

## UPPER CISURALIAN-LOWER GUADALUPIAN BRACHIOPODS FROM THE QARARI UNIT, BATAIN PLAIN, NORTHEAST OMAN: SYSTEMATICS, PALAEOECOLOGY AND CORRELATION

MARCO VIARETTI<sup>1</sup>, ALAN P. HEWARD<sup>2</sup>, ALESSANDRO GEMENTI<sup>1</sup> & LUCIA ANGIOLINI<sup>1</sup>

<sup>1</sup>Dipartimento di Scienze della Terra “Ardito Desio”, Università degli Studi di Milano, Via Mangiagalli 34, I-20133 Milano;  
E-mail: marco.viaretti@unimi.it, alessandro.gementi@studenti.unimi.it, lucia.angiolini@unimi.it

<sup>2</sup>23 Croftdown Court, Malvern, WR14 3HZ, UK; E-mail: alanpheward@gmail.com

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*Keywords:* Brachiopods; Cisuralian-Guadalupian; Oman; correlation; palaeobiogeography.

*Abstract.* Permian brachiopods from Oman are well-known as valuable tools for correlation and palaeobiogeographical and palaeoclimatic reconstructions. Here, we describe a new brachiopod fauna from the Qarari Unit of the allochthonous Batain Group in northeast Oman. Brachiopods were collected from four localities: Wadi Khawr al Jaramah (WKJ), Jebel Qarari (JQ1), Jebel X (JX3) and Shiya (SH11). The age of the fossiliferous localities is well-constrained to the late Kungurian-early Roadian by conodonts and fusulines, in agreement with the age suggested by the brachiopod ranges.

The brachiopod fauna consists of 339 specimens belonging to 68 species of 8 orders, among which five species are here identified as new. Based on the taphonomic attributes and the analysis of the brachiopod life-styles, the assemblages from the Qarari Unit are interpreted as life assemblages thriving on varied substrates, with limited post-mortem exposure on the sea floor and rapid burial at depths around the storm wave base.

Based on the generally high biodiversity indices (Shannon-Wiener and Margalef indices), the Qarari brachiopod fauna can be considered a biodiversity hotspot, only comparable, in term of biodiversity, to the coeval faunas from West Texas and South China. However, palaeobiogeographical affinities of the Qarari brachiopods with these faunas are scanty, as well as the affinities with coeval faunas from the northern Gondwana margin and the Cimmerian and Cathaysian blocks, except for some similarities with the upper Kungurian brachiopods of Myanmar. This may be explained by the fact that the Qarari succession was deposited in the Madagascar arm of Neo-Tethys, and thus rather isolated from the main Gondwanan margin.

## INTRODUCTION

The Batain area of northeast Oman has a unique geology compared to the remainder of the Arabian plate. It consists of crystalline basement, autochthonous Neoproterozoic rocks of the Huqf Supergroup, a <2.5 km stack of deformed sedimentary nappes of the Batain Group capped locally

by ophiolite, and a partial cover of Cenozoic sediments (Fig. 1). The origins of the Batain nappes and ophiolite lay in the Madagascar arm of Neo-Tethys, later the Indian Ocean (Schreurs & Immenhauser 1999; Immenhauser et al. 2000; Peters et al. 2001; Hauser et al. 2002). It is a windswept landscape of scattered outcrops in low hills, surrounded by gravel terraces, wadis and sabkhas (Fig. 1). There are few extensively-exposed sections or contacts other than faulted ones. Initial mapping compared these large-

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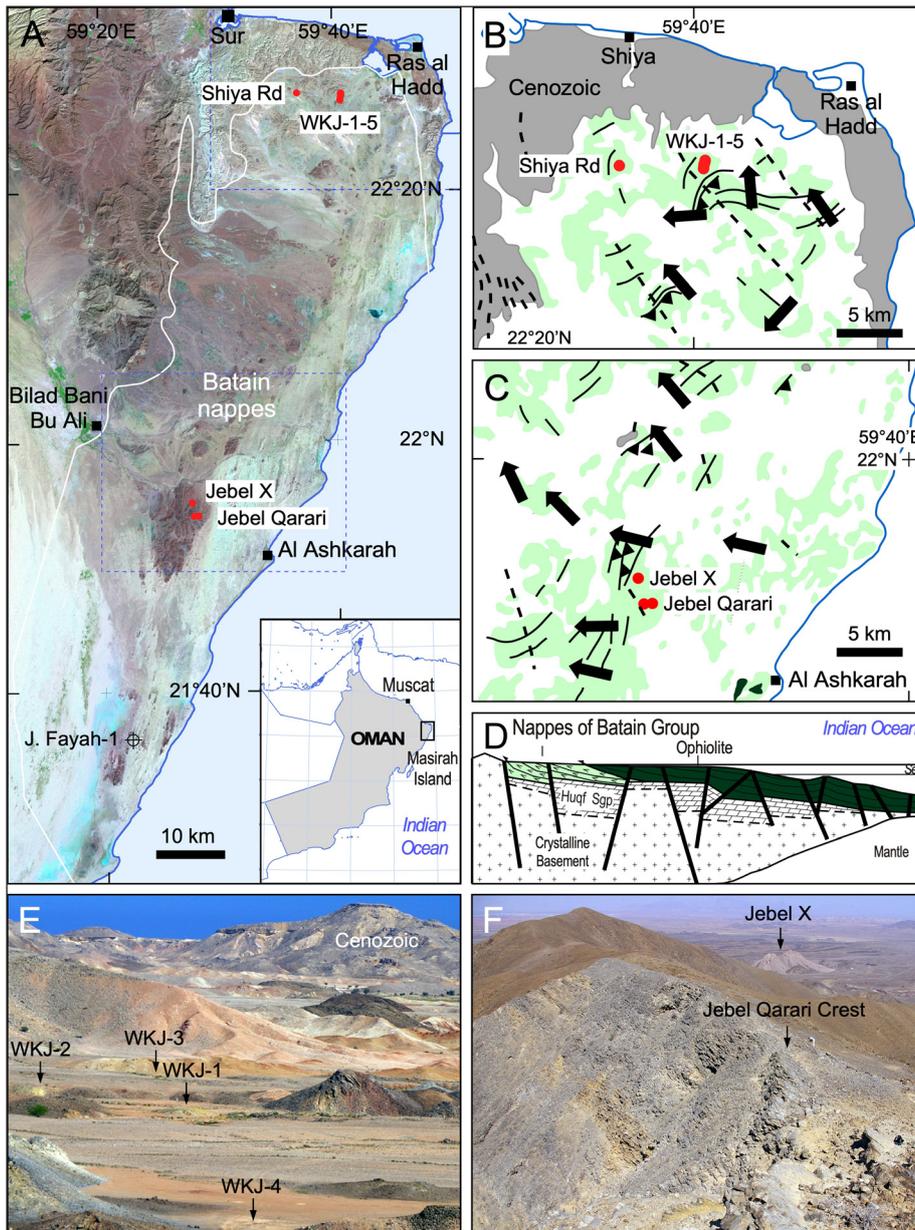


Fig. 1 - A) Satellite image of the Batain coastal area of northeast Oman, Ash Sharqiyah Province. B) and C) Structural maps of the two areas with collected fossiliferous localities in the Permian Qarari Unit within the Batain nappes (based on Immenhauser et al. 2000). Arrows indicate emplacement direction, solid lines - axial traces of 1st phase folds, dotted lines- axial traces of 2nd phase folds, the latter also affect the Cenozoic cover. D) NW-SE summary cross-section of the northeastern margin showing the setting of the Batain nappes and Masirah Ophiolite emplaced over the eastern margin of Oman from the Indian Ocean (from Peters et al. 2001). The Jebel Fayah-1 exploration well-shown in 1A drilled through 2.5 km of allochthonous Batain nappes into the autochthonous succession below consisting of Cretaceous Aruma Group, Permian Khuff Formation and Precambrian Huqf Supergroup (Mount et al. 1998). E) Overview of the outcrops of Qarari Unit, just west of Wadi Khawr al Jaramah. F) The more prominent outcrops at Jebel Qarari and Jebel X.

ly deep-water sediments to those of the Hawasina Complex of the Oman Mountains: indeed some of the lithologies are similar, and the names of formations still reflect this (Wyns et al. 1992; Béchenec et al. 1992). Structurally, the geology appears chaotic due to the scattered nature of the outcrops and the effects of thrusting and two phases of folding. The Batain Group was interpreted as a tectonic 'melange' by Shackleton et al. (1990). Later work on Masirah Island revealed that the Masirah ophiolites, and the sedimentary cap of the first ophiolite, originated in Indian Ocean and were emplaced over the east margin of the Arabian plate some 15-20 Ma later than the emplacement of the Hawasina nappes and Semail Ophiolite over the northern margin of the plate (Fig. 1). The Batain plain was re-mapped,

as a logical extension of this work, confirming these conclusions with further stratigraphic and structural data (Immenhauser et al. 1998, 2000; Schreurs & Immenhauser 1999; Peters et al. 2001; Hauser et al. 2002). Schreurs & Immenhauser (1999) concluded there was far more structural coherence within the Batain nappes than had been recognised by Shackleton et al. (1990).

In the allochthonous Batain, two Permian units occur: the Qarari Unit and the Aseelah Unit. The Qarari Unit comprises mainly thin bedded grey limestone, yellow marly partings or marlstone and 'Green Grits' and conglomerate at one locality. Ages of Kungurian-Wordian have been concluded for deposits of the Qarari Unit at various locations (Wyns et al. 1992; Immenhauser et al. 2000; Peters et

Location	Horizon	WGS84 Lat.	WGS84 Long.	Age *	Comments
Wadi Khawr al Jaramah	(outcrops occur over a distance of 1.25 km; not shown on map of Peters et al. 2001)				
WKJ-1	Qarari Unit	22°27'37.97"	59°40'50.75"	Kubergandian fusulines, Kungurian conodonts	450 m <sup>2</sup> , ~20 m section
WKJ-2	Qarari Unit	22°27'40.51"	59°40'50.92"		In wadi bank, ~4 m of section
WKJ-3	Qarari Unit	22°27'43.24"	59°40'52.32"	Kubergandian fusulines	On wadi flank and in small bowl nearby
WKJ-4	Qarari Unit	22°27'26.93"	59°40'45.22"		Isolated hummock
WKJ-5	Qarari Unit	22°27'08.52"	59°40'35.43"		Small outcrop in bank
Road to/from Shiya	Qarari Unit	22°27'45.54"	59°36'55.17"		Small roadside outcrop, mapped by Peters et al. (2001)
Jebel X	(map of Peters et al. 2001 unfortunately does not extend this far west)				Loc. 302 of Shackleton et al. (1990), Jebel X? of Lee (1990) and Webster and Sevastopulo (2007).
1	Qarari Unit?	21°55'07.50"	59°27'41.80"		
3	Qarari Unit?	21°55'03.40"	59°27'39.20"	Fusulines, not younger than Kubergandian (Leven, pers. comm. 2016)	~20 m of greenish gritstones and conglomerates overlying basalts, fossiliferous near top, below brecciated carbonates (Qarari Unit or Asselah Unit?)
Jebel Qarari	(map of Peters et al. 2001 unfortunately does not extend this far west)				
Wadi	Qarari Unit	21°53'56.82"N	59°27'43.79"E	?Wordian ammonoids, upper Kungurian-Roadian conodonts	Loc. 604 of Shackleton et al. (1990), 60-170 m of section, wadi to crest
Crest	Qarari Unit	21°53'57.37"N	59°27'58.78"E		

Tab. 1 - Locations in the Qarari Unit from which the brachiopods were collected. \* Leven & Heward (2013). Lambert, in Fortey & Heward (2015). Immenhauser et al. (1998).

al. 2001; Leven & Heward 2013; Fortey & Heward 2015). The Aseelah Unit consists of conglomerate bodies in the Triassic Sal Formation, the boulders of which are of Permian carbonate, many of which are richly fossiliferous (clasts of carbonate ranging in age from the late Cisuralian to the Lopingian). The Aseelah boulders in the conglomerate indicate that the recorded Permian succession spans a longer time interval and is shallower water and more varied than that of the Qarari Unit (Hauser et al. 2000; Peters et al. 2001; Hauser et al. 2001, 2002).

Our work in the Qarari Unit began at the request of Gary Webster who re-examined Permian crinoid and blastoid specimens collected by Shackleton and others, and was intrigued by the similarities to the well-known Permian crinoid faunas of Timor and Western Australia (Webster & Sevastopulo 2007). Initial visits of one of the authors (APH) to the Jebel Qarari area were of limited success, but after being alerted to localities in the north of the plain, we collected crinoids, blastoids, trilobites and brachiopods, as well as fusulines and conodonts for dating (Leven & Heward 2013; Fortey & Heward 2015). Work on the crinoid, blastoid and ophiuroid faunas continues and shows that they are stunningly preserved and more abundant and diverse than the fauna from Western Australia (Johnny Waters & Ben Thuy, pers. comm. to Alan Heward).

This paper is focused on the very rich and generally well-preserved brachiopod faunas collected during these surveys which disclose a biodiversity hotspot rather unusual for settings along the Gondwanan margin in the Permian. Brachiopods from the Batain plain have never been described before; only three species have been listed by Lee (1990) as a personal communication of D.V. Ager and one species by Shackleton et al. (1990) and given respectively an Early Permian and a Permian age. The systematic descriptions and the discussion on the age and correlations here provided constitute a benchmark for future studies on brachiopod palaeoecology and palaeobiogeography.

## MATERIAL AND METHODS

### Provenance of the material

The rich brachiopod assemblages comprising a total of 339 specimens we collected from the Qarari Unit come from locations in the north and south of the Batain area (Fig. 1-2; Tab. 1). The typical appearance of outcrops of the Qarari Unit is of grey, thinly bedded (50-250 mm), fine-grained limestone that sometimes contains partings of yellow marlstone. The limestone beds appear to have formed as diagenetic segregations, and are locally nodular and cherty. There are occasional grainstone and rudstone beds, but few sedimentary structures other than the trace fossils *Zoophycos*, *Chondrites*, and *Ophiomorpha* and large horizontal arthropod burrows. Immenhauser et al. (1998) interpreted the Qarari Unit as a toe-of-slope deposit formed below storm wave base, but above the carbonate compensation depth (i.e. at 1000s of m). Fortey & Heward (2015) suggested quiet,

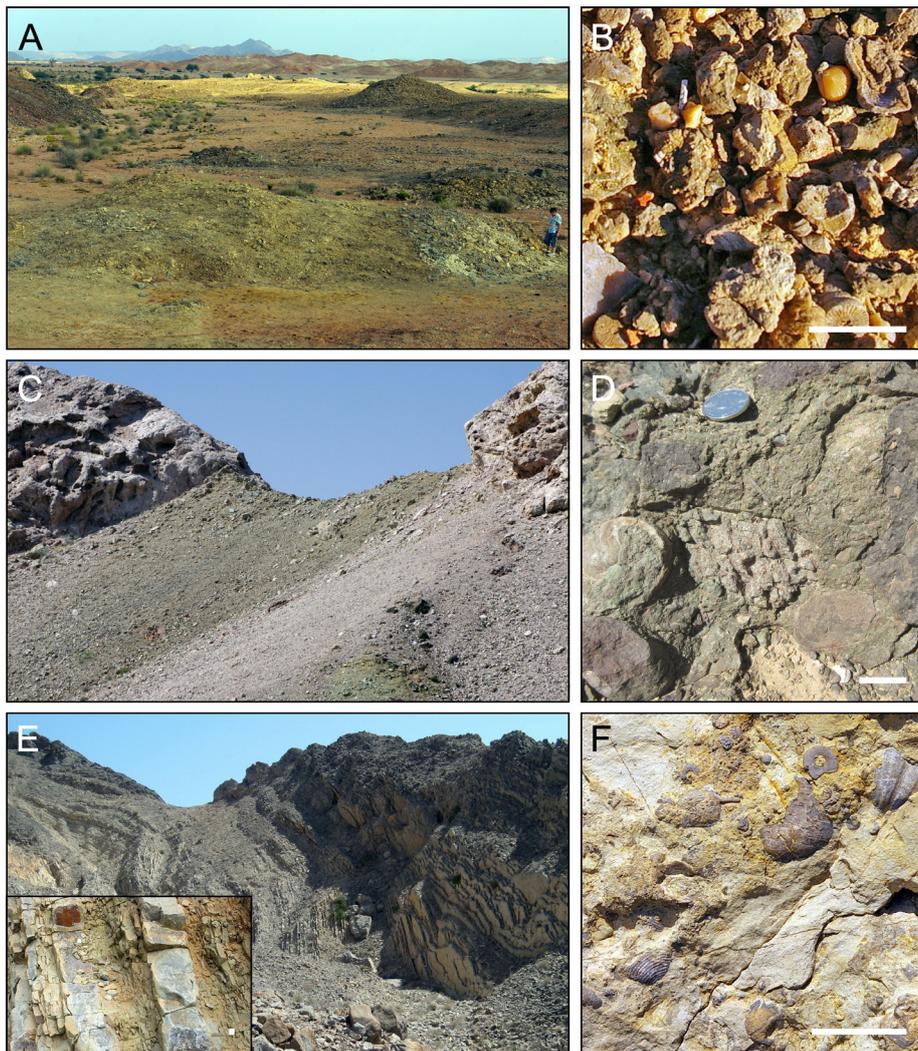


Fig. 2- A) Small mound of abundantly fossiliferous, marly limestone just west of Wadi Khawr al Jaramah (WKJ-1). B) Fossils on the weathered surface of the mound. 25 mm scale bar. C) Fossiliferous horizon near the top of ‘Green Grits’ underlying brecciated ?Qarari Unit (Jebel X-1). D) Brachiopods and fusulines in matrix of conglomeratic bed within the ‘Green Grits’ (Jebel X-3), 25 mm scale bar. E) Typical, thinly bedded limestone at Jebel Qarari Wadi (JQ1). Section overturned, younging from right to left. Yellow marly layers separate the diagenetic limestone beds. F) Brachiopods, crinoid columnals and other bioclastic debris on the surface of a limestone bed. 25 mm scale bars.

muddy shelf carbonate, below normal storm-wave base, with occasional perturbations which led the trilobites to enroll. Gary Webster (pers. comm. to Alan Heward), considered the Batain crinoid faunas to be from shelf environments, probably from middle to outer shelf depths. The presence of *Zoophycos* in marly outcrops at Wadi Khawr al Jaramah and Jebel Qarari is in accordance with this (Knaust 2009).

The most extensive collections are from the weathered surface of five small mounds of yellow marly limestone over about 1.25 km distance lying near the base of a thrust sheet just west of Wadi Khawr al Jaramah (WKJ-1-5) (Fig. 1-2). The largest of these outcrops is 450 m<sup>2</sup> and exposes about 20 m of section (WKJ-1; Fig. 1A, B, C, 2A, B). The limestone beds from WKJ-1 and WKJ-3 have been dated by fusulines as Kubergandian (=late Kungurian-early Roadian according to Angiolini et al. 2015) and WKJ-1 by conodonts (*Mesogondolella zuzsanna*, *Sweetognathus guizhouensis*, *Hindeodus excavatus*) as Kungurian (Leven & Heward 2013; Lance Lambert pers. comm. in Fortey & Heward 2015), which means a late Kungurian age for WKJ-1 and a late Kungurian-early Roadian for WKJ-3. Indeed, the species *Sweetognathus guizhouensis* does not range to the Kungurian-Roadian boundary (Charles Henderson pers. comm. to Lucia Angiolini) so it is possible that the age of these outcrops is not younger than late Kungurian. All the specimens collected from WKJ-1-5 are here collectively referred to as WKJ. A small roadside outcrop of consolidated limestone and marlstone, 6.7 km to the west, proved sparsely fossiliferous in comparison (SH11 fossiliferous locality, Shiya Rd; Fig. 1A, B).

Jebel Qarari is a prominent landscape feature around 65 km to the south (Fig. 1A). A distinctive hill just to the north of this is the ‘Green Grits’ outcrop 302 of Shackleton et al. (1990). A fossiliferous band caps coarse clastic sediments which rest on basaltic volcanics. The fossiliferous band is in turn capped by brecciated carbonates (Fig. 1A, C, 2C, D). This outcrop was erroneously marked as Jebel X, west of Jebel Qarari by Lee (1990) and subsequently by Webster & Sevastopulo (2007). It also appears that some specimens in the appendix of Shackleton et al. (1990) may have become mixed between locations 302 and 604 over time. Fusulines from green clastic and nodular limestone beds from Jebel X, loc. 302, are interpreted as Kubergandian (=late Kungurian-early Roadian). Brachiopods from this fossiliferous locality are labelled JX3. A single specimen collected near the top of the “Green Grits” (Fig. 2C) is labelled JX1.

The most extensive outcrops of the Qarari Unit occur at Jebel Qarari in a section which runs from a wadi at the base (JQ1 fossiliferous locality), to the crest, 170 m as measured by Wyns et al. (1992) or two sheets of 60-80 m by Immenhauser et al. (1998) (Fig. 1A, C, F, 2E, F). The interbedded limestone and marlstone vary in richness of fauna and locally there is some silicification. Sediments from Jebel Qarari have been dated as Wordian by both ammonoids and conodonts (Immenhauser et al. 1998; Lambert pers. comm. in Fortey & Heward 2015). However, Fortey & Heward (2015, p. 3) wrote that there are uncertainties about the taxonomic identification of these ammonoids. Furthermore, the conodont species reported in Fortey & Heward (2015) is *Mesogondolella siciliensis*, which has a

range upper Kungurian-Roadian (Henderson 2018), possibly extending into the Wordian (Angiolini et al. 2015). Consequently, also the age of JQ1 probably straddles the Cisuralian-Guadalupian boundary. Webster & Sevastopulo (2007) considered the blastoids and crinoids from Jebel Qarari as Artinskian, but this attribution is inconsistent with data from fusulines and conodonts.

Despite the tectonic complexity and folding of some lithologies in the Batain nappes (Schreurs & Immenhauser 1999), the faunas in the Qarari marlstone and marly limestone seem to have escaped relatively unscathed. A colour alteration index of 1 for conodonts from WKJ-1 and Jebel Qarari (equating to a temperature of around 50°C, Giles Miller pers. comm. in Fortey & Heward 2015) implies a maximum burial of <1000 m since deposition.

### Methods

Brachiopods have been collected from the weathered surface of the marly limestone beds at five small outcrops at Wadi Khawr al Jaramah, a small outcrop by the Shiya road, two locations at Jebel Qarari and from 'Green Grits' at Jebel X (Fig. 1-2). The largest outcrops are those of Jebel Qarari, but only loose specimens from marlstone layers and a few that could be removed from limestone beds were collected. The brachiopod collections may be biased to well-preserved specimens, particularly at Wadi Khawr al Jaramah where they are particularly abundant.

The specimens, almost totally consisting of articulate body fossils, have been cleaned and when necessary prepared with compressed air powered scribes in the laboratories of the Department of Earth Sciences 'A. Desio', University of Milan. Their taphonomical attributes have been described in detail prior to identification. The study of internal characters has been performed by serial sections. They have been coated with smoked ammonium chloride, and photographed with Nikon D5000 and D3100 cameras, with two different macro lenses (Nikon micro nikkor 60mm and 105mm), under Kaiser rb 5000 dl lights on an IFF Super Repro copy stand.

The classification follows: Brunton et al. (2000) for the order Productida; Williams et al. (2000) for the order Orthotetida; Williams & Harper (2000) for the order Orthida; Savage et al. (2002) for the order Rhynchonellida; Alvarez & Rong (2002) for the order Athyridida; Carter et al. (2006) for the order Spiriferida; Carter & Johnson (2006) for the order Spiriferinida; Lee et al. (2006) for the order Terbratulida.

The specimens are permanently curated in the Palaeontological Museum of the Department of Earth Sciences 'A. Desio', University of Milan, Italy and registered with a prefix MPUM.

### The brachiopod faunas: composition, taphonomy and life styles

The brachiopod faunas collected from the four fossiliferous localities (WKJ, SH11, JQ1, JX3) comprise 339 specimens belonging to 68 species of eight orders (Tab. 2). The most represented order is Productida with 23 taxa, followed by Spiriferida with 12 taxa and Rhynchonellida with 11 taxa; the other orders have three to six species each.

The richest locality is WKJ with 295 specimens in 59 species of eight orders. Rhynchonellida and Spiriferida are dominant both in terms of species and specimens; the other orders have few species each, but Orthotetida and Athyridida have

Taxon	WKJ	JQ1	JX3	SH11
<i>Neochonetes (Nongtaia) arabicus</i>	2			
<i>Costispiriferini</i>	1			
<i>Comuquia</i> sp.	4			
<i>Neoplicatifera</i> sp.	5			
<i>Spinomarginifera</i> sp.	2			
<i>Caricula</i> sp.	5			
<i>Retimarginifera</i> aff. <i>R. celeteria</i>	4			
<i>Retimarginifera auricolata</i> n. sp.	17			
<i>Transennatia insculpta</i>	8			
<i>Transennatia</i> sp. 1	3			
<i>Transennatia</i> sp. 2		3		
<i>Kozlowskia cornuta</i>	6			
<i>Callytharella websteri</i> n. sp.	17		1	
<i>Calliprotonia</i> sp.	11		1	
<i>Juresania omanensis</i>	1		1	
<i>Juresania</i> sp.		5		
<i>Bilotina yanagidai</i>			1	
<i>Bilotina</i> sp.	1			
<i>Waagenoconcha (Gruntoconcha)</i> sp.	2			
Auriculispininae		1		
<i>Magniplicatina johannis</i>	1			
<i>Edriosteges</i> sp.	2			
<i>Eolyttonia</i> sp.	2			
<i>Derbyia</i> aff. <i>D. scobina</i>	8			
<i>Perigeyerella</i> aff. <i>P. raffaellae</i>	11		1	
<i>Goniarina</i> sp.	5			1
<i>Rhipidomella hessensis</i>	5			
<i>Enteletes</i> aff. <i>E. oehlerti</i>	1	1	2	
<i>Enteletes</i> sp.	1			
<i>Parenteletes</i> sp.	3			
<i>Acosarina</i> aff. <i>A. mesoplatys</i>	5			
<i>Orthotichia</i> aff. <i>magnifica</i>	5			
<i>Stenosisma</i> aff. <i>S. abbreviatum</i>	2			
<i>Stenosisma</i> aff. <i>S. bellatulum</i>	2			
<i>Stenosisma qararensis</i> n. sp.	17		4	
<i>Torynechus</i> sp.	9			
<i>Camarophorinella</i> sp.	2			
? <i>Goleomixa</i> sp.	1			
<i>Wellerella</i> sp.	2			
<i>Uncinellina</i> sp.	5			
<i>Anchorhynchia multicostata</i> n. sp.	10			
<i>Fasciscosta</i> aff. <i>F. longaeva</i>	4			
<i>Gerassimovia</i> sp.	4			
<i>Cleiothyridina</i> sp.	6			
<i>Posicomta advena</i>	1			
<i>Hustedia funaria</i>	9			
<i>Hustedia</i> aff. <i>H. indica</i>				2
<i>Hustedia ratburiensis</i>	6			
<i>Martinia</i> sp.	3			
? <i>Chapursania</i> sp.	1	3		
<i>Tirannia</i> aff. <i>T. semiglobosa</i>		3		
<i>Cartorhium</i> aff. <i>C. multiradiatus</i>	7		3	
<i>Spiriferella posterosulcata</i> n. sp.	7	2		3
<i>Arcullina</i> sp.		1		3
<i>Aequalicosta</i> sp.	5			
<i>Tipispirifer</i> sp.	2			
<i>Permophrichodothyris</i> aff. <i>P. affinis</i>	5			
<i>Permophrichodothyris inaequilateralis</i>	5			
<i>Squamularia marcouxii</i>	11			
<i>Squamularia</i> sp.	10			
<i>Paraspiriferina gentilis</i>	1			
<i>Callispirina</i> cf. <i>C. rotunda</i>				1
<i>Spiriferellina aduncata</i>	2			
<i>Spiriferellina yanagidai</i>	11			
<i>Notothyris</i> sp.	1			
<i>Rostranteris mediterraneum</i>	4			
<i>Dielasma</i> sp.	2		1	

Tab. 2 - Distribution of brachiopod taxa in the fossiliferous localities.

Locality	N° species	N° specimens	Margalef index	Shannon-Wiener index
WKJ	59	295	10.19	3.74
SH11	5	10	1.73	1.50
JQ1	9	19	2.71	1.92
JX3	9	15	2.95	2.02

Tab. 3 - Diversity indices (Margalef and Shannon-Wiener) in the different fossiliferous localities.

rather numerous specimens. Shannon-Wiener and Margalef indices are very high for WKJ (respectively SI: 3.7 and MI: 10.2), indicating that particularly specific richness is high for the WKJ localities (Tab. 3). JQ1 and JX3 have biodiversity indices in the range of SI:  $\sim 2$  and MI:  $\sim 3$ , and both specific richness and evenness are rather high.

Instead, SH11 is characterized by low diversity, but this may be related to sampling as this exposure is more consolidated and collections were limited.

The size of the studied specimens is reported in Tab. S3. Most have a small to medium size (respectively 5-12 mm and 12-30 mm in length), except for species of *Callytharrella*, *Orthotichia*, *Cartorbium*, *Martinia* and *Chapursania* which can reach a large size when adults, up to 80 mm in width; they reach their largest size in the WKJ localities.

The taphonomical analysis of the Qarari brachiopods is synthetized in Tab. S1. In all the fossiliferous localities the overwhelming majority of the specimens are articulated (99%), and show no sign of abrasion, selection or orientation by transport. A certain percentage of specimens (>55% in all localities, they exceed 70% in JQ1 and JX3) show sign of superficial corrosion, but this may be linked to exposure to desert weathering on the bedding surface which in a few cases lead to the production of internal moulds. Fracturing and deformation are generally uncommon and produced by diagenetic compaction. Bioencrustation by bryozoans, sponges and other brachiopods is generally very rare, slightly higher in WKJ (8.5%). There is no trace of bioencrustation crossing the anterior commissure or located on the internal side of the shells. Even bioerosion, produced by domichnia of barnacles and sponges, is infrequent and never exceeds 7% of each assemblage. Bioerosion is observed mostly on the external surface of thick-shelled specimens, and is species-specific, as species of *Cleiothyridina*, *Orthotichia*, and *Wellerella* are colonized by barnacles,

whereas those of *Martinia* and *Posicomta* by sponges. Traces of predation are negligible and limited to two specimens: one of *Acosarina* aff. *A. mesoplatys* and one of *Anchorhynchia multicostata* n. sp. Both bioerosion and bioencrustation are absent from JX3 and SH11.

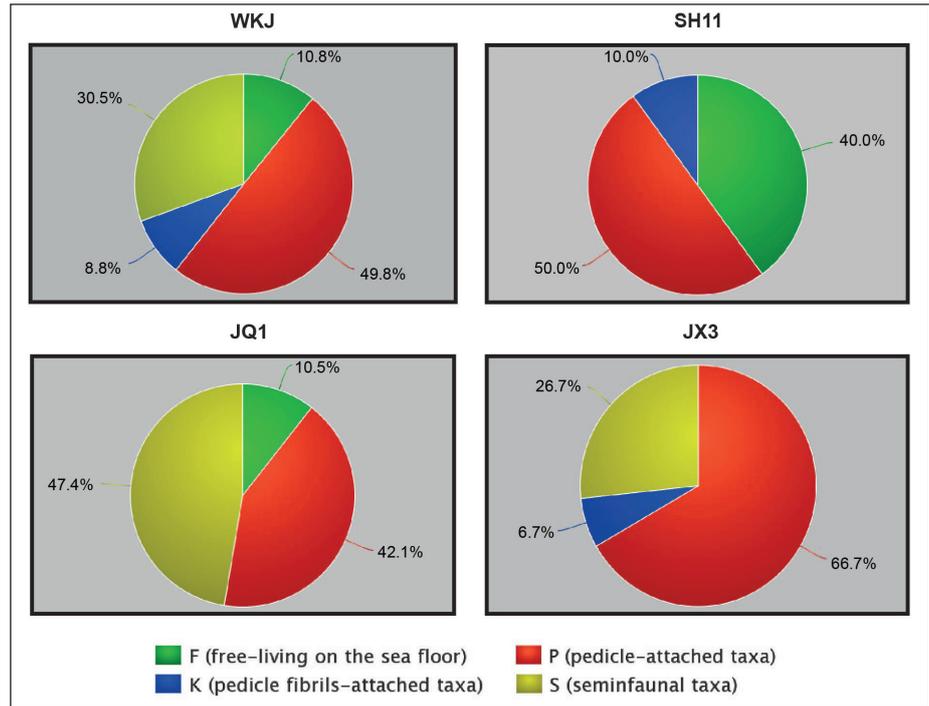
The life-styles of the identified brachiopods from the Qarari Unit are reported in Table S2 and synthetized in Fig. 3. We identified epifaunal ambitopic taxa (pedicle-attached as juveniles, but free-living on the sea floor at the adult stage), pedicle-attached taxa, pedicle fibrils-attached taxa (i.e. bearing koskinoid perforations for pedicle fibrils), and seminafaunal taxa. WKJ localities record a dominance of pedicle-attached individuals (50%), a good proportion of seminafaunal taxa (30.5%) and a minority of free-living at the adult stage and of pedicle fibrils-attached species; JQ1 has a similar proportion of pedicle-attached and seminafaunal taxa alongside a few free-living species; JX3 is largely dominated by pedicle-attached and pedicle fibrils-attached species, with one-third of species being seminafaunal; in SH11 most are free-living and there is no seminafaunal species.

### Palaeoecological implications

Based on the taphonomic attributes described above, the brachiopod assemblages from the Qarari Unit are interpreted as life assemblages sensu Brenchley & Harper (1998). The degree of bioencrustation and bioerosion is low and, in any case, produced during the life of the brachiopods, not post-mortem. The time of post-mortem exposure of brachiopods on the sea floor was thus limited, and bottom conditions were sufficiently quiet not to disarticulate the shells, but also characterized by rapid burial events avoiding subsequent disturbance, as already suggested based on the analysis of the trilobites, found articulated and enrolled (Fortey & Heward 2015). This and the occasional occurrence of grainstone and rudstone in the succession suggest burial by periodic storms in a shelf setting at depths around the storm wave base, so less deep than previously interpreted (Immenhauser et al. 1998).

Substrates varied in the different localities: the highest diversity assemblage from WKJ testifies to varied coarser-grained detrital substrates and higher energy conditions, favouring pedicle or pedicle-fibrils attached taxa and ambitopic ones, but

Fig. 3 - Pie-charts showing the life styles of brachiopods in the different fossiliferous localities.



with the occurrence also of soft muddy substrates colonized by seminafaunal spinose, concave-convex productides; richness and evenness are high, but the richness is particularly high indicating that the palaeocommunity was well-structured, and with a very high number of species. JQ1 has moderate diversity and seems to be characterized by the occurrence of both soft substrates and coarser-grained detrital ones. JX3 is more similar to WKJ in terms of substrates and hydrodynamic energy, but with a more limited occurrence of soft muddy substrates. SH11 cannot be discussed, because the recorded specimens and species are very few.

Interestingly, in the high-diversity WKJ assemblage, both taxa with a complex feeding apparatus (*Martinia* sp., ?*Chapursania* sp., and *Cartorbium* aff. *C. multiradiatus*), and those with a simple lophophore (*Orthotichia* aff. *O. magnifica*) grow to a large size. This may suggest variable rates of nutrient supply, as a low and sparse nutrient supply favour brachiopods with a simple feeding apparatus able to create multidirectional currents, whereas higher, concentrated food supply favour spire-bearers (Perez-Huerta & Sheldon 2006); competition for space was probably high among the epifaunal taxa, which are the most abundant in this fossiliferous locality. WKJ localities record a well-developed tiering, from small seminafaunal productides and pedicle-attached athyridides, rhynchonellides, spiriferinides, and terebratulides elevating less than 1 cm above the seafloor, to an

intermediate level with larger seminafaunal productides, pedicle or pedicle-fibrils attached and ambiotopic taxa, and finally a high level of tiering with the large orthides and spiriferides reaching 6-8 cm above the substrate.

The other fossiliferous localities are less diverse and tiering is developed on about two levels. In general food supply was variable in all the localities, as also testified by different growth strategies directed toward an increase of the food-uptake area

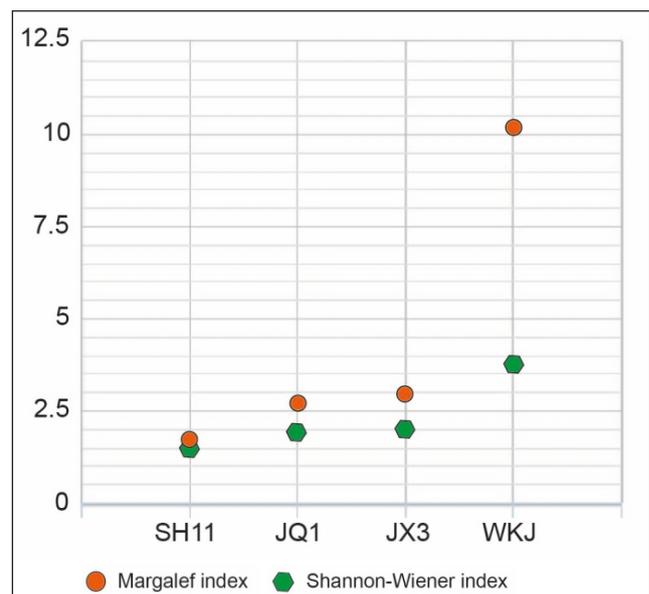


Fig. 4 - Diversity indices (Margalef and Shannon-Wiener) in the different fossiliferous localities.

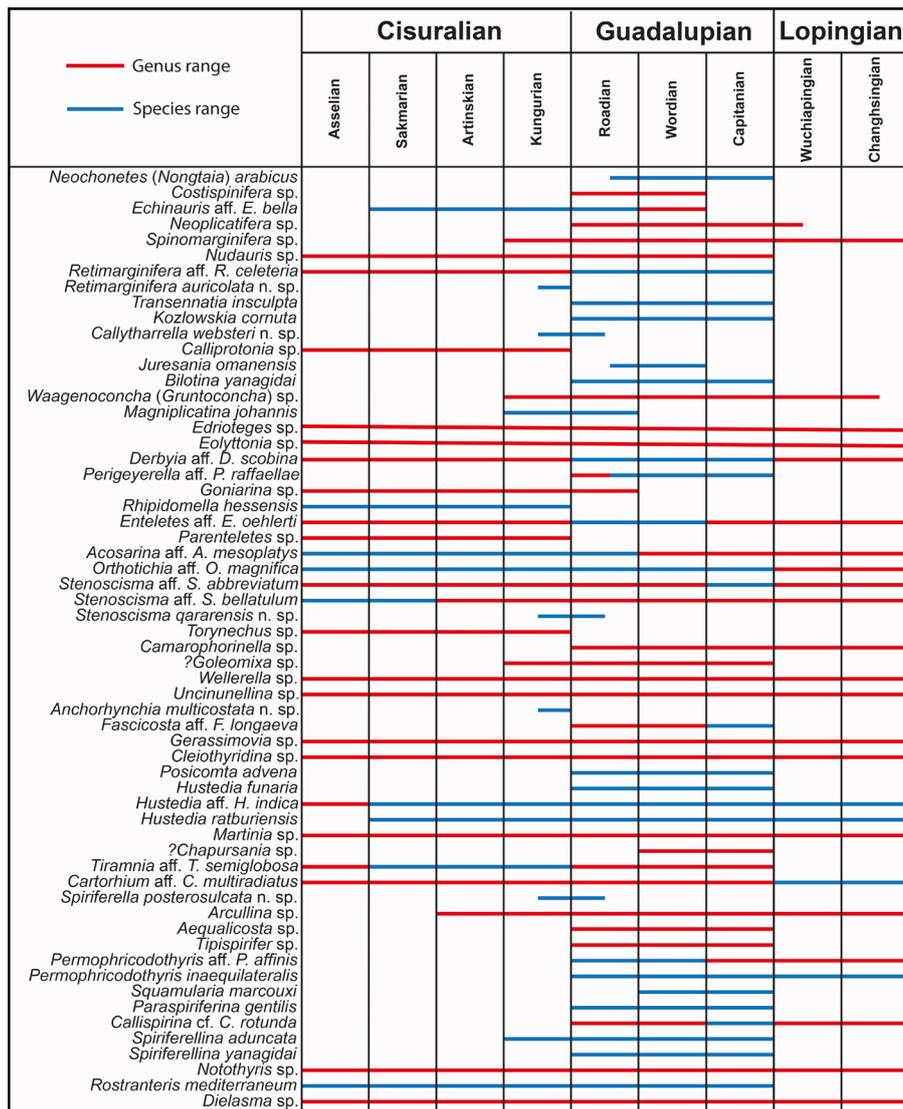


Fig. 5 - Stratigraphic range of the brachiopods species and genera occurring in the Qarari fossiliferous localities.

(the commissure) as developing an uniplicate commissure (*Orthotichia* aff. *O. magnifica*, ?*Chapursania* sp., *Squamularia marcouxi*) or a more transverse shape with growth (*Stenosiscisma* aff. *S. abbreviatum*, *Camorphorinella* sp., *Aequalicosta* sp.). This is in agreement with the inferred depositional setting at depth around the storm wave base.

### Age and correlations

The conodont and fusuline data reported above indicate a late Kungurian age for WKJ, a late Kungurian-early Roadian age for JX3, and a late Kungurian-Roadian age for JQ1. The stratigraphic distributions of the brachiopod taxa from these three localities agrees well with these ages (Fig. 5), with ranges overlapping mostly at the Cisuralian-Guadalupian boundary. In WKJ, the species of the genera *Calliprotonia*, *Rhipidomella*, *Parenteleles*, *Torynechus* have a range that ends in the Kungurian, where-

as *Edriostege* sp., *Goniarina* sp. and *Acosarina* aff. *A. mesoplatus* enter the Roadian; these are associated to several taxa appearing in the Roadian (Fig. 5), suggesting that the age is close to the Kungurian-Roadian boundary. The same holds true for JX3, which is characterized by a species of *Calliprotonia*, along with Guadalupian productides, orthotetides and orthides, but also by a species of *Cartorbium* which is similar to a Lopingian species. In JQ1, again most taxa appear in the Roadian, but the recorded species of *Tiramnia* is close to a Sakmarian-Kungurian species and so the age may be close to the Cisuralian-Guadalupian boundary and thus late Kungurian-early Roadian. The low diversity SH11 fossiliferous locality has no Kungurian species, but only Guadalupian taxa, so its age may be Roadian.

The Qarari brachiopods are different in age from the already described faunas from the Interior Oman, which are respectively Sakmarian and

Wordian (Angiolini et al. 1997, 1998, 2003a,b, 2004, 2014; Angiolini & Bucher 1999; Angiolini 2001, 2007). They are very different from the Sakmarian brachiopods from the Saiwan Formation, but they have a few taxa in common with the younger (Wordian) Khuff fauna, i.e. *Neochonetes* (*Nongtaiia*) *arabicus*, *Juresania omanensis*, *Bilotina yanagidai*, a similar species of *Perigeyerella* (*P. aff. P. raffaellae*), and the genus *Kozłowskaia*; the other taxa are different. The occurrence of these taxa in common with the Khuff Formation along with other typical Guadalupian taxa as reported in Fig. 5, suggests that the Qarari brachiopods are quite advanced in character for the late Kungurian.

Brachiopod faunas of similar late Kungurian-early Roadian age from the northern Gondwana margin and peripheral blocks (Cimmerian and Cathaysian regions) are known mainly from Karakoram (Pakistan) (Angiolini 1995, 1996), the Irrawaddy Block, Myanmar (Xu et al. 2021), South China (Shen 2018 and references therein), Western Australia (e.g. Archbold 1998; Archbold & Thomas 1986; Archbold & Skwarko 1998; Archbold et al. 1993) and Eastern Australia (e.g. Waterhouse 1986, 1987; Briggs 1998).

The faunas from the Kungurian-lower Roadian of Karakoram (defined as Bolorian-Kubergandian in Angiolini 1996) comprise 21 species of 16 genera, of which only eight (*Neochonetes*, *Callytharella*, *Retimarginifera*, *Transennatia*, *Magniplicatina*, *Derbyia*, *Enteleles*, *Permophricothyris*) are in common with the Qarari fauna. The differences can be explained by the fact that Karakoram was lying at the other side of the opening Neo-Tethys Ocean by the Kungurian, as shown by the palaeogeographic maps of Kent & Muttoni (2020). In the same way, we can say that there are only a few affinities with the brachiopod faunas of South China, which comprise a similar richness (nearly 60 genera), with 16 genera in common, but these are mostly wide- and/or long-ranging taxa (for example *Neochonetes*, *Derbyia*, *Acosarina*, *Orthotichia*, *Enteleles*, *Stenosisma*, *Cleiothyridina*, *Posicomta*, *Martinia*, *Notothyris*, *Dielasma*). Worthy of note is the occurrence in both regions of *Transennatia*, *Permophricothyris*, *Spinomarginifera* and *Squamularia*, the former two present also in Karakoram.

We observe some similarities with the upper Kungurian brachiopods of Myanmar (Irrawaddy Block) which include about 48 genera, 15 shared with Oman; the common taxa are: *Magniplicatina*,

*Caricula*, *Comuquia*, *Spiriferella*, and some spiriferinids, in addition to those shared with South China and listed above. The younger, mostly Wordian, brachiopod fauna from the Rat Buri Limestone of Thailand described by Grant (1976) includes 73 identified genera, 24 of which occurring in the Qarari fauna. However, the Rat Buri Limestone brachiopods are more similar to the coeval ones of the Khuff Formation of Oman as shown by Angiolini et al. (2013).

Western Australia is along the Gondwanan margin, but at more southern latitudes than Oman and they share only a few genera. Finally, the Eastern Australia fauna is completely different at the generic level. These differences may be explained by the fact that the Qarari succession was deposited in the Madagascan arm of Neo-Tethys, and thus rather isolated from the main Gondwanan margin, and also by the quite advanced character of the fauna as explained above.

## CONCLUSIONS

The systematic study of the brachiopods from the Qarari Unit of the Batain Plain (Oman) discloses upper Kungurian-lower Roadian well-structured palaeocommunities of unparalleled biodiversity, comparable in terms of species richness only to the coeval faunas of South China and West Texas.

The Qarari brachiopods were thriving in the Madagascan arm of Neo-Tethys, rather isolated from the main Gondwanan margin, and displayed various life-styles in settings characterized by different substrates, from soft muddy ones to more varied coarser-grained detrital substrates at depth around the storm wave base.

The Qarari brachiopods do not show many affinities with the coeval faunas from the northern Gondwana margin and the Cimmerian and Cathaysian blocks, except from some relationships with the upper Kungurian fauna from Myanmar (Xu et al. 2021).

The particular characters of the Qarari faunas open new perspectives for future palaeobiogeographical and palaeoclimatological studies in this crucial interval of the Permian, characterized by the widening of the Neo-Tethys Ocean and climate amelioration from the Cisuralian to the Guadalupian.

## SYSTEMATIC DESCRIPTIONS

Class **STROPHOMENATA** Williams, Howard, Brunton & Cocks, 1996

Order **Productida** Sarytcheva & Sokolskaya, 1959

Suborder **Chonetidina** Muir-Wood, 1955

Superfamily Chonetoidea Bronn, 1862

Family Rugosochonetidae Muir-Wood, 1962

Subfamily Rugosochonetinae Muir-Wood, 1962

Genus *Neochonetes* Muir-Wood, 1962

Subgenus *Neochonetes (Nongtaia)* Archbold, 1999

**Type species:** *Neochonetes (Nongtaia) taoni* Archbold, 1999

*Neochonetes (Nongtaia) arabicus* Hudson & Sudbury, 1959

Pl. 1, fig. 1-4

1959 *Chonetes arabicus* Hudson & Sudbury, p. 26-28, pl. 3, fig. 6-16, pl. 6, fig. 14-18.

1990 *Neochonetes (Sommeriella) arabicus* - Archbold & Burret, p. 121, fig. 1 A-C.

1999 *Neochonetes (Sommeriella) arabicus* - Angiolini in Angiolini & Bucher, p. 678, 12.15-21, pl. 3.

**Material:** Two figured articulated specimens: MPUM12538 (WKJd-34), MPUM12539 (WKJd-66).

**Description.** Small sized, slightly concave-convex shell with subrectangular outline, wider than long. Maximum width at the hinge. Ears small, triangular, flat. Anterior commissure rectimarginate. Ventral valve convex with shallow median sulcus starting anteriorly to the umbo. Dorsal valve with median fold widening anteriorly.

Ornamentation of fine costellae, growth lamellae, rare spine bases along the cardinal margin.

**Remarks.** *Neochonetes (Nongtaia) arabicus* Hudson & Sudbury, 1959 is characterized by its small size and shallow sulcus (Angiolini & Bucher 1999).

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kun-gurian.

**Distribution.** Khuff Formation, Wordian, Oman (Angiolini & Bucher 1999); Pamuçak Formation, Wordian-Capitanian, Western Taurus, Turkey (Verna et al. 2011).

Suborder **Productidina** Waagen, 1883  
Superfamily **Productoidea** Gray, 1840  
Family **Productellidae** Schuchert, 1929

Subfamily **Overtoniinae** Muir-Wood & Cooper, 1960

Tribe **Costispiniferini** Muir-Wood & Cooper, 1960

Genus *Comuquia* Grant, 1976

**Type species:** *Comuquia modesta* Grant, 1976

**Remarks.** *Comuquia* Grant, 1976 is characterized by a small size, an ovate shape, rather strong, irregular growth lamellae, and spines arranged in transverse rows on the ventral valve.

*Comuquia* sp.

Pl. 1, fig. 5-8

**Material:** Two figured articulated specimens: MPUM12541 (WKJb-12), MPUM12542 (WKJb-26); two articulated specimens: MPUM12543 (WKJb-13, WKJb-27).

**Description.** Small sized concave-convex shell with suboval outline, slightly wider than long. Ears small. Maximum width anterior to the hinge. Anterior commissure rectimarginate. Ventral valve convex, with no median sulcus. Dorsal valve with no fold.

Ornamentation of comparatively strong growth lamellae and regularly arranged spines covering both valves.

**Remarks.** The specimens under study differ from *C. modesta* Grant, 1976 from the Guadalupian Rat Buri Limestone of Thailand (Grant, 1976) because of the denser spines on the ventral valve which are not clearly organized in transverse rows.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kun-gurian.

Genus *Neoplicatifera* Ching, Liao & Hou, 1974

**Type species:** *Plicatifera huangi* Ustritsky in Ustritsky et al., 1960

**Remarks.** *Neoplicatifera* Ching, Liao & Hou, 1974 differs from *Paraplicatifera* Zhao & Tan, 1984, because the latter has well-defined costae and rugae. The species of *Neoplicatifera* are characterized by poorly defined ribs on the trail and absence of spines and rugae on the ears.

*Neoplicatifera* sp.

Pl. 1, fig. 9-12

**Material:** Two figured articulated specimens: MPUM12544 (WKJb-6), MPUM12545 (WKJc-14); three articulated specimens: MPUM12546 (WKJb-8, WKJb-21, WKJb-32).

**Description.** Small sized concave-convex shell with subquadrate outline. Ears small, but well-defined. Maximum width at the hinge. Anterior commissure rectimarginate. Ventral valve convex, strongly geniculated, with very shallow median sulcus. Dorsal valve with no fold.

Ornamentation of very weak rugae on the visceral disc and poorly defined ribs on the trail, and spines on both valves. Ears not ornamented. Dimples on the dorsal valve.

**Remarks.** The specimens under study apparently show a different outline because of their different state of preservation, only a few preserving the trail, but they seem to belong to the same species. They differ from *Neoplicatifera huangii* Ustritsky in Ustritsky et al., 1960 from the Guadalupian Maokou Formation of China, because of the longer trail and the presence of weak ribs on the trail. *N. costata* Ni in Yang et al., 1977, from the Guadalupian Maokou Formation of China has stronger ribs.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Subfamily Marginiferinae Stehli, 1954

Tribe Marginiferini Stehli, 1954

Genus *Spinomarginifera* Huang, 1932

**Type species:** *Spinomarginifera kweichowensis* Huang, 1932

*Spinomarginifera* sp.

Pl. 1, fig. 13-16

**Material:** Two figured articulated specimens: MPUM12547 (WKJb-5), MPUM12548 (WKJb-29).

**Description.** Medium to large sized for the genus, concave-convex shell with a subrectangular outline, wider than long. Ears small. Maximum width near mid-length. Anterior commissure rectimarginate. Ventral valve convex, slightly geniculated, with very shallow sulcus starting in the posterior third of the valve. Dorsal valve slightly concave.

Ornamentation of coarse spines on both valves, densely arranged in quincunx posteriorly, becoming more widely and less uniformly arranged in the anterior half, and more elongate forming

small ridges on the trail. Fine rugae on both valves, more evident on visceral disk and flanks of the ventral valve.

**Remarks.** The genus *Spinomarginifera* Huang, 1932 comprises many species from the Guadalupian-Lopingian. Based on shell outline and spine arrangement, the specimens under study are closer to *S. belica* (Abich, 1878) and *S. iranica* Fantini Sestini, 1965 from the upper Guadalupian and the Lopingian of Iran and Turkey (e.g. Angiolini & Carabelli 2010; Verna et al. 2011; Ghaderi et al. 2014; Viaretti et al. 2021). However, they differ from *S. iranica* because of the outline, the rugae on both valves and the more elongate spine bases; from *S. belica* because of the rugae on both valves and the more densely distributed spine bases. A species of *Spinomarginifera*, *S. concentrica* He & Shi, 2008 has been reported from the Kungurian of Southern Qinghai, northwest China: however it has a much stronger concentric ornamentation on the visceral disc and less dense spines. Due to these differences the nomenclature is left open.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Tribe Paucispiriferini Muir-Wood & Cooper, 1960

Genus *Caricula* Grant, 1976

**Type species:** *Caricula salebrosa* Grant, 1976

**Remarks.** *Caricula* Grant, 1976 is characterized by a small size, extended ears, costae absent in the sulcus, which is deep, and subdued ribs anteriorly.

*Caricula* sp.

Pl. 1, fig. 17-20

**Material:** Two figured articulated specimens: MPUM12549 (WKJd-14), MPUM12550 (WKJd-16); three articulated specimens: MPUM12551 (WKJd-8, WKJd-10, WKJd-15).

**Description.** Small sized, concave-convex shell with subrectangular outline, wider than long. Ears very expanded, pointed. Maximum width at the hinge. Anterior commissure uniplicate. Ventral valve convex, with a deep and wide median sulcus starting anteriorly to the visceral disc. Dorsal valve with a low median fold starting on the visceral disc.

Ornamentation reticulate on the visceral disc; rugae rather strong on the visceral disc, but irregular, a few interrupted along the midline; ribs continuing on the trail, but becoming very fine and disappearing in the sulcus and towards the anterior margin; spines on ventral valve only: in a row along the cardinal margin, fine and dense on the umbo, larger and sparse on the trail. Ears ornamented by rugae.

**Remarks.** The specimens under study differ from *C. salebrosa* Grant, 1976 from the Guadalupian Rat Buri Limestone of Thailand (Grant, 1976) because of the more extended and pointed ears, which protrude from the outline. Also they have less marked rugae on the visceral disc.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Genus *Retimarginifera* Waterhouse, 1970

**Type species:** *Retimarginifera perforata* Waterhouse, 1970

**Remarks.** *Retimarginifera* Waterhouse, 1970 differs from the allied *Caricula* Grant, 1976 because of its stronger ribs, which occur also in the sulcus; from *Transennatia*, Waterhouse, 1975 because of its more distinct ears and regularly arranged rows of spines on the visceral disc. Also, *Retimarginifera* has a more subdued ornamentation with respect to *Transennatia*.

***Retimarginifera auriculata* n. sp.**

Pl 1, fig. 21-28

**Derivation of name:** From its distinctly pointed ears.

**Holotype:** One articulated specimen, MPUM12552 (WKJd-51) (Pl. 1, fig. 21-22). Maximum width 15.9 mm, corresponding length 9.1 mm.

**Type locality:** WKJ, Wadi Khawr al Jaramah, Oman, Qarari Unit, Batain Group, late Kungurian.

**Material.** Holotype MPUM12552 (WKJd-51), three figured articulated specimens: MPUM12553 (WKJd-34B), MPUM12554 (WKJd-37), MPUM12555 (WKJd-62); thirteen articulated specimens: MPUM12556 (WKJd-36, WKJd-41, WKJd-43, WKJd-44, WKJd-47, WKJd-49, WKJd-50, WKJd-54, WKJd-56, WKJd-58, WKJd-60, WKJd-63, WKJd-64).

**Diagnosis:** Small sized *Retimarginifera* with distinct, pointed ears and uniformly deep and wide sulcus.

**Description.** Concave-convex shell with sub-rectangular outline, wider than long. Ears very distinct, triangular, pointed and enrolled. Maximum width at the hinge. Anterior commissure uniplicate with a narrow fold. Ventral valve convex, geniculated,

ed, with a deep median sulcus starting at mid-length of the visceral disc, uniform in width. Dorsal valve geniculated with a narrow but distinct median fold developed anteriorly on the trail.

Ornamentation reticulate on the visceral disc, with rugae stronger than ribs; ribs continuing on the trail but becoming obsolete anteriorly; they number 7 per 5 mm on the trail and do not converge into the sulcus; spines on the ventral valve: sparse on the visceral disc, one row of 2-3 spines at each side of the sulcus increasing in diameter anteriorly, one row of spines delimiting the ears. Dimples on the dorsal valve.

**Remarks.** The specimens under study are characterized by a fold-sulcus uniform in width and by distinct and pointed ears; also the ribs do not converge in the ventral sulcus. These features are very distinctive and support the erection of a new species.

*Retimarginifera auriculata* n. sp. differs from *R. celeteria* from the Guadalupian Rat Buri Limestone of Thailand (Grant, 1976) because of its small size, more pointed ears and costae not converging in the sulcus and becoming obsolete anteriorly; from *R. perforata* Waterhouse, 1970 from the Artinskian-Roadian Byro Group of Western Australia because of its more pointed ears, shallower sulcus which does not widen anteriorly and costae not converging in the sulcus; from *R. alata* Waterhouse, 1981 from the Cisuralian of Thailand because of its shallower and narrower sulcus and finer ornamentation; from *R. praelecta* (Reed, 1925) from the Cisuralian of Karakoram because of its uniformly wide sulcus and the ribs not converging in the sulcus; from *R. rimuensis* (Reed, 1925) from the Cisuralian of Karakoram because of its enrolled ears and sulcus starting more posteriorly.

The specimens figured as *Lammimargus himalayensis* (Diener, 1899) by Yang et al. (1990, pl. 25) from the Cisuralian of Mayang, SW Tibet seem similar to this species.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

***Retimarginifera* aff. *R. celeteria* Grant, 1976**

Pl. 1, fig. 29-31

**Material:** Two figured articulated specimens: MPUM12557 (WKJd-26), MPUM12558 (WKJd-30); two articulated specimens: MPUM12559 (WKJc-7A), MPUM12560 (WKJf-8).

**Description.** Concave-convex shell with subrectangular outline, wider than long. Ears expanded. Maximum width at the hinge. Anterior commissure uniplicate. Ventral valve convex, with a deep and narrow median sulcus starting at mid-length of the visceral disc. Dorsal valve transverse with a relatively low median fold starting on the visceral disc and widening anteriorly.

Ornamentation neatly reticulate on the visceral disc; ribs continuing on the trail, and converging in the sulcus; they number 5-6 per 5 mm on the trail; spines on ventral valve only: few, widely spaced and arranged in concentric rows on the trail; a row of spines delimiting the ears. Dimples on the dorsal valve.

**Remarks.** The specimens under examination belong to a species of the genus *Retimarginifera* because of their transverse outline, reticulate visceral disc, fine ribs and spines arranged in concentric rows. Species of *Transennatia* have a much sharper external ornamentation (Grant, 1976). The specimens under study are close to *R. celeiteria* based on their shape, ears and ornamentation, but they differ because of their deeper sulcus starting more posteriorly. They are similar to *R. praelecta* because of the outline and ornamentation, but are larger in size. The shape of their sulcus make them similar to *R. perforata*, but they do not show the extended ears of the latter.

They differ from *R. auriculata* n. sp. because of their larger size, the ribs converging in the sulcus and the smaller and less distinct ears.

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kungurian.

Genus *Transennatia* Waterhouse, 1975

**Type species:** *Productus gratiosus* Waagen, 1884

***Transennatia insculpta*** (Grant, 1976)

Pl. 1, fig. 32-38

1976 *Gratiosina insculpta* Grant, p. 135, pl. 32, fig. 1-37; pl. 33, fig. 1-16.

**Material:** Four figured articulated specimens: MPUM12561 (WKJb-23), MPUM12562 (WKJc-8), MPUM12563 (WKJc-16), MPUM12564 (WKJd-18); four articulated specimens: MPUM12565 (WKJb-22, WKJb-28, WKJb-31), MPUM12566 (WKJc-15).

**Description.** Concave-convex shell with

subrectangular outline, wider than long. Ears well-defined. Maximum width at the hinge. Anterior commissure uniplicate. Ventral valve convex, geniculated, with a deep median sulcus starting at the end of the visceral disc, uniform in width and depth. Dorsal valve with a median fold starting at mid-length of the visceral disc.

Ornamentation neatly reticulate on the visceral disc; ribs continuing on the trail increasing in width anteriorly and converging into the sulcus; spines on ventral valve, denser on the visceral disc and less numerous on trail and ears. Dimples on the dorsal valve.

**Remarks.** The specimens under examination differ from *Transennatia reedi* Angiolini, 1995 from the Kungurian of Karakoram because of their coarser rugae and shallower sulcus. They belong to *T. insculpta* because of their outline, ornamentation and spine arrangement.

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Rat Buri Limestone, Guadalupian, Thailand (Grant 1976).

### ***Transennatia* sp. 1**

Pl. 1, fig. 39-42

**Material:** Two figured articulated specimens: MPUM12567 (WKJd-17), MPUM12568 (WKJd-19); one articulated specimen: MPUM12569 (WKJb-24).

**Description.** Small sized concave-convex shell with subquadrate outline, longer than wide. Maximum width anterior to the hinge. Anterior commissure uniplicate. Ventral valve strongly convex, geniculated, with a deep and narrow median sulcus starting anteriorly to the visceral disc. Dorsal valve with a low median fold on the trail.

Ornamentation reticulate on the visceral disc with thin irregular rugae and ribs; ribs strong on the trail; spines on both valves, more numerous on the trail.

**Remarks.** The specimens under study differ from *Transennatia insculpta* because of their subquadrate outline, inflated ventral valve and because of coarser spines.

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kungurian.

***Transennatia* sp. 2**

Pl. 1, fig. 43-45

**Material:** Two figured articulated specimens: MPUM12570 (JQ1-2), MPUM12571 (JQ1-10); one articulated specimen: MPUM12572 (JQ1-5).

**Description.** Concave-convex shell with subrectangular outline wider than long. Maximum width at the hinge. Anterior commissure uniplicate. Ventral valve convex, geniculated, with shallow median sulcus. Dorsal valve with a low median fold on the trail.

Ornamentation reticulate on the visceral disc; ribs continuing on the trail and converging into the sulcus; spines on ventral valve.

**Remarks.** The specimens under examination are poorly preserved and cannot be safely assigned to any species of *Transennatia*, even if they show the general features of the species of the genus. However, they clearly differ from *Transennatia insculpta* and *Transennatia* sp. 1 by having finer costae.

**Occurrence.** Oman, loc. JQ1, Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian.

Family Productidae Gray, 1840

Subfamily Productinae Gray, 1840

Tribe Kozłowskiini Brunton, Lazarev &amp; Grant, 1995

Genus *Kozłowskia* Fredericks, 1933**Type species:** *Productus capaci* D'Orbigny, 1842

**Remarks.** *Kozłowskia* Fredericks, 1933 is characterized by a transverse outline, well-developed ears, multiple trails, weak rugae and costae and a variably developed sulcus.

***Kozłowskia cornuta* Grant, 1976**

Pl. 1, fig. 46-49

1976 *Kozłowskia cornuta* Grant, p. 118, pl. 26, fig. 24-29; pl. 27, fig. 35-38.

**Material:** Two figured articulated specimens: MPUM12573 (WKJb-15), MPUM12574 (WKJb-25); four articulated specimens: MPUM12575 (WKJb-33), MPUM12576 (WKJc-3, WKJc-11, WKJc-13).

**Description.** Concave-convex shell with subquadrate outline (excluding ears). Ears extended, well-defined. Maximum width at the hinge.

Anterior commissure rectimarginate. Ventral valve convex, geniculated, with no median sulcus. Dorsal valve with no fold, with multiple trails.

Ornamentation weakly reticulate on the visceral disc; costae fine, disappearing on the trail; spines on ventral valve: in row along the cardinal margin with the largest near the hinge end, sparse on the visceral disc and on the trail.

**Remarks.** The specimens under examination differ from *Kozłowskia tescorum* (Hudson & Sudbury, 1959) of the Wordian Khuff Formation of Oman (Angiolini & Bucher 1999) because they lack a ventral sulcus; they differ from *K. opipara* Grant, 1976 from the Guadalupian of Thailand (Grant 1976) and from the Guadalupian of Turkey (Verna et al. 2011) because of their weaker costae anteriorly on the trail. They are assigned to *K. cornuta* Grant, 1976 because of their ornamentation and the large size for the genus.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Rat Buri Limestone, Guadalupian, Thailand (Grant 1976).

Subfamily Dictyoclostinae Stehli, 1954

Genus *Callytharrella* Archbold, 1985**Type species:** *Dictyoclostus callytharrensensis* Prendergast, 1943

**Remarks.** *Callytharrella* Archbold, 1985 is similar to *Stereochia* Grant, 1976, but differs from it because of a deeper sulcus and by having ribs on the ears, a feature which is very characteristic of this genus. *Chaoiella* Fredericks, 1933 has poorly expressed ribs, while *Liraplecta* Jin & Sun, 1981 is characterized by numerous capillae between and on the ribs. *Costiferina* Muir-Wood & Cooper, 1960 has a stronger dorsal fold and much coarser ribs. *Reticulatia* Muir-Wood & Cooper, 1960 has a shallower sulcus, smaller ears and no ribs on the ears. *Kutorginella* Ivanova, 1951 may appear superficially similar, but it differs by its smaller size, the occurrence of a nasute trail and denser spines on the visceral disc.

***Callytharrella websteri* n. sp.**

Pl. 1, fig. 50-55

**Derivation of name:** In honour of Gary Webster, a distinguished fossil crinoid specialist and a deep expert of the Omani palaeontology.

**Holotype:** One articulated specimen, MPUM12577 (WKJb-19) (Pl. 1, fig. 52-53). Maximum width 40.7 mm, corresponding length 36.7 mm.

**Type locality:** WKJ, Wadi Khawr al Jaramah, Oman, Qarari Unit, Batain Group, late Kungurian.

**Material:** Holotype MPUM12577 (WKJb-19); two figured articulated specimens: MPUM12578 (WKJb-18), MPUM12579 (WKJc-12); fourteen articulated specimens: MPUM12580 (WKJb-1, WKJb-2, WKJb-3, WKJb-10, WKJb-11, WKJb-16, WKJb-17, WKJb-20, WKJb-30), MPUM12581 (WKJc-2, WKJc-4, WKJc-6, WKJc-10), MPUM12582 (JX3-2). One dorsal valve: MPUM12583 (WKJb-34).

**Diagnosis:** Large sized *Callytharrella* with shallow sulcus and numerous non-fasciculate ribs.

**Description.** Large sized, concave-convex shell with subrectangular outline, wider than long. Ears expanded. Maximum width at the hinge. Anterior commissure uniplicate. Ventral valve very convex, with narrow median sulcus, deeper on the trail. Dorsal valve with very low fold.

Ornamentation reticulate on the visceral disc; ribs continuing on the trail increasing in width anteriorly and occasionally converging into the sulcus; ribs less numerous and wider on the lateral flanks than in the sulcus, numbering 8 per 5 mm on the visceral disc and 4 per 5 mm on the trail; spines on ventral valve: at least four large on the trail, smaller, more numerous and uniformly arranged on the visceral disc, in a row along the cardinal margin. Dorsal valve with dimples; ears ornamented by rugae and ribs.

Interior of dorsal valve with brachial ridge, median septum, dendritic adductor scars, indistinct ear baffles.

**Remarks.** *Callytharrella websteri* n. sp. is similar to *C. callytharrensensis* (Prendergast, 1943) from the Sakmarian-Artinskian of Western Australia, to *C. dongshanpoensis* Shen, Shi & Zhu, 1999 from the Sakmarian-Artinskian of west Yunnan and to *C. sinensis* (Sun, 1983) from the Kungurian of north-west Tibet and Kungurian-Roadian of Karakoram (Angiolini 1996). It differs from *C. callytharrensensis* because of its shallower ventral sulcus; from *C. dongshanpoensis* by the absence of a sulcus delimiting the ears and the more numerous and finer ribs; from *C. sinensis* because of the coarser ribs which do not form fascicles on the trail; from *C. khalii* Archbold & Barkham, 1987 from the Sakmarian of west Timor by the less numerous ribs which generally do not bifurcate anteriorly to the spine bases.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Superfamily Echinoconchoidea Stehli, 1954

Family Echinoconchidae Stehli, 1954

Subfamily Echinoconchinae Stehli, 1954

Tribe Calliprotonini Lazarev, 1985

Genus *Calliprotonia* Muir-Wood & Cooper, 1960

**Type species:** *Calliprotonia renfrarum* Muir-Wood & Cooper, 1960

**Remarks.** *Calliprotonia* Muir-Wood & Cooper, 1960 is externally very similar to *Vediproductus* Sarytcheva, 1960. The main differences between the two genera rely on the outline, subquadrate in the former and subtriangular in the latter, the geniculation of the ventral valve, the median sulcus occurring only in the former, and the ornamentation: *Calliprotonia* has shorter and more numerous growth lamellae bearing more numerous prostrate spines, which are not supported by elongate ridges as in *Vediproductus*. Another allied genus is *Karavankina* Ramovs, 1969, which differs because it is characterized by high relief concentric bands bearing spines, separated by wide smooth bands which may be wider than the area occupied by the spines (fig. 1d in Brunton et al. 2000).

*Calliprotonia* sp.

Pl. 1, fig. 56-59

**Material:** Two figured articulated specimens: MPUM12584 (WKJe-140), MPUM12585 (WKJe-141); ten articulated specimens: MPUM12586 (WKJc-9), MPUM12587 (WKJd-302), MPUM12588 (WKJe-137, WKJe-138, WKJe-139, WKJe-302A, WKJe-302B), MPUM12589 (WKJf-4, WKJf-20), MPUM12590 (JX3-4).

**Description.** Concave-convex to plano-convex shell with subquadrate outline. Ears small. Maximum width at mid-length. Anterior commissure rectimarginate. Ventral valve convex, with a shallow median sulcus, widening anteriorly.

Ornamentation of numerous low relief asymmetrical growth lamellae each bearing prostrate spines arranged in rows and not supported by ridges. The spines are of two sizes on each band, the posterior ones being coarser than the anterior ones; in the ventral valve the lamellae bear 5 rows of spines, except anteriorly where the rows are more numerous; in the dorsal valve the number of rows of spines for each lamella is lower, about 2-3. Each lamella has a very narrow smooth band posteriorly.

Interior of dorsal valve with trifold cardinal process and a long median septum.

**Remarks.** The specimens under study show the characteristic features of species of the genus *Calliprotonia* which are the subquadrate outline, the occurrence of the ventral median sulcus and the ornamentation of lamellae with spines. In fact, they bear low relief asymmetrical growth lamellae with unsupported prostrated spines for most of the length of the lamella; posteriorly located smooth bands are very narrow, much narrower than the area occupied by the spines. The specimens under examination differ from *Calliprotonia renfrarum* Muir-Wood & Cooper, 1960 from the Pennsylvanian of Texas (Muir-Wood & Cooper 1960) because they have a different outline, subquadrate rather than suboval, less distinct ears and growth lamellae which are not jagged as in the type species. *C. inexpectum* Cooper, 1957 from the Sakmarian to Kungurian Coyote Butte Formation of Oregon (Cooper 1957) is smaller, has a more elongate outline and a different arrangement of spines, as they are not differentiated in size on each lamella in the posterior half of the valve.

The specimens from Oman may represent a new species, but their state of preservation is not so good to support the erection of a new taxon.

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kungurian.

Subfamily Juresaniinae Muir-Wood & Cooper, 1960  
Tribe Juresaniini Muir-Wood & Cooper, 1960  
Genus *Juresania* Fredericks, 1928

**Type species:** *Productus juresanensis* Tschernyschew, 1902

**Remarks.** *Juresania* Fredericks, 1928 is similar to the genera *Vediproductus* and *Calliprotonia*, which however differ in having concentric bands on the ventral valve. *Juresania* has an ornamentation of quincuncially arranged spine bases on the visceral disc and spines in bands only anteriorly.

### *Juresania omanensis* Hudson & Sudbury, 1959

Pl. 2, fig. 1-2

1959 *Juresania omanensis* Hudson & Sudbury, p. 29, pl. 1, fig. 1-4.

1959 *Juresania* sp. - Hudson & Sudbury, p. 31, pl. 2, fig. 1-3.

1999 *Juresania omanensis* - Angiolini in Angiolini & Bucher, p. 684, tab. 7, fig. 14.1-16.

**Material:** One figured articulated specimen: MPUM12591 (WJKc-5); one articulated specimen: MPUM12592 (JX3-3).

### PLATE 1

*Neochonetes (Nongtaiia) arabicus* Hudson & Sudbury, 1959

1 – MPUM12538 (WKJd-34), ventral view, 2x. 2 – MPUM12538 (WKJd-34), dorsal view, 2x. 3 – MPUM12539 (WKJd-66), ventral view, 2x. 4 – MPUM12539 (WKJd-66), dorsal view, 2x.

*Comuquia* sp.

5 – MPUM12541 (WKJb-12), ventral view, 2x. 6 – MPUM12541 (WKJb-12), dorsal view, 2x. 7 – MPUM12542 (WKJb-26), ventral view, 2x. 8 – MPUM12542 (WKJb-26), dorsal view, 2x.

*Neoplicatijera* sp.

9 – MPUM12544 (WKJb-6), ventral view, 1x. 10 – MPUM12544 (WKJb-6), dorsal view, 1x. 11 – MPUM12545 (WKJc-14), ventral view, 1x. 12 – MPUM12545 (WKJc-14), dorsal view, 1x.

*Spinomarginijera* sp.

13 – MPUM12547 (WKJb-5), ventral view, 1x. 14 – MPUM12547 (WKJb-5), dorsal view, 1x. 15 – MPUM12548 (WKJb-29), ventral view, 1x. 16 – MPUM12548 (WKJb-29), dorsal view, 1x.

*Caricula* sp.

17 – MPUM12549 (WKJd-14), ventral view, 1x. 18 – MPUM12549 (WKJd-14), dorsal view, 1x. 19 – MPUM12550 (WKJd-16), ventral view, 1x. 20 – MPUM12550 (WKJd-16), dorsal view, 1x.

*Retimarginijera auriculata* n. sp.

21 – MPUM12552 (WKJd-51), ventral view, 2x. 22 – MPUM12552 (WKJd-51), dorsal view, 2x. 23 – MPUM12553 (WKJd-34B), ventral view, 1x. 24 – MPUM12553 (WKJd-34B), dorsal view, 1x. 25 – MPUM12554 (WKJd-37), ventral view, 1x. 26 – MPUM12554 (WKJd-37), dorsal view, 1x. 27 – MPUM12555 (WKJd-62), ventral view, 1x. 28 – MPUM12555 (WKJd-62), dorsal view, 1x.

*Retimarginijera* aff. *R. celeteria* Grant, 1976

29 – MPUM12557 (WKJd-26), ventral view, 1x. 30 – MPUM12558 (WKJd-30), ventral view, 1x. 31 – MPUM12558 (WKJd-30), dorsal view, 1x.

*Transennatia insculpta* (Grant, 1976)

32 – MPUM12561 (WKJb-23), ventral view, 1x. 33 – MPUM12561 (WKJb-23), dorsal view, 1x. 34 – MPUM12562 (WKJc-8), ventral view, 1x. 35 – MPUM12563 (WKJc-16), ventral view, 1x. 36 – MPUM12563 (WKJc-16), dorsal view, 1x. 37 – MPUM12564 (WKJd-18), ventral view, 1x. 38 – MPUM12564 (WKJd-18), dorsal view, 1x.

*Transennatia* sp. 1

39 – MPUM12567 (WKJd-17), ventral view, 1x. 40 – MPUM12567 (WKJd-17), dorsal view, 1x. 41 – MPUM12568 (WKJd-19), ventral view, 1x. 42 – MPUM12568 (WKJd-19), dorsal view, 1x.

*Transennatia* sp. 2

43 – MPUM12570 (JQ1-2), ventral view, 1x. 44 – MPUM12571 (JQ1-10), ventral view, 1x. 45 – MPUM12571 (JQ1-10), dorsal view, 1x.

*Kozłowskaia cornuta* Grant, 1976

46 – MPUM12573 (WKJb-15), ventral view, 1x. 47 – MPUM12573 (WKJb-15), dorsal view, 1x. 48 – MPUM12574 (WKJb-25), ventral view, 1x. 49 – MPUM12574 (WKJb-25), dorsal view, 1x.

*Calytharrella websteri* n. sp.

50 – MPUM12578 (WKJb-18), ventral view, 1x. 51 – MPUM12578 (WKJb-18), dorsal view, 1x. 52 – MPUM12577 (WKJb-19), ventral view, 1x. 53 – MPUM12577 (WKJb-19), dorsal view, 1x. 54 – MPUM12579 (WKJc-12), ventral view, 1x. 55 – MPUM12579 (WKJc-12), dorsal view, 1x.

*Calliprotonia* sp.

56 – MPUM12584 (WKJe-140), ventral view, 1x. 57 – MPUM12584 (WKJe-140), dorsal view, 1x. 58 – MPUM12585 (WKJe-141), ventral view, 1x. 59 – MPUM12585 (WKJe-141), dorsal view, 1x.

Scale-bar is 1 cm for 1x specimens and 0.5 cm for 2x specimens.

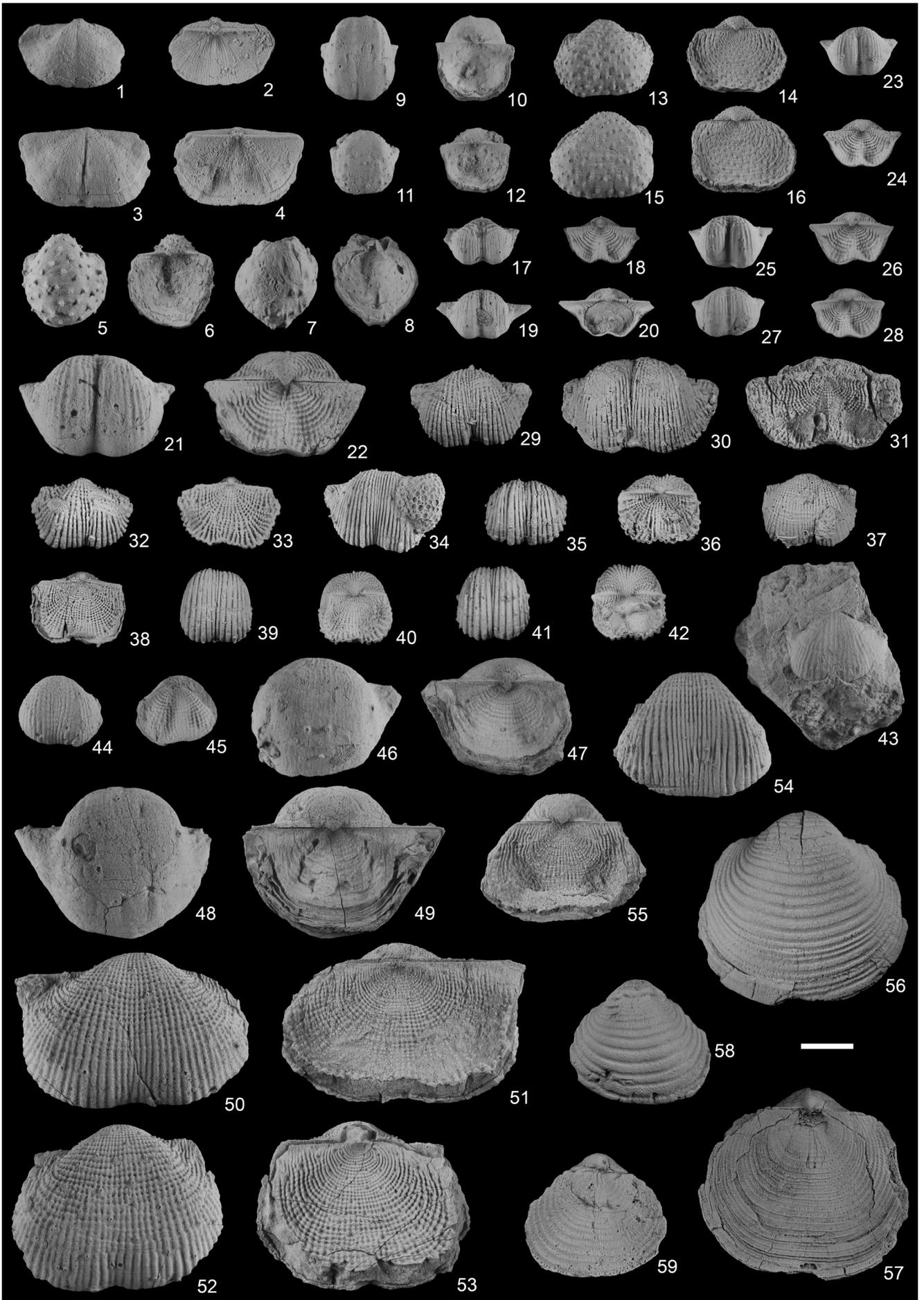


PLATE 1

**Description.** Concave-convex shell with subquadrate outline. Ears small. Maximum width at the hinge. Anterior commissure weakly uniplicate. Ventral valve convex, with a shallow and wide median sulcus. Ventral umbo with cicatrix of attachment.

Ornamentation of weak growth lamellae forming bands anteriorly; prostrate and suberect spines with elongate bases on both valves; suberect spines seem to be slightly larger than prostrate ones.

**Remarks.** The specimen under examination fits with description of *Juresania omanensis* Hudson & Sudbury, 1959.

Five articulated specimens from loc. JQ1, Jebel Qarari, Qarari Unit, Batain Group – MPUM12593 (JQ1-4), MPUM12594 (JQ1-8), MPUM12595 (JQ1-1, JQ1-3, JQ1-7) – may belong also to this species, but being poorly preserved they are left under open nomenclature as *Juresania* sp. (Pl. 2, fig. 3-4).

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Khuff Formation, Wordian, Oman (Angiolini & Bucher 1999).

#### Genus *Bilotina* Reed, 1944

**Type species:** *Strophalosia (Bilotina) subpecta* Reed, 1944

#### *Bilotina yanagidai* Angiolini, 1999

Pl. 2, fig. 5-6

1999 *Bilotina yanagidai* Angiolini in Angiolini & Bucher, p. 686, fig. 14. 17-22, tab. 8.

2011 *Bilotina yanagidai* - Verna & Angiolini in Verna et al., p. 21, pl. 2, fig 9-17.

2012 *Bilotina yanagidai* - Crippa & Angiolini, p. 146, fig. 12 c-f.

**Material:** One figured articulated specimen: MPUM12596 (WKJd-9).

**Description.** Concave-convex shell with subrectangular outline wider than long; maximum width at mid-length. Ventral valve convex, geniculated. Dorsal valve concave, geniculated.

Ornamentation of rugae and growth lines on the visceral disc; spine bases elongate to form ribs on the trail numbering 4 per 5 mm; weak growth lamellae anteriorly.

**Remarks.** *Bilotina yanagidai* Angiolini, 1999 differs from *B. acantha* Waterhouse & Piyasin, 1970 from the Guadalupian of Thailand because of its

transverse outline, the absence of a sulcus and the shorter and more widely spaced spine bases; from *B. subpecta* Reed, 1944 from the Guadalupian of the Salt Range, Pakistan because of its shorter trail and less numerous spines.

A poorly preserved specimen from Jebel X – MPUM12597 (JX3-15) – may belong to a species of *Bilotina*, but the preservation is too poor to allow any specific assignment.

**Occurrence.** Oman, loc. JX = loc. 302 of Shackleton et al. (1990), Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian.

**Distribution.** Khuff Formation, Wordian, Oman (Angiolini & Bucher 1999); Pamuçak Formation, Wordian-Capitanian, Turkey (Verna et al. 2011); Ruteh Limestone, Guadalupian, North Iran (Crippa & Angiolini 2012).

Tribe Waagenoconchini Muir-Wood & Cooper, 1960

Genus *Waagenoconcha* Chao, 1927

Subgenus *Waagenoconcha (Gruntoconcha)* Angiolini, 1995

**Type species:** *Waagenoconcha (Gruntoconcha) macrotuberculata* Angiolini, 1995

**Remarks.** *Waagenoconcha (Gruntoconcha)* has been established to include those species of *Waagenoconcha* characterized by coarse spine bases and a short trail, as *W. abichi* (Waagen, 1884) from the Lopingian Middle Productus Limestone of Salt Range, Pakistan, and *W. macrotuberculata* Angiolini, 1995 from the Kungurian-Roadian of Karakoram.

#### *Waagenoconcha (Gruntoconcha)* sp.

Pl. 2, fig. 7-10

**Material:** Two figured articulated specimens: MPUM12598 (WKJd-1), MPUM12599 (WKJd-38).

**Description.** Plano-convex shell with suboval outline, longer than wide. Ears small. Maximum width anterior to the hinge. Anterior commissure weakly uniplicate. Ventral valve convex, with a shallow and wide median sulcus. Ventral umbo with cicatrix of attachment. Dorsal valve flat with two shallow concavity separated by a low median bulge.

Ornamentation of ventral valve with elongate spine bases, 1.1 mm long and 0.5 mm wide, quincuncially arranged in the posterior half of the valve; an-

teriorly the spine bases are finer (0.2 mm in diameter) and more closely set on concentric bands; ornamentation of dorsal valve with uniformly distributed and sized spine bases.

**Remarks.** The specimen under examination is characterized by rather coarse spine bases and concentric bands developed only anteriorly. It is thus similar to *Waagenoconcha (Gruntoconcha) abichi*, but it differs by a suboval rather than subrectangular outline. *W. (G.) macrotuberculata* has a deeper sulcus and steeper flanks. Some of the specimens figured as different species of *Aulosteges* by Yang et al. (1990) from the Cisuralian of Mayang, SW Tibet probably belong to species of *Waagenoconcha (Gruntoconcha)*.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Superfamily Linoproductoidea Stehli, 1954  
Family Monticuliferidae Muir-Wood & Cooper,  
1960

Subfamily Auriculispiniinae Waterhouse, 1968  
Genus *Magniplicatina* Waterhouse, 1983

**Type species:** *Cancrinella magniplica* Campbell, 1953

**Remarks.** *Magniplicatina* Waterhouse, 1983 is characterized by a subrectangular outline and a convex ventral valve with rugae increasing in length anteriorly and coarse spine bases.

*Magniplicatina johannis* Angiolini, 1995  
Pl. 2, fig. 11

1925 *Productus cancriniformis* Reed, p. 24, pl. 5, fig. 7, 8.  
1939 *Productus cancriniformis* - Renz, p. 18, pl. 3, fig. 6, 7.  
1965 *Cancrinella cancriniformis* - Fantini Sestini, p.190.  
1995 *Magniplicatina johannis* Angiolini, p. 109, fig. 16.5.  
1996 *Magniplicatina johannis* - Angiolini, p. 19, pl. 4, fig. 3-10.

**Material:** One figured articulated specimen: MPUM12600 (WKJb-14).

**Description.** Concave-convex shell with suboval outline wider than long. Ventral valve convex.

Ornamentation of ribs and rugae; ribs are fine and uniform numbering 9-10 per 5 mm anteriorly; the rugae increase in length anteriorly from 0.2 mm on the visceral disc to 1.5 mm near the anterior margin. Spine bases on the visceral disc.

**Remarks.** The specimen under examination is included in *Magniplicatina johannis* because of the

outline, the dimensions of the rugae and the number of ribs.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Lashkargaz Formation, Kungurian-Roadian, Karakoram, Pakistan.

Suborder **Strophalosiidina** Schuchert, 1913  
Superfamily Aulostegoidea Muir-Wood & Cooper,  
1960

Family Aulostegidae Muir-Wood & Cooper, 1960  
Subfamily Echinosteginae Muir-Wood & Cooper,  
1960

Genus *Edriosteges* Muir-Wood & Cooper, 1960

**Type species:** *Edriosteges multispinosus* Muir-Wood & Cooper, 1960

*Edriosteges* sp.  
Pl. 2, fig. 12-13

**Material:** One figured articulated specimen: MPUM12601 (WKJb-4); one articulated specimen: MPUM12602 (WKJe-125).

**Description.** Concave-convex shell with transverse subrectangular outline wider than long. Ventral valve convex with a wide median sulcus starting at the end of the visceral disc. Dorsal valve slightly concave with a low median fold, widening anteriorly.

Ornamentation of fine and uniform ribs; irregular rugae mostly on the flanks of the valves; spines on ventral valve only: along the cardinal margin and densely distributed on the trail. Dimples on the dorsal valve.

**Remarks.** The specimens under examination differ from the species of *Edriosteges* of the Cathedral Mountain Formation and Road Canyon Formation of Texas (Cooper & Grant 1975), because of the outline, the median sulcus and the spine arrangement. Due to their poor state of preservation, they are left under open nomenclature.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Suborder **Lyttoniidina** Williams, Harper & Grant,  
2000

Superfamily Lyttonioidea Waagen, 1883  
Family Lyttoniidae Waagen, 1883  
Subfamily Lyttoniinae Waagen, 1883

Genus *Eolyttonia* Frederiks, 1924

**Type species:** *Oldhamina (Lyttonia) mira* Frederiks, 1916

**Remarks.** Among the genera of the subfamily, *Leptodus* Kayser, 1883, *Collemataria* Cooper & Grant, 1974, *Eolyttonia* Frederiks, 1924, *Matanoleptodus* Liao, 1983, *Oldhamina* Waagen, 1883 and *Petasmaia* Cooper & Grant, 1969 are similar to each other. The genus *Leptodus* is characterized by sharp latiseptate to anguliseptate lateral septa and a low median septum; *Collemataria* lacks muscle scars; *Eolyttonia* is characterized by thick symmetrical crenellated lateral septa and a pustulose ventral interior; *Matanoleptodus* is characterized by a strong median septum, thick arcuate lateral septa, small size and by using much of the external surface to attach; *Oldhamina* is characterized by anguliseptate lateral septa inclined anteriorly at 45°; *Petasmaia* is characterized by having many lateral septa more closely spaced compared to other genera.

*Eolyttonia* sp.

Pl. 2, fig. 14

**Material:** Two figured ventral valves: MPUM12603 (WKJc-7B, C).

**Description.** Small sized with subrhomboidal to longitudinally elongate outline. From circumvallate, with three indentation on each side, to septivallate. Median septum strong and anguliseptate, becoming very flat in the cowl. Lateral septa solidiseptate, symmetrically disposed, slightly arcuate, crenellated on the sides.

Internal surface faintly pustulose, sometimes forming ridges. Muscle scars drop-shaped, surrounded by weak ridges.

**Remarks.** Both specimens are attached by their external surface to the dorsal valve of a specimen of *Retimarginifera* aff. *R. celeteria*. The two valves represent different ontogenetic stages, the circumvallate one being the juvenile phase. They belong to a species of the Pennsylvanian-Lopingian genus *Eolyttonia* based on the thick, crenellated and symmetrical lateral septa and the pustulose ventral interior.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Order **Orthotetida** Waagen, 1884Suborder **Orthotetidina** Waagen, 1884

## Superfamily Orthotetoidea Waagen, 1884

## Family Derbyiidae Stehli, 1954

## Subfamily Derbyiinae Stehli, 1954

Genus *Derbyia* Waagen, 1884

**Type species:** *Derbyia regularis* Hall & Clarke, 1882

*Derbyia* aff. *D. scobina* Grant, 1976

Pl. 2, fig. 15-20

**Material:** Three figured articulated specimens: MPUM12604 (WKJe-3), MPUM12605 (WKJf-17), MPUM12606 (WKJf-22); five articulated specimens: MPUM12607 (WKJf-18, WKJf-19, WKJf-21, WKJf-25, WKJf-33).

**Description.** Convexo-plane shell with subrectangular to semicircular outline wider than long. Ears small, pointed. Maximum width generally at mid-length. Anterior commissure rectimarginate to slightly unisulcate. Ventral valve flat, with a low interarea and closed delthyrium. Ventral umbo with koskinoid perforations. Dorsal valve convex with a shallow sulcus, starting at mid-length and widening and shallowing anteriorly.

Ornamentation of ventral valve of coarser costellae intercalated by 4-5 finer ones; on the dorsal valve the finer costellae are less numerous (1-2); the number of costellae is 10-12 per 5 mm. Growth lamellae on both valves.

Interior of ventral valve with a high and thin median septum, disjunct from the dental lamellae; interior of dorsal valve with a thick cardinal process.

**Remarks.** The specimens under study are very similar to *Derbyia scobina* Grant, 1976, because of their small to medium size, the low interarea and the ornamentation of costellae of unequal strength. However, *D. scobina* has a subquadrate outline and a biconvex shape. They differ from the specimens from Oman described as *D. cf. D. diversa* Reed, 1944 by Angiolini and Bucher (1999), because they are smaller, they have more numerous costellae, no rugae on the ventral valve and a thinner median septum. Based on their features, they are identified as *D. aff. D. scobina*.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Rat Buri Limestone, Guadalupian, Thailand (Grant 1976).

Family Meekellidae Stehli, 1954  
 Subfamily Meekellinae Stehli, 1954  
 Genus *Perigeyerella* Wang, 1955

**Type species:** *Perigeyerella costellata* Wang, 1955

**Remarks.** *Perigeyerella* is characterized by an elevated spondylium posteriorly, passing to a sessile spondylium and then to separate and parallel dental plates anteriorly.

*Perigeyerella* aff. *P. raffaellae* Angiolini in Angiolini & Bucher, 1999

Pl. 2, fig. 21-26

**Material:** Three figured articulated specimens: MPUM12608 (WKJe-12), MPUM12609 (WKJe-119), MPUM12610 (WKJe-134); nine articulated specimens: MPUM12611 (WKJe-109, WKJe-118, WKJe-123, WKJe-129, WKJe-130, WKJe-132, WKJe-133), MPUM12612 (WKJf-9), MPUM12613 (JX3-16).

**Description.** Biconvex shell with ovatotriangular to transverse suboval outline, wider than long. Ears small, pointed. Maximum width at mid-length. Anterior commissure unisulcate. Ventral valve slightly convex, with wide interarea and closed delthyrium; low median fold starting at mid length. Ventral umbo with koskinoid perforations. Dorsal valve more convex with a shallow sulcus, starting at mid-length and widening anteriorly.

Ornamentation of ventral valve of bifurcating costellae, numbering 4-5 per 2 mm anteriorly, and concentric filae. Growth lamellae on both valves.

Interior of ventral valve with an apical spondylium and subparallel dental plates anteriorly (Fig. S4).

**Remarks.** The specimens under examination are similar to *Perigeyerella tricosia* Grant, 1976 from the Guadalupian of Thailand, *P. miriae* Verna & Angiolini in Verna et al., 2011 from the Guadalupian of Turkey, *P. rutebiana* Crippa & Angiolini, 2012 from the Guadalupian of North Iran, and *P. raffaellae* Angiolini in Angiolini & Bucher, 1999 from the Wordian of Oman.

*P. tricosia* differs because of its low interarea and more numerous costellae; *P. miriae* is concave-convex with less numerous costellae and a rectimarginate commissure; *P. rutebiana* has a subcircular outline, a rectimarginate to slightly unisulcate anterior commissure and a low interarea.

The specimens under study are very close to *P. raffaellae* because of their shape, outline, interarea, low fold and shallow sulcus and ornamentation. However, their commissure is unisulcate and not rectimarginate; so they are identified as *P. aff. P. raffaellae*.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian; loc. JX = loc. 302 of Shackleton et al. (1990), Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian.

**Distribution.** Khuff Formation, Wordian, Oman (Angiolini & Bucher 1999); Pamučak Formation, Wordian-Capitanian, Turkey (Verna et al. 2011).

Family Schuchertellidae Williams, 1953  
 Subfamily Schuchertellinae Williams, 1953  
 Genus *Goniarina* Cooper & Grant, 1969

**Type species:** *Goniarina pyelodes* Cooper & Grant, 1969

**Remarks.** *Goniarina* is similar to *Schuchertella* Girty, 1904 but differs because of its smaller subconical shell more coarsely costellate and by its internal characters.

*Goniarina* sp.

Pl. 2, fig. 27-30

**Material:** Three figured articulated specimens: MPUM12614 (WKJf-23), MPUM12615 (WKJf-27), MPUM12616 (SH11-3); three articulated specimens: MPUM12617 (WKJf-24, WKJf-28, WKJf-126).

**Description.** Small sized plano-convex subconical shell with suboval outline slightly wider than long. Ears small, pointed. Maximum width at mid-length. Anterior commissure rectimarginate to slightly unisulcate. Ventral valve convex, with a subconical profile and a small recurved umbo with koskinoid perforations; high interarea with pseudodeltidium and perideltidial areas. Dorsal valve flat with a shallow sulcus, starting at mid-length.

Ornamentation of coarser costellae intercalated by 1-2 finer ones; the costellae number 3-4 per 2 mm anteriorly. Growth lamellae on both valves.

Interior of ventral valve with dental lamellae and a thin median septum posteriorly; interior of dorsal valve with a bilobed cardinal process (Fig. S4).

**Remarks.** Among the species of *Goniarina* from the Asselian-Roadian of Texas (Cooper & Grant 1974), the specimens under study are more similar to *G. pyelodes* Cooper & Grant, 1969 because of their subconical profile and outline; however, they have a larger size, a much lower number of costellae per 2 mm and growth lamellae on all valve surface, so they are left under open nomenclature.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian-early Roadian; loc. SH11, Shiya, Qarari Unit, Batain Group, Roadian.

Class **RHYNCHONELLATA** Williams, Carlson, Brunton, Holmer & Popov, 1996  
 Order **Orthida** Schuchert & Cooper, 1932  
 Suborder **Dalmanellidina** Moore, 1952  
 Superfamily Dalmanelloidea Schuchert, 1913  
 Family Rhipidomellidae Schuchert, 1913  
 Subfamily Rhipidomellinae Schuchert, 1913  
 Genus *Rhipidomella* Oehlert, 1890

**Type species:** *Terebratulina michelini* Lèveillé, 1835

**Remarks.** *Rhipidomella* Oehlert, 1890 is externally similar to *Acosarina* Cooper & Grant, 1969 and to *Orthotichia* Hall & Clarke, 1892, but differs because of the absence of dental plates and brachiophore plates. Also, the species of *Acosarina* have a rectimarginate to unisulcate anterior commissure, while those of *Orthotichia* may have an uniplicate anterior commissure and no spines.

***Rhipidomella bessensis* R.E. King, 1931**

Pl. 2, fig. 31-34

1931 *Rhipidomella bessensis* R.E. King, p. 43, pl. 1, fig. 2a-d, 3a-b, 4.  
 1954 *Rhipidomella bessensis* - Stheli, p. 291, pl. 17, fig. 1-6.  
 1976 *Rhipidomella bessensis* - Cooper & Grant, p. 2610, pl. 663, fig. 11-12, 23-26, 32-68, pl. 665, fig. 1-66, pl. 666, fig. 1-33, pl. 667, fig. 27-43.

**Material:** Two figured articulated specimens: MPUM12618 (WKJd-3), MPUM12619 (WKJe-105); three articulated specimens: MPUM12620 (WKJd-5), MPUM12621 (WKJe-81, WKJe-101).

**Description.** Small sized biconvex shell with suboval outline wide as long. Maximum width at mid-length. Anterior commissure rectimarginate. Ventral valve weakly convex, with interarea and open delthyrium. Dorsal valve convex.

Ornamentation of tubular costellae becoming coarser anteriorly, numbering 5 per 2 mm at the anterior margin, and growth lamellae. The costellae bear spines on the flanks in the ventral valve and on all the dorsal valve.

Interior of ventral valve without dental plates; interior of dorsal valve without brachiophore plates.

**Remarks.** The specimens under examination are identified as *Rhipidomella bessensis* R.E. King, 1931 because of their size, outline and the arrangement of spines, which are confined to the lateral flanks in the ventral valve.

They differ from *R. bispidula* Cooper & Grant, 1976 and *R. miscella* Cooper & Grant, 1976 because of their suboval outline, comparatively wider interarea and fewer spines, arranged laterally on the ventral valve.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Hueco, Bone Spring, Hess, Skinner Ranch, and Cibolo formations, Cisuralian, West Texas (Cooper & Grant, 1976).

Superfamily Enteletoidea Waagen, 1884

Family Enteletidae Waagen, 1884

Genus *Enteleles* Fischer de Waldheim, 1825

**Type species:** *Enteleles glabra* Fischer de Waldheim, 1825

***Enteleles* aff. *E. oehlerti* Gemmellaro, 1892**

Pl. 2, fig. 35-37

**Material:** One figured articulated specimen: MPUM12622 (WKJf-12); four articulated specimens: MPUM12623 (JQ1-302), MPUM12624 (JX3-6, JX3-7).

**Description.** Medium sized, biconvex shell with suboval outline. Maximum width at about mid-length. Anterior commissure uniplicate. Ventral valve convex with an angular median sulcus starting at about 10 mm from the umbo, slightly increasing in width and depth anteriorly; four angular plicae occur at each side of the sulcus. Interearea catacline, delthyrium open. Dorsal valve slightly more convex than the ventral one with an angular median fold starting at 10 mm from the umbo; four angular plicae occur at each side of the fold and are slightly narrower than the fold itself.

Ornamentation of fine and dense capillae; growth lines and lamellae.

Interior of ventral valve with converging dental plates bisected by a ventral median septum.

**Remarks.** The specimens under examination are characterized by their valves nearly equal in size and by their angular, relatively narrow fold/sulcus and sharply angular lateral plicae. Based on these features, they are very similar to *Enteleles oehlerti* Gemmellaro, 1892 from the Guadalupian of the Sosio Valley, Sicily, but they have a narrower sulcus and fold, the latter not prominent with respect to the lateral plicae. They also recall for their angular plicae *E. waageni* Gemmellaro, 1892. However, the latter is a very variable species, generally larger, with the dorsal valve much more convex than the ventral one and with the sulcus starting near the umbo. Among the species from West Texas, the specimens under examination are similar to *E. plummeri* R.E. King, 1931 from the Cathedral Mountain and Bone Spring formations, but differ by a less transverse outline and a lower fold anteriorly.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian; loc. JQ1, Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian; loc. JX= loc. 302 of Shackleton et al. (1990), Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian.  
**Distribution.** Roadian-Wordian, Pietra di Salomone and Rocca di San Benedetto, Sosio Valley, Sicily (Gemmellaro 1892).

#### *Enteleles* sp.

**Material:** One articulated specimen: MPUM12625 (WKJd-7).

**Description.** Small sized, biconvex shell with suboval outline. Maximum width at about mid-length. Anterior commissure uniplicate. Ventral valve convex with a shallow median sulcus starting at about 10 mm from the umbo; three rounded plicae occur at each side of the sulcus. Intearea catacline, delthyrium open. Dorsal valve slightly more convex than the ventral one with a low and round-topped median fold starting at 10 mm from the umbo; two rounded plicae occur at each side of the fold.

Ornamentation of fine and dense capillae; growth lines and lamellae.

**Remarks.** The specimen under study differs from the specimens identified as *E. aff. E. oehlerti* because of its lower and more rounded fold and plicae, shallower and comparatively wider ventral sulcus.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Genus *Parenteleles* R.E. King, 1931

**Type species:** *Parenteleles cooperi* R.E. King, 1931

**Remarks.** *Parenteleles* R.E. King, 1931 is characterized by convexo-plane shape, an unisulcate anterior commissure and cella under the ventral median septum. It is externally similar to *Peltichia* Jin & Sun, 1981, but differs because of its convexo-plane shape and the occurrence of a cella under the median septum.

#### *Parenteleles* sp.

Pl. 2, fig. 38-43

**Material:** Two figured articulated specimens: MPUM12626 (WKJe-87), MPUM12627 (WKJf-30); one articulated specimen: MPUM12628 (WKJe-80).

**Description.** Medium sized, convexo-plane shell with suboval outline, wider than long. Maximum width at mid-length. Anterior commissure unisulcate. Ventral valve flat with an angular median fold starting at about 5 mm from the umbo, slightly increasing in width anteriorly. Intearea catacline, delthyrium open. Dorsal valve convex with a median sulcus of uniform width and depth starting at 4 mm from the umbo.

Ornamentation of fine and dense capillae giving origin to tubular spines; growth lines and lamellae.

Interior of ventral valve with well-developed dental plates and a cella under the anterior extension of the ventral median septum (Fig. S4).

**Remarks.** The specimens under examination may be compared to *Parenteleles cooperi* R.E. King, 1931, from the Gaptank, Neal Ranch and Skinner Ranch formations of the Cisuralian of West Texas, because of the width and depth of the fold/sulcus; however, they are smaller in size, have a suboval rather than a subpentagonal outline, the fold/sulcus starting more posteriorly, and do not possess lateral plicae.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Family Schizophoriidae Schuchert & LeVene,  
1929  
Genus *Acosarina* Cooper & Grant, 1969

**Type species:** *Acosarina dorsisulcata* Cooper & Grant, 1969

**Remarks.** *Acosarina* is characterized by a small to medium size, biconvex shell, tubular costellae in the ventral valve and a rectimarginate - in the Cisuralian species - to unisulcate - in the Lopingian species - commissure. Internally, the dental plates are arcuate and divergent and the brachiophore plates are divergent. It differs from *Orthotichia* Hall & Clarke, 1892 because of the anterior commissure, uniplicate in the latter, and the dental plates, subparallel and stronger in the latter.

*Acosarina* aff. *A. mesoplatys* (R.E. King, 1931)

Pl. 2, fig. 44-47

**Material:** Two figured articulated specimens: MPUM12629 (WKJd-45), MPUM12630 (WKJd-53); three articulated specimens: MPUM12631 (WKJe-120, WKJe-127, WKJe-134).

**Description.** Large sized for the genus, biconvex shell with suboval outline wider than long. Maximum width at mid-length. Anterior commissure rectimarginate. Ventral valve weakly convex, with interarea and open delthyrium. Dorsal valve slightly more convex than the ventral one.

Ornamentation of tubular costellae numbering 7-8 per 2 mm at the anterior margin, and growth lamellae.

Interior of ventral valve with dental plates and a low median septum; interior of dorsal valve with divergent brachiophore plates.

**Remarks.** Based on their rectimarginate commissure, the specimens under examination are similar to *Acosarina rectimarginata* Cooper & Grant, 1976 and *A. dunbari* Cooper & Grant, 1976 from the Cisuralian of West Texas, but being slightly larger in size. However, *A. rectimarginata* has a larger number of costellae (4-5 per 1 mm) and deeper valves, whereas *A. dunbari* has a dorsal sulcus.

The specimens under examination are similar in size and ornamentation to *A. mesoplatys* Cooper & Grant, 1976, but the latter is diagnosed as having a dorsal sulcus. However, the commissure is described as varying from nearly rectimarginate to broadly unisulcate and the sulcus as shallow throughout (Cooper & Grant, 1976, p. 2622-2623),

therefore the specimens from Oman are identified as *A. aff. A. mesoplatys*.

PLATE 2

*Juresania omanensis* Hudson & Sudbury, 1959

1 – MPUM12591 (WJKc-5), ventral view, 1x. 2 – MPUM12591 (WJKc-5), dorsal view, 1x.

*Juresania* sp.

3 – MPUM12593 (JQ1-4), ventral view, 1x. 4 – MPUM12594 (JQ1-8), ventral view, 1x.

*Bilotina yanagidai* Angiolini, 1999

5 – MPUM12596 (WKJd-9), ventral view, 1x. 6 – MPUM12596 (WKJd-9), dorsal view, 1x.

*Waagenoconcha (Gruntoconcha)* sp.

7 – MPUM12598 (WKJd-1), ventral view, 1x. 8 – MPUM12598 (WKJd-1), dorsal view, 1x. 9 – MPUM12599 (WKJd-38), ventral view, 1x. 10 – MPUM12599 (WKJd-38), dorsal view, 1x.

*Magniplicatina johannis* Angiolini, 1995

11 – MPUM12600 (WKJb-14), ventral view, 1x. *Edriosteges* sp. 12 – MPUM12601 (WKJb-4), ventral view, 1x. 13 – MPUM12601 (WKJb-4), dorsal view, 1x.

*Eolyttonia* sp.

14 – MPUM12603 (WKJc-7B, C), dorsal view, 2x.

*Derbyia* aff. *D. scobina* Grant, 1976

15 – MPUM12604 (WKJe-3), ventral view, 1x. 16 – MPUM12604 (WKJe-3), dorsal view, 1x. 17 – MPUM12605 (WKJf-17), ventral view, 1x. 18 – MPUM12605 (WKJf-17), dorsal view, 1x. 19 – MPUM12606 (WKJf-22), ventral view, 1x. 20 – MPUM12606 (WKJf-22), dorsal view, 1x.

*Perigeyerella* aff. *P. raffaellae* Angiolini in Angiolini & Bucher, 1999

21 – MPUM12608 (WKJe-12), ventral view, 1x. 22 – MPUM12608 (WKJe-12), dorsal view, 1x. 23 – MPUM12609 (WKJe-119), ventral view, 1x. 24 – MPUM12609 (WKJe-119), dorsal view, 1x. 25 – MPUM12610 (WKJe-134), ventral view, 1x. 26 – MPUM12610 (WKJe-134), dorsal view, 1x.

*Goniarina* sp.

27 – MPUM12614 (WKJf-23), ventral view, 1x. 28 – MPUM12614 (WKJf-23), dorsal view, 1x. 29 – MPUM12615 (WKJf-27), dorsal view, 1x. 30 – MPUM12616 (SH11-3), ventral view, 1x.

*Rhipidomella bessensis* R.E. King, 1931

31 – MPUM12618 (WKJd-3), ventral view, 1x. 32 – MPUM12618 (WKJd-3), dorsal view, 1x. 33 – MPUM12619 (WKJe-105), ventral view, 1x. 34 – MPUM12619 (WKJe-105), dorsal view, 1x.

*Enteleles* aff. *E. oehlerti* Gemmellaro, 1892

35 – MPUM12622 (WKJf-12), ventral view, 1x. 36 – MPUM12622 (WKJf-12), dorsal view, 1x. 37 – MPUM12622 (WKJf-12), anterior view, 1x.

*Parenteleles* sp.

38 – MPUM12626 (WKJe-87), ventral view, 2x. 39 – MPUM12626 (WKJe-87), dorsal view, 2x. 40 – MPUM12626 (WKJe-87), anterior view, 2x. 41 – MPUM12627 (WKJf-30), ventral view, 1x. 42 – MPUM12627 (WKJf-30), dorsal view, 1x. 43 – MPUM12627 (WKJf-30), anterior view, 1x.

*Acosarina* aff. *A. mesoplatys* (R.E. King, 1931)

44 – MPUM12629 (WKJd-45), ventral view, 1x. 45 – MPUM12629 (WKJd-45), dorsal view, 1x. 46 – MPUM12630 (WKJd-53), ventral view, 1x. 47 – MPUM12630 (WKJd-53), dorsal view, 1x.

*Orthotichia* aff. *O. magnifica* Grabau, 1936

48 – MPUM12632 (WKJf-13), ventral view, 1x. 49 – MPUM12632 (WKJf-13), dorsal view, 1x. 50 – MPUM12633 (WKJf-15), ventral view, 1x.

Scale-bar is 1 cm for 1x specimens and 0.5 cm for 2x specimens.

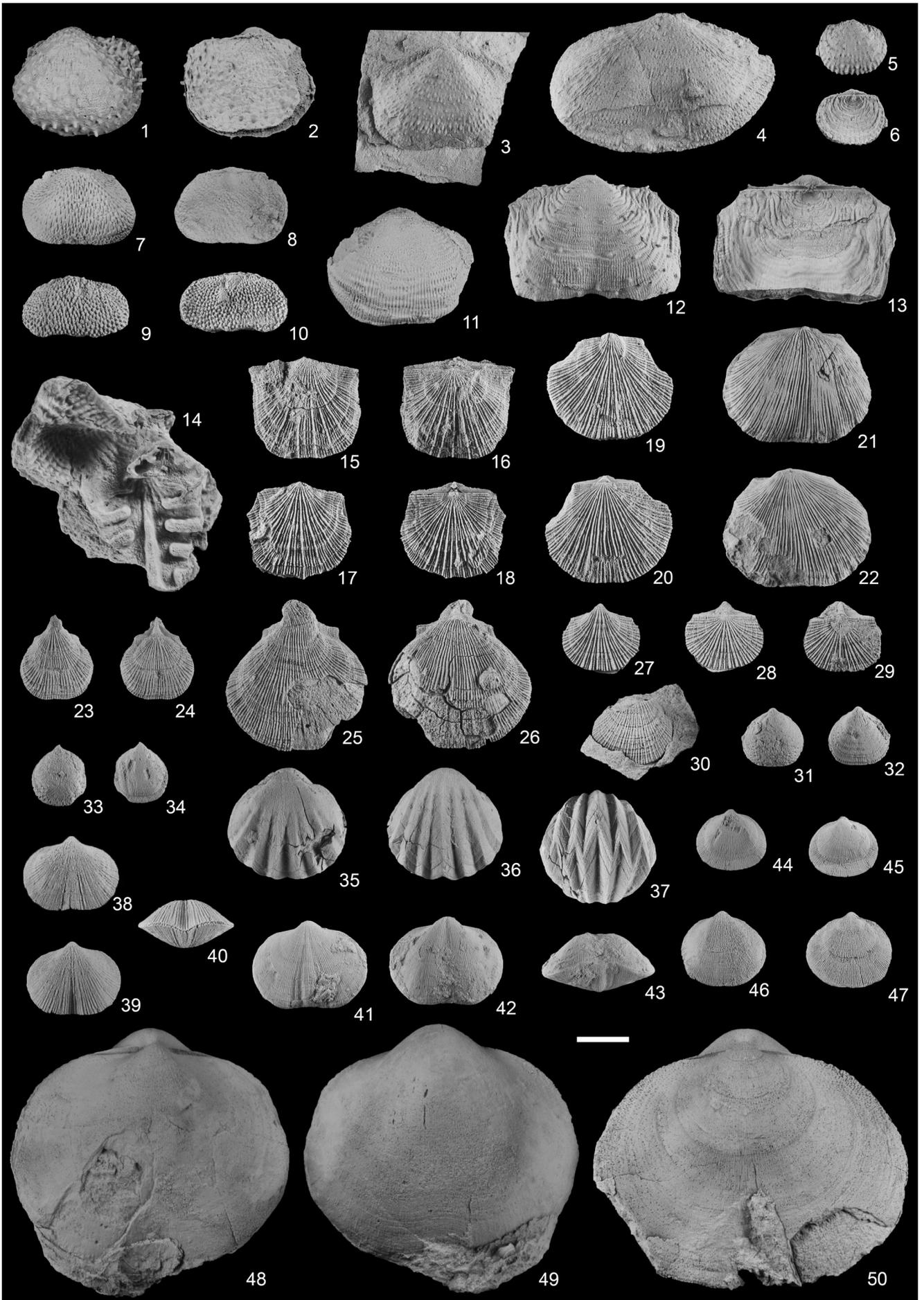


PLATE 2

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kun-gurian.

**Distribution.** Cathedral Mountain, Road Canyon, Cibolo, and Bone Spring formations, Artinskian-Roadian, West Texas (Cooper & Grant 1976).

Genus *Orthotichia* Hall & Clarke, 1892

**Type species:** *Orthis? morganiana* Derby, 1874

**Remarks.** *Orthotichia* Hall & Clarke, 1892 is characterized by a medium size, a biconvex shell, an uniplicate commissure, an ornamentation of tubular costellae, strong dental plates extending forward and a median septum in the ventral valve, and long brachiophore plates delimiting a tripartite muscle field in the dorsal valve. Another similar genus, of Guadalupian-Lopingian age, is *Kotlaia* Grant, 1993, characterized by an unisulcate emarginate anterior commissure, arcuate and divergent dental plates, a low but long ventral median septum, and short and divergent brachiophore plates. The differences among these taxa (including *Acosarina*) have been discussed in Angiolini et al. (2005), Verna et al. (2011) and Crippa & Angiolini (2012).

***Orthotichia* aff. *O. magnifica* Grabau, 1936**

Pl. 2, fig. 48-50; Pl. 3, fig. 1-2

**Material:** Three figured articulated specimens: MPUM12632 (WKJf-13), MPUM12633 (WKJf-15), MPUM12634 (WKJf-31); two articulated specimens: MPUM12635 (WKJf-32, WKJf-34).

**Description.** Large sized, dorsi-biconvex shell with suboval outline, wider than long. Maximum width at mid-length. Anterior commissure uniplicate, with a narrow fold. Ventral valve weakly convex, with interarea and open delthyrium. Ventral sulcus narrow and shallow starting before mid-length and deepening anteriorly, with a small sulcal tongue. Dorsal valve much more convex than the ventral one with a narrow rounded fold anteriorly.

Ornamentation of tubular costellae, numbering 6-7 per 2 mm at the anterior margin, and growth lamellae.

Interior of ventral valve with parallel dental plates and a median septum; interior of dorsal valve with long and divergent brachiophore plates.

**Remarks.** The specimens under study are mostly similar to *Orthotichia magnifica* Grabau, 1936 from the Artinskian of South China, because of their large size, the dorsi-biconvex shape, the suboval outline, and the ornamentation, but differ because of their deeper sulcus and sulcal tongue. They are also similar to the specimens described as *O. magnifica* from the Guadalupian of Velebit (Croatia) (Sremac 1986) because of their large size and their uniplicate commissure with a linguiform extension. However, the specimens from Velebit are few, poorly preserved and not adequately illustrated. The specimens from Oman differ from *O. waterhousei* Grant, 1976 from the Guadalupian of Thailand because of their outline, more convex dorsal valve and uniplicate anterior commissure. There are also differences in outline and convexity of the dorsal valve with the large sized species of *Orthotichia* from West Texas as *O. kozłowskii* R.E. King, 1931 and *O. newelli* Cooper & Grant, 1976, which in any case are smaller.

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kun-gurian.

**Distribution.** Dingjiazhai Formation, As-selian, Baoshan Block (Shen et al. 2000); Mapping Formation, Artinskian, South China, (Li et al. 1987; Shen 2016); Guadalupian, Velebit, Croatia, (Sremac 1986); Guadalupian, Primorye, Russia (Licharew & Kotlyar 1978).

**Order Rhynchonellida** Kuhn, 1949

Superfamily Stenoscismatoidea Oehlert, 1887

Family Stenoscismatidae Oehlert, 1887

Subfamily Stenoscismatinae Oehlert, 1887

Genus *Stenoscisma* Conrad, 1839

**Type species:** *Terebratula schlottheimii* Von Buch, 1834

**Remarks.** *Stenoscisma* Conrad, 1839 is similar to *Coledium* Grant, 1965, from which it probably evolved, but it differs because of a more transverse outline, a richer ornamentation and the development of a stolidium, which is absent or poorly developed in *Coledium*.

***Stenoscisma* aff. *S. abbreviatum* Cooper & Grant, 1976**

Pl. 3, fig. 3-5

**Material:** One figured articulated specimen: MPUM12636 (WKJe-29); one articulated specimen: MPUM12637 (WKJe-67).

**Description.** Biconvex shell with a transverse outline, wider than long. Maximum width at about mid-length. Anterior commissure uniplicate. Ventral valve weakly convex; ventral sulcus narrow and deep starting anteriorly to the umbo. Dorsal valve strongly convex with a high and narrow fold starting at mid-length.

Ornamentation of few low, wide and rounded costae, numbering 4-5 on the fold and 4 in the sulcus, absent on the flanks.

Interior of ventral valve with a spondylium.

**Remarks.** The specimens under study are close to *Stenosisma abbreviatum* Cooper & Grant, 1976 from West Texas because of their transverse outline, high fold, and few and low costae. However, they differ because *S. abbreviatum* possesses ribs also on the flanks, even if they are poorly expressed and variable in number. Also their outline is even more transverse than that of *S. abbreviatum*.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Bell Canyon Formation, Capitania, West Texas (Cooper & Grant 1976).

*Stenosisma* aff. *S. bellatulum* Cooper & Grant, 1976

Pl. 3, fig. 6-8

**Material:** One figured articulated specimen: MPUM12638 (WKJe-36); one articulated specimen: MPUM12639 (WKJe-23).

**Description.** Small sized, biconvex shell with a subtriangular to suboval outline, slightly wider than long. Maximum width anterior to mid-length. Anterior commissure uniplicate; narrow stolidium. Ventral valve convex; umbo strongly recurved and appressed to the dorsal one. Ventral sulcus well-defined, but rather shallow, starting at about mid-length and with a subrectangular section. Dorsal valve convex with a low and wide fold.

Ornamentation of coarse and high costae, numbering 3 on the fold, 4 in the sulcus, and 3 weaker on each flank; the lateral costae on the fold bifurcate near the anterior margin.

Interior of ventral valve with a spondylium.

**Remarks.** The specimens under study are very close to *Stenosisma bellatulum* Cooper & Grant, 1976 from West Texas because of the number of costae and their bifurcation anteriorly on the fold,

but they are less thick and have a more recurved ventral umbo. Another similar species is *S. solitaria* (Gemmellaro, 1899) from the Guadalupian of the Sosio Valley, Sicily, but it is characterized by a more transverse outline, wider costae and a straight umbo. The specimens described as *S. aff. S. abbreviatum* are much more transverse and have weaker costae. Both have strongly recurved umbos.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Neal Ranch Formation, Asselian-Sakmarian, West Texas (Cooper & Grant 1976).

*Stenosisma qararensis* n. sp.

Pl. 3, fig. 9-17

**Derivation of name:** From the stratigraphic unit, Qarari Unit.

**Holotype:** One articulated specimen, MPUM12640 (WKJe-20) (Pl. 3, fig. 9-11). Maximum width 20.2 mm, corresponding length 17.2 mm.

**Type locality:** WKJ, Wadi Khawr al Jaramah, Oman, Qarari Unit, Batain Group, late Kungurian.

**Material:** Holotype MPUM12640 (WKJe-20). Two figured articulated specimens: MPUM12641 (WKJe-26), MPUM12642 (WKJe-47); eighteen articulated specimens: MPUM12643 (WKJe-16, WKJe-21, WKJe-24, WKJe-27, WKJe-29, WKJe-52, WKJe-56, WKJe-60, WKJe-61, WKJe-63, WKJe-64, WKJe-69, WKJe-70, WKJe-73), MPUM12644 (JX3-10; JX3-12; JX3-13; JX3-14).

**Diagnosis:** Large sized *Stenosisma* with a strongly recurved umbo and ornamented by thin costae.

**Description.** Medium to large sized, biconvex shell with a subtriangular to suboval outline, slightly wider than long, but wider than long in the largest specimens. Maximum width anterior to mid-length. Anterior commissure uniplicate; stolidium. Ventral valve convex; umbo strongly recurved on the dorsal one. Ventral sulcus wide and shallow, starting at about mid-length. Dorsal valve slightly less convex than the ventral one with a low and wide fold starting at about mid-length and with a subrectangular section anteriorly.

Ornamentation of numerous thin costae, starting at few mm from the umbo and numbering 4-7 on the fold, 3-6 in the sulcus, and 3-5 on each flank; growth lamellae.

Interior of ventral valve with a spondylium.

**Remarks.** The specimens under examination show a certain variability in the outline and ornamentation, but are characterized by a recurved ventral umbo and thin costae.

They are similar to *S. exutum* Cooper & Grant, 1976 and *S. hucconianum* Girty, 1929 from West Texas, and *S. acuminata* Gemmellaro, 1899 and *S. paronae* Gemmellaro, 1899 from Sicily. *S. exutum* and *S. acuminata* are similar in size, but they are characterized by a larger number of costae on the flanks (6-8 on each flank). *S. paronae* is smaller, has more numerous costae (up to 7 on each flank) and a deeper sulcus. *S. hucconianum* has a less recurved umbo and coarser costae starting more anteriorly. The specimens from Oman identified as *S. aff. S. abbreviatum* have a much more transverse outline and a weaker ornamentation, whereas those of *S. aff. S. bellatulum* have fewer and coarser costae.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian; loc. JX= loc. 302 of Shackleton et al. (1990), Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian.

Genus *Torynechus* Cooper & Grant, 1962

**Type species:** *Torynechus caelatus* Cooper & Grant, 1962

**Remarks.** *Torynechus* Cooper & Grant, 1962 has the same internal characters of *Stenosisma*, but differs externally by an anteriorly thick lateral profile and an ornamentation of thin and dense bifurcating ribs originating at the umbo.

### *Torynechus* sp.

Pl. 3, fig. 18-23

**Material:** Two figured articulated specimens: MPUM12645 (WKJd-33), MPUM12646 (WKJe-33); seven articulated specimens: MPUM12647 (WKJd-2, WKJd-57, WKJd-65), MPUM12648 (WKJe-42, WKJe-45, WKJe-50, WKJe-450).

**Description.** Small sized for the genus, biconvex shell with subtriangular to subpentagonal outline, wider than long. Maximum width at about mid-length. Anterior commissure uniplicate. Ventral valve convex, with wide and shallow sulcus, starting at about mid-length. Dorsal valve with a low and wide fold starting at about mid-length.

Ornamentation of numerous thin and dense costae, starting at few mm from the umbo and numbering 7 on the fold, and 5-7 on each flank.

Interior of ventral valve with a spondylium. Interior of dorsal valve with camarophorium with intracamarophorial plate.

**Remarks.** The specimens under examination differ from *Torynechus alectorius* Cooper & Grant, 1976 and *T. caelatum* Cooper & Grant, 1962 because of their smaller size and lower number of costae. As the specimens are poorly preserved, they are left under open nomenclature.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Family Psilocamaridae Grant, 1965  
Subfamily Psilocamarinae Grant, 1965  
Genus *Camarophorinella* Licharew, 1936

**Type species:** *Camarophoria caucasica* Licharew, 1936

**Remarks.** *Camarophorinella* Licharew, 1936 differs from *Cyrolexis* Grant, 1965 because of its flatter lateral profile and more distinct and numerous costae.

### *Camarophorinella* sp.

Pl. 3, fig. 24-26

**Material:** One figured articulated specimen: MPUM12649 (WKJe-34), one articulated specimen: MPUM12650 (WKJe-68).

**Description.** Biconvex shell with subtriangular to suboval outline. Maximum thickness posterior to mid-length. Anterior commissure uniplicate. Ventral valve convex, with recurved umbo and wide and very shallow sulcus, starting at about mid-length. Dorsal valve with a low and wide fold starting at about mid-length.

Ornamentation of low costae, starting anteriorly to the umbo and numbering 6 on the fold, 5 in the sulcus, and very low and starting very anteriorly 3-4 costae on each flank, nearly indistinct; growth lamellae.

Interior of ventral valve with a spondylium.

**Remarks.** The specimens under study differ from *C. caucasica* Licharew, 1936 because of the very poorly defined delayed costae on the flanks. *C. sinensis* Ching & Ye, 1979 from the Cisuralian of Wulan County, China has different internal characters and is ornamented by more numerous ribs.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Genus *Goleomixa* Grant, 1976

**Type species:** *Goleomixa acymata* Grant, 1976

**Remarks.** Similar to *Stenoscisma*, *Goleomixa* Grant, 1976 differs because of a more pronounced fold/sulcus, the absence of a stolidium and, internally, of the intracamorphorial plate. *Goleomixa* differs from *Torynechus* because of its smaller size, more strongly biconvex shape, more distinct and less numerous costae.

**?*Goleomixa* sp.**

Pl. 3, fig. 27-29

**Material:** One figured articulated specimen: MPUM12651 (WKJd-13).

**Description.** Small sized, biconvex shell with subtriangular outline wide as long. Maximum width at mid-length. Anterior commissure uniplicate. Ventral valve convex, with wide and rather deep sulcus. Dorsal valve with a high and wide fold starting at about mid-length.

Ornamentation of strong and acute costae, starting at few mm from the umbo and absent on the flanks.

Interior of ventral valve with a spondylium.

**Remarks.** The single specimen under examination seems to belong to a species of *Goleomixa*, but the identification is not certain.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Superfamily Wellerelloidea Licharew, 1956

Family Wellerellidae Licharew, 1956

Subfamily Wellerellinae Licharew, 1956

Genus *Wellerella* Dunbar & Condra, 1932

**Type species:** *Wellerella tetrahedra* Dunbar & Condra, 1932

**Remarks.** *Wellerella* Dunbar & Condra, 1932 comprises a high number of species characterized by a biconvex shape, small size subtriangular to subpentagonal outline, suboval foramen, and few but coarse rounded costae; internally they have vertical dental plates and fused cardinal plates. *Allorhynchus* Weller, 1910 has a flatter lateral profile, more numerous costae and disjunct deltidial plates.

***Wellerella* sp.**

Pl. 3, fig. 30-32

**Material:** One figured articulated specimen: MPUM12652 (WKJe-51); one articulated specimen: MPUM12653 (WKJe-58).

**Description.** Small sized, biconvex shell with subtriangular outline longer than wide. Maximum width at mid-length. Anterior commissure uniplicate. Ventral valve convex, with narrow and shallow sulcus starting from the umbo; delthyrium closed by deltidial plates with an oval foramen. Dorsal valve very convex with a low fold starting at about mid-length.

Ornamentation of thick costae, starting from the umbo, numbering 3 on the fold, 2 in the sulcus and 3 on each flank.

Interior of ventral valve with separate and vertical dental plates.

**Remarks.** The specimens under examination are similar to *W. girtyi* Cooper & Grant, 1976 from the Roadian-Wordian Cherry Canyon Formation of West Texas, because of the height of the fold and the thickness and number of costae. However, given the paucity of the available specimens and the high degree of morphological variability inside the species, the nomenclature is left open.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Subfamily Uncinunellinae Savage, 1996

Genus *Uncinunellina* Grabau, 1931

**Type species:** *Uncinulus theobaldi* Waagen, 1883

***Uncinunellina* sp.**

Pl. 3, fig. 33-41

**Material:** Three figured articulated specimens: MPUM12654 (WKJe-18), MPUM12655 (WKJe-83), MPUM12656 (WKJe-91); two articulated specimens: MPUM12657 (WKJd-12), MPUM12658 (WKJe-76).

**Description.** Medium to large sized for the genus, biconvex shell with suboval outline wider than long. Maximum width at mid-length. Anterior commissure uniplicate and zig-zag, with high fold. Ventral valve convex, with wide and shallow sulcus starting at mid-length. Dorsal valve weakly convex with a high subtrapezoidal fold at the anterior margin.

Ornamentation of thin costae, starting at 7 mm from the umbo, numbering 8-9 in the fold/sulcus and 8-10 on the flanks; about 4 per 5 mm anteriorly; the ribs extend across the commissure forming spines.

**Remarks.** The specimens under examination belong to a species of *Uncinunellina* because of their thin and numerous costae starting anteriorly from the umbo. However they have a larger number of ribs in the fold/sulcus than other species of *Uncinunellina*. The number of available specimens does not allow to erect a new species.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

#### Genus *Anchorhynchia* Jin & Ye, 1979

**Type species:** *Anchorhynchia medoensis* Jin & Ye, 1979

**Remarks.** *Anchorhynchia* Jin & Ye, 1979 is very similar to *Uncinunellina* Grabau, 1931, with which it was frequently confused in the past (Shen et al. 2003), but it differs because of its ornamentation of numerous, bifurcating ribs starting right at the umbo. Another allied genus is *Glyptorhynchia* Shen & He, 1994, which however can be readily distinguished because it possesses a stolidium along the margins.

#### *Anchorhynchia multicosata* n. sp.

Pl. 3, fig. 42-53

**Derivation of name:** From its numerous bifurcating ribs.

**Holotype:** One articulated specimen, MPUM12659 (WKJe-85) (Pl. 3, fig. 51-53). Maximum width 28.6 mm, corresponding length 21.6 mm; thickness: 12.3.

**Type locality:** WKJ, Wadi Khawr al Jaramah, Oman, Qarari Unit, Batain Group, late Kungurian.

**Material:** Holotype MPUM12659 (WKJe-85); three figured articulated specimens: MPUM12660 (WKJd-52), MPUM12661 (WKJd-55), MPUM12662 (WKJe-82); six articulated specimens: MPUM12663 (WKJb-9), MPUM12664 (WKJd-11, WKJd-59, WKJd-35, WKJd-48), MPUM12665 (WKJe-39).

**Diagnosis:** *Anchorhynchia* characterized by an ornamentation of numerous ribs and by an ontogenetic trend of reduction in thickness with growth, the largest specimens being comparatively flatter than the smaller ones.

**Description.** Medium to large sized for the genus, biconvex shell with suboval outline wider than long. Maximum width at mid-length. Width vs thickness ratio increasing with growth. Anterior

commissure uniplicate and zig-zag, with high sub-rectangular fold. Ventral valve convex, with wide and shallow sulcus starting at mid-length. Dorsal valve more convex than the dorsal one, with fold developed anteriorly.

Ornamentation of thin and numerous bifurcating ribs, starting at the umbo, numbering 11 in the sulcus, 12 on the fold and 18-20 on each flank, about 5-6 per 5 mm anteriorly; the ribs extend across the commissure forming spines.

Interior of ventral valve with short dental plates close to the valve walls.

**Remarks.** The specimens under examination differ from *Anchorhynchia sarciniformis* Shen, He & Zhu, 1992 of the Lopingian of Sichuan, which are similar in size and shape because of the more numerous ribs on the sulcus and flanks; from *A. subpentagona* Shen, He & Zhu, 1992 from the same unit because of the larger size and more numerous ribs; from *A. grandis* Shen & He, 1994 of the Lopingian of Guizhou, because of their flatter shape at the adult stage, the width vs thickness ratio changing during growth in favour of the width. *A. medoensis* Jin & Ye, 1979 from the Guadalupian of Madoi Qinghai and *A. cimmerica* Angiolini, 1996 from the Guadalupian of Karakoram are characterized by an ornamentation of less numerous ribs. *A. multiplicata* from the Asselian-Sakmarian of Guizhou has more numerous ribs in the fold/sulcus and a different subpentagonal outline, with higher umbonal slopes; also its dorsal fold starts more posteriorly.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

#### Family Allorhynchidae Cooper & Grant, 1976

##### Genus *Fascicosta* Stehli, 1955

**Type species:** *Rhynchonella? longaeva* Girty, 1909

**Remarks.** The genera of the Family Allorhynchidae can be differentiated based on the characters of the delthyrium, open with disjunct deltidial plates in *Allorhynchus*, *Deltarina* Cooper & Grant, 1976, *Fascicosta* Stehli, 1955 or partially closed with the development of a foramen as in *Terebratuloida* Waagen, 1883, *Pseudowellereia* Licharew, 1956, and *Gerassimovia* Licharew, 1956. The ornamentation comprises bifurcating costae in *Fascicosta*, *Deltarina*, *Pseudowellereia* and *Gerassimovia* or simple ribs as in *Allorhynchus*.

***Fascicosta* aff. *F. longaeva* (Girty, 1909)**

Pl. 3, fig. 54-59

**Material:** Two figured articulated specimens: MPUM12666 (WKJe-41), MPUM12667 (WKJe-59); two articulated specimens: MPUM12668 (WKJe-25, WKJe-92).

**Description.** Small sized, biconvex shell with subtriangular to subpentagonal outline wider than long. Maximum width slightly anterior to mid-length. Anterior commissure uniplicate. Ventral valve weakly convex, with wide and shallow sulcus starting at mid-length; delthyrium open with disjunct deltidial plates. Dorsal valve weakly convex with a low and wide fold starting at mid-length.

Ornamentation of low, thin, numerous costae, starting at the umbo, increasing by bifurcation and intercalation and numbering 8-9 on the fold, 7-8 in the sulcus and 10-12 on each flank.

Interior of ventral valve with dental plates close to the valve walls.

**Remarks.** The specimens under examination are similar to *Fascicosta longaeva* (Girty, 1909), but have more numerous and finer ribs in the fold/sulcus and on the flanks. They differ in size, outline and pattern of ornamentation from the other species of *Fascicosta*.

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Capitan and Bell Canyon formations, Capitanian, West Texas (Cooper & Grant 1976).

Genus *Gerassimovia* Licharew, 1956

**Type species:** *Gerassimovia gegoensis* Licharew, 1956

***Gerassimovia* sp.**

Pl. 3, fig. 60-62

**Material:** One figured articulated specimen: MPUM12669 (WKJe-40); one articulated specimen: MPUM12670 (WKJe-400).

**Description.** Small sized, biconvex shell with subpentagonal outline wider than long. Maximum width anterior to mid-length. Anterior commissure uniplicate. Ventral valve convex, with deep sulcus starting at mid-length; short umbo with foramen. Dorsal valve convex with a fold starting at mid-length.

Ornamentation of wide, acute costae, starting at the umbo, numbering 3 on the fold, 2 in the sulcus and 4 on each flank.

Interior of ventral valve with dental plates closely set to the walls.

**Remarks.** The specimens under examination differ from *Gerassimovia gegoensis* Licharew, 1956 from the Lopingian of northern Caucasus because of the costal pattern and the much smaller size; from *G. abalakovi* Grunt, 1973, *G. bactriana* Grunt, 1973, *G. pamirica* Grunt, 1973 from the Cisuralian-Lopingian of South-East Pamir because of their fewer costae starting from the umbo.

Two poorly preserved specimens – MPUM12671 (WKJe-44, WKJe-65) – probably belong to the same taxon, but for minor differences in the number of costae and for an anterior geniculation they are provisionally identified as *?Gerassimovia* sp.

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kungurian.

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 in 1840-1846

***Cleiothyridina* sp.**

Pl. 3, fig. 63-68

**Material:** Three figured articulated specimens: MPUM12672 (WKJe-111), MPUM12673 (WKJe-116), MPUM12674 (WKJe-131); three articulated specimens: MPUM12675 (WKJd-40), MPUM12676 (WKJe-90, WKJe-114).

**Description.** Biconvex shell with suboval outline, wider than long. Maximum width at mid-length. Anterior commissure rectimarginate. Ventral valve weakly convex, with suberect umbo with foramen. Dorsal valve more convex than the ventral valve.

Ornamentation of growth lines and lamellae with numerous, solid, flat spines.

## PLATE 3

*Orthotichia* aff. *O. magnifica* Grabau, 1936

1 – MPUM12633 (WKJf-15), dorsal view, 1x. 2 – MPUM12634 (WKJf-31), dorsal view, 1x.

*Stenosisma* aff. *S. abbreviatum* Cooper & Grant, 1976

3 – MPUM12636 (WKJe-29), ventral view, 1x. 4 – MPUM12636 (WKJe-29), dorsal view, 1x. 5 – MPUM12636 (WKJe-29), anterior view, 1x.

*Stenosisma* aff. *S. bellatulum* Cooper & Grant, 1976

6 – MPUM12638 (WKJe-36), ventral view, 1x. 7 – MPUM12638 (WKJe-36), dorsal view, 1x. 8 – MPUM12638 (WKJe-36), anterior view, 1x.

*Stenosisma qararensis* n. sp.

9 – MPUM12640 (WKJe-20), ventral view, 1x. 10 – MPUM12640 (WKJe-20), dorsal view, 1x. 11 – MPUM12640 (WKJe-20), anterior view, 1x. 12 – MPUM12641 (WKJe-26), ventral view, 1x. 13 – MPUM12641 (WKJe-26), dorsal view, 1x. 14 – MPUM12641 (WKJe-26), anterior view, 1x. 15 – MPUM12642 (WKJe-47), ventral view, 1x. 16 – MPUM12642 (WKJe-47), dorsal view, 1x. 17 – MPUM12642 (WKJe-47), anterior view, 1x.

*Torynechus* sp.

8 – MPUM12645 (WKJd-33), ventral view, 1x. 19 – MPUM12645 (WKJd-33), dorsal view, 1x. 20 – MPUM12645 (WKJd-33), anterior view, 1x. 21 – MPUM12646 (WKJe-33), ventral view, 1x. 22 – MPUM12646 (WKJe-33), dorsal view, 1x. 23 – MPUM12646 (WKJe-33), anterior view, 1x.

*Camarophorinella* sp.

24 – MPUM12649 (WKJe-34), ventral view, 1x. 25 – MPUM12649 (WKJe-34), dorsal view, 1x. 26 – MPUM12649 (WKJe-34), anterior view, 1x.

?*Goleomixa* sp.

27 – MPUM12651 (WKJd-13), ventral view, 1x. 28 – MPUM12651 (WKJd-13), dorsal view, 1x. 29 – MPUM12651 (WKJd-13), anterior view, 1x.

*Wellerella* sp.

30 – MPUM12652 (WKJe-51), ventral view, 2x. 31 – MPUM12652 (WKJe-51), dorsal view, 2x. 32 – MPUM12652 (WKJe-51), anterior view, 2x.

*Uncinunellina* sp.

33 – MPUM12654 (WKJe-18), ventral view, 1x. 34 – MPUM12654 (WKJe-18), dorsal view, 1x. 35 – MPUM12654 (WKJe-18), anterior view, 1x. 36 – MPUM12655 (WKJe-83), ventral view, 1x. 37 – MPUM12655 (WKJe-83), dorsal view, 1x. 38 – MPUM12655 (WKJe-83), anterior view, 1x. 39 – MPUM12656 (WKJe-91), ventral view, 1x. 40 – MPUM12656 (WKJe-91), dorsal view, 1x. 41 – MPUM12656 (WKJe-91), anterior view, 1x.

*Anchorhynchia multicostata* n. sp.

42 – MPUM12660 (WKJd-52), ventral view, 1x. 43 – MPUM12660 (WKJd-52), dorsal view, 1x. 44 – MPUM12660 (WKJd-52), anterior view, 1x. 45 – MPUM12661 (WKJd-55), ventral view, 1x. 46 – MPUM12661 (WKJd-55), dorsal view, 1x. 47 – MPUM12661 (WKJd-55), anterior view, 1x. 48 – MPUM12662 (WKJe-82), ventral view, 1x. 49 – MPUM12662 (WKJe-82), dorsal view, 1x. 50 – MPUM12662 (WKJe-82), anterior view, 1x. 51 – MPUM12659 (WKJe-85), ventral view, 1x. 52 – MPUM12659 (WKJe-85), dorsal view, 1x. 53 – MPUM12659 (WKJe-85), anterior view, 1x.

*Fascicosta* aff. *F. longaeva* (Girty, 1909)

54 – MPUM12666 (WKJe-41), ventral view, 1x. 55 – MPUM12666 (WKJe-41), dorsal view, 1x. 56 – MPUM12666 (WKJe-41), anterior view, 1x. 57 – MPUM12667 (WKJe-59), ventral view, 1x. 58 – MPUM12667 (WKJe-59), dorsal view, 1x. 59 – MPUM12667 (WKJe-59), anterior view, 1x.

*Gerassimovia* sp.

60 – MPUM12669 (WKJe-40), ventral view, 1x. 61 – MPUM12669 (WKJe-40), dorsal view, 1x. 62 – MPUM12669 (WKJe-40), anterior view, 1x.

**Remarks.** The specimens under examination differ from the species of *Cleiothyridina* from the Guadalupian of Turkey and Tunisia (Verna et al. 2010, 2011) because of their rectimarginate anterior commissure. *Cleiothyridina seriata* Grant, 1976 from the Guadalupian of Thailand is a very variable species, in terms of outline and tipology of anterior commissure. *Cleiothyridina tribulosa* Grant, 1976 has a subcircular outline and denser spines along the margins. The specimens are thus left under open nomenclature.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Subfamily Spirigerellinae Grunt, 1965

Genus *Posicomta* Grunt, 1986

**Type species:** *Posicomta gundarensis* Grunt, 1986

**Remarks.** *Posicomta* Grunt, 1986 is closely allied to the Genus *Composita* Brown, 1845, from which it differs because of its smaller size and thicker shell substance. Furthermore, generally *Posicomta* has a rectimarginate to weakly uniplicate commissure.

*Posicomta advena* (Grant, 1976)

Pl. 3, fig. 69-71

1976 *Composita advena* Grant, p. 205, pl. 56, fig. 1-60.

2010 *Composita advena* - Verna & Angiolini in Verna et al., p. 333, pl. 2, fig. 21-26; fig. 6.

**Material:** One figured articulated specimen: MPUM12677 (WKJe-122).

*Cleiothyridina* sp.

63 – MPUM12672 (WKJe-111), ventral view, 1x. 64 – MPUM12672 (WKJe-111), dorsal view, 1x. 65 – MPUM12673 (WKJe-116), ventral view, 1x. 66 – MPUM12673 (WKJe-116), dorsal view, 1x. 67 – MPUM12674 (WKJe-131), ventral view, 1x. 68 – MPUM12674 (WKJe-131), dorsal view, 1x.

*Posicomta advena* (Grant, 1976)

69 – MPUM12677 (WKJe-122), ventral view, 1x. 70 – MPUM12677 (WKJe-122), dorsal view, 1x. 71 – MPUM12677 (WKJe-122), anterior view, 1x.

*Hustedia funaria* Grant, 1976

72 – MPUM12678 (WKJe-6), ventral view, 2x. 73 – MPUM12678 (WKJe-6), dorsal view, 2x.

74 – MPUM12678 (WKJe-6), anterior view, 2x. 75 – MPUM12679 (WKJe-53), ventral view, 2x.

Scale-bar is 1 cm for 1x specimens and 0.5 cm for 2x specimens.

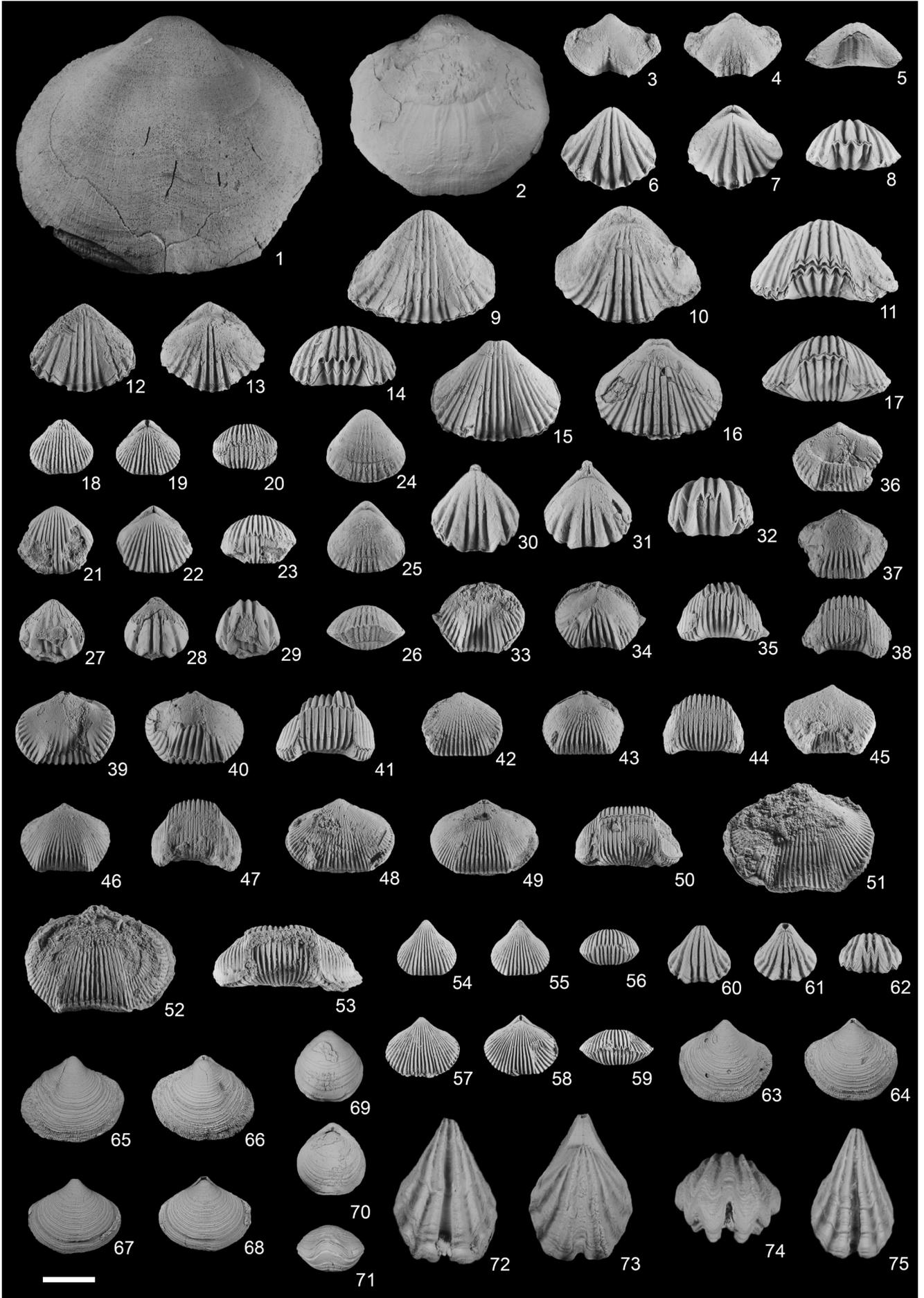


PLATE 3

**Description.** Small sized, biconvex shell with subpentagonal outline, longer than wide. Maximum width at mid-length. Anterior commissure weakly uniplicate. Ventral weakly convex, with rather deep ventral sulcus; high and recurved umbo with subcircular foramen. Dorsal valve less convex than the ventral valve with low fold anteriorly.

Ornamentation of growth lines and lamellae, more evident anteriorly.

**Remarks.** The specimen under examination is identified as *Posicomta advena* (Grant, 1976) because of its longitudinally subpentagonal outline, the convexity of the valves, and the weakly uniplicate anterior commissure. *P. dolabrata* (Grant, 1976) differs because of its subtriangular outline and rectimarginate anterior commissure; *P. subsolana* (Grant, 1976) is equally biconvex, has a larger foramen and an uniplicate anterior commissure.

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Rat Buri Limestone, Guadalupian, Thailand (Grant 1976); Guadalupian, Djebel Tebaga, Tunisia (Verna et al. 2010).

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

Superfamily Retzioidea Waagen, 1883

Family Neoretziidae Dagys, 1972

Subfamily Hustediinae Grant, 1986

Genus *Hustedia* Hall & Clarke, 1893

**Type species:** *Terebratulula mormoni* Marcou, 1858.

***Hustedia funaria* Grant, 1976**

Pl. 3, fig. 72-75; Pl. 4, fig. 1-2

1976 *Hustedia funaria* Grant, p. 243, pl. 67, fig. 59-60

**Material:** Two figured articulated specimens: MPUM12678 (WKJe-6), MPUM12679 (WKJe-53); seven articulated specimens: MPUM12680 (WKJe-1, WKJe-2, WKJe-22, WKJe-28, WKJe-35, WKJe-66, WKJe-72).

**Description.** Medium sized, biconvex shell with elongate teardrop-shaped outline, much longer than wide. Maximum width anterior to mid-length. Anterior commissure emarginate and crenulated. Ventral valve weakly convex, with high and recurved umbo and delthyrium closed by conjunct

deltidial plates with mesothyrid foramen; deep ventral sulcus. Dorsal valve more convex than the ventral valve.

Ornamentation of high and acute costae, starting from the umbo and numbering 8 on the ventral valve and 9 on the dorsal valve. The dorsal median costa ends more posteriorly than the lateral ones, producing an emarginate commissure.

**Remarks.** *Hustedia funaria* Grant, 1976 is characterized by an elongate outline, high ventral umbo and interarea, deep ventral sulcus and an emarginate anterior commissure. These features make the species quite distinctive from the congeneric ones.

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Rat Buri Limestone, Guadalupian, Thailand (Grant 1976).

***Hustedia* aff. *H. indica* (Waagen, 1883)**

(Pl. 4, fig. 3-8)

**Material:** Two figured articulated specimens: MPUM12681 (SH11-6), MPUM12682 (SH11-7).

**Description.** Small sized, biconvex shell with tear-shaped outline, longer than wide. Maximum width anterior to mid-length. Anterior commissure rectimarginate and crenulated. Ventral valve convex, with blunt and recurved umbo and delthyrium closed by conjunct deltidial plates with mesothyrid foramen. Dorsal valve with a subcircular outline.

Ornamentation of robust and rounded costae, numbering 10 on the ventral valve and 9-11 on the dorsal valve.

**Remarks.** The specimens under examination are similar to *Hustedia indica* (Waagen, 1883) because of the outline and the robust rounded costae; however they possess a higher number of costae than the Salt Range species.

**Occurrence.** Oman, loc. SH11, Shiya, Qarari Unit, Batain Group, Roadian.

**Distribution.** Amb Formation, Roadian-Wordian, Salt Range, Pakistan (Waagen 1883); Cirusalian of Mayang, SW Tibet (Yang et al. 1990); Lopingian, South China (Huang 1933; Liao 1980; Xu & Grant 1994); Sakmarian-Changhsingian, Japan (Tazawa 2012; Tazawa & Shintani 2014).

***Hustedia ratburiensis*** Waterhouse & Piyasin,  
1970

Pl. 4, fig. 9-14

- 1970 *Hustedia ratburiensis* Waterhouse & Piyasin, p. 138, pl. 23, fig. 15-30.  
 1970 *Hustedia thailandica* Waterhouse & Piyasin, text-fig. 12, 13.  
 1970 *Hustedia nakornsrii* Yanagida, p. 79, pl. 14, fig. 9a-d.  
 1976 *Hustedia ratburiensis* - Grant, p. 241, pl. 66, fig. 1-69.  
 1991 *Hustedia ratburiensis* - Sun, p. 254, pl. 6, fig. 5-8.  
 1999 *Hustedia ratburiensis* - Yanagida & Nakornsri, p. 118, pl. 32, fig. 11-16.  
 2001 *Hustedia ratburiensis* - Tazawa, p. 299, fig., 8.6a-b.

**Material:** Two figured articulated specimens: MPUM12683 (WKJe-14), MPUM12684 (WKJe-45); four articulated specimens: MPUM12685 (WKJe-7, WKJe-48, WKJe-49, WKJe-53).

**Description.** Small sized, equally biconvex shell with tear-shaped outline, longer than wide. Maximum width at about mid-length. Anterior commissure rectimarginate and crenulated. Ventral valve convex, with low and recurved umbo and delthyrium closed by conjunct deltidial plates with a large mesothyrid foramen. Dorsal valve with a median depression with 2-3 costae which are depressed with respect to the lateral ones.

Ornamentation of costae, numbering 8-10 on the ventral valve and 7 on the dorsal valve; growth lamellae.

**Remarks.** The specimens under examination are identified as *Hustedia ratburiensis* Waterhouse & Piyasin, 1970 because of the occurrence of the characteristic median depression in the dorsal valve, hosting 2-3 costae.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Rat Buri Limestone, Guadalupian, Thailand (Waterhouse & Piyasin 1970; Grant 1976); Sakmarian-Artinskian, Xizang Tibet (Sun 1991); Kungurian-Wuchiapingian, Japan (Tazawa & Nakamura 2015; Tazawa et al. 2015).

Order **Spiriferida** Waagen, 1883

Suborder **Spiriferidina** Waagen, 1883

Superfamily **Martinoidea** Waagen, 1883

Family **Martiniidae** Waagen, 1883

Subfamily **Martiniinae** Waagen, 1883

Genus *Martinia* M'Coy, 1844

**Type species:** *Spirifer glaber* Sowerby, 1820 in 1818-1821

***Martinia* sp.**

Pl. 4, fig. 15-18

**Material:** Two figured articulated specimens: MPUM12686 (WKJd-29), MPUM12687 (WKJf-11); one articulated specimen: MPUM12688 (WKJe-128).

**Description.** Large sized, biconvex shell with suboval outline, wider than long. Cardinal margin shorter than maximum width which is at mid-length; cardinal extremities obtuse. Anterior commissure weakly uniplicate. Ventral valve convex with slightly recurved umbo; ventral sulcus narrow and shallow starting before mid-length with a median furrow. Dorsal valve slightly less convex than the ventral one, with a very low median fold evident only at the anterior margin.

Ornamentation of poorly developed growth lines and lamellae.

**Remarks.** The specimens under study are rather similar to *Martinia orbicularis* Gemmellaro, 1899 because of the slightly transverse outline, the width of the cardinal margin and the shallow, "V" shaped ventral sulcus. However, both the ventral and dorsal umbos are much higher and far apart in *M. orbicularis* producing a different outline. They share some features of *M. semiplana* Waagen, 1883, but differ because of the convex dorsal valve and the lower and closer umbos. Given the paucity of the available material the nomenclature is left open.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Genus *Chapursania* Angiolini, 1995

**Type species:** *Chapursania tatiana* Angiolini, 1995

**Remarks.** *Chapursania* Angiolini, 1995 includes species similar to *Martinia* M'Coy, 1844, but thick-shelled, with a transverse outline, a wide cardinal margin, a strongly uniplicate anterior commissure and sinuous and branching vascular channels.

**?*Chapursania* sp.**

Pl. 4, fig. 19-23

**Material:** Two figured articulated specimens: MPUM12689 (JQ1-9), MPUM12690 (JQ1-15); one articulated specimen: MPUM12691 (JQ1-16).

**Description.** Large sized, biconvex shell with transverse suboval outline and thick shell substance. Wide cardinal margin, but shorter than maximum width which is at mid-length; cardinal extremities obtuse. Anterior commissure strongly uniplicate. Ventral valve convex with recurved umbo; ventral sulcus starting before mid-length and widening and deepening anteriorly forming a marked "U" shaped sulcal tongue. Dorsal valve slightly less convex than the ventral one, with a low median fold starting anteriorly to mid-length, poorly differentiated from the flanks.

Ornamentation of growth lines and lamellae.

**Remarks.** The specimens under examination show the characteristic external features of *Chapursania* in terms of the transverse outline, shell thickness, uniplicate commissure with sulcal tongue. However, as we could not investigate the arrangement of the vascular channels, the identification is left questionable.

The specimen described as *Mayangella mayangensis* Xiong in Yang & Nie, 1990 from the Cisuralian of Mayang, SW Tibet, figured by Yang et al. (1990, pl. 24, fig. 2) probably belongs to a species of *Chapursania*, due to the pattern of the vascular markings.

**Occurrence.** Oman, loc. JQ1, Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian.

Genus *Tiramnia* Grunt, 1977

**Type species:** *Martinia uralica* Tschernyschew, 1902

**Remarks.** Grunt (1977) erected the genus *Tiramnia* to include species externally similar to those of *Martinia* but characterized by simple, coarse and curved vascular channels and a long median furrow dividing the muscle scars.

*Tiramnia* aff. *T. semiglobosa* (Tschernyschew, 1902)

Pl. 4, fig. 24-29

**Material:** Two figured articulated specimens: MPUM12692 (JQ1-17), MPUM12693 (JQ1-302); two articulated specimens: MPUM12694 (JQ1-11; JQ1-14).

**Description.** Unequally biconvex shell with subpentagonal outline, longer than wide. Maximum width at mid-length. Cardinal extremities weakly

auriculate. Anterior commissure uniplicate. Ventral valve deep and convex, with a high and recurved umbo and interarea well-defined from the flanks; a median depression occurs anteriorly, prolonging into a short linguiform extension which raises the commessural fold. Dorsal valve less convex than the ventral valve, particularly so anteriorly.

Ornamentation of few growth lines and lamellae.

**Remarks.** The specimens under examination are mostly similar to *Tiramnia semiglobosa* (Tschernyschew, 1902) because of their unequally biconvex shell with subpentagonal outline, longer than wide, the high and recurved umbo and the absence of a ventral sulcus. The latter character is however quite variable in the specimens from the Urals, and thus the determination is left open.

**Occurrence.** Oman, loc. JQ1, Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian.

**Distribution.** Cisuralian, Urals and Timan, Russia (Tschernyschew 1902); Coyote Butte Limestone, Sakmarian-Kungurian, Oregon (Cooper 1957).

Superfamily Spiriferoidea King, 1846  
Family Trigonotretidae Schuchert, 1893  
Subfamily Neopiriferinae Waterhouse, 1968  
Genus *Cartorbium* Cooper & Grant, 1976

**Type species:** *Cartorbium retusum* Cooper & Grant, 1976

**Remarks.** *Cartorbium* Cooper & Grant, 1976 is characterized by a cardinal margin narrower than maximum width, which makes it distinct from the other Neopiriferinae, and by poorly defined fold/sulcus and rather coarse ribs which form asymmetrical fascicles.

According to Cooper & Grant (1976, p. 2192) and Angiolini (1996) the genus *Cartorbium* includes the species from the Lopingian of the Salt Range assigned by Reed (1944) to *Purdonella*.

*Cartorbium* aff. *C. multiradiatus* (Reed, 1944)

Pl. 4, fig. 30-32; Pl. 5, fig. 1-6

**Material:** Three figured articulated specimens: MPUM12695 (WKJd-22), MPUM12696 (WKJd-23), MPUM12697 (WKJf-10); seven articulated specimens: MPUM12698 (WKJb-302), MPUM12699 (WKJf-6, WKJf-35, WKJf-36), MPUM12700 (JX1-1, JX3-1, JX3-5).

**Description.** Large sized, equally biconvex shell with suboval outline, slightly wider than long. Cardinal margin shorter than maximum width which is at mid-length; cardinal extremities rounded in the juveniles, but auriculate, with small pointed ears, in the adults. Anterior commissure uniplicate. Ventral valve convex, with a high and hooked umbo and trapezoidal apsacline interarea with trace of denticulation; ventral sulcus well-defined, starting from the umbo, widening and deepening anteriorly, but remaining rather shallow, except at the anterior margin where it forms a short linguiform extension which raises the commensural fold. Dorsal convex, with a low, but well-defined fold with an “U” shaped section.

Ornamentation of numerous, rounded ribs, starting from the umbo and becoming broader and flatter anteriorly; they increase by asymmetrical bifurcation and form, posteriorly, poorly defined fascicles of 2-3 ribs; the ribs number 4-5 per 5 mm at 10 mm of distance from the umbo, and 2-3 per 5 mm at the anterior margin. In the adults, the ribs number 9-11 in the sulcus and on the fold anteriorly; growth lamellae denser at the anterior margin.

Interior of ventral valve with thick, slightly divergent dental plates.

**Remarks.** The specimens under examination show a conspicuous ontogenetic variation, the juvenile having more rounded cardinal extremities, finer and more distinctly fasciculated ribs and a much narrower sulcus. They are mostly similar to *Cartorbium multiradiatus* (Reed, 1944) from the Lopingian Middle Productus Limestone of Salt Range, Pakistan because of their large size, shape of the fold/sulcus, height of the ventral umbo and number of ribs on the flanks. However, they differ because they have no median costa on the fold, which characterizes the Salt Range species; they also have wider ribs, a lower number of ribs in the sulcus/fold, and auriculate cardinal extremities, which remain rounded in *C. multiradiatus*. Another very similar species for the rather wide cardinal margin, auriculate ears and fascicles fading anteriorly is *C. latum* (R.E. King, 1931) from the Kungurian of Texas, but it has a more transverse outline and stronger fascicles of ribs and different cardinal extremities. The examined material shows some unique features which may justify the erection of a new species, in case additional material is provided.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian; loc. JX= loc. 302 of Shackleton et al. (1990), Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian.

**Distribution.** Middle Productus Limestone, Lopingian, Salt Range, Pakistan (Reed 1944).

Family Spiriferellidae Waterhouse, 1968  
Subfamily Spiriferellinae Waterhouse, 1968  
Genus *Spiriferella* Tschernyschew, 1902

**Type species:** *Spirifer saranae* Verneuil, 1845

**Remarks.** *Spiriferella* Tschernyschew, 1902 is similar to the allied genera *Arcullina* Waterhouse, 1986 and *Tintoriella* Angiolini, 1996. It differs from *Arcullina* because of the occurrence of a shallow sulcus on the dorsal fold, the presence of ears and the fasciculate ornamentation; from *Tintoriella* because of its less strongly fasciculate ornamentation, wider ventral sulcus, and the absence of a bulbous ventral myophragm.

*Spiriferella posterosulcata* n. sp.

Pl. 5, fig. 7-15

**Derivation of name:** From its posteriorly sulcate dorsal fold.

**Holotype:** One articulated specimen, MPUM12701 (WKJf-16) (Pl. 5, fig. 13-15). Maximum width 25.9 mm, corresponding length 25.1 mm.

**Type locality:** WKJ, Wadi Khawr al Jaramah, Oman, Qarari Unit, Batain Group, late Kungurian.

**Material:** Holotype MPUM12701 (WKJf-16); two figured articulated specimens: MPUM12702 (WKJd-39), MPUM12703 (WKJf-1); nine articulated specimens: MPUM12704 (WKJe-11), MPUM12705 (WKJf-3, WKJf-5), MPUM12706 (JQ1-13, JQ1-18), MPUM12707 (SH11-8, SH11-9, SH11-10); one ventral valve: MPUM12708 (WKJd-42).

**Diagnosis:** Large sized *Spiriferella* with sulcus on the dorsal fold developed posteriorly, but dying out anteriorly and ornamented by a low number of plicae.

**Description.** Large sized biconvex shell with suboval to subtriangular outline, about as wide as long. Cardinal margin wide, but less than maximum width which is at mid-length; cardinal extremities auriculate also in the adults. Anterior commissure uniplicate. Ventral valve convex, with a recurved umbo and subpentagonal interarea with delthyrium delimited by two furrows for stegidial plates insertion; ventral sulcus deep, starting from the umbo,

slightly widening anteriorly. Posterior region of the ventral valve with thick shell substance. Dorsal valve convex, with a rather high, acute fold, posteriorly sulcate, but with furrow dying out anteriorly.

Ornamentation of rounded plicae, numbering 3-4 on each flank, bearing fasciculate ribs numbering about 3 per 5 mm at the anterior margin and 5-7 in the sulcus; ribs on the dorsal valve thinner and more acute; intercostal troughs with striae. Micror ornamentation with poorly expressed pustules (Fig. S4).

Interior of ventral valve with thick apical callus, divergent dental plates, depressed and oval muscle field.

**Remarks.** *Spiriferella posterosulcata* n. sp. differs from the species *S. embriibes* Cooper & Grant, 1976, *S. clypeata* Cooper & Grant, 1976, *S. gravis* Cooper & Grant, 1976, *S. propria* Cooper & Grant, 1976 from the Guadalupian Word Formation of West Texas because of their suboval to subtriangular outline, the lower number of sulcal ribs and the dorsal sulcus which occurs only posteriorly on the fold. *S. modesta* Waterhouse, 1981 from the Kungurian of Taungnyo Group, Myanmar and the Ko Yao Noi Formation, southern Thailand (Xu et al. 2021) has a tranverse outline and no sulcus on the dorsal fold. *S. saranae* from the Cisuralian of Russia has a more elongate outline, a deeper “V” shaped sulcus and more numerous plicae.

**Occurrence.** Oman, loc. WKJ, Wadi Khawral Jaramah, Qarari Unit, Batain Group, late Kungurian-early Roadian; loc. JQ1, Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian; loc. SH11, Shiya, Qarari Unit, Batain Group, Roadian.

Genus *Arcullina* Waterhouse, 1986

**Type species:** *Spiriferina polaris* Wiman, 1941

**Remarks.** *Arcullina* Waterhouse, 1986 is similar to *Alispiriferella* Waterhouse & Waddington, 1982 from which it differs because of its larger size, the less transverse outline, the non sulcate fold, and the ornamentation of fasciculate ribs.

### *Arcullina* sp.

Pl. 5, fig. 16-21

**Material:** One figured articulated specimen: MPUM12709 (SH11-2); two figured ventral valves: MPUM12710 (JQ1-6), MPUM12711 (SH11-4); one ventral valve: MPUM12712 (SH11-5).

**Description.** Large sized biconvex shell with ovatotriangular outline, wide as long. Cardinal margin wide, but less than maximum width which is anterior to mid-length. Anterior commissure unipli-cate. Ventral valve convex, with a recurved umbo and triangular interarea with open delthyrium; ventral sulcus rather deep, starting from the umbo, slightly widening anteriorly. Dorsal valve convex, with a rather high, non-sulcate fold.

Ornamentation of strong slightly angular smooth plicae, numbering 5-6 on each flank; ventral sulcus with a median costa.

Interior of ventral valve with thick apical callus, divergent dental plates, depressed and oval muscle field.

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## PLATE 4

*Hustedia funaria* Grant, 1976

1 – MPUM12679 (WKJe-53), dorsal view, 2x. 2 – MPUM12679 (WKJe-53), anterior view, 2x.

*Hustedia* aff. *H. indica* (Waagen, 1883)

3 – MPUM12681 (SH11-6), ventral view, 2x. 4 – MPUM12681 (SH11-6), dorsal view, 2x. 5 – MPUM12681 (SH11-6), anterior view, 2x. 6 – MPUM12682 (SH11-7), ventral view, 2x. 7 – MPUM12682 (SH11-7), dorsal view, 2x. 8 – MPUM12682 (SH11-7), anterior view, 2x.

*Hustedia rathuriensis* Waterhouse & Piyasin, 1970

9 – MPUM12683 (WKJe-14), ventral view, 2x. 10 – MPUM12683 (WKJe-14), dorsal view, 2x. 11 – MPUM12683 (WKJe-14), anterior view, 2x. 12 – MPUM12684 (WKJe-45), ventral view, 2x. 13 – MPUM12684 (WKJe-45), dorsal view, 2x. 14 – MPUM12684 (WKJe-45), anterior view, 2x.

*Martinia* sp.

15 – MPUM12686 (WKJd-29), ventral view, 1x. 16 – MPUM12686 (WKJd-29), dorsal view, 1x. 17 – MPUM12687 (WKJf-11), ventral view, 1x. 18 – MPUM12687 (WKJf-11), dorsal view, 1x.

?*Chapursania* sp.

19 – MPUM12689 (JQ1-9), ventral view, 1x. 20 – MPUM12689 (JQ1-9), dorsal view, 1x. 21 – MPUM12689 (JQ1-9), anterior view, 1x. 22 – MPUM12690 (JQ1-15), ventral view, 1x. 23 – MPUM12690 (JQ1-15), dorsal view, 1x.

*Tirannia* aff. *T. semiglobosa* (Tschernyschew, 1902)

24 – MPUM12692 (JQ1-17), ventral view, 1x. 25 – MPUM12692 (JQ1-17), dorsal view, 1x. 26 – MPUM12692 (JQ1-17), anterior view, 1x. 27 – MPUM12693 (JQ1-302), ventral view, 1x. 28 – MPUM12693 (JQ1-302), dorsal view, 1x. 29 – MPUM12693 (JQ1-302), anterior view, 1x.

*Cartorbium* aff. *C. multiradiatus* (Reed, 1944)

30 – MPUM12695 (WKJd-22), ventral view, 1x. 31 – MPUM12695 (WKJd-22), dorsal view, 1x. 32 – MPUM12695 (WKJd-22), anterior view, 1x.

Scale-bar is 1 cm for 1x specimens and 0.5 cm for 2x specimens.

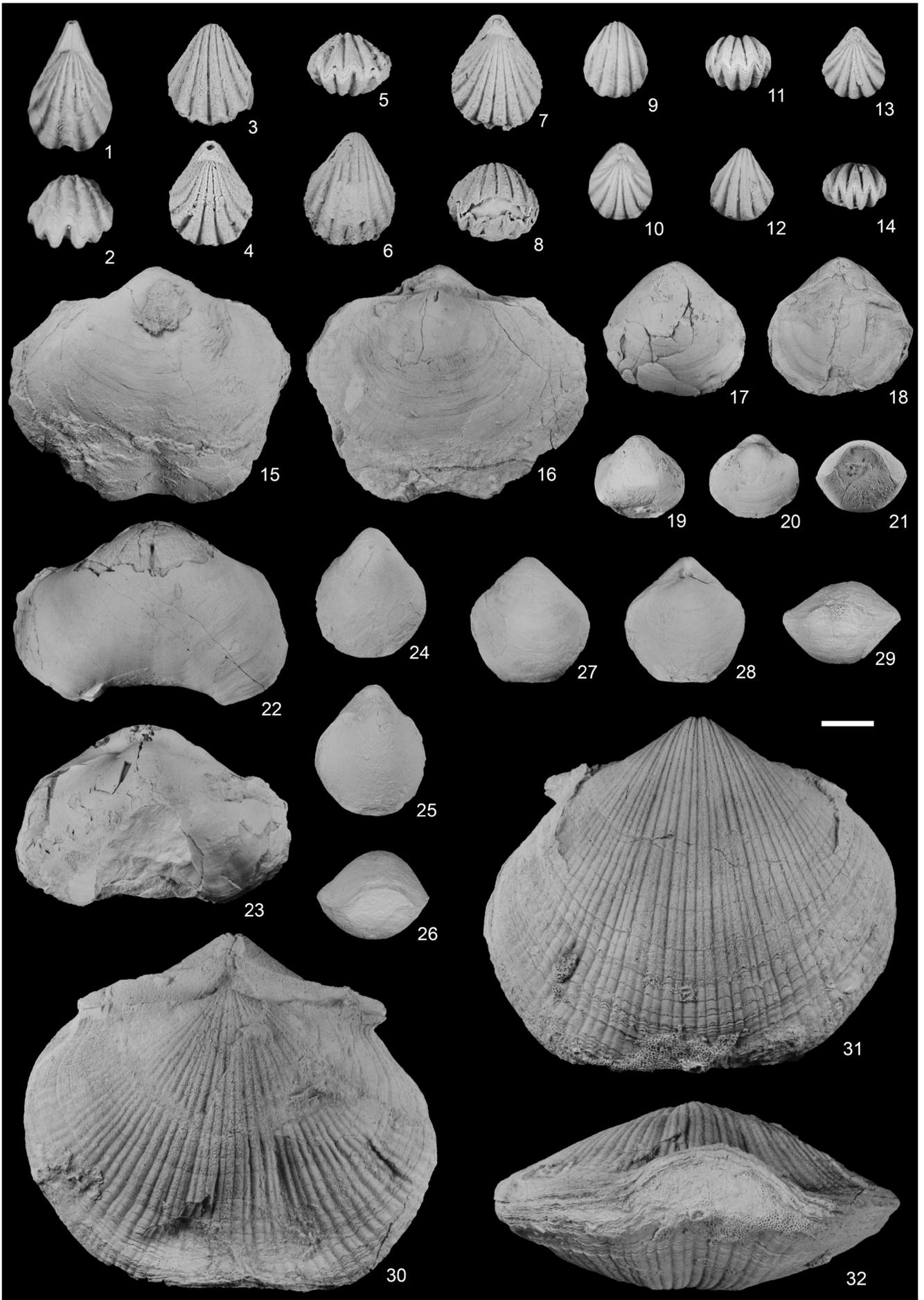


PLATE 4

**Remarks.** The specimens under examination differ from *Arcullina polaris* (Wiman, 1914) from the Kungurian of Spitzbergen because of the lower, less angular and more numerous plicae; from *A. humilis* Waterhouse, 2001 from the Artinskian McLean Peaks Formation because of the larger size, the less elongate outline and the smooth plicae; from *A. kupangensis* (Beyrich, 1864) from Basleo, Timor because of the less elongate outline, wider cardinal margin, and the stronger plicae; from *A. angiolinii* Waterhouse, 2001 from the Lopingian Marsyangdi Formation of Nepal for the less elongate outline and the smooth plicae. Due to the paucity of the material they are left under open nomenclature.

**Occurrence.** Oman, loc. JQ1, Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian; loc. SH11, Shiya, Qarari Unit, Batain Group, Roadian.

Subfamily Hunzininae Angiolini, 2001  
Genus *Aequalicosta* Waterhouse, 2004

**Type species:** *Eliva inflata* Cooper & Grant, 1976

**Remarks.** The subfamily Hunzininae was erected by Angiolini (2001) to include Spiriferellidae characterized by relatively narrow cardinal margin, variably sulcate dorsal fold, non plicate lateral slopes, and lamellose micror ornamentation, as *Hunzina* Angiolini, 1995, *Darbandia* Angiolini, 1995 and *Elivina* Fredericks, 1924. Waterhouse (2004) erected *Aequalicosta* with type species *Eliva inflata* Cooper & Grant, 1976, including it in the Purdonellinae Poleaev, 1986 of the Choristitidae Waterhouse, 1968. Based on the shape, which is not distinctively elongate, the wider cardinal margin, the low fold, and the lamellose micror ornament, *Aequalicosta* is here placed in the Hunzininae.

*Aequalicosta* differs from *Hunzina* because of the thinner, subequal ribs and the lower fold ornamented by bifurcating ribs in a particular pattern; the type species has a fold ornamented by one costa that bifurcate to form two ribs which bifurcate anteriorly and so it is not sulcate as the typical Spiriferellidae fold. *Aequalicosta* differs from *Elivina*, because of its smaller size, the absence of flat fascicles of bifurcating ribs on the ventral valve, and the more uniform ribs.

### *Aequalicosta* sp.

Pl. 5, fig. 22-27

**Material:** Two figured articulated specimens: MPUM12713 (WKJd-32), MPUM12714 (WKJf-2); three articulated specimens: MPUM12715 (WKJd-6, WKJd-46), MPUM12716 (WKJf-7).

**Description.** Small sized unequally biconvex shell with cordiform outline, wide as long. Cardinal margin narrower than maximum width, which is at mid-length; small, alate cardinal extremities. Anterior commissure uniplicate and slightly emarginate. Ventral valve deep and convex, with a high and recurved umbo and triangular interarea with open delthyrium; ventral sulcus deep, starting from the umbo, widening anteriorly. Dorsal valve weakly convex, with very low fold.

Ornamentation of ribs with a distinct pattern of bifurcation: on the ventral valve only the sulcal bounding costae bifurcate twice, the lateral ones being simple and a median costa occurs in the sulcus; on the dorsal valve only the three median costae bifurcate. The ribs number 4-6 per 5 mm at the anterior margin; weak growth lamellae. Micror ornamentation lamellose.

Interior of ventral valve with thick apical callus, and long dental plates.

**Remarks.** The specimens under examination differ from *Aequalicosta inflata* (Cooper & Grant, 1976) from the Capitanian of West Texas because of the more transverse outline and the pattern of ribbing on the fold, characterized by three costae which bifurcate anteriorly; from *A. shumardi* (Cooper & Grant, 1976) from the Capitanian of West Texas, because of its non fasciculate and thinner ribs. However, they show the characteristic features of a species of the genus.

The specimens figured as *Eliva* sp. A by Yang et al. (1990, pl. 26) from the Cisuralian of Mayang, SW Tibet may belong to *Aequalicosta*.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Superfamily Paeckelmanelloidea Ivanova, 1972  
Family Strophopleuridae Carter, 1974  
Genus *Tipispirifer* Grant, 1976

**Type species:** *Tipispirifer oppilatus* Grant, 1976

**Remarks.** When erected, the nonpunctate, transverse and alate genus *Tipispirifer* was included in the Cyrtospiriferidae Termier & Termier, 1949, but then relocated into the Spiriferellidae by Carter et al. (1994) and later in the Strophopleuridae by Angiolini (2001) because of its transverse shape, multicostate ornamentation, and high interarea. The internal characters of *Tipispirifer* are peculiar, consisting of converging dental plates, in some cases forming a spondylium.

*Tipispirifer* sp.

Pl. 5, fig. 28-33

**Material:** Two figured articulated specimens: MPUM12717 (WKJd-4), MPUM12718 (WKJd-27).

**Description.** Small sized unequally biconvex shell with transverse subtriangular outline, much wider than long. Cardinal margin long, corresponding to the maximum width, with alate cardinal extremities. Anterior commissure parasulcate. Ventral valve deep and convex, conical, with a pointed and recurved umbo; interarea high, catacline, with trace of denticulation and delthyrium covered by imbricated stegidial plates; ventral sulcus deep and narrow bounded by two costae. Dorsal valve flat, with fold delimited by two furrows.

Ornamentation of bifurcating ribs numbering 4-6 per 2 mm at the anterior margin and 10-13 on the fold; growth lamellae.

Interior of ventral valve with converging dental plates.

**Remarks.** The specimens under examination differ from *Tipispirifer oppilatus* Grant, 1976 of the Guadalupian of Thailand, because of their parasulcate anterior commissure and flatter interarea; from *Tipispirifer psittacus* (Merla, 1934) of the Guadalupian of Karakoram (Angiolini 2001) because of their catacline, instead of apsacline, interarea and the more numerous ribs.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Suborder **Delthyridina** Ivanova, 1972  
Superfamily Reticularioidea Waagen, 1883  
Family Elythidae Frederick, 1924  
Subfamily Phricodothyridinae Caster, 1939

Genus *Permophricodothyris* Pavlova, 1965

**Type species:** *Permophricodothyris ovata* Pavlova, 1965

*Permophricodothyris* aff. *P. affinis* (Gemmellaro, 1899)

Pl. 5, fig. 34-42; Pl. 6, fig. 30-32

**Material:** Four figured articulated specimens: MPUM12719 (WKJd-21), MPUM12720 (WKJe-46), MPUM12721 (WKJe-78), MPUM12722 (WKJd-25); one articulated specimen: MPUM12723 (WKJd-24).

**Description.** Biconvex shell with suboval to subpentagonal outline, slightly wider than long. Maximum width at mid-length. Anterior commissure weakly uniplicate. Ventral valve deep and convex, with a prominent and recurved umbo; ventral sulcus starting posteriorly to mid-length, slightly widening and deepening anteriorly. Dorsal valve less convex than the ventral valve, with low fold, more evident at the anterior margin.

Ornamentation of growth lines and lamellae with thin spines regularly arranged in two rows on each lamella: the spines are both biramous with triangular bases and simple with subcircular bases.

Interior of dorsal valve with long, longitudinally directed crura.

**Remarks.** The specimens under examination are mostly similar to *Permophricodothyris affinis* (Gemmellaro, 1899) because of the subequally biconvex shape, the outline with width slightly exceeding length, the weakly uniplicate anterior commissure, but they differ because of the absence of angular cardinal extremities and the height of the ventral umbo which is more similar to that of *P. caroli* (Gemmellaro, 1894). However, *P. caroli* has an asymmetrical umbo, a high interarea, and a subtriangular outline of the ventral valve.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Roadian-Wordian, Rupe del passo di Burgio, Pietra di Salomone and Rocca di San Benedetto, Sosio Valley, Sicily (Gemmellaro 1892); Guadalupian, Djebel Tebaga, Tunisia (Verna et al. 2010).

*Permophricodothyris inaequilateralis* (Gemmellaro, 1894)

Pl. 5, fig. 43-47

- 1894 *Reticularia inaequilateralis* Gemmellaro, p. 3.  
 1899 *Reticularia inaequilateralis* - Gemmellaro, p. 336, pl. 35, fig. 2-21.  
 1911 *Spirifer (Reticularia) inaequilateralis* - French, p. 169, pl. 28, fig. 1.  
 1913 *Reticularia inaequilateralis* - Mansuy, p. 120, text-fig. 12, pl. 13, fig. 7.  
 1933 *Squamularia inaequilateralis* - Huang, p. 31, pl. 4, fig. 10-11.  
 1934 *Reticularia dieneri* - Solignac, p. 10.  
 1944 *Squamularia (Neophricodothyris) inaequilateralis* - Reed, p. 240, pl. 31, fig. 5.  
 1957 *Reticularia inaequilateralis* - Termier & Termier, p. 209, pl. 5d-h.  
 1977 *Permophricodothyris inaequilateralis* - Termier, Termier & Vachard, p. 58.  
 2010 *Permophricodothyris inaequilateralis* - Verna & Angiolini in Verna et al., p. 340, pl. 3, fig. 7-11, 26-29; fig. 8.

**Material:** Three figured articulated specimens: MPUM12724 (WKJe-79), MPUM12725 (WKJe-115), MPUM12726 (WKJe-136); two articulated specimens: MPUM12727 (WKJe-43, WKJe-86).

**Description.** Biconvex shell with suboval, but inequilateral outline, slightly longer than wide. Maximum width at mid-length. Anterior commissure weakly uniplicate. Ventral valve convex, with a narrow and hooked umbo with asymmetrical slopes and apex pointing laterally; ventral sulcus starting at mid-length, slightly widening and deepening anteriorly and slightly displaced laterally. Dorsal valve convex with low fold, more evident at the anterior margin and slightly asymmetrical.

Ornamentation of growth lines and lamellae with thin spines regularly arranged in two alternating rows on each lamella: the spines are both biramous with triangular bases and simple, very small and with subcircular bases.

Interior of dorsal valve with long, longitudinally directed crura.

**Remarks.** The specimens under examination are included in *Permophricodothyris inaequilateralis* (Gemmellaro, 1894) based on their characteristic asymmetrical outline, with a lateral side shorter than the other. All the other morphological features correspond to those described by Gemmellaro (1899, p. 336). *P. inaequilateralis* differs from *P. caroli* because of its larger size, more convex dorsal valve, lower ventral umbo, and laterally displaced fold/sulcus.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Radian-Wordian, Rupe del passo di Burgio, Pietra di Salomone and Rocca di San Benedetto, Sosio Valley, Sicily (Gemmellaro 1892); Guadalupian, Djebel Tebaga, Tunisia (Verna et al. 2010); Chhidru Formation, Lopingian, Salt Range, Pakistan (Reed 1944); Lopingian, Guizhou, South China (Huang 1933).

## Genus *Squamularia* Gemmellaro, 1899

**Type species:** *Squamularia rotundata* Gemmellaro, 1899

**Remarks.** We follow Verna & Angiolini in Verna et al. (2011) for the emendation of the diagnosis of the genus *Squamularia* Gemmellaro, 1899 and the discussion about its supra-generic position. These authors did not share the view of Shen et al. (2003) that the direction of the spiral axes allows for discriminating *Squamularia* from the allied *Permophricodothyris* Pavlova, 1965, as the direction of the axes of spiralia in the former can be either laterally or posterolaterally directed. Verna & Angiolini in Verna et al. (2011, p. 36) put more emphasis on the shape of the spiralia themselves, which show a wide base and short axis, with a low number of coils in *Squamularia*, but have a narrow diameter with respect to the axis length and a high number of coils in *Permophricodothyris*.

Also, *Squamularia* can be distinguished because of the more transverse outline, with width usually exceeding length, the short crura, and the occurrence of biramous spines only. *Permophricodothyris* has uniramous spines in addition to more elaborate biramous ones.

## *Squamularia marcouxii* Verna & Angiolini in Verna et al., 2011

Pl. 5, fig. 48-53; Pl. 6, fig. 33-35

2011 *Squamularia marcouxii* Verna & Angiolini, in Verna et al., p. 87, pl. 4, fig. 1-10; pl. 5, fig. 1-5; pl. 6, fig. 1-4, 8, 10-11.

**Material:** Four figured articulated specimens: MPUM12728 (WKJe-32), MPUM12729 (WKJe-98), MPUM12730 (WKJe-121), MPUM12731 (WKJe-113); six articulated specimens: MPUM12732 (WKJe-84, WKJe-88, WKJe-89, WKJe-102, WKJe-108).

**Description.** Biconvex shell with suboval to subrectangular outline, wider than long. Maximum width slightly posterior to mid-length. Anterior commissure rectimarginate to weakly uniplicate. Ventral valve convex, with a hooked and recurved umbo; ventral sulcus absent. Dorsal valve transverse, slightly less convex than the ventral one, with no fold or developed only at the anterior margin.

Ornamentation of growth lamellae with elaborate biramous spines with diamond-shaped bases, arranged in two alternating rows on each lamella; the spines have secondary processes symmetrically disposed along the longitudinal axis.

**Remarks.** *Squamularia marcouxi* Verna & Angiolini in Verna et al., 2011 is characterized by a transverse subrectangular outline, more marked in the dorsal valve which differentiates the species from allied ones as *S. dieneri* Gemmellaro, 1899 and *S. rotundata* Gemmellaro, 1899 from the Guadalupian of Sicily. The specimen WKJd-31, very poorly preserved, may also belong to this species.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Pamuçak Formation, Wordian-Capitanian, Turkey (Verna et al. 2011).

*Squamularia* sp.

Pl. 5, fig. 54-58; Pl. 6, fig. 1

**Material:** Three figured articulated specimens: MPUM12733 (WKJd-20), MPUM12734 (WKJe-103), MPUM12735 (WKJe-112); seven articulated specimens: MPUM12736 (WKJe-96, WKJe-99, WKJe-100, WKJe-104, WKJe-107, WKJe-110, WKJe-117).

**Description.** Biconvex shell with suboval to subpentagonal outline, wider than long. Maximum width slightly posterior to mid-length. Anterior commissure weakly uniplicate. Ventral valve convex, with a high and recurved umbo; ventral sulcus developed anteriorly. Dorsal valve transverse, rather flat, with fold at the anterior margin.

Ornamentation of growth lines and lamellae with poorly preserved, coarse biramous spines.

Interior of dorsal valve with short crura and laterally directed spiralia.

**Remarks.** The specimens under examination differ from *S. dieneri* because of the different outline and convexity of the dorsal valve; from *S. rotundata* because of the wider than long outline; from *S. marcouxi* because of the lack of a transverse shape and the higher umbo; from *S. extensiformis* Chang, 1977 from the Guadalupian of Baoshan Block, western Yunnan because of the different outline and the anterior commissure. The specimens are left under open nomenclature because of their poor preservation.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Order **Spiriferinida** Ivanova, 1972  
Suborder **Spiriferinidina** Ivanova, 1972  
Superfamily Pennospiriferinoidea Dagens, 1972  
Family Paraspiriferinidae Cooper & Grant, 1976

Genus *Paraspiriferina* Reed, 1944

**Type species:** *Spiriferina* (*Paraspiriferina*) *ghundiensis* Reed, 1944

**Remarks.** *Paraspiriferina* Reed, 1944 differs from the allied *Callispirina* Cooper & Muir-Wood, 1951 and *Spiriferellina* Frederiks, 1924 because of its convex valves, and flatter and more rounded costae. *Spiriferellina* differs also because of its angular cardinal extremities, which are rounded in *Callispirina* and *Paraspiriferina*.

*Paraspiriferina gentilis* Grant, 1976

Pl. 6, fig. 2-4

1976 *Paraspiriferina gentilis* Grant, p. 236, pl. 64, fig. 1-36.

**Material:** One figured articulated specimen: MPUM12737 (WKJe-38).

**Description.** Biconvex, subglobose shell with transverse suboval outline, wider than long. Maximum width anterior to the cardinal margin; cardinal extremities rounded. Anterior commissure weakly uniplicate. Ventral valve convex, with a high umbo and long inter-area; ventral sulcus shallow, evident anteriorly. Dorsal valve rather flat, with fold slightly higher than the lateral costae.

Ornamentation of coarse, rounded costae, numbering 4 on each flank on the ventral valve and 3 on each flank on the dorsal valve.

Interior of ventral valve with high median septum.

**Remarks.** The specimen under examination belongs to *Paraspiriferina gentilis* Grant, 1976 because of its small size, the number of costae and the high ventral septum.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Rat Buri Limestone, Guadalupian, Thailand (Grant 1976).

Genus *Callispirina* Cooper & Muir-Wood, 1951

**Type species:** *Spiriferina ornata* Waagen, 1883

**Remarks.** *Callispirina* differs from *Paraspiriferina* Reed, 1944 because of its strongly uniplicate anterior commissure, sharper and angular costae with flat top, and regularly arranged growth lamellae.

***Callispirina* cf. *C. rotunda* Cooper & Grant, 1976**

Pl. 6, fig. 5

**Material:** One figured articulated specimen: MPUM12738 (SH11-1).

**Description.** Biconvex, subglobose shell with transverse suboval outline, wider than long. Maximum width at mid-length. Cardinal extremities rounded. Anterior commissure strongly uniplicate. Ventral valve convex, with shallow ventral sulcus. Dorsal valve less convex than the ventral one, with fold higher than lateral costae.

Ornamentation of sharp costae with steep flanks and flat top, numbering 4 on each flank on the ventral valve and 3 on each flank on the dorsal valve; regularly spaced growth lines and lamellae.

**Remarks.** The specimen under examination is mostly similar to *Callispirina rotunda* Cooper & Grant, 1976 because of its shape and the number of costae. It differs from *C. ornata* (Waagen, 1883) and *C. austrina* Grant, 1976 because they have more angular costae, which are also more numerous in the latter species.

**Occurrence.** Oman, loc. SH11, Shiya, Qarari Unit, Batain Group, Roadian.

**Distribution.** Bell Canyon Formation, Capitanian, West Texas (Cooper & Grant 1976).

Family Spiriferellinidae Ivanova, 1972

Genus *Spiriferellina* Frederiks, 1924**Type species:** *Terebratulides cristatus* von Schlotheim, 1816***Spiriferellina aduncata* Waterhouse & Piyasin, 1970**

Pl. 6, fig. 6-11

1970 *Spiriferellina aduncata* Waterhouse & Piyasin, p. 149, pl. 26, fig. 19-22; pl. 27, fig. 1-15; pl. 28, fig. 1-10; pl. 29, fig. 1-5; text-fig. 15, 16, 18, 21.

1976 *Spiriferellina aduncata* - Grant, p. 236, pl. 64, fig. 37-38.

1983 *Spiriferellina yunnanensis* Fang, p. 102, pl. 5, fig. 89; pl. 6, fig. 1-4.

1994 *Spiriferellina yunnanensis* - Fang & Fan, p. 88, pl. 24, fig. 3-7; pl. 25, fig. 1; pl. 32, fig. 7-8.

2002 *Spiriferellina aduncata* - Shen et al., p. 679, fig. 6: 1-3.

**Material:** Two figured articulated specimens: MPUM12739 (WKJe-5), MPUM12740 (WKJe-9).

**Description.** Unequally biconvex shell with transverse suboval outline, wider than long. Maximum width slightly anterior to the cardinal margin. Cardinal extremities weakly angular. Anterior com-

missure uniplicate. Ventral valve convex, with pointed umbo and wide interarea with open delthyrium; ventral sulcus shallow. Dorsal valve less convex than the ventral one, with relatively high fold.

## PLATE 5

*Cartorbium* aff. *C. multiradiatus* (Reed, 1944)

1 – MPUM12696 (WKJd-23), ventral view, 1x. 2 – MPUM12696 (WKJd-23), dorsal view, 1x. 3 – MPUM12696 (WKJd-23), anterior view, 1x. 4 – MPUM12697 (WKJf-10), ventral view, 1x. 5 – MPUM12697 (WKJf-10), dorsal view, 1x. 6 – MPUM12697 (WKJf-10), anterior view, 1x.

*Spiriferella posterosulcata* n. sp.

7 – MPUM12702 (WKJd-39), ventral view, 1x. 8 – MPUM12702 (WKJd-39), dorsal view, 1x. 9 – MPUM12702 (WKJd-39), anterior view, 1x. 10 – MPUM12703 (WKJf-1), ventral view, 1x. 11 – MPUM12703 (WKJf-1), dorsal view, 1x. 12 – MPUM12703 (WKJf-1), anterior view, 1x. 13 – MPUM12701 (WKJf-16), ventral view, 1x. 14 – MPUM12701 (WKJf-16), dorsal view, 1x. 15 – MPUM12701 (WKJf-16), anterior view, 1x.

*Arcullina* sp.

16 – MPUM12710 (JQ1-6), ventral view, 1x. 17 – MPUM12710 (JQ1-6), dorsal view, 1x. 18 – MPUM12709 (SH11-2), ventral view, 1x. 19 – MPUM12709 (SH11-2), dorsal view, 1x. 20 – MPUM12711 (SH11-4), ventral view, 1x. 21 – MPUM12711 (SH11-4), dorsal view, 1x.

*Aequalicosta* sp.

22 – MPUM12713 (WKJd-32), ventral view, 1x. 23 – MPUM12713 (WKJd-32), dorsal view, 1x. 24 – MPUM12713 (WKJd-32), anterior view, 1x. 25 – MPUM12714 (WKJf-2), ventral view, 1x. 26 – MPUM12714 (WKJf-2), dorsal view, 1x. 27 – MPUM12714 (WKJf-2), anterior view, 1x.

*Tipispirifer* sp.

28 – MPUM12717 (WKJd-4), ventral view, 1x. 29 – MPUM12717 (WKJd-4), dorsal view, 1x. 30 – MPUM12717 (WKJd-4), anterior view, 1x. 31 – MPUM12718 (WKJd-27), ventral view, 1x. 32 – MPUM12718 (WKJd-27), dorsal view, 1x. 33 – MPUM12718 (WKJd-27), anterior view, 1x.

*Ppermophricodothyris* aff. *P. affinis* (Gemmellaro, 1899)

34 – MPUM12719 (WKJd-21), ventral view, 1x. 35 – MPUM12719 (WKJd-21), dorsal view, 1x. 36 – MPUM12719 (WKJd-21), anterior view, 1x. 37 – MPUM12720 (WKJe-46), ventral view, 1x. 38 – MPUM12720 (WKJe-46), dorsal view, 1x. 39 – MPUM12720 (WKJe-46), anterior view, 1x. 40 – MPUM12721 (WKJe-78), ventral view, 1x. 41 – MPUM12721 (WKJe-78), dorsal view, 1x. 42 – MPUM12721 (WKJe-78), anterior view, 1x.

*Ppermophricodothyris inaequilateralis* (Gemmellaro, 1899)

43 – MPUM12724 (WKJe-79), ventral view, 1x. 44 – MPUM12725 (WKJe-115), ventral view, 1x. 45 – MPUM12725 (WKJe-115), dorsal view, 1x. 46 – MPUM12726 (WKJe-136), ventral view, 1x. 47 – MPUM12726 (WKJe-136), dorsal view, 1x.

*Squamularia marouxi* Verna & Angiolini in Verna et al., 2011

48 – MPUM12728 (WKJe-32), ventral view, 1x. 49 – MPUM12728 (WKJe-32), dorsal view, 1x. 50 – MPUM12729 (WKJe-98), ventral view, 1x. 51 – MPUM12729 (WKJe-98), dorsal view, 1x. 52 – MPUM12730 (WKJe-121), ventral view, 1x. 53 – MPUM12730 (WKJe-121), dorsal view, 1x.

*Squamularia* sp.

54 – MPUM12733 (WKJd-20), ventral view, 1x. 55 – MPUM12733 (WKJd-20), dorsal view, 1x. 56 – MPUM12734 (WKJe-103), ventral view, 1x. 57 – MPUM12734 (WKJe-103), dorsal view, 1x. 58 – MPUM12735 (WKJe-112), ventral view, 1x.

Scale-bar is 1 cm.

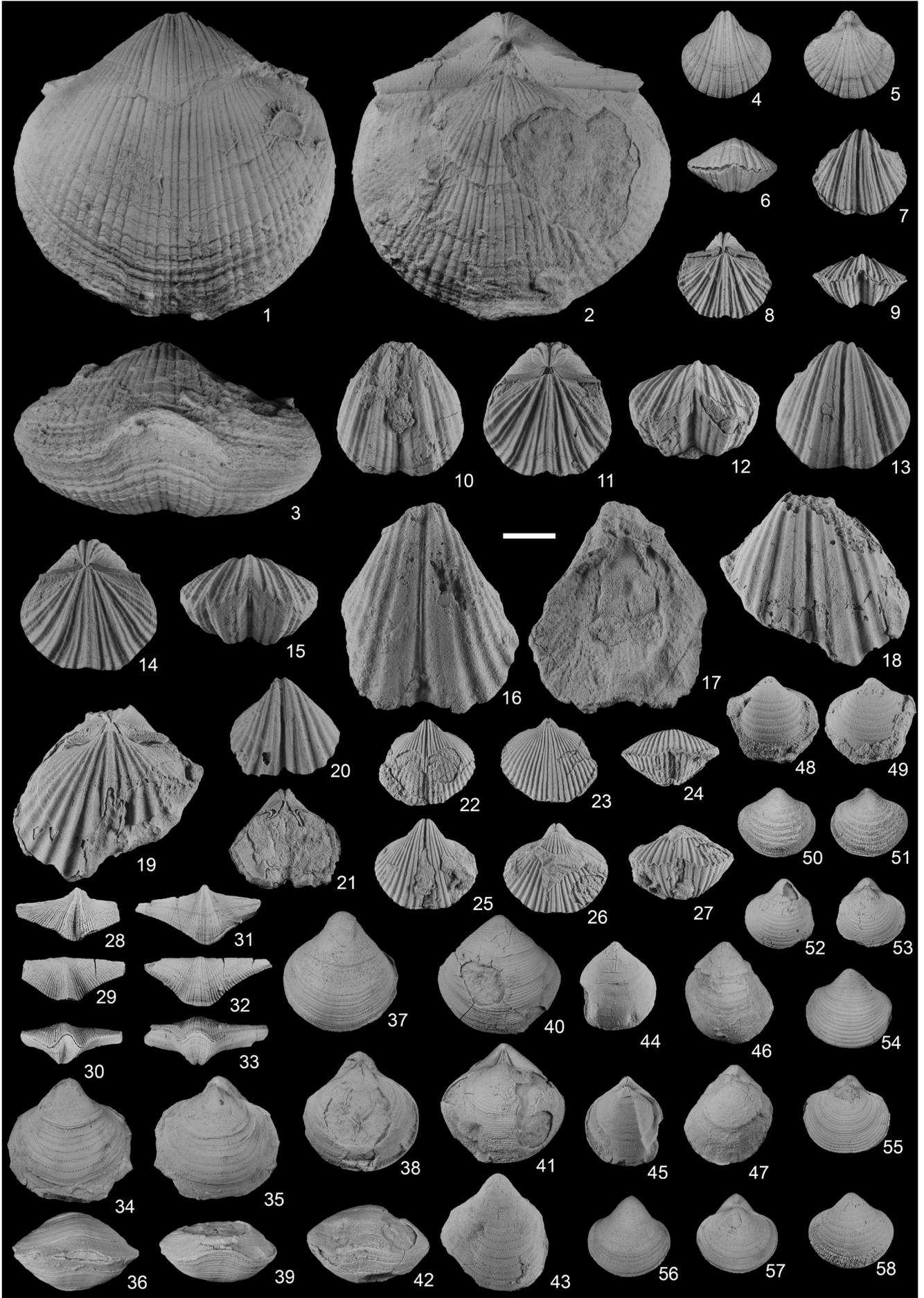


PLATE 5

Ornamentation of sharp, angular costae, numbering 4 on each flank on the ventral valve and 3 on each flank on the dorsal valve; irregularly spaced growth lines and lamellae; microramentation of pustules.

**Remarks.** The specimens under examination are identified as *Spiriferellina aduncata* Waterhouse & Piyasin, 1970 because of the number of angular costae and the wide interarea.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Rat Buri Limestone, Guadalupian, Thailand (Grant 1976); Yongde and Guayinshan formations, Kungurian-Wordian, Baoshan and Tengchong blocks, western Yunnan (Shen et al. 2002).

### *Spiriferellina yanagidai* Grant, 1976

Pl. 6, fig. 12-17

1976 *Spiriferellina yanagidai* Grant, p. 237, pl. 65, fig. 1-34.

**Material:** Two figured articulated specimens: MPUM12741 (WKJe-30), MPUM12742 (WKJe-71); nine articulated specimens: MPUM12743 (WKJe-4, WKJe-8, WKJe-10, WKJe-13, WKJe-15, WKJe-17, WKJe-31, WKJe-62, WKJe-75).

**Description.** Unequally biconvex shell with transverse subtriangular outline, wider than long. Maximum width at the cardinal margin; cardinal extremities angular. Anterior commissure uniplicate. Ventral valve convex, with pointed umbo and triangular catacline to apsacline interarea with open delthyrium; ventral sulcus deep. Dorsal valve less convex than the ventral one, with relatively high fold.

Ornamentation of high, angular costae, numbering 4 on each flank on the ventral valve and 3-4 on each flank on the dorsal valve; irregularly spaced growth lines and lamellae; microramentation of pustules.

**Remarks.** The specimens under examination are identified as *Spiriferellina yanagidai* Grant, 1976 because of the outline, the number and the height of the costae, and the angular cardinal extremities. *S. aduncata* has more numerous costae, less angular cardinal extremities and an oval outline.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Rat Buri Limestone, Guadalupian, Thailand (Grant 1976).

## Order **Terebratulida** Waagen, 1883

### Suborder **Terebratulidina** Waagen, 1883

#### Superfamily **Cryptonelloidea** Thomson, 1926

#### Family **Notothyrididae** Licharew, 1960

#### Genus *Notothyris* Waagen, 1882

**Type species:** *Terebratula subvesicularis* Davidson, 1862

#### PLATE 6

##### *Squamularia* sp.

1 – MPUM12735 (WKJe-112), dorsal view, 1x.

##### *Paraspiriferina gentilis* Grant, 1976

2 – MPUM12737 (WKJe-38), ventral view, 2x. 3 – MPUM12737 (WKJe-38), dorsal view, 2x. 4 – MPUM12737 (WKJe-38), anterior view, 2x. *Callispirina* cf. *C. rotunda* Cooper & Grant, 1976. 5 – MPUM12738 (SH11-1), antero-dorsal view, 1x.

##### *Spiriferellina aduncata* Waterhouse & Piyasin, 1970

6 – MPUM12739 (WKJe-5), ventral view, 1x. 7 – MPUM12739 (WKJe-5), dorsal view, 1x. 8 – MPUM12739 (WKJe-5), anterior view, 1x. 9 – MPUM12740 (WKJe-9), ventral view, 2x. 10 – MPUM12740 (WKJe-9), dorsal view, 2x. 11 – MPUM12740 (WKJe-9), anterior view, 2x.

##### *Spiriferellina yanagidai* Grant, 1976

12 – MPUM12741 (WKJe-30), ventral view, 1x. 13 – MPUM12741 (WKJe-30), dorsal view, 1x. 14 – MPUM12741 (WKJe-30), anterior view, 1x. 15 – MPUM12742 (WKJe-71), ventral view, 1x. 16 – MPUM12742 (WKJe-71), dorsal view, 1x. 17 – MPUM12742 (WKJe-71), anterior view, 1x.

##### *Notothyris* sp.

18 – MPUM12744 (WKJe-94), ventral view, 2x. 19 – MPUM12744 (WKJe-94), dorsal view, 2x. 20 – MPUM12744 (WKJe-94), anterior view, 2x.

##### *Rostranteris mediterraneum* Gemmellaro, 1899

21 – MPUM12745 (WKJe-77), ventral view, 1x. 22 – MPUM12745 (WKJe-77), dorsal view, 1x. 23 – MPUM12745 (WKJe-77), anterior view, 1x. 24 – MPUM12746 (WKJe-97), ventral view, 1x. 25 – MPUM12746 (WKJe-97), dorsal view, 1x. 26 – MPUM12746 (WKJe-97), anterior view, 1x.

##### *Dielasma* sp.

27 – MPUM12748 (WKJe-126), ventral view, 1x. 28 – MPUM12748 (WKJe-126), anterior view, 1x. 29 – MPUM12748 (WKJe-126), dorsal view, 1x.

Scale-bar is 1 cm for 1x specimens and 0.5 cm for 2x specimens.

##### *Permophricodothyris* aff. *P. affinis* (Gemmellaro, 1899)

30 – MPUM12722 (WKJd-25), SEM vision of well-preserved simple spine bases. Scale-bar is 200 micron. 31 – MPUM12722 (WKJd-25), SEM vision of corrugated bifid spine bases. Scale-bar is 200 micron. 32 – MPUM12722 (WKJd-25), SEM vision of simple spines on the anterior margin of growth lamellae.

Scale-bar is 500 micron.

##### *Squamularia marcouxii* Verna & Angiolini in Verna et al., 2011

33 – MPUM12731 (WKJe-113), SEM vision of well spaced spines with secondary processes. Scale-bar is 200 micron. 34 – MPUM12731 (WKJe-113), SEM vision of well-preserved spines. Scale-bar is 500 micron.

35 – MPUM12731 (WKJe-113), SEM vision of a detail of a spine, with symmetric secondary processes.

Scale-bar is 200 micron.

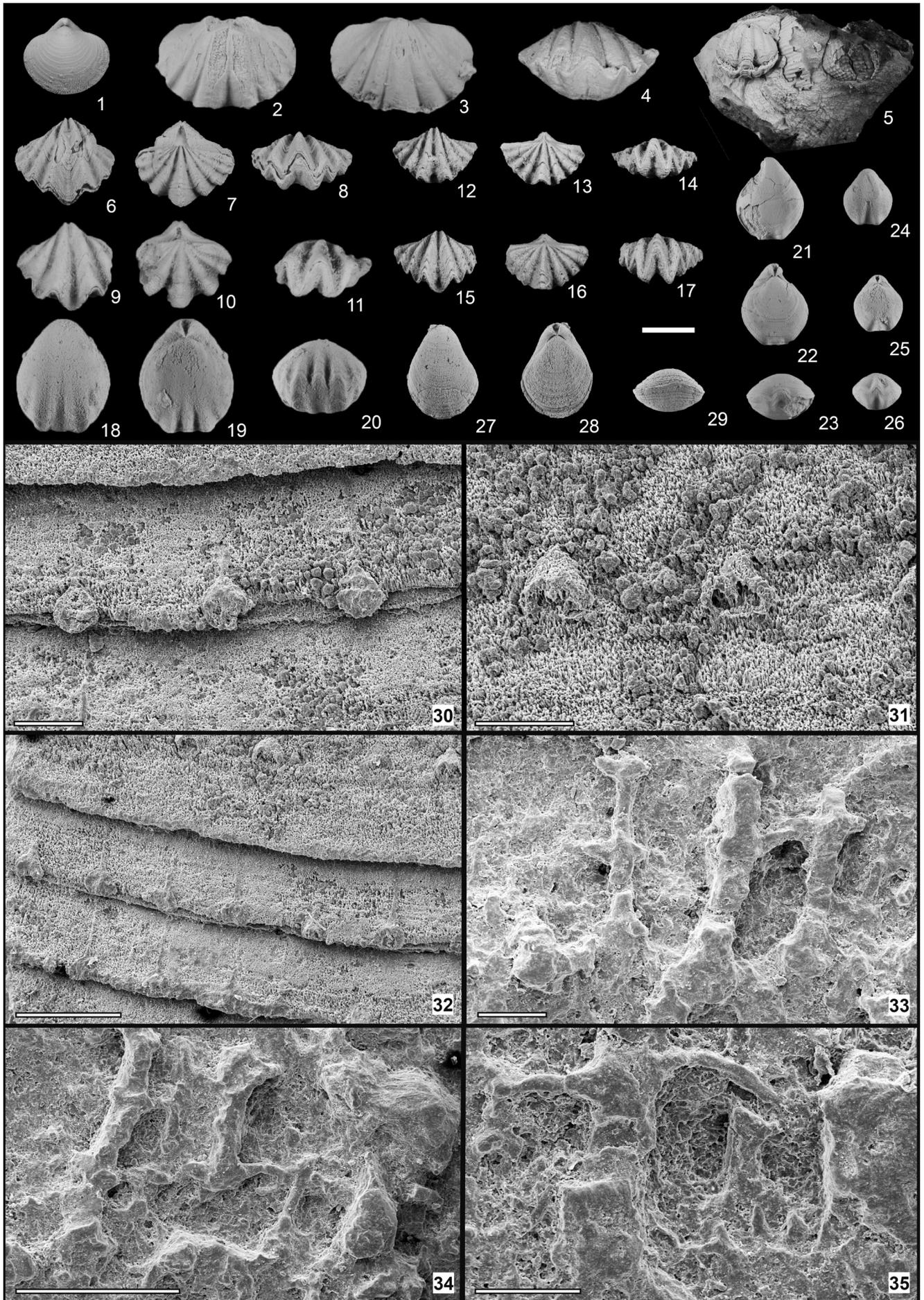


PLATE 6

**Remarks.** *Notothyris* Waagen, 1882 is similar to *Notothyrina* Licharew, 1936 and *Rostranteris* Gemmellaro, 1899. *Notothyrina* differs because of its very small size and the occurrence of two large ventral folds; *Rostranteris* has a similar size to *Notothyris* and the same high intraspecific variability, but its anterior commissure is generally plicosulcate, more rarely unisulcate. *Notothyris* has a rectimarginate commissure, more rarely weakly unisulcate.

***Notothyris* sp.**

Pl. 6, fig. 18-20

**Material:** One figured articulated specimen: MPUM12744 (WKJe-94).

**Description.** Small sized biconvex shell with suboval outline, longer than wide. Maximum width at mid-length. Anterior commissure rectimarginate. Ventral valve strongly convex, with prominent and recurved umbo with labiate foramen; two median folds and two lower lateral folds start anteriorly to mid-length. Dorsal valve convex with three median folds and two very low lateral ones starting anteriorly to mid-length.

**Remarks.** The specimen under examination belongs to a species of *Notothyris* because of its size and the rectimarginate anterior commissure.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

Genus *Rostranteris* Gemmellaro, 1898

**Type species:** *Dielasma adrianense* Gemmellaro, 1894

***Rostranteris mediterraneum* Gemmellaro, 1899**

Pl. 6, fig. 21-26

1899 *Rostranteris mediterraneum* Gemmellaro, p. 108, pl. 26, figs 1-6.

**Material:** Two figured articulated specimens: MPUM12745 (WKJe-77), MPUM12746 (WKJe-97); two articulated specimens: MPUM12747 (WKJe-74, WKJe-106).

**Description.** Small sized biconvex shell with elongate subpentagonal outline, longer than wide. Maximum width at mid-length. Anterior commissure plicosulcate, with a high dorsal fold. Ventral valve strongly convex, with prominent and recurved umbo with labiate foramen; two high folds and two lower lateral folds start anteriorly to mid-length.

Dorsal valve convex with a high median fold and two low lateral ones starting anteriorly to mid-length.

Interior of ventral valve with pedicle collar and dental plates fused to the valve walls; interior of dorsal valve with unsupported hinge plate.

**Remarks.** The specimens under examination are identified as *Rostranteris mediterraneum* Gemmellaro, 1899 because of the size, outline and the number of folds.

*R. exile* Gemmellaro, 1899 is more elongate, more narrow posteriorly and less ornamented; *R. inflatum* Gemmellaro, 1899 is much thicker.

Some of the specimens figured as different species of *Heterelasma* by Yang et al. (1990, pl. 26) from the Cisuralian of Mayang, SW Tibet may belong to *Rostranteris*.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian.

**Distribution.** Roadian-Wordian, Pietra di Salomone, Sosio Valley, Sicily (Gemmellaro 1892); Lengwu Formation, Guadalupian, Zhejiang Province, southern China (Liang 1990); Cisuralian-Guadalupian, Huayin Mountains, Sichuan (Zeng et al. 1995); Wordian-Capitanian, exotic limestone block, Lhaze County, Tibet (Shen et al. 2003).

Superfamily Dielasmatoidea Schuchert, 1913

Family Dielasmatidae Schuchert, 1913

Subfamily Dielasmatinae Schuchert, 1913

Genus *Dielasma* King, 1856

**Type species:** *Terebratulites elongatus* von Schlotheim, 1816

***Dielasma* sp.**

Pl. 6, fig. 27-29

**Material:** One figured articulated specimen: MPUM12748 (WKJe-126); two articulated specimens: MPUM12749 (WKJe-135), MPUM12750 (JX3-8).

**Description.** Biconvex shell with suboval outline, longer than wide, narrow posteriorly. Maximum width anterior to mid-length. Anterior commissure uniplicate. Ventral valve convex, with prominent and recurved umbo with labiate foramen; ventral sulcus shallow, starting at mid-length. Dorsal valve weakly convex with a low median fold starting at mid-length.

Interior of ventral valve with thin dental plates; interior of dorsal valve with “V” shaped inner hinge plates and short loop.

**Remarks.** The internal characters indicate that these specimens belong to a species of *Dielasma*. However, the nomenclature is left open due to the paucity of the material. The poorly preserved specimen JX3-8 may also belong to a species of *Dielasma*.

**Occurrence.** Oman, loc. WKJ, Wadi Khawr al Jaramah, Qarari Unit, Batain Group, late Kungurian; loc. JX= loc. 302 of Shackleton et al. (1990), Jebel Qarari, Qarari Unit, Batain Group, late Kungurian-early Roadian.

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