Rivista Italiana di Paleontologia e Stratigrafia	volume 120	no. 1	5 pls.	pp. 27-59	March 2014

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

ABBAS GHADERI [1], CLAUDIO GARBELLI [2], LUCIA ANGIOLINI [2], ALI REZA ASHOURI [1], DIETER KORN [3], ROBERTO RETTORI [4] & MOHAMMAD HOSSEIN MAHMOUDI GHARAIE [1]

Received: September 25, 2013; accepted: December 17, 2013

Key words: Biostratigraphy, correlation, palaeoecology, brachiopod systematics, Lopingian faunal composition.

Abstract. The Julfa Formation in the Ali Bashi Mountains, 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 Bashi 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, Rhynchonellida, Athyridida, Spiriferida, 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 few of the brachiopod taxa range up into the Changhsingian *Paratirolites* 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 shallowing 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 Bashi 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 Bashi Mountains (= Kuh-e-Ali Bashi), Julfa, Iran, and those of the Araxes (Aras) Gorge, near Dorasham, Azerbaijan (Abich 1878; Frech & Arthaber 1900; Stoyanow 1910, 1915; Bonnet 1912; Rieben 1934; Bonnet & Bonnet 1947; Ruzhentsev & Sarytcheva 1965; Stepanov et al. 1969; Teichert et al. 1973; Rostovtsev & 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 to 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 Bashi Mountains, northwest Iran (Figs 1-2). These outcrops were discovered in the 1850's by Abich and described by many authors (e.g. Frech & Arthaber 1900; Stoyanow 1910, 1915; Rieben 1934; Stepanov et al. 1969; Teichert et al. 1973; Baud et al. 1974; Altiner et al. 1980; Kozur 2004, 2005, 2007; Richoz 2006; Richoz et al. 2010; Ghaderi et al. 2013;

1 Department of Geology, Faculty of Sciences, Ferdowsi University of Mashhad, Azadi Square, 9177948974, Mashhad, Iran.
2 Dipartimento di Scienze della Terra "A. Desio", Via Mangiagalli 34, 20133 Milano, Italy.
3 Museum fur Naturkunde, Leibniz Institute for Research on Evolution and Biodiversity, Invalidenstraße 43, 10115 Berlin, Germany.
4 Dipartimento di Scienze della Terra, Piazza Università, 06100 Perugia, Italy.

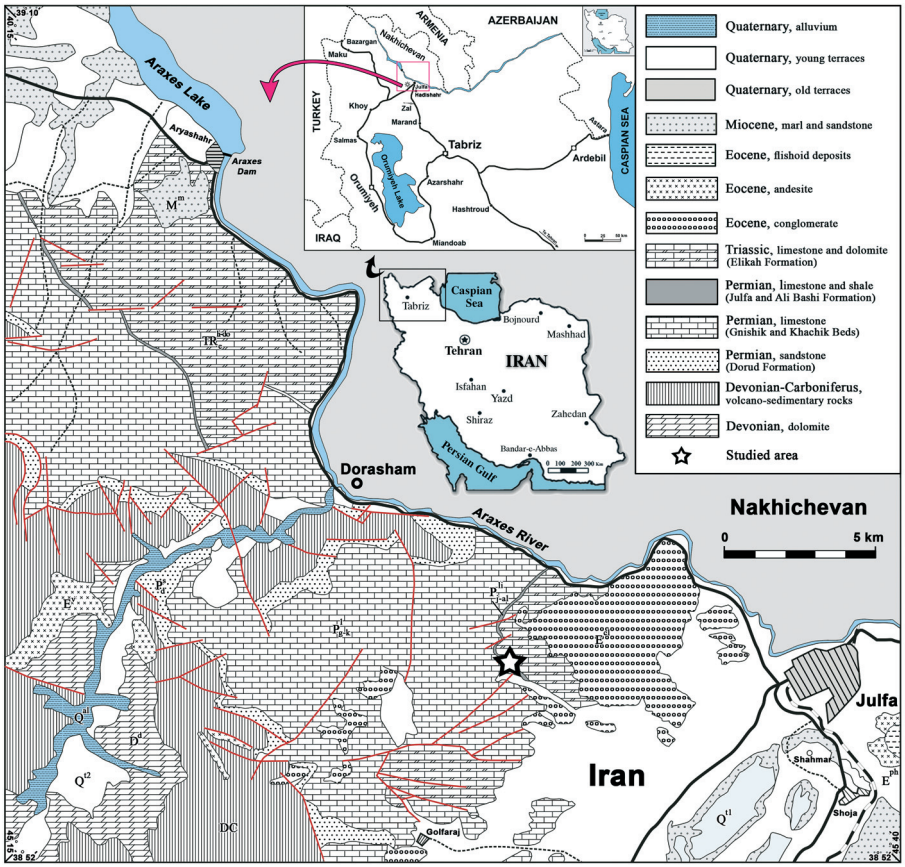


Fig. 1 - Location map and geological map of the study area. The star shows the location of the sections of the Ali Bashi Mountains, Julfa, NW Iran. Modified from Abdolahi & Hosseini (1996), Oskuie & Hajialilu (1995) and Bolourchi & Saidi (1987).

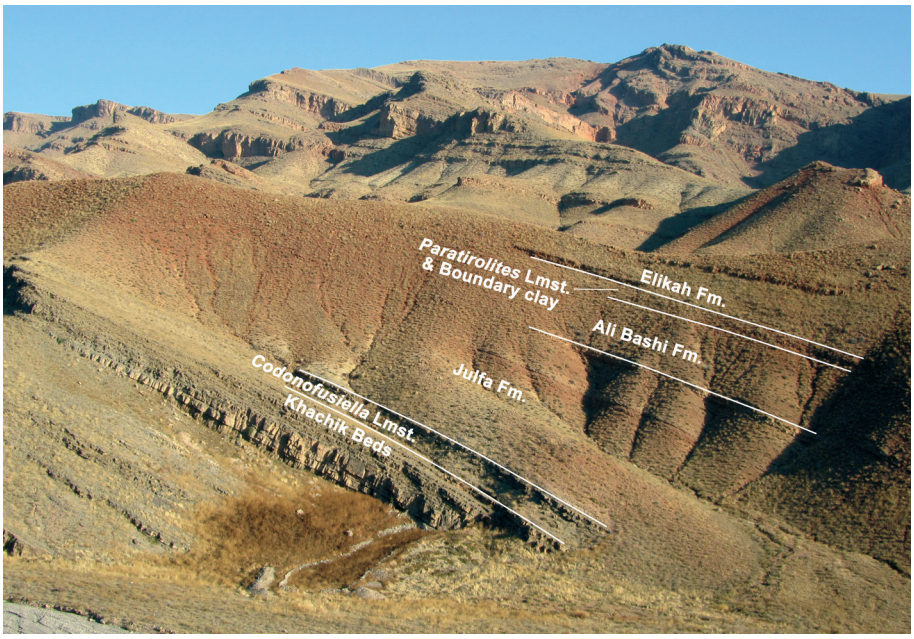


Fig. 2 - Photo of the Main Valley section pointing to NE.

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), Ruzhentsev & 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-

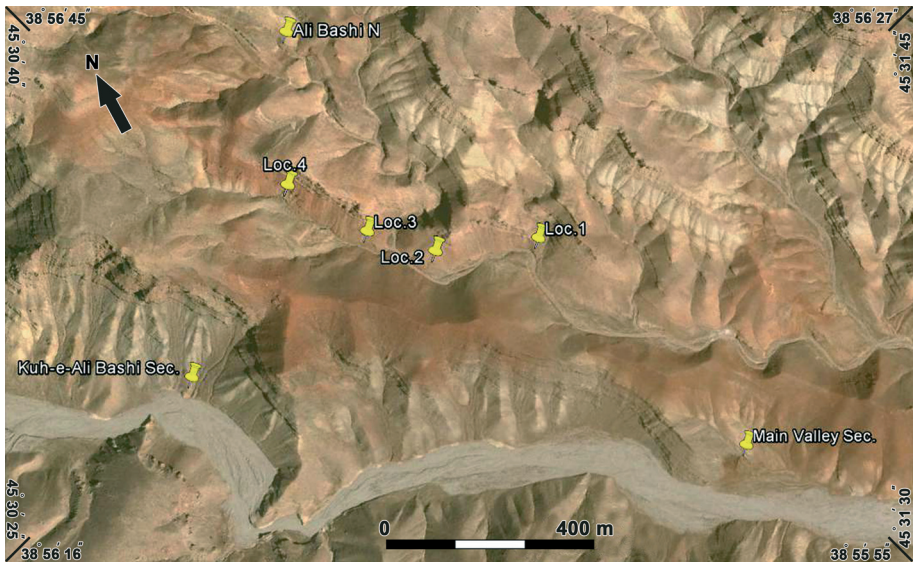


Fig. 3 - Satellite map of the Ali Bashi Mountains showing the location of the sections of Stepanov et al. 1969, Teichert et al. 1973 (Localities 1-4), Leda et al. 2013 (Localities 1, 4 and Ali Bashi N) and of the section described in the present paper (Main Valley Section).

vide systematic descriptions of the brachiopods from these regions and none in particular describes the systematics 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 1120.5 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 Elikah 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 at 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..."

NORTHWEST IRAN												
Stepanov et al. 1969				Teichert et al. 1973			This study					
Induan	Unit G	Lower Elikah Formation	*Claraia* Beds	Elikah Formation	*Claraia* Beds	Induan	Elikah Formation	*Claraia* Beds	Induan			
								Boundary Clay	Changhsingian			
	Unit F	Paratirolites Limestone	*Paratirolites*	Ali Bashi Formation	*Paratirolites*	Dorashamian	Ali Bashi Formation	*Paratirolites* Limestone				
	Unit E	P-T Transition Beds	*Bernhardites*		*Shevyrevites*			Unnamed Shaly Unit				
			Dzhulfites		*Dzhulfites*							
			Tompophiceras		*Iranites*							
			Phisonites-Comelicania		*Phisonites*							
Dzhulfian	Unit D	Upper Julfa Beds	*Haydenella-Pseudowellerella*	Julfa Beds	*Haydenella-Pseudowellerella (Vedioceras)*	Dzhulfian	Julfa Formation	Upper Julfa Beds	Wuchiapingian			
	Unit C	Lower Julfa Beds	*Pseudogastrioceras-Permophricodothyris*					Lower Julfa Beds				
			Araxilevis-Orthotetina									
Guadalupian	Unit B	Khachic Beds	*Codonofusiella*	Khachic Beds		Guadalupian		*Codonofusiella* Limestone				
								Khachic Beds	Guadalupian			
	Unit A	Gnishik Beds		Gnishik Beds				Gnishik Beds				

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.

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):

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 overlays a dark grey bioclastic packstone, named *Codonofusiella* Limestone, that is the uppermost member of the underlying Khachik Formation. According to the for-

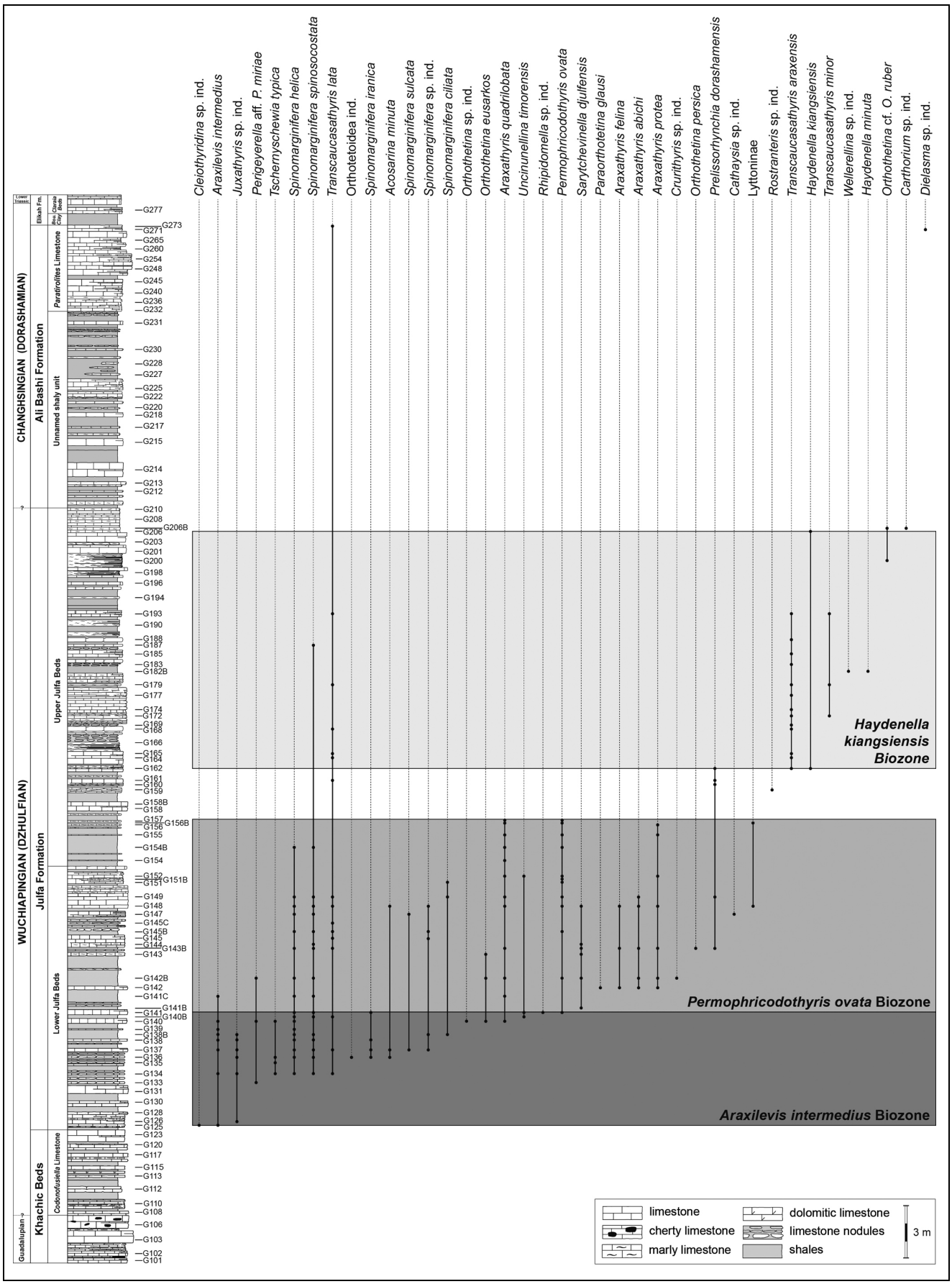


Fig. 4 - Stratigraphic log of the Main Valley Section (38°56'06" N, 45°31'21" E) showing the range of the studied brachiopods.

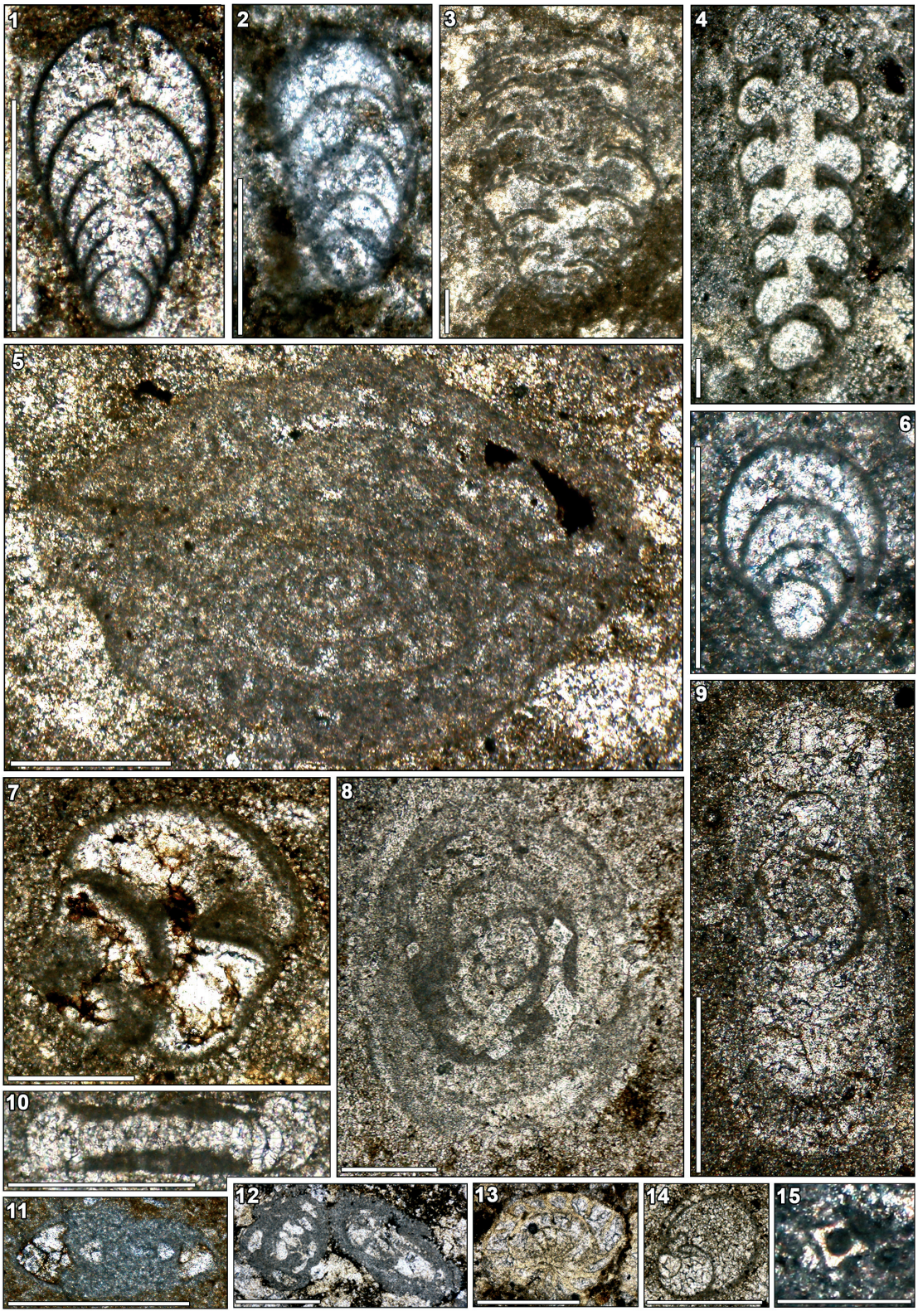


Fig. 5 - Foraminifers from the Julfa and Ali Bashi formations. Scale bar is 200 micron.
1, 6) *Frondina* ex gr. *permica*; 1 - subaxial section, Sample G119; 6 - subaxial section, Sample G125. 2) *Frondina* sp.; Sample G120. 3) *Climacammina* sp.; subaxial section, Sample G120. 4) *Palaeotextularia* sp.; subaxial section, Sample G125. 5) *Codonofusiella* cf. *kwangsiana*; equatorial section, Sample G124. 7) *Globivalvulina* cf. *vonderschmitti*; subequatorial section, Sample G118. 8) *Pseudobaisalina* sp.; subequatorial section, Sample G111. 9) *Agathammina* sp.; longitudinal sections, Sample G124. 10) *Hemigordius* sp.; longitudinal sections, Sample G120. 11) *Neoendothyra* sp.; axial section, Sample G264. 12) *Glomomidiella nestellorum*; oblique section, Sample G106B. 13) *Nankinella* sp.; subequatorial section, Sample G106. 14) *Paraglobivalvulina gracilis*; subequatorial section, Sample G110. 15) *Rectostipulina quadrata*; transverse section, Sample G247.

aminiferal content (i.e. *Agathammina* sp., *Codonofusiella* sp., *Codonofusiella kwangasiana*, *Climacammina* sp., *Frondina* ex gr. *permica*, *Frondina* sp., *Globivalvulina* cf. *vonderschmitti*, *Glomomidiella nestellorum*, *Hemigordius* spp., *Nankinella* sp., *Palaeotextularia* sp., *Paraglobivalvulina gracilis*, *Pseudobaisalina* sp.), which we illustrate for the first time in Fig. 5, the *Codonofusiella* 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 *Shervyrevites* 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 ostracod- and crinoid-rich 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 reddish, 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.

Elikah 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 spheres, and an oncoid 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 (*Transcaucasathyris 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, Transcaucasathyris, Juxathyris, Araxathyris, Permophrycodothyris, Acosarina, Rhipidomella, Uncinunellina, Wellerellina, Prelissorhynchia, Crurithyris, Cartorhium, Rostranteris, Dielasma)*, 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 *Paraorthotetina)*. These numerically represent 5% of the total fauna.

A different settling preference is shown by free-living concavo-convex spiny semi-infaunal productids (*Cathaysia*, *Spinomarginifera, Haydenella, Tschernyschewia,* and *Sarytchevinella*) and large concavo-convex shells with stout halteroid 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 Lyttonines have been found cemented on other brachiopod taxa, suggesting they were exploiting limited hard substrates offered by larger coexisting shells.

Seminfaunal 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 *Spinomarginifera,* 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 ubiquitary; even if they are more abundant in the more limey 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 *Paratirolites* 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-

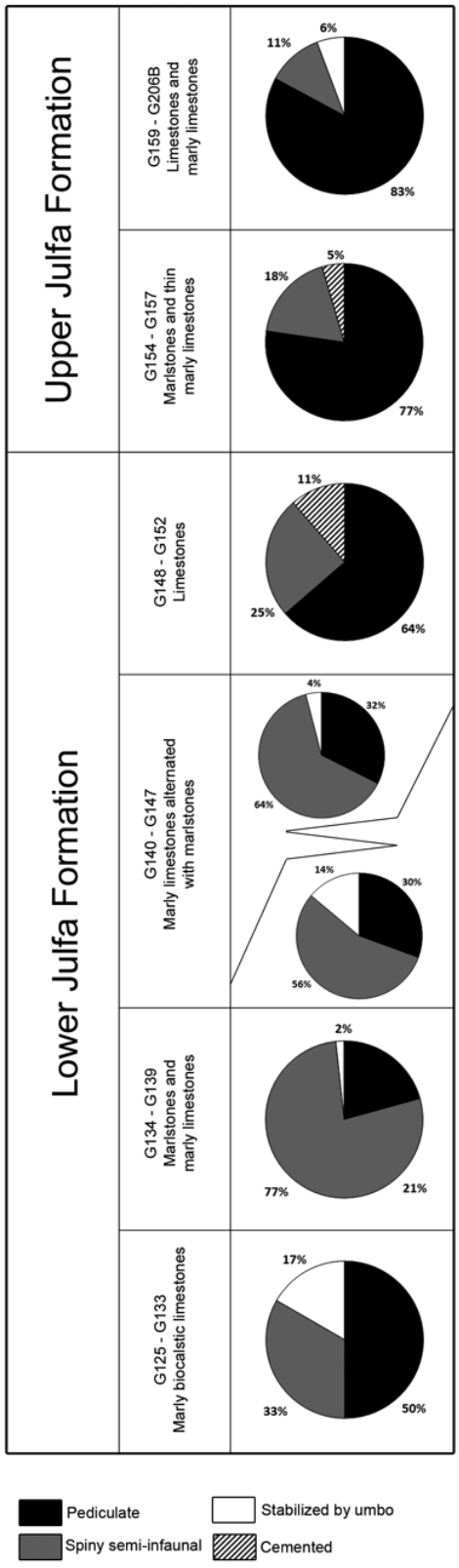


Fig. 6 - Change of brachiopod life-style through the Julfa Formation, from a dominance of free living concavo-convex spiny semi-infaunal productids and and large concavo-convex shells with stout halteroid spines in the lower part of the formation to a dominance of pediculate taxa with a few cemented 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.

sion 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-Permophricodothyris* zone to the *Araxoceras-Oldhamina* beds of Dorasham and the *Haydenella-Pseudowellerella* zone to the *Vedioceras-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, *Permophricodothyris ovata* biozone, and *Haydenella kiangsiensis* biozone respectively, based on the taxonomic revision of the fauna (Fig. 4). The recorded species of the genus *Orthothetina* in fact occurs at the very top of the *Araxilevis intermedius* biozone and extend into the *Permophricodothyris ovata* biozone; we could not find any species of *Pseudowellerella*, but of *Wellerellina*, which however occur in just one sample (G182B) in the *Haydenella kiangsiensis* biozone.

More complex is the correlation between the succession 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 Transcaucasia – and thus NW Iran – and so for instance, the *Araxilevis intermedius* biozone of the Alborz Mountains is correlative to the *Araxilevis* zone of Transcaucasia and of Ali Bashi. However, the overlying *Permophricodothyris ovata* biozone shares some taxa with the *Oldhamina* beds of Transcaucasia and with the *Permophricodothyris* 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 Wuchiapingian because of the shift to deep water depositional environments, which are less favourable for large sized reticularioids that need high nutrient supply in high hydrodynamic energy settings. Upward, the *Enteletes lateroplicatus* biozone of the Alborz Mountains has been roughly correlated to the Changhsingian "*Comelicania*" (= *Gruntallina*) 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 Tethyan 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 regions 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 limestone at the base of the Julfa Formation, which are dominated by semi-infaunal productids, to the bioclastic limestone above. Here, more diversified pedicle attached 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 pediculate taxa do occur, attaching to synsedimentary 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. Desio", University of Milan, Italy. Specimens are registered with a prefix MPUM followed by a four to five digit number. The systematic study follows the classifications of Brunton et al. in Williams et al. (2000) for the productidines and strophalosiidines, Williams & Brunton in Williams et al. (2000) for the orthotetidines, Williams & Harper in Williams et al. (2000) for the orthids, Savage et al. in Williams et al. (2002) for the rhynchonellids, Alvarez & Rong in Williams et al. (2002), Alvarez in Williams et al. (2007) for the athyridids, Johnson et al. in Williams et al. (2006) for the ambocoelioids, Carter & Gourvennec in Williams et al. (2006) for the reticularioids and Jin et al. in Williams et al. (2006) for the dielasmatoids.

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

Order **Productida** Sarytcheva & Sokolskaya, 1959

Suborder **Productidina** Waagen, 1883

Superfamily Productoidea Gray, 1840

Family Productellidae Schuchert, 1929

Subfamily Productininae Muir-Wood & Cooper, 1960

Tribe Chonetellini Licharew in Licharew et al., 1960

Genus *Haydenella* Reed, 1944

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

Haydenella kiangsiensis (Kayser, 1883)

Pl. 1, figs 1-2

1883 *Productus kiangsiensis* Kayser, p. 185, pl. 26, figs 6-11.

1911 *Productus kiangsiensis* - Frech, p. 129, 168, 172, pl. 2, fig. 2, pl. 21, figs 3, 4.

1927 *Avonia kiangsiensis* - Chao, p. 125, pl. 14, figs 14-16.

1928 *Thomasia kiangsiensis* - Chao, p. 50, pl. 6, fig. 18.
1932 *Linoproductus kiangsiensis* - Huang, p. 46, pl. 3, figs 13-19.
1944 *Productus (Haydenella) kiangsiensis* - Reed, p. 78.
1948 *Paramarginifera kiangsiensis* - Branson, p. 448.
1960 *Haydenella kiangsiensis* - Muir-Wood & Cooper, p. 224, 395, pl. 65, figs 1-14.
1961 *Argentiproductus kiangsiensis* - Zhang & Ching, p. 411, pl. 3, figs 13, 14.
1964 *Haydenella kiangsiensis* - Yanagida, p. 8, text-fig. 3, pl. 2, fig. 1, pl. 3, fig. 4.
1965 *Haydenella kiangsiensis* - Ruzhentsev & Sarytcheva, pl. 38, figs 6-8.
1978 *Haydenella kiangsiensis* - Jing & Hu, p. 113, pl. 2, fig. 25.
1979 *Haydenella kiangsiensis* - Zhan, p. 81, pl. 5, figs 3,4.
1984 *Haydenella kiangsiensis* - Yang, p. 218, pl. 33, fig. 9.
1995 *Haydenella kiangsiensis* - Zeng et al., pl. 5, fig. 8.
2005 *Haydenella kiangsiensis* - Campi et al., p. 111, pl. 1, figs Z, bb, cc, ee.
2008 *Haydenella kiangsiensis* - Li & Shen, p. 311, fig. 4 (7).
2009 *Haydenella kiangsiensis* - Shen & Clapham, p. 721, pl. 1, fig. 28, pl. 2, fig. 1.
2012 *Haydenella kiangsiensis* - Crippa & Angiolini, p. 138, figs 11c-j.

Material: One figured ventral valve: MPUM11211 (G206), one ventral valve: MPUM11212 (G162-3).

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 (Ruzhentsev & 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 Ruzhentsev & Sarytcheva, 1965

Pl. 1, figs 3-4

1965 *Haydenella minuta* Sarytcheva in Ruzhentsev & 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.

Occurences. Julfa Formation, G182B

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

Tribe Paramarginiferini Lazarev, 1986

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

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

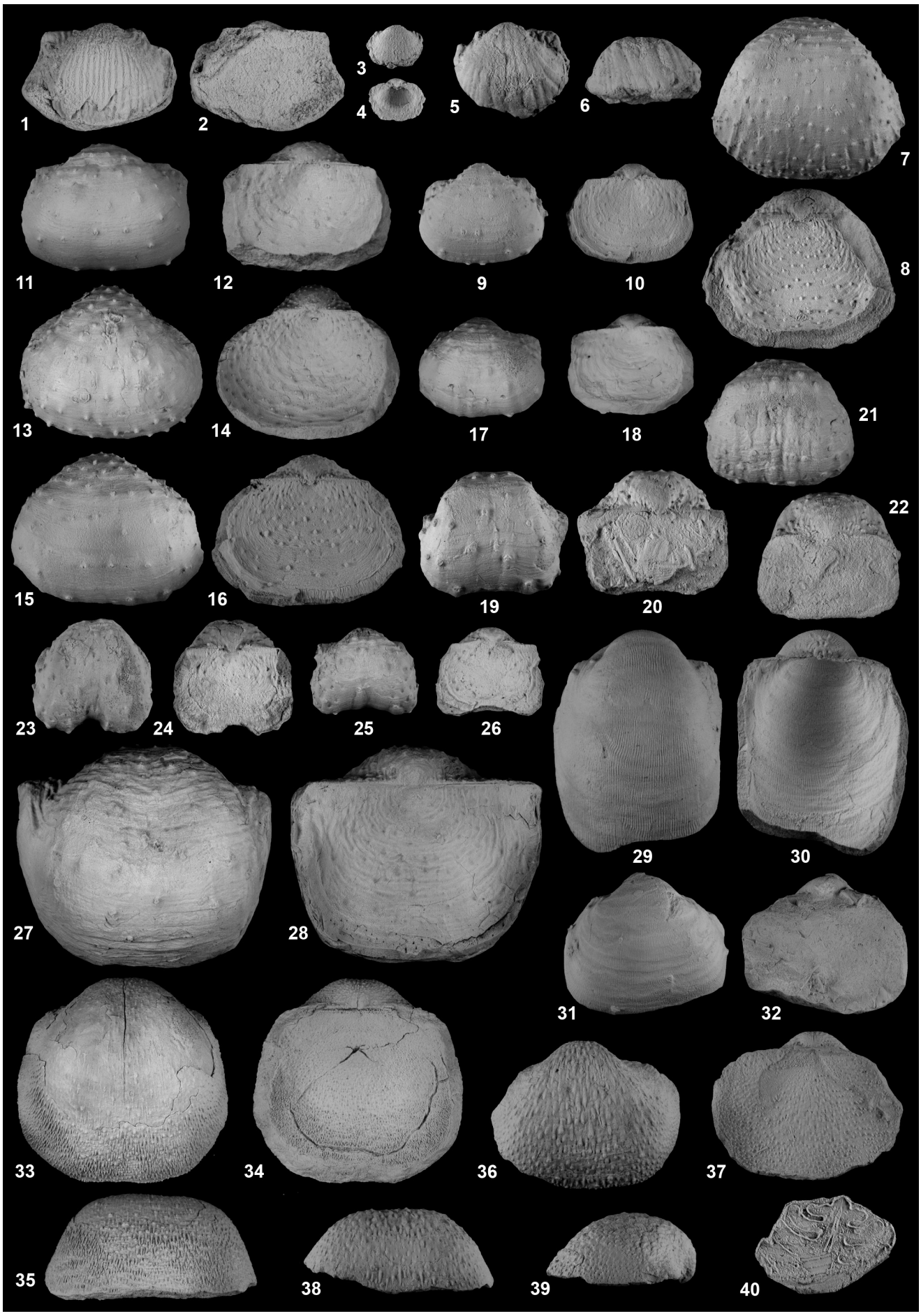
Cathaysia sp. ind.

Pl. 1, figs 5-6

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

PLATE 1

Figs 1-2 - *Haydenella kiangsiensis*, 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 - *Spinomarginifera ciliata*, MPUM11215 (G151-4), articulated shell, ventral and dorsal views respectively, x2.
Figs 9-12 - *Spinomarginifera helica*, 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 - *Spinomarginifera iranica*, 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 - *Spinomarginifera spinosocostata,* 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 - *Spinomarginifera sulcata,* 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 - *Araxilevis intermedius,* MPUM11232 (G138-15), articulated shell, ventral and dorsal views respectively, x1.
Figs 29-32 - *Sarytchevinella djulfensis,* 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 - *Tschernyschewia 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.
Fig. 40 - Lyttoninae gen. et sp. ind., MPUM11305 (G148-2bis), x2.


1
2
3
4
5
6
7
11
12
9
10
8
13
14
17
18
21
15
16
19
20
22
23
24
25
26
29
30
27
28
31
32
33
34
36
37
35
38
39
40

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.

Distribution. Julfa Formation, G147.

Subfamily Marginiferinae Stehli, 1954

Tribe Marginiferini Stehli, 1954

Genus *Spinomarginifera* Huang, 1932

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

Spinomarginifera ciliata (Arthaber, 1900)

Pl. 1, figs 7-8

1900 *Marginifera spinosocostata* var. *ciliata* Arthaber, p. 264, pl. 20, figs 9a-c.

1965 *Spinomarginifera ciliata* - Sarytcheva & Sokolskaya in Ruzhentsev & Sarytcheva, pl. 37, figs 12a-c.

1966 *Spinomarginifera ciliata* - Fantini Sestini & Glaus, 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, G 149-13), 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.

Occurrence. Julfa Formation, beds G138, G149, G151.

Distribution. Wuchiapingian *Oldhamina* and *Haydenella* beds of Transcaucasia (Ruzhentsev & Sarytcheva 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 3, 12-13, 17, 19-20.

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

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

1878 *Productus indeterminatus* Abich, p. 47, pl. 10, fig. 16; p. 48, pl. 10, figs 4, 18.

1900 *Marginifera intermedia helica* - Arthaber, p. 265, pl. 20, figs 10-12.

1903 *Marginifera helica* - Diener, p. 74, pl. 3, fig. 9.

1933 *Marginifera intermedia helica* - Simic, p. 42, pl. 3, figs 1-4.

1937 *Productus (Marginifera) intermedius-helicus* var. *multispinosa* - Licharew, p. 69, pl. 10, figs 7-10.

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

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

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

1960 *Spinomarginifera intermedia-helica* - Sarytcheva et al., p. 228, pl. 38, fig. 14.

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

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

1965 *Spinomarginifera helica* - Sarytcheva & Sokolskaya in Ruzhentsev & Sarytcheva, p. 226, pl. 37, figs 9-11.

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

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

2010 *Spinomarginifera helica* - Angiolini & Carabelli, p. 53, pl. 1, figs 10-11.

2011 *Spinomarginifera helica* - Verna & Angiolini in Verna et al., p. 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, G154B-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 Sarytcheva & 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 spinosocostata* (Abich, 1878). We refer to the discussion of Angiolini & Carabelli (2010, p. 53) for the differences with other species belonging to the genus *Spinomarginifera.*

Occurrence. Julfa Formation, beds G134, G137, G138, G138B, G139, G140, G140B, G141, G142B, G143B, G145B, G147, G148, G154B.

Distribution. Wuchiapingian *Araxilevis*, *Oldhamina* and *Haydenella* beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965); Guadalupian Ruteh Formation of North Iran (Fantini Sestini 1965b); Changhsingian of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010); Lopingian of Himalaya (Diener 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

Pl. 1, figs 13-16

1965a *Spinomarginifera iranica* Fantini Sestini, p. 992, pl. 94, figs 2-5.

2010 *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-trapezoidal 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.

Occurrence. Julfa Formation, beds G136, G137, G138, G141.

Distribution. Guadalupian-Lopingian of Turkey (Angiolini et al. 2007; Verna & Angiolini in Verna et al. 2011); Wuchiapingian-Changhsingian of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010).

Spinomarginifera spinosocostata (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. *cariniferus* Abich, p. 41, pl. 10, fig. 8.

1878 *Productus spinoso-costatus* var. *expansus* Abich, p. 42, pl. 5, figs 8, 11.

1900 *Marginifera spinoso costata* - Arthaber, p. 262, pl. 20, figs 5-8.

1911 *Productus (Marginifera) spinuloso-costatus* - Frech, p. 175, pl. 27, figs 1-2.

1937 *Productus (Marginifera) spinosocostatus* - Licharew, p. 71, pl. 10, fig. 37.

1965b *Marginifera spinosocostata* - Fantini Sestini, p. 43, pl. 5, figs 2-3.

1965 *Spinomarginifera spinosocostata* - Sarytcheva & Sokolskaya in Ruzhentsev & Sarytcheva, p. 225, pl. 37, figs 6-8.

1966 *Spinomarginifera spinosocostata* - Fantini Sestini & Glaus, p. 905, pl. 64, fig. 5.

2010 *Spinomarginifera spinosocostata* - Angiolini & Carabelli, p. 56, pl. 1, figs 21-22

2011 *Spinomarginifera spinosocostata* - 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-15); thirty articulated valves: MPUM11227 (G134-1-3, G136-7-11, G137-2-8-11, G138-4, G138B-4-7-8, G 140B-5, G141-4, G141C-3-4-6, G142B -16, G143B-18-19-20-23, G144-1, G145B-6, G147-2, G148-3-5, G149-2, G154B-3-4, G187-1).

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 rugae closely spaced in the umbonal 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 rugae, 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. helica* 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 G134, G136, G137, G138, G140, G141, G141C, G142B, G143B, G144, G145B, G147, G148, G149, G154B, G187.

Distribution. Wuchiapingian *Araxilevis* beds and *Oldhamina* beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965); Guadalupian-Lopingian Ruteh and Nesen Formations of the the Alborz Mountains, North Iran (Fantini Sestini 1965b; Fantini Sestini & Glaus 1966; Angiolini & Carabelli 2010); Lopingian of North Caucasus (Licharew 1937). *S.* cf. *S. spinosocostata* has been reported from the Changhsingian of Turkey (Angiolini et al. 2007).

Spinomarginifera sulcata Shen, He & Zhu, 1992

Pl. 1, figs 23-26

1992 *Spinomarginifera sulcata* Shen, He & Zhu, p. 179, pl. 3, figs 4-7.

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 incurved 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 rugae 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 rugae 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 at al. (1992).

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.

Occurrence. Julfa Formation, beds G137, G138B, G145B, G148.

Family Productidae Gray, 1840

Subfamily Leioproductinae Muir-Wood & Cooper, 1960

Tribe Tyloplectini 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.

1878 *Productus martini* Abich, p. 32, pl. 5, fig. 1; pl. 9, fig. 4.

1900 *Productus intermedius* - Arthaber, p. 254, pl. 19, figs 7-8.

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

1960 *Plicatifera intermedia* -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., pl. 3, figs 1a-c.

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

Material: One figured articulated shell: MPUM11232 (G 138-15); 15 articulated shells: MPUM11233 (G125-1-2, G134-9, 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-quadrate outline. Dorsal valve slightly convex 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.

Occurence. Julfa Formation, beds G125, G134, G137, G138, G138B, G139, G140, G141C, G70-float.

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 Compressiproductinae Jin & Hu, 1978

Genus *Sarytchevinella* Waterhouse, 1983

Type species: *Productus djulfensis* Stoyanov, 1915 from the Capitanian of Armenia

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

Sarytchevinella djulfensis (Stoyanov, 1910)

Pl. 1, figs 29-32

1910 *Productus djulfensis* Stoyanov, p. 101.

1915 *Productus djulfensis* - Stoyanov, 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 (G143B-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, G144-2-3, 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-quadrate 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.

Occurences. Julfa Formation, beds G141, G142, G142B, G143, G143B, G144, G148.

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

Suborder **Strophalosiidina** Schuchert, 1913

Superfamily Aulostegoidea Muir-Wood & Cooper, 1960

Family Scacchinellidae Licharew, 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 scabriculus* Abich (non Martin, 1809), p. 33, pl. 5, fig. 3.

1900 *Productus abichi* - 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. 13, fig. 7; pl. 18, fig. 6.

1958 *Tschernyschewia typica* - Ramovs, p. 524, pl. 9, figs 3-4.

1960 *Tschernyschewia typica* - Muir-Wood & Cooper, p. 127, pl. 25, figs 1-9.

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 22-24.

1965 *Tschernyschewia typica* - Sarytcheva & Sokolskaya in Ruzhentsev & Sarytcheva, pl. 33, figs 8-9.

2010 *Tschernyschewia 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.

Occurrence. Julfa Formation, beds G134, G135, G140.

Distribution. Wuchiapingian *Araxilevis* and *Oldhamina* beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965); Changhsingian Nesen Formation of the Alborz Mountains, North Iran (Angiolini & Carabelli 2010); Lopingian of southeastern Europe (Simic 1933; Ramovs 1958; Schréter 1963); Lopingian of Salt Range (Reed 1944); Changhsingian 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. 26, fig. 3.

1965 *Orthothetina persica* (Schellwien) - Sokolskaya in Ruzhentsev & Sarytcheva, 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. Apsacline ventral interarea with pseudodeltidium and strong monticulus. Brachial 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. Wuchiapingian *Oldhamina* beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965), Wuchiapingian-Changhsingian 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. *incurvus* Abich, p. 73, pl. 5, fig. 5.

1961 *Perigeyerella costellata subquadrata* - Zhang & Jin, p. 408, pl. 3, figs 21-23.

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

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

1981 *Schellwienella* sp. - Shimizu, p. 69, pl. 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 umbonal region, become flat anteriorly. Widely apsacline interarea with a triangular pseudodeltidium and a convex monticulus. 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.

Occurrence. Julfa Formation, beds G140, G142B, G143.

Distribution. Dzhulfian beds of the lower Julfa Formation, North Iran (Stepanov et al. 1969); Wuchia-

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 (G200-1).

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 interarea allow this specimen to be assigned to the genus *Orthothetina*, but the shell preservation and the strong distortion do not allow specific assignment.

Occurences. Julfa Formation, G140.

Genus *Paraorthotetina* He & Zhu, 1985

Type species: *Orthotetina provecta* Liao, 1980 from the Lopingian of South China

Paraorthotetina glausi (Fantini Sestini & Glaus, 1966)

Pl. 2, figs 15-16

1965 *Orthothetina* sp. - Glaus, p. 71.

1966 *Orthothetina glausi* Fantini Sestini & Glaus, p. 900, pl. 63, figs 6-7.

2010 *Paraorthotetina glausi* - 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, apsacline to orthocline, transversally striated, with long, triangular and narrow pseudodeltidium. Dorsal valve with sub-eliptical 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 orthocline. 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* Oehelrt, 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 hessensis* King, 1931. However, the latter species is very variable.

Occurence. Julfa Formation, bed G141.

Superfamily Enteletoidea Waagen, 1884

Family Schizophoriidae Schuchert & Lavene, 1929

Genus *Acosarina* Cooper & Grant, 1969

Type species: *Acosarina dorsisulcata* Cooper & Grant, 1969 from the Guadalupian of West Texas

Acosarina minuta (Abich, 1878)

Pl. 3, figs 7-9

1878 *Streptorhynchus peregrinus* var. *minutus* Abich, p. 78, pl. 9, fig. 1a.

1965 *Orthothichia minuta* - Sokoloskaja in Ruzhentsev & Sarytcheva, p. 200, pl. 29, figs 4-5.

2007 *Acosarina 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 midlength.

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

Occurence. Julfa Formation, beds G136, G137, G148.

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

Order **Rhynchonellida** Moore, 1952

Superfamily Wellerelloidea Licharew, 1956

Family Wellerellidae Licharew, 1956

Subfamily Uncinunellininae Savage, 1996

Genus *Uncinunellina* Grabau, 1932

Type species: *Uncinulus 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 *Uncinulus theobaldi* - Waagen, p. 425, pl. 34, fig.1.

1892 *Rhynchonella timorensis* - Rothpletz, p. 70, pl. 10, fig. 6.

1897 *Uncinulus 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.

1961 *Uncinunellina timorensis* - Zhang & Jin, 1961, p. 404, pl. 1, figs 9-16.

1964 *Uncinunellina timorensis* - Wang et al., p. 394, pl. 66, figs 9-10.

1965 *Uncinunellina timorensis* - Sokoloskaja in Ruzhentsev & Sarytheva, pl. 40, figs 1a-b.

1976 *Uncinunellina theobaldi* - Grant, p. 1976, pl. 48, figs 1-9.

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 - *Orthothetina persica*, MPUM11240 (G143B-1), articulated shell, ventral, dorsal, anterior and lateral views respectively, x1.

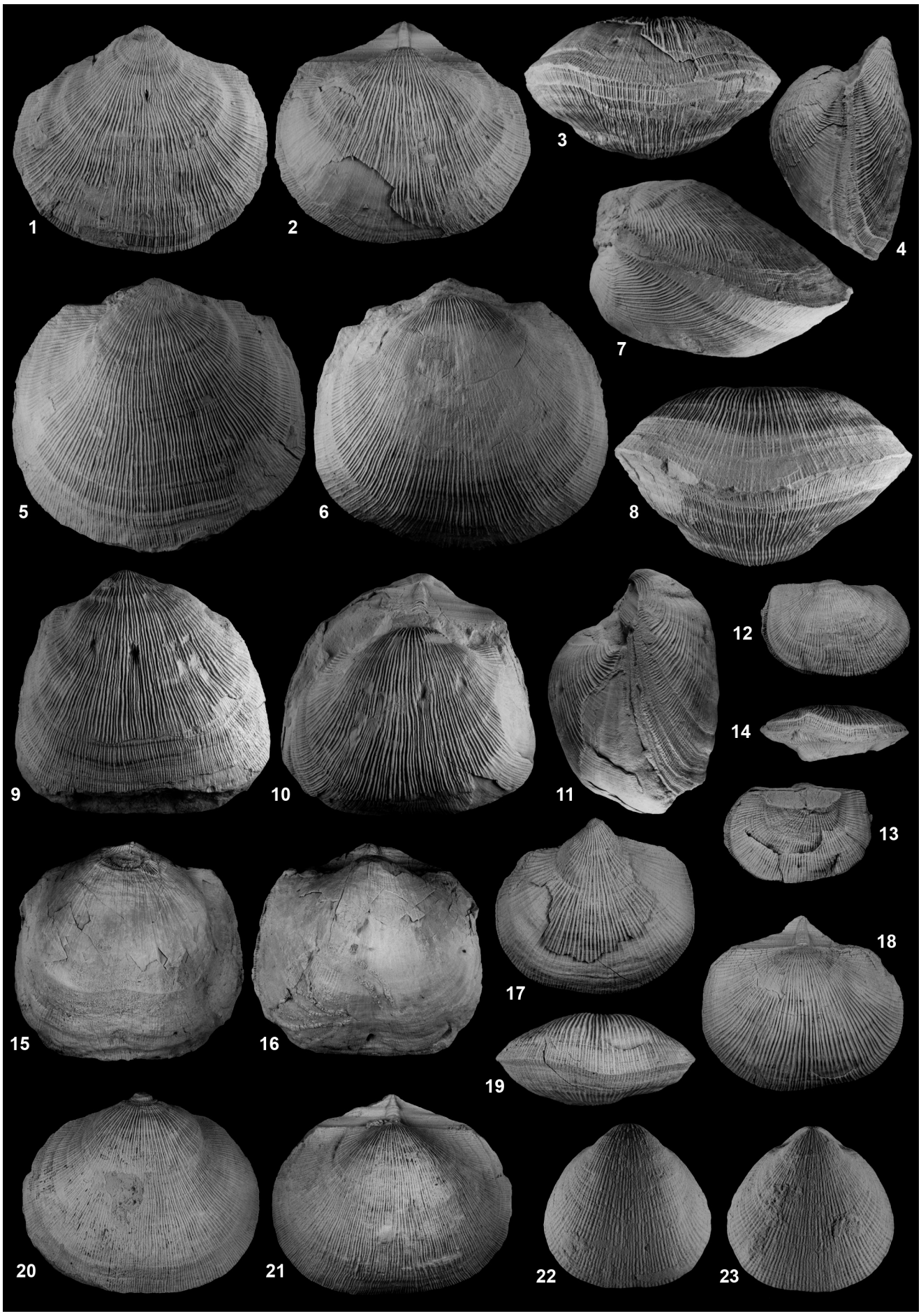
Figs 5-11 - *Orthothetina eusarkos,* MPUM11241 (G142B-9), articulated shell, ventral, dorsal, lateral and anterior views respectively, x1; MPUM11242 (G143-1), articulated shell, ventral, dorsal and lateral views respectively, x1.

Figs 12-14 - *Orthothetina* cf. *O. ruber*, MPUM11244 (G206B-2), articulated shell, ventral, dorsal and anterior views respectively, x1.

Figs 15-16 - *Paraorthothetina glausi*, MPUM11247 (G142-5), articulated shell, ventral and dorsal views respectively, x1.

Figs 17-21 - *Perigeyerella* aff. *P. miriae*, MPUM11248 (G133-1), articulated shell, ventral, dorsal and anterior views respectively, x1; MPUM11249 (G140-13), articulated shell, ventral and dorsal views respectively, x1.

Figs 22-23 - *Rhipidomella* sp. ind., MPUM11250 (G141-3), articulated shell, ventral and dorsal views respectively, x2.


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

1982 *Uncinunellina timorensis* - Wang et al., p. 233, pl. 84, fig. 3; pl. 93, fig. 5.

1982 *Uncinunellina timorensis* - Liu et al., p. 192, pl. 138, figs 11a-d.

1984 *Uncinunellina timorensis* - Yang, p. 227, pl. 36, fig. 6.

2007 *Uncinunellina 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 commisure 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 slighty anterior to mid-length, resulting in a smooth umbonal region. Costae numbering 8-9 in the sulcus, 11-12 on each flank.

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

Occurence. Julfa Formation, beds G140, G141, G152.

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

Family Pontisiidae Cooper & Grant, 1976b

Genus *Prelissorhynchia* Xu & Grant, 1994

Type species: *Pugnax pseudoutah* Huang, 1933 from the Lopingian of southwest China

Prelissorhynchia dorashamensis (Sokoloskaja in Ruzhentsev & Sarytcheva, 1965)

Pl. 3, figs 10-16

1965 *Wellerella dorashamensis* Sokoloskaja in Ruzhentsev & Sarytcheva, p. 233, text-fig. 37; pl. 40, fig. 7.

Material: Two figured articulated shells: MPUM11256 (G143B-21), MPUM11257 (G160-1), 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.

Occurence. Julfa Formation, G143, G149, G160, G161, G162.

Distribution. Wuchiapingian *Haydenella* beds of Transcaucasia (Ruzhentsev & Sarytcheva 1965).

PLATE 3

Figs 1-6 - *Uncinunellina timorensis*, MPUM11253 (G141-7), articulated shell, ventral, lateral, dorsal and anterior views respectively, x2; MPUM11254 (G152-4), articulated shell, ventral and dorsal views respectively, x2.

Figs 7-9 - *Acosarina minuta*, MPUM11251 (G136-2), articulated shell, ventral, dorsal and anterior views respectively, x2.

Figs 10-16 - *Prelissorhynchia dorashamensis*, MPUM112596 (G143B-21), articulated shell, ventral, dorsal, lateral and anterior views respectively, x2; MPUM11257 (G160-1), articulated shell, ventral, dorsal and anterior views respectively, x2.

Figs 17-20 - *Wellerellina* sp. ind., MPUM11259 (G182B-2), articulated shell, ventral, dorsal, lateral and anterior views respectively, x2.

Figs 21-22 - *Cleiothyridina* sp. ind., MPUM11260 (G125-3), articulated shell, ventral and dorsal views respectively, x2.

Figs 23-29 - *Transcaucasathyris araxensis*, MPUM11262 (G172-2), articulated shell, ventral, dorsal, lateral and anterior views respectively, x2; MPUM11261 (G168-2), articulated shell, ventral, dorsal and anterior views respectively, x2.

Figs 30-38 - *Transcaucasathyris lata*, MPUM11264 (G145C-2), articulated shell, ventral, dorsal and anterior views respectively, x2; MPUM11265 (G145-2), articulated shell, ventral and dorsal views respectively, x2; MPUM11266 (G149-7), articulated shell, ventral, dorsal and anterior views respectively, x2.

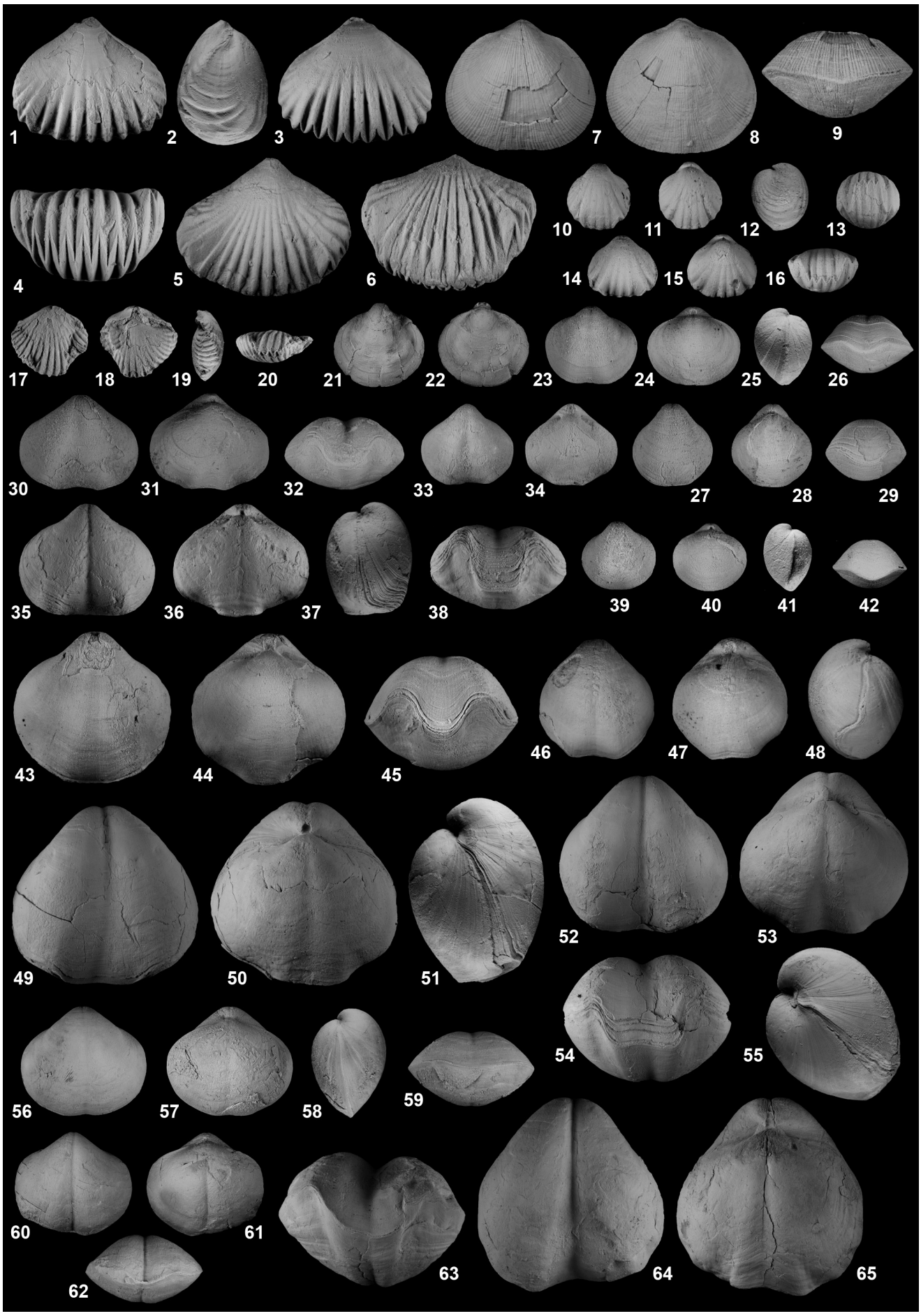
Figs 39-42 - *Transcaucasathyris minor*, MPUM11268 (G172-1), articulated shell, ventral, dorsal and anterior views respectively, x2.

Figs 43-48 - *Juxathyris* sp. ind., MPUM11270 (G126-2), articulated shell, ventral, dorsal and anterior views respectively, x2; MPUM11271 (G136-8), articulated shell, ventral, dorsal and lateral views respectively, x2.

Figs 49-55 - *Araxathyris protea*, MPUM11273 (G143B-17), articulated shell, ventral, dorsal and lateral views respectively, x1; MPUM11274 (G148-13), articulated shell, ventral, dorsal, anterior and lateral views respectively, x1.

Figs 56-62 - *Araxathyris abichi*, MPUM11276 (G142B-4), articulated shell, ventral, dorsal, lateral and anterior views respectively, x1; MPUM11277 (G148-11), articulated shell, ventral, dorsal and anterior views respectively, x1.

Figs 63-65 - *Araxathyris felina*, MPUM11279 (G143B-16), articulated shell, anterior, ventral and dorsal views respectively, x1.


1
2
3
7
8
9
4
5
6
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
30
31
32
33
34
27
28
29
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Genus *Wellerellina*

Type species: *Wellerellina chongqingensis* Shen, He & Zhu, 1992 from the Changhsingian 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 *Prelissorhynchia*. 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 **Athyridida** Boucot, Johnson & Staton, 1964

Suborder **Athyrididina** Boucot, Johnson & Staton, 1964

Superfamily Athyridoidea Davidson, 1881

Family Athyrididae Davidson, 1881

Subfamily Cleiothyridininae Alvarez, Rong & Boucot, 1998

Genus *Cleiothyridina* Buckman, 1906

Type species: *Atrypa pectinifera* 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 Transcaucasathyriinae Angiolini & Carabelli, 2010

Genus *Transcaucasathyris* Shen, Grunt & Jin, 2004

Type species: *Araxathyris araxensis* Grunt in Ruzhentsev & Sarytcheva, 1965 from the Lopingian of Transcaucasia

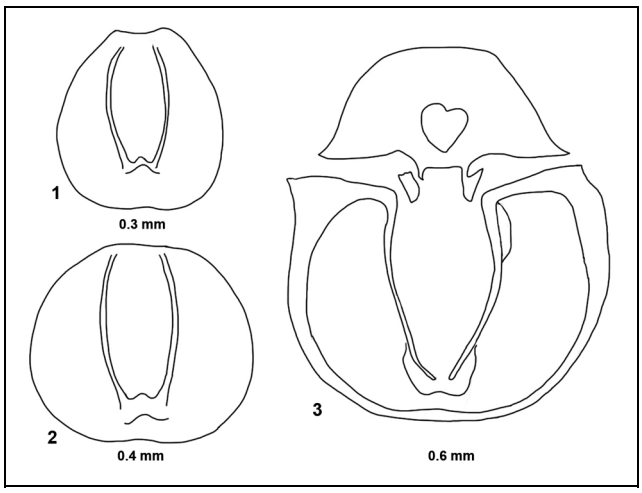


Fig. 7 - *Transcaucasathyris araxensis* MPUM11290 (G169-0): Line drawing of serial sections shown in Plate 5, figs 1, 2 and 3 respectively. Number in mm represents distances from the umbo.

Transcaucasathyris araxensis (Grunt in Ruzhentsev & Sarytcheva, 1965)

Pl. 3, figs 23-29; Fig. 7

1878 *Spirigera protea var. globularis* - Abich, p. 58, pl. 7, fig. 9; pl. 10, fig. 9.

1965 *Araxathyris araxensis araxensis* Grunt in Ruzhentsev & Sarytcheva, p. 247, pl. 43, fig. 6.

1986 *Araxathyris 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 (G174), MPUM11292 (G179-3), 10 articulated shells: MPUM11263 (G162-2, G164, G165, G169-2, G177, G183-1, G185-1, G188-1, G193-2, G193-4).

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 parasulcate. 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.

Occurence. Julfa Formation, beds G162, G164, G165, G168, G169, G172, G174, G177, G179, G183, G185, G188, G193.

Distribution. Wuchiapingian *Araxilevis* and *Haydenella* beds of Transcaucasia (Ruzhentsev & Sar-

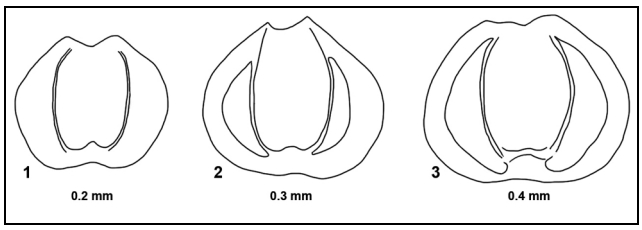


Fig. 8 - *Transcaucasathyris lata*, MPUM11293 (G149-11): Line drawing of serial sections shown in Plate 5, figs 11, 12 and 13 respectively. Number in mm represents distances from the umbo.

ytcheva 1965), but it ranges also into the Changhsingian according to Shen et al. (2004).

Transcaucasathyris lata (Grunt in Ruzhentsev & Sarytcheva, 1965)

Pl. 3, figs 30-34; Fig. 8

1878 *Spirigera protea* var. *alata* - Abich, p. 56, pl. 9, fig. 10.

1900 *Spirigera protea* var. *alata* - Arthaber, p. 282, pl. 22, fig. 3.

1900 *Spirigera* sp. ind. - Arthaber, p. 282, pl. 22, fig. 13.

1965 *Araxathyris lata* Grunt in Ruzhentsev & Sarytcheva, p. 249, pl. 43, fig. 5; text-fig. 45.

1986 *Araxathyris lata* - Grunt, pl. 15, fig. 6.

2010 *Araxathyris lata* - Angiolini & Carabelli, p. 80, pl. 5, figs 12-15.

Material: Four figured articulated shells: MPUM11264 (G145C-2), MPUM11265 (G145-2), MPUM11266 (G149-7), MPUM11293 (G149-11), 16 articulated shells: MPUM11267 (G134, G137-4, G140B-2, G143B-25, G145B-3-4-8, G145C-1, G148-8-9, G161-1, G164/165, G168-1, G179-2, G193-5, G 273).

Description. Small to medium sized, unequally biconvex shell, with maximum width ranging from 6.5 to 18.1 mm; corresponding length: 6.0-16.5 mm. Slightly transverse in outline, with parasulcate anterior commissure. Ventral valve more convex than the dorsal one. Ventral sulcus starting at the umbo, initially narrow, it becomes wide anteriorly; sulcal tongue variably developed, from moderately expressed to very low. Dorsal valve with narrow sulcus delimited by two rounded and straight folds.

Remarks. Shen et al. (2004, p. 889) have already discussed the doubtful generic assignment of *Araxathyris lata* Grunt in Ruzhentsev & Sarytcheva, 1965, that they decided to leave still pending in absence of the analysis of internal characters of this species.

The specimens under examination have the same external characters of the Transcaucasian species, but they show separate dental plates suggesting inclusion in the genus *Transcaucasathyris.* The latter in fact differs from *Araxathyris* by having dental plates instead of a sessile spondylium as shown by Angiolini & Carabelli (2010).

T. lata differs from *T. araxensis* by being generally larger, having a more transverse outline, a strongly parasulcate anterior commissure, a more developed sulcal tongue and by the occurrence of a dorsal sulcus.

Occurrence. Julfa Formation, beds G134, G137, G140, G143, G145, G145B, G145C, G148, G149, G161, G164, G165, G168, G179, G193, G273.

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

Transcaucasathyris minor (Grunt in Ruzhentsev & Sarytcheva, 1965)

Pl. 3, figs 39-42

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

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

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

Material: One figured articulated shell: MPUM11268 (G172-1), two articulated shells: MPUM11269 (G179-1, 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. *Transcaucasathyris minor* differs from the other species of this genus by its very small size and the mostly uniplicate anterior commissure.

Occurence. 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 apionucula* 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, G136-6, G137-6, G138-1-2-3, G138B-5).

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-

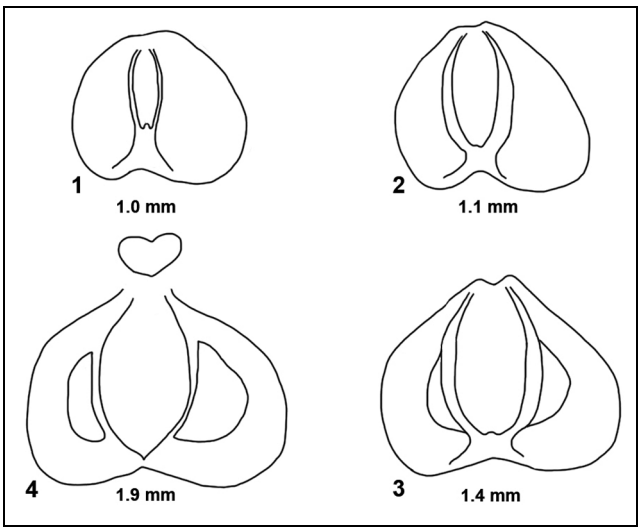


Fig. 9 - *Araxathyris protea*, MPUM11294 (142-2): Line drawing of serial sections shown in Plate 5, figs 14, 15, 17 and 18 respectively. Number in mm represents distances from the umbo.

sure parasulcate. Ventral valve sub-pentagonal in outline with anteriorly broad sulcus. Dorsal valve with rounded outline. Both valves ornamented by growth lines, more evident in the anterior half of the shell.

Remarks. The outline of the analysed specimens is similar to that of *Juxathyris bisulcata* (Liao, 1980). However, they differ in having a more convex shape and a parasulcate commissure. It differs from *Juxathyris guizhouensis* (Liao, 1980) by its more transverse outline; from *J. zhijingensis* (Liao, 1980) in having a parasulcate commissure and a more transverse outline.

Occurrence. Julfa Formation, beds G126, G134, G136, G137, G138.

Subfamily Araxathyriinae Shen, Grunt & Jin, 2004

Genus *Araxathyris* Grunt in Ruzhentsev & Sarytcheva, 1965

Type species: *Spirigera protea* Abich, 1878 from the Lopingian of Transcaucasia

Araxathyris protea (Abich, 1878)

Pl. 3, figs 49-55; Fig. 9

1878 *Spirigera protea* var. *multilobata* Abich, p. 55, pl. 7, figs 4-5; pl. 9, fig. 11.

1900 *Spirigera protea* var. *multilobata* - Arthaber, p. 273, pl. 21, fig. 8.

1900 *Spirigera protea* var. *quadrilobata* - Arthaber, p. 274, pl. 21, fig. 6.

1939 *Athyris (Composita) protea* var. *multilobata* - Licharew, p. 117, pl. 29, fig. 4.

1965 *Araxathyris protea* - Grunt in Ruzhentsev & Sarytcheva, p. 241, pl. 42, figs 4-6.

1966 *Araxathyris protea* - Fantini Sestini & Glaus, p. 915, pl. 65, fig. 2.

1969 *Araxathyris protea* - Stepanov et al., pl. 5, fig. 4a-d.

1986 *Araxathyris protea* - Grunt, pl. 15, fig. 9; pl. 16, fig. 1; pl. 27, figs 2-3.

2010 *Araxathyris 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 parasulcate 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. *Araxathyris protea* is very similar in size, shape and outline to *Araxathyris 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. Julfa 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).

Araxathyris abichi (Arthaber, 1900)

Pl. 3, figs 56-62

1878 *Spirigera royssii* - Abich, p.62, pl. 7, fig. 8.

1878 *Spirigera protea* var. *ambigua* - Abich, p. 62, pl. 6, fig. 9.

1878 *Spirigera protea* var. *subtilita* - Abich, p. 63, pl. 6, figs 11-12.

1878 *Spirigera plano sulcata* - Abich, p. 63, pl. 8, figs 4.

1878 *Spirigera plano sulcata* var. *rugosa* - Abich, p. 64, pl. 8, figs 3.

1900 *Spirigera abichi* - Arthaber, p. 280, pl. 22, figs 10-12.

1965 *Araxathyris abichi* - Grunt in Ruzhentsev & Sarytcheva, p. 244, pl. 43, figs 2-3.

1986 *Araxathyris abichi* - Grunt, p. 113, fig. 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, G149-5-10).

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.

Occurrence. Julfa Formation, beds G142, G143, G148, G149.

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

Araxathyris felina (Arthaber, 1900)

Pl. 3, figs 63-65

1878 *Spirigera protea* var. *globularis* Abich, p. 58, pl. 7, fig. 7; pl. 8, fig. 12.

1878 *Spirigera protea* var. *subtilita* Abich, p. 59, pl. 8, figs 10-11.

1900 *Spirigera protea* var. *alata* Arthaber, p. 275, pl. 22, fig. 2.

1900 *Spirigera protea* var. *armeniaca* Arthaber, p. 277, pl. 22, figs 6-7.

1900 *Spirigera felina* Arthaber, p. 279, pl. 22, figs 8-9.

1965 *Araxathyris felina* - Grunt in Ruzhentsev & Sarytcheva, p. 244, pl. 43, fig. 4; text-fig. 42.

1966 *Araxathyris felina* - Fantini Sestini & Glaus, p. 911, pl. 65, fig. 3.

1986 *Araxathyris felina* - Grunt, p. 112, fig. 57.

2010 *Araxathyris felina* - Angiolini & Carabelli, p. 80, pl. 5, figs 8-11.

Material: One figured articulated shell: MPUM11279 (G143B-16), three articulated shells: MPUM11280 (G142-6, G143B-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 parasulcate 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.

Occurrence. Julfa Formation, beds G142, G143, G148.

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

Araxathyris quadrilobata (Abich, 1878)

Pl. 4, figs 1-4

1878 *Spirigera protea* var. *quadrilobata* Abich, p.53, pl. 7, fig. 6; pl. 9, figs 8-9.

1939 *Athyris (Composita) protea* var. *quadrilobata* – Licharew, p. 117, pl. 24, fig. 3.

1965 *Araxathyris quadrilobata* - Grunt in Ruzhentsev & Sarytcheva, p. 101, pl. 43, figs 1a-c, 2a-c.

1969 *Araxathyris quadrilobata* - Stepanov, pl. 4, figs 4a-d.

1986 *Araxathyris quadrilobata* - Grunt, pl. 15, figs 8, 10.

Material: Two figured articulated shell: MPUM11281 (G143B-6), MPUM11295 (G157-1), 16 articulated shells: MPUM11282 (G140-6, G141C-2, G142B-1-2-10-19, G148-12, G149-12, G152-1, G154-1, G154B-1, G155-0-2-4, G156B-01, 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 parasulcate. 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.

Occurrence. Julfa Formation, beds G140, G141, G142, G143, G148, G149, G152, G154, G154B, G155, G156B, G157.

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

Order **Spiriferida** Waagen, 1883

Superfamily Ambocoelioidea George, 1931

Family Ambocoeliidae George, 1931

Subfamily Ambocoeliinae George, 1931

Genus *Crurithyris* George, 1931

Type species: *Spirifer urei* Fleming, 1828 from the Mississippian of Great Britain

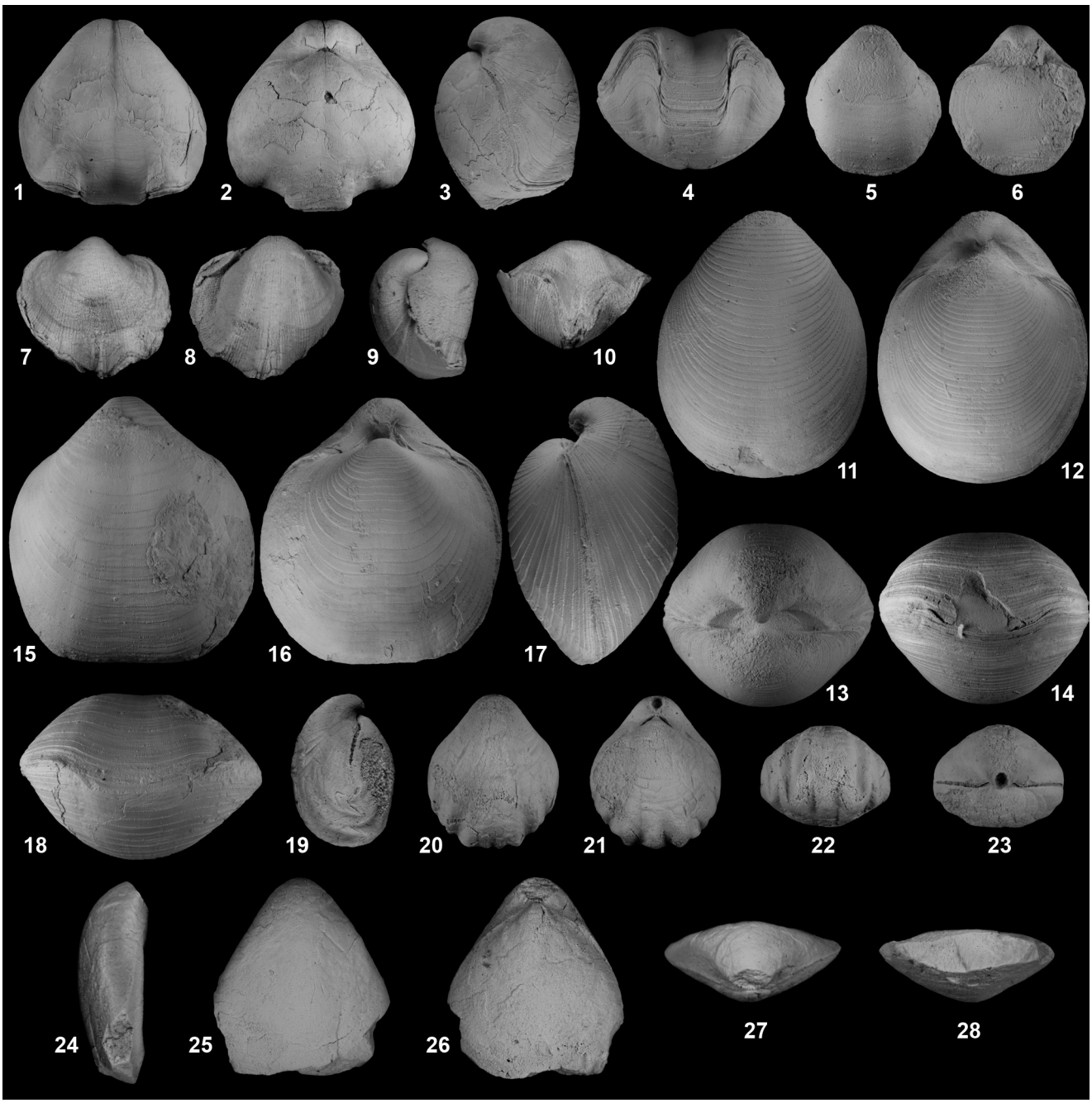


PLATE 4

Figs 1-4 - *Araxathyris quadrilobata*, MPUM11281 (G143B-6), articulated shell, ventral, dorsal, lateral and anterior views respectively, x1.

Figs 5-6 - *Crurithyris* 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 - *Permophricodothyris 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 - *Rostranteris* sp. ind., MPUM11288 (G159-1), articulated shell, lateral, ventral, dorsal, anterior and posterior views respectively, x2.

Figs 24-28 - *Dielasma* 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 micrornamentation of spinules, 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 Spiriferoidea King, 1846

Family Trigonotretidae Schuchert, 1893

Subfamily Neospiriferinae Waterhouse, 1968

Genus *Cartorhium* Cooper & Grant, 1976

Type species: *Cartorhium retusum* Cooper & Grant, 1976 from the Guadalupian of Texas

Cartorhium 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 *Cartorhium twifurcifer* 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 Transcaucasia

Permophricodothyris ovata Pavlova, 1965

Pl. 4, figs 11-18

1878 *Spirifer lineatus* - Abich, p. 79, pl. 6, figs 6-8; pl. 8, fig. 14; pl. 9, fig. 5.

1900 *Reticularia indica* - Arthaber, p. 270, pl. 21, figs 4-5.

1900 *Reticularia waageni* - Arthaber, p. 269, pl. 21, figs 2-3; pl. 20, fig. 15.

1939 *Neophricodothyris indica* - Licharew, p. 114, pl. 27, fig. 5.

1965 *Neophricodothyris indica* - Ivanova in Ruzhentsev & Sarytcheva, pl. 40, fig. 12a-c.

1965 *Permophricodothyris ovata* Pavlova, p. 135, figs 1-4.

1966 *Permophricodothyris ovata* - Fantini Sestini and Glaus, 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.

2010 *Permophricodothyris ovata* - Angiolini & Carabelli, p. 82, pl. 5, figs 25-26.

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.

Occurrence. Julfa Formation, beds G142B, G145B, G148, G149, G151, G152, G154B, G156B, G157.

Distribution. Guadalupian Gnishik Formation and Wuchiapingian *Oldhamina* beds of Transcaucasia (Ruzhentsev & 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 adrianense* Gemmellaro, 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

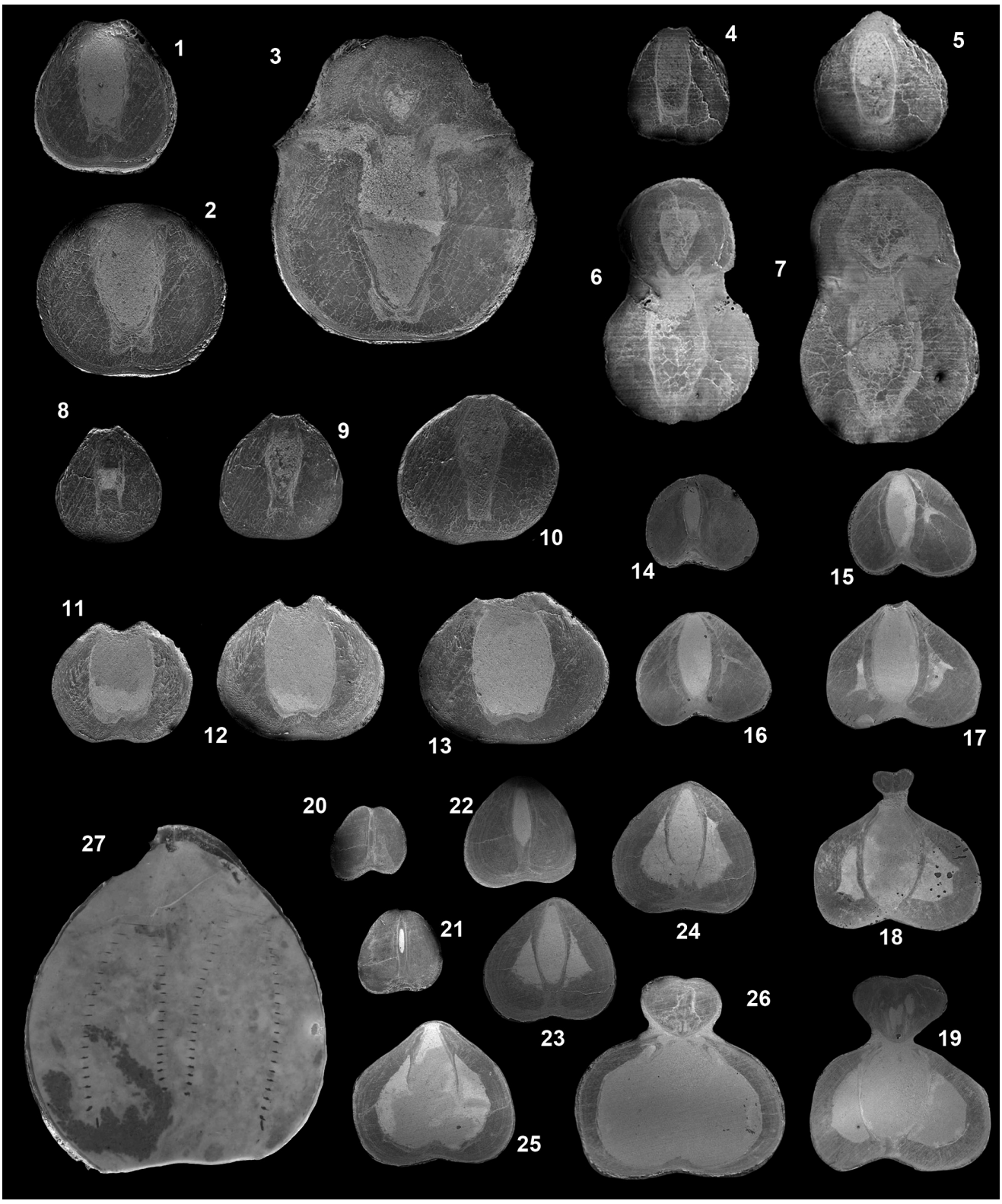


PLATE 5

Figs 1-3 - Serial sections of *Transcaucasathyris araxensis* MPUM11290 (G169-0) at 0.3, 0.4 and 0.6 mm from the umbo respectively, x10.
Figs 4-7 - Serial sections of *Transcaucasathyris araxensis,* MPUM11291 (G174) at 0.2, 0.3, 0.5 and 0.6 mm from the umbo respectively, x10.
Figs 8-10 - Serial sections of *Transcaucasathyris araxensis,* MPUM11292 (G179-3) at 0.15, 0.2 and 0.3 mm from the umbo respectively, x10.
Figs 11-13 - Serial sections of *Transcaucasathyris lata*, MPUM11293 (G149-11) at 0.25, 0.3 and 0.4 mm from the umbo respectively, x10.
Figs 14-19 - Serial sections of *Araxathyris 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 *Araxathyris quadrilobata*, 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 *Permophricodothyris ovata* showing the spiralia, MPUM11304 (G152-5), x 1.2.

few, but strong plications and antiplicate anterior commissure.

Occurrence. Julfa Formation, bed G159.

Superfamily Dielasmatoidea Schuchert, 1913

Family Dielasmatidae Schuchert, 1913

Subfamily Dielasmatinae Schuchert, 1913

Genus *Dielasma* King, 1859

Type species: *Terebratulites elongatus* Schlotheim, 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.

Aknowledgements. Abbas Ghaderi would like to acknowledge the assistance of Davoud Rahdan, Babak Imanpour, Reza Heydarian and Mehdi Badpa during the field work and the technical support by Arezu Sadeghi (Mashhad). Abbas Ghaderi is particularly indebted to Dr. Adel Najafzadeh, Mehdi Abbasi and Hossein Hobbi from Aras Free Zone Office for the support of the field sessions in the Julfa region. The Authors warmly thank Aymon Baud, Alberto Perez-Huerta and Elisabeth Weldon for their revision, constructive criticism and precious suggestions.

L. Angiolini and C. Garbelli were supported by 2011 Italian Ministry PRIN Project "Past Excess CO2 worlds: biota responses to extreme warmth and ocean acidification" to Elisabetta Erba.

REFERENCES

Abdolahi M.R. & Hosseini M. (1996) - Geological map of Julfa in 1/100000 scale. Geological Survey of Iran.

Abich H. (1878) - Geologische Forschungen in den Kaukasischen Landern, I: Eine Bergkalkfauna aus der Araxesenge bei Djoulfa in Armenien. *Holder Wien,* 128 S.

Altiner D., Baud, A., Guex J. & Stampfli G. (1980) - La limite Permien-Trias dans quelques localités du Moyen-Orient: recherches startigraphiques et micropaléontologiques. *Riv. It. Paleont. Strat*., 85: 683-714.

Amiot M., Ciry R., Fantini Sestini N., Premoli Silva I., Rossi Ronchetti C., Sartenaer P., Vandercammen A., Von Schouppé A., Zanini Buri C., Gridelli E., Müller G. & Williams L.H.J. (1965) - In: Brill E.J. (Ed.) - Italian expeditions to the Karakorum (K2) and Hindu Kush. Scientific reports, part iv palaeontology-zoology-botany, volume 1. Leiden, 431 pp.

Angiolini L. (2007) - Quantitative palaeoecology in the *Pachycyrtella* Bed, Early Permian of Interior Oman. *Palaeoworld*, 16, 233-245.

Angiolini L. & Carabelli L. (2010) - Upper Permian brachiopods from the Nesen Formation, North Iran. *Spec. Pap. Palaeontol.*, 84: 41-90.

Angiolini L., Carabelli L., Nicora A., Crasquin-Soleau S., Marcoux J. & Rettori R. (2007) - Brachiopods and other fossils from the Permo-Triassic boundary beds of the Antalya Nappes (SW Taurus, Turkey). *Geobios,* 40: 715-729.

Angiolini L., Checconi L., Gaetani M. & Rettori R. (2010) - The latest Permian mass extinction in the Alborz Mountains (North Iran). *Geol. J.*, 45: 216-229.

Arthaber G. Von (1900) - Das jüngere Paläozoicum aus der Araxes-Enge bei Djulfa. 209-308. In: Frech F. & Arthaber G. Von (Eds) - Über das Paläozoicum in Hocharmenein und Persien. Bieträge zur Paläontologie und Geologie Österreich-Ungarns und des Orients, 12, Wien, 308 pp., 22 pls.

Baud A. (2008) - Correlation of upper Permian localities in the Kuh-e-Ali Bashi area NW Iran: old collections, old and new data. *Permophiles,* 52: 6-11.

Baud A., Broennimann P. & Zaninetti L. (1974) - Sur la presence de *Meandrospira pusilla* (Ho) (Foraminifere) dans le Trias inferieur de Kuh e Ali Bashi, Julfa, NW Iran. *Palaont. Z*., 483: 205-213.

Beyrich E. (1864) - Ueber eine Kohlenkalk Fauna von Timor. *Abh. D. K. Acad. D. Wiss. Berlin*: 61-98.

Bolourchi M.H. & Saidi A. (1987) - Geological map of Poldasht in 1/100000 scale. Geological Survey of Iran.

Bonnet P. (1912) - Note préliminaire sur la constitution géologique de la Gorge de Djoulfa et ses environs. *Bull. Soc. Geol. Fr.*, 12: 312-340.

Bonnet P. & Bonnet N. (1947) - Description geologique de la Transcaucasie meridionale (chaines de l'Araxe moyen). *Mem. Soc. Geol. Fr.*, 25: 1-292.

Brand U., Posenato R., Came R., Affek H., Angiolini L., Azmy K. & Farabegoli E. (2012) - The end-Permian mass extinction: a rapid volcanic CO_2 and CH_4-climatic catastrophe. *Chem. Geol.*, 322-323: 21-144.

Branson C.C. (1948) - Bibliographic index of Permian invertebrates. *Geol. Soc. Am. Mem*., 26: 1-1049.

Buckman S.S. (1906) - Brachiopod nomenclature: *Epithyris*, *Hypothyris*, *Cleiothyris* Phillips, 1841. *Ann. Mag. Nat. Hist.*, ser. 7, 18 (107): 321-327.

Campi M.J., Shi J.R. & Leman M.S. (2005) - Guadalupian (Middle Permian) brachiopods from Slungai Toh, a *Leptodus* Shales locality in the Central Belt of Peninsular Malaysia. *Palaeontogr., Abt. A,* 273: 97-160.

Chao Y.T. (1927) - Brachiopod fauna of the Chihsia Limestone. *Geol. Soc. China Bull.,* 6: 83-120.

Chao Y.T. (1928) - Productidae of China. Part II, Chonetinae, Productinae and Richtofeniinae. *Acta Palaeontol. Sinica* (Series B), 5(3), 103 pp.

Clapham M.E. & Payne J.L. (2011) - Acidification, anoxia, and extinction: A multiple logistic regression analysis of extinction selectivity during the Middle and Late Permian, *Geology*, 39: 1059-1062.

Cooper G.A. & Grant R.E. (1972) - Permian brachiopods of west Texas. *I. Sm. C. Paleob*., 14: 1-231.

Cooper G.A. & Grant R.E. (1976) - Permian Brachiopods of west Texas. *IV Sm. C. Paleob*., 21: 1923-2607.

Crippa G. & Angiolini L. (2012) - Guadalupian (Permian) brachiopods from the Ruteh Limestone, North Iran. *Geoarabia*, 17: 125-176.

Diener C. (1897) - Himalayan fossils. The Permo-Carboniferous fauna from Chitichun, No. 1. *Palaeontol. Indica*, *Series 15,* 1 (3): 1-105.

Diener C. (1903) - The Permian fossils of the Central Himalayas. *Palaeontol. Indica, Series 15,* 1 (5): 1-204.

Erwin D.H. (1993) -The Great Paleozoic Crisis: life and death in the Permian. The Perspectives in Paleobiology and Earth History. Columbia University Press, New York: 1- 327.

Erwin D.H. (2006) - Extinction: How Life on Earth Nearly Ended 250 Million Years Ago. Princeton University Press: 1- 296.

Fantini Sestini N. (1965a) - The geology of the upper Djadjerud and Lar valleys (North Iran). II. Palaeontology. On some "*Spinomarginifera*" from the Upper Permian of Mubarak-Abad. *Riv. It. Paleont. Strat.,* 71: 989-996.

Fantini Sestini N. (1965b) - The geology of the Upper Djadjerud and Lar Valleys (North Iran). II. Palaeontology. Bryozoans, brachiopods and molluscs from the Ruteh Limestone (Permian*). Riv. It. Paleont. Strat.,* 71: 13-108.

Fantini Sestini N. & Glaus M. (1966) - Brachiopods from the Upper Permian Nesen Formation (North Iran). *Riv. It. Paleont. Strat*., 72: 887-930.

Fleming J. (1828) - A History of British animals, exhibiting the Descriptive Characters and Systematical Arrangement of the Genera and Species of Quadrupeds, Birds, Reptiles, Fishes, Mollusca, and Radiata of the United Kingdom. Bell & Bradfute and James Duncan, Edimburgh and London, 565 pp.

Frech F. & Arthaber G.V. (1900) - Über das Paläozoicum in Hocharmenien und Persien. Mit einem Anhang über die Kreide von Sirab in Persien. *Beitr. Paläontol. Geol. Österreich-Ungarn Orients*, 12: 161-308.

Frech F. (1911) - Die Obercarbon China, die Dyas. In: Richthofen E.K.H. Von (Ed.) - China, 5: 97-202, 243-266. Dietrich Reimer, Berlin, 289 pp.

Gaetani M., Angiolini L., Ueno K., Nicora A., Stephenson M., Sciunnach D., Rettori R., Price G. & Sabouri J. (2009) - Pennsylvanian to Early Triassic stratigraphy in Alborz Mountains (Iran). In: Brunet M.-F., Wilmsen M., Granath J.W. (Eds) - South Caspian to Central Iran Basins. *Geol. Soc. London, Spec. Pub.,* 312: 79-127.

Gemmellaro G.G. (1894) - Sopra tre famiglie di brachiopodi (Spiriferidae, Rhynchonellidae e Terebratulidae) provenienti dai calcari con *Fusulina* della valle del fiume Sosio nella Provincia di Palermo. *Boll. Soc. Nat. Econ. Palermo*, 25 Aprile 1894, 1: 1-7.

Gemmellaro G.G. (1899) - La fauna dei calcari con *Fusulina* della valle del Fiume Sosio nella Provincia di Palermo. *Giorn. Sc. Nat. Econ. Pal.,* 22: 59-214.

George T.N. (1931) - *Ambocoelia* Hall and certain similar British Spiriferidae. *Geol. Soc. London, Q. J.,* 87: 30-61.

Ghaderi A., Ashouri A.R., Korn D., Mahmoudi Gharaie M.H. & Leda L. (2013) - New insight on Stratigraphic correlation of the Permian-Triassic transitional beds in the Transcaucasus and northwest of Iran: Problems and guidelines. *Sedim. Facies*, 5(2): 221-24 (in Farsi).

Glaus M. (1964) - Trias und Oberperm in zentralen Elburs (Persien). *Eclogae Geol. Helv.,* 57 (2): 497-508.

Glaus M. (1965) - Die Geologie des Gebietes nordlich des Kandevan-Passes (Zentral-Elburz), Iran. *Mitt. Geol. Inst. ETH Zürich*, 48, 165 pp.

Grabau A. W. (1931) - The Permian of Mongolia. A report on the Permian fauna of the Jisu Honguer Limestone of Mongolia and its relations to the Permian of other parts of the World. In: Reeds C. A. (Ed.) - Natural History of Central Asia, vol. 4. American Museum of Natural History, New York, 665 pp.

Grant R.E. (1976) - Permian brachiopods from southern Thailand. *Paleontol. Soc. Mem. 9*, *suppl. J. Paleontol*., 50(3): 1-269.

Grant R.E. (1993) - Permian brachiopods from Khios Island, Greece. *Paleontol. Soc. Mem. 33*, *suppl. J. Paleontol*, 67(4): 1-21.

Grunt T.A. (1986) - Classification of brachiopods of the Order Athyridida. *Ak. Nauk SSSR, Trudy Paleontologischeskogo Instituta,* 215: 1-200. [in Russian].

Hallam A. & Wignall P.B. (1997) - Mass Extinction and Their Aftermath. Oxford University Press, Oxford, 1-328.

He X.L. & Zhu M.L. (1985) - Some Upper Permian new genera and species of Orthotetacea in south west China. *Acta Palaeontol. Sinica,* 24: 198-204.

Henderson C.M., Mei S., Shen S. & Wardlaw B.R. (2008) - Resolution of the reported Upper Permian conodont occurrences from northwestern Iran. *Permophiles,* 5: 2-8

Hou H.F., Zhan L.P. & Chen B.W. (1979) - The coal-bearing strata and fossils of the late Permian from Guangtung. Geological Publishing House, Beijing, 166 pp.

Huang T.K. (1932) - Late Permian brachiopod fossils of south-western China. *Palaeontol. Sinica, Series B,* 9 (1): 1-138.

Huang T.K. (1933) - Late Permian brachiopod fossils of south-western China. *Palaeontol. Sinica, Series B,* 9 (2): 1-172.

Jin Y.G. & Hu S.Z. (1978) - Brachiopods from the Kuhfeng Formation in south Anhui and Nanjiing Hills. *Acta Palaeontol. Sinica*, 17(2): 101-134.

Jin Y.G., Shen S.Z., Henderson C.M., Wang X.D., Wang W., Wang Y., Cao C.Q. & Shang Q.H. (2006) - The Glo-

bal Stratotype Section and Point (GSSP) for the boundary between the Capitanian and Wuchiapingian stage (Permian). *Episodes* 29: 253-262.

Kayser E. (1883) - Obercarbonische Fauna von Loping. In Richthofen E.K.H. Von (Ed.) - China, 4. Dietrich Reimer, Berlin, 160-208.

King W. (1859) - On *Gwynia, Dielasma* and *Macadrevia*, three new genera of Palliobranchiata Mollusca, one of wich has been dredge in the Strangford Lough. *Dublin Univ. Zool. Bot. Ass., Proceedings,* 1: 256-262.

King R.E. (1931) - The geology of the Glass Mountains, Texas, part II: Faunal summary and correlation of the Permian formations with description of Brachiopoda. *Univ. Texas Bull.,* 3042: 1-245

Knoll A.H., Bambach R.K., Payne J.L., Pruss S. & Fischer W. (2007) - Paleophysiology and end-Permian mass extinction. *Earth Planet. Sc. Lett.,* 256: 295-313.

Kotlyar G.V., Zakharov Y.D., Koczyrkevicz B.V., Kropatcheva G.S., Rostovcev K.O., Chedija I.O., Vuks, G.P. & Guseva E.A. (1983) - Pozdnepermskiy etap evolyutsii organicheskogo mira. Dzulficheskiy i dorashamskiy yarusy SSSR. In: Gramm, M.N., & Rostovcev, K.O. (Eds.), Permo-Triasovaya stadiya geologicheskoy evolyutsii. *Mezhdunarodnoy programmy geologicheskoy korrelatsii*, 106: 1-70.

Kozur H.W. (2004) - Pelagic uppermost Permian and the Permian-Triassic boundary conodonts of Iran, Part I: Taxonomy. *Hallesches Jahr. Geowiss. B, Beiheft*, 18: 39-68.

Kozur H.W. (2005) - Pelagic uppermost Permian and the Permian-Triassic boundary conodonts of Iran. Part II: Investigated sections and evaluation of the conodont faunas. *Hallesches Jahr. Geowiss. B, Beiheft,* 19: 49-86.

Kozur H.W. (2007) - Biostratigraphy and event stratigraphy in Iran around the Permian-Triassic Boundary (PTB): implications for the causes of the PTB biotic crisis. *Glob. Planet. Change*, 55: 155-176.

Kozur H., Leven, E.Y. Lozovskiy V.R. & Pyatakova M.V. (1980) - Subdivision of Permian-Triassic Boundary beds in Transcaucasia on the basis of conodonts. *Int. Geol. Rev.*, 22(3): 361-368.

Leda L., Korn D., Ghaderi A., Hairapetian V., Struck U. & Reimold W.U. (2013) - Lithostrati-graphy and carbonate microfacies across the Permian-Triassic boundary near Julfa (NW Iran) and in the Baghuk Mountains (Central Iran). *Facies*, Doi: 10.1007/s10347-013-0366-0.

Leman M.S. (1994) - The significance of Upper Permian brachiopods from Merapoh area, northwest Pahang. *Geol. Soc. Malaysia Bull.*, 35: 113-121.

Léveillé C. (1835) - Aperçue géologique de quelques Localité très riches en coquilles sur les frontières de France et de Belgique. *Mém. Soc. Géol. France,* 2: 29-40.

Li W.Z & Shen, S.Z. (2008) - Lopingian (Late Permian) brachiopods around the Wuchiapingian-Changsingian boundary at the Meishan Sections C and D, Chanxing, South China. *Geobios,* 41: 307-320.

Liang W.P. (1990) - Lengwu Formation of Permian and its brachiopod fauna in Zhejiang Province. *PRC Ministry Geol. Min. Res., Geol. Mem., Ser. 2,* 10, 1-435, pls 1-84. [in Chinese, English summary].

Liao Z.T. (1980) - Upper Permian brachiopods from Western Guizhou. 241-277. In: Nanjing Institute of Geology and Palaeontology (Ed.) - Stratigraphy and palaeontology of Upper Permian coal-bearing formations in western Guizhou and eastern Yunnan, China. Science Press, Beijing, 286 pp. [in Chinese]

Licharew B.K. (1937) - Brachiopoda of the Permian System of the USSR, Fascicule I. Permian Brachiopoda of North Caucasus. Families: Chonetidae Hall & Clarke and Productidae Gray. *Monografii po Paleontologii SSSR,* 39. Leningrad, 152 pp. [In Russian].

Licharew B.K (1939) - Class Brachiopoda. In: Licharew, B.K. (Ed.) - Atlas of the Leading Forms of the Fossil Faunas of the USSR, Vol. 6: 76-121, Moscow. [In Russian].

Licharew B.K (1956) - Superfamily Rhynchonellacea Gray, 1948. In: Kiparisova L.D., Marcowskii B.P. & Radchenko G.P. (Eds) - Materials for Paleontology, new families and genera. *VSEGEI, Materialy (Paleontologiia)*, 12, 56-61. [In Russian].

Liu Z.H., Tan Z.X. & Ding Y.L. (1982) - Phylum Brachiopoda. Paleontological Atlas of Hunan. *Geol. Bur. Huann, Geol. Mem., Series 2*, 1: 996 pp., 440 pls. [In Chinese].

Martin W. (1809) - Petrificata Derbiensia; or figures and descriptions of petrefactions collected in Derbyshire. D. Lyon. Wigan, 28 pp.

Muir-Wood H.M. & Cooper G.A. (1960) - Morphology, classification, and life habits of the Productoidea (Brachiopoda). *Geol. Soc. Am. Mem.*, 81, 447 pp.

Muttoni G., Gaetani M., Kent D.V., Sciunnach D., Angiolini L., Berra F., Garzanti E., Mattei M. & Zanchi A. (2009) - Opening of the Neo-Tethys Ocean and the Pangea B to Pangea A transformation during the Permian. *GeoArabia*, 14: 17-48.

Oskuie A. & Hajialilu B. (1995) - Geological map of Qara-Ziaaddin in 1/100000 scale. Geological Survey of Iran.

Pavlova E. (1965) - Revision of the genus *Neophricodothyris* (order Spiriferida). *Paleontol. Zh.,* 2: 133-137.

Ramovs A. (1958) - Die Entwicklung des Oberperms im Bergland von Skofja Loka und Polhov Gradec. *Slovenka Akademija Znanosti in Umetnosti Razprave,* 4: 450-662.

Reed F. R. C. (1944) - Brachiopoda and Mollusca from the *Productus* Limstones of the Salt Range. *Palaeontol. Indica,* 23: 1-678.

Richoz, S. (2006) - Stratigraphie et variations isotopiques du carbone dans le Permien supérieur et le Trias inférieur de la Neotéthys (Turquie, Oman et Iran). In: Guex J. (Ed.), *Mém. Geol. Lausanne*, p. 264.

Richoz S., Krystyn L., Baud A., Bradner R., Horacek M. & Mohtat-Aghai P. (2010) - Permian-Triassic boundary interval in the Middle East (Iran and N Oman): Progressive environmentral change from detailed carbonate carbon isotope marine curve ad sedimentary evolution. *J. Asian Earth Sci.*, 39: 236-253.

Rieben H. (1934) - Contribution à la géologie de l'Azerbeidjan person. *Bull. Soc. neuchâtel. Sci. Nat.*, 59: 19-144.

Rothpletz A. (1892) - Die PermTrias und Jura Formation auf Timor und Rotti im indeschen Archipel. *Palaeontographica*, 39: 57-106.

Rostovtsev K.O. & Azaryan N.R. (1973) - The Permian-Triassic Boundary in Transcaucasia. In: The Permian and Triassic systems and their mutual boundary. *Canadian Soc. Petr. Geol. Mem.*, 2: 89-99.

Ruzhentsev V.E. & Sarytcheva T.G. (1965) - Evolution and succession of marine organisms at the Permo-Triassic boundary. *Ak. Nauk SSSR, Trudy Paleontologicheskogo Instituta*, 108: 431 pp. [in Russian].

Sarytcheva T.G, Licharew B.K. & Sokolskaya, A.N. (1960) - Order Productida. In: Orlov Y.A. (Ed.) - Osnovi Paleontologii, 7: 221-238. Izdatel'stvo Akademiia Nauk SSSR, 343 pp. [In Russian].

Schellwien E. (1900) - Beitrage zur systematik der Strophomeniden des oberen Palaozoicum. *Neues Jb. Miner., Geol. U. Palaeont.,* 1:1-15.

Schlotheim E.F. Von (1816) - Beitrage zur Naturgeschichte der Versteinerungen in geognosticher Hinsicht. *Denkschr. Bayer. Akad. Wissen.,* 6: 13-36.

Schréter Z. (1963) - Die Brachiopoden aus dem oberen Perm des Bükkgebirges in Nordungarn. *Geol. Hung.,* 28: 79-179.

Sengor A.M.C. (1979) - Mid-Mesozoic closure of Permo-Triassic Tethys and its complications. *Nature*, 279: 590-593.

Sepkoski J.J.Jr. (1984) - A kinetic model of Phanerozoic taxonomic diversity. III, Post-Paleozoic families and mass extinctions. *Paleobiology,* 10: 246-267.

Shen S. (2007) - The conodont species *Clarkina orientalis* (Barskov and Koroleva, 1970) and its spatial and temporal distribution. *Permophiles,* 50: 25-37.

Shen S.Z. & Clapham M. E. (2009) - Wuchapingian (Lopingian, Late Permian) brachiopods from the Episkopi formation of Hydra Island, Greece. *Palaeontology*, 52(4): 713-743.

Shen S. Z & He X. L. (1994) - Changhsingian brachiopod fauna from Guiding, Guizhou. *Acta Palaeontol. Sinica,* 33: 440-454. [In Chinese with English abstract].

Shen S. & Mei S. (2010) - Lopingian (Late Permian) high-resolution conodont biostratigraphy in Iran with comparison to South China zonation. *Geol. J.,* 45: 135-161.

Shen S.Z. & Shi G. R. (2007) - Lopingian (Late Permian) brachiopods from South China, Part1: Orthotetida, Orthida and Rhynchonellida. *Bull. Tohoku Univ. Mus.,* 6: 1-102.

Shen S.Z., He X.L. & Zhu M.L. (1992) - Changhsingian brachiopods from Zhongliang Hill of Chongqing, Sichuan Province, South China. 171-196. In: Gu D.Y. (Ed.) - Stratigraphy and palaeontology of oil and gas bearing areas in China (3). The Petroleum Industry Press, Beijing, 218 pp. [in Chinese with English abstract].

Shen S.Z, Grunt T.A. & Jin Y.G. (2004) - A comparative study of Comelicaniidae Merla, 1930 (Brachiopoda Athyridida) from the Lopingian (late Permian) of south China and Transcaucasia in Azerbaijan and Iran. *J. Paleontol.,* 78: 884-899.

Shen S.Z., Crowley J.L., Wang Y., Bowring S.A., Erwin D.H., Sadler P.M., Cao C.Q., Rothman D.H., Henderson C.M., Ramezani J., Zhang H., Shen Y., Wang X.-D., Wang W., Mu L., Li W.Z., Tang Y.G., Liu X.L., Liu L.J., Zeng Y., Jiang Y.F. & Jin Y.G. (2011) - Calibrating the end-Permian mass extinction. *Science* 334: 1367-1372.

Shimizu D. (1981) - Upper Permian brachiopod fossils from Guryul Ravine and the Spur Three Kilometres North of Barus. In: Nakazawa K. & Kapoor H.M. (Eds) - The Upper Permian and Lower Triassic faunas of Kashmir. *Palaeontol. Indica*, 46: 67-82.

Smirnova T.N. (2007) - Permian terebratulids of Eurasia: Morphology, systematics, and phylogeny. *Paleontol. J.,* 47(7): 708 - 813.

Simic V. (1933) - Das Oberperm in Westserbien. *Mém. Serv. Géol. Roy. Yougoslavie,* 1, 130 pp.

Sokolskaja A. N. (1965) - Orthids, Strophomenids, Chonetids, and Rhynchonellids. In: The Development and Change of Marine Organisms at the Palaeozoic-Mesozoic Boundary. *Trudy Paleontologischeskii Institut*, 108:198-236.

Sowerby J.C. (1840-1846) - The Mineral Conchology of Great Britain, volume 7. London, 80 pp.

Stampfli G.M., Marcoux J. & Baud A. (1991) - Tethyan margins in space and time. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 87: 373-409.

Stampfli G.M. & Borel G.D. (2002) - A plate tectonic model for the Paleozoic and Mesozoic constrained by dynamic plate boundaries and restored synthetic oceanic isochrons. *Earth Planet. Sc. Lett.*, 196: 17-33

Stanley S.M & Yang X. (1994) - A double mass extinction at the end of the Paleozoic era. *Science,* 266: 1340-1344.

Stepanov D.L., Golshani F. & Stöcklin J. (1969) - Upper Permian and Permian-Triassic boundary in North Iran. *Geol. Surv. Iran Rep.*, 12: 72 pp.

Stoyanow A.A. (1910) - A new brachiopod genus. *Bull. Acad. Imper. Sci. St. Petersbourg, Series 6*, 4: 853-855. [In Russian].

Stoyanow A.A. (1915) - On some Permian brachiopods of Armenia. *Trudy Geologicheskogo Komiteta*, 111, 1-95. [In Russian].

Stoyanow A.A. (1942) - Revision of the Permo-Triassic section at Djulfa, Armenia. *Geol. Soc. Am. Bull.*, 53, 12: 1823.

Sweet W.C. & Mei S. (1999a) - The Permian Lopingian and basal Trassic Sequence in Northwest Iran. *Permophiles*, 33: 14-18.

Sweet W.C. & Mei S. (1999b) - Conodont succession of Permian Lopingian and basal Trassic in Northwest Iran. In: Yin H., Tong J. (Eds.) - Proceedings of the International Conference on Pangea and the Paleozoic-Mesozoic Transition. Wuhan, China University of Geosciences Press, 154-156.

Teichert C., Kummel B. & Sweet W.C. (1973) - Permian-Triassic Strata, Kuh-E-Ali Bashi, Northwest Iran. *Bull. Mus. Comp. Zool. Harvard Univ.*, 145 (8): 359-472.

Tong Z.X. (1978) - Brachiopoda. In: Geological institute of SW China (Ed.) - Palaeontological Atlas of SW Chi-

na, Sichuan, 2: 210-267. Geological Publishing House, Beijing. [in Chinese]

Verna V., L. Angiolini, A. Baud, S. Crasquin & A. Nicora (2011) - Guadalupian Brachiopods from Western Taurus, Turkey. *Riv. It. Paleont. Strat*., 117:1-52.

Waagen W. H. (1882-1885) - Salt Range fossils: *Productus* Limestone fossils. Part 4: Brachiopoda. *Mem. Geol. Surv. India*, *Palaeontol. Indica,* Series 13, 1: 329-770.

Wang G. P, Liu Q. Z., Jin Y. G., Hu S. Z., Liang W. P. & Liao Z. T. (1982) - Brachiopoda. 186-256. In: Nanjing Inst. Geol. Mineral. Min. Geol. (Ed.) - Palaeontological atlas of Eastern China, 2. Geological Publishing House, Beijing. 657 pp., 176 pls.

Wang Y. (1955) - New genera of Brachiopods. *Acta Paleontol. Sinica,* 4, 327-357.

Wang Y., Jin Y.G. & Fang D. W. (1964) - Brachiopod fossils from China, 1-2. Science Press, Beijing, 777 pp. [in Chinese].

Wang Y., Jin Y. G. & Fang D. W. (1966) - Brachiopod fossils. Science Press, Beijing, 702 pp. [in Chinese].

Waterhouse J. B. (1983) - Permian brachiopods form Pjia Member, Senja Formation, in Manang district of Nepal, with new brachiopod genera and species from other regions. *Indian Geol. Ass., Bull*, 16(2): 11-151.

Wignall P.B. & Hallam A. (1992) - Anoxia as a cause of the Permian/Triassic mass extinction: facies evidence from northern Italy and the western United States. *Palaeogeogr., Palaoeclimatol., Palaeoecol.,* 93: 21-46.

Williams A., Carlson S.J., Brunton C.H.C., Holmer L.E., Popov L.E., Mergl M., Laurie J.R., Bassett M.G., Cocks L.R.M., Rong J.Y., Lazarev S.S., Grant R.E., Racheboeuf P.R., Jin Y.G., Wardlaw B.R., Harper D.A.T. & Wright A.D. (2000) - Treatise on Invertebrate Paleontology. Part H Brachiopoda (revised): Volumes 2 & 3, Linguliformea, Craniiformea, Rhynchonelliformea (part): 1-919.

Williams A., Brunton C.H.C., Carlson S.J., Alvarez F., Blodgett R.B., Boucot A.J., Copper P., Dagys A.S., Grant R.E., Jin Y.G., MacKinnon D I., Mancenido M.O., Owen E F., Rong J.Y. Savage N. M. & Sun D.L. (2002) - Treatise on Invertebrate Paleontology. Part H Brachiopoda (revised): Volume 4, Rhynchonelliformea (part): 921-1688.

Williams A., Brunton C.H.C., Carlson S.J., Carter J.L., Curry G.B., Dagys A.S., Gourvennec R., Hou H.F., Jin Y.G., Johnson J.G., Lee D.E., MacKinnon D.I., Racheboeuf P.R., Smirnova T.N. & Sun D.L. (2006) - Treatise on Invertebrate Paleontology, Part H, Brachiopoda. Volume 5, Rhynchonelliformea (part): 1689-2320.

Williams A., Brunton C. H. C. & Carlson S. J., Alvarez F., Baker P.G., Bassett M.G., Boucot A.J., Carter J.L., Cocks L.R.M., Cohen B.L., Curry G.B., Cusack M., Emig C.C., Gourvennec R., Harper D.A.T., Holmer L.E., Lee D.E., Logan A., Luter D., MacKinnon D.I., Mancenido M.O. & Mergl M. (2007) - Treatise on Invertebrate Paleontology, Part H, Revised, Brachiopoda Volume 6, Supplement: 2321-2355.

Xu G.R. & Grant R.E. (1994) - Brachiopods near the Permian-Triassic Boundary in South China. *Sm. C. Paleob.*, 76: 1-68.

Yanagida J. (1964) - Permian Brachiopods from Central Thailand. *Mem. Fac. Sci., Kyushu Univ., Series D (Geology),* 15: 1-22.

Yang D.L. (1984) - Brachiopoda. 27-102. In: Feng S.N., Xu S.Y, Lin, J X. & Yang D.L. (Eds) - Biostratigraphy of the Yangtze Geroge Area 3, 2. Geological Publishing House, Beijing, 239 pp. [in Chinese].

Yang D.L., Ni S.Z., Chang M.L. & Chao R.X. (1977) - Brachiopoda. 303-470. In: Palaeontological atlas of central South China, 2. Geological Publishing House, Beijing, 856 pp. [In Chinese].

Zanchi A., Zanchetta S., Berra F., Mattei M., Garzanti E., Molyneux S., Nawab A. & Sabouri J. (2009) - The Eo-Cimmerian (Late? Triassic) orogeny in North Iran. In: Brunet M.F., Wilmsen M. & Granath J.W. (Eds) - South Caspian to Central Iran Basins *Geol. Soc. London, Sp. Publ.,* 312: 31-55.

Zeng Y., He X.L. & Zhu M.L. (1995) - Brachiopod communities and their succession and replacement in the Permian of Huayingshan area. *China Univ. Mining Tecnol. Press, Xuzhou*, 187 pp. [In Chinese].

Zhan L.P. (1979) - Brachiopoda. In: Hou H.F., Zhan L.P. & Chen B.W. The coal bearing strata and fossils of Late Permian from Guangtung. Geological Publishing House, Peking: 61-100.

Zhang Y. & Jin Y.G. (1961) - An Upper Permian Brachiopoda fauna from Jingxian, Anhui Province. *Acta Palaeontol. Sinica,* 9: 401-425. [In Chinese].