 (G169-0) at 0.3, 0.4 and 0.6 mm from the umbo respectively, x10.
Figs 4-7 - Serial sections of *Truncocarathys arxensis*, MPUM11291 (G174) at 0.2, 0.3, 0.5 and 0.6 mm from the umbo respectively, x10.
Figs 8-10 - Serial sections of *Truncocarathys arxensis*, MPUM11292 (G179-3) at 0.15, 0.2 and 0.3 mm from the umbo respectively, x10.
Figs 11-13 - Serial sections of *Truncocarathys lata*, MPUM11293 (G149-11) at 0.25, 0.3 and 0.4 mm from the umbo respectively, x10.
Figs 14-19 - Serial sections of *Araxathys protea*, MPUM11294 (142-2) at 1, 1.1, 1.2, 1.4, 1.9 and 2.7 mm from the umbo respectively, x2.5.
Figs 20-26 - Serial sections of *Araxathys quadribata*, MPUM11295 (G157-1) at 0.2, 0.3, 0.4, 0.6, 0.7, 1.2 and 2 mm from the umbo respectively, x2.5.
Fig. 27 - Section along the commissural plane of *Pemphricodothyris ovata* showing the spiralia, MPUM11304 (G152-5), x 1.2.
few, but strong plications and antiplicate anterior commissure.

**Occurrence.** Julfa Formation, bed G159.

**Superfamily Dielasmaeidea Schuchert, 1913**

**Family Dielasmataeidae Schuchert, 1913**

**Subfamily Dielasmataeinae Schuchert, 1913**

**Genus Dielasma King, 1859**

Type species: Terebratalis elongata Schloethelm, 1816 from the Guadalupian of Germany

**Dielasma** sp. ind.

Pl. 4, figs 24-28

**Material.** One figured articulated shell: MPUM11289 (G271).

**Remarks.** The specimen seems to belong to the genus *Dielasma* because of its inner hinge plates joined at the valve floor. However, its state of preservation prevents any specific assignment.

**Occurrence.** Julfa Formation, bed G271.

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