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Jurassic brachiopods from east-central Iran

Debahuti Mukherjee & Franz T. Fürsich

Mukherjee, D. & Fürsich, F.T. 2014. Jurassic brachiopods from east-central Iran. – Beringeria **44**, 107-127, 9 text-figs., 9 tabs, 2 pls; Erlangen.

Abstract. Fourteen species of brachiopods are described and illustrated from Middle Jurassic strata of the Tabas Block, east-central Iran. They belong to the genera *Dorsoplicathyris, Moeschia, Moisseevia, Conarithyris, Tubithyris, Somalithyris, Arabatia, Daghanirhynchia, Burmirhynchia, Cardinirhynchia, Digonella,* and *Aulacothyris.* Among the 12 genera only one is an endemic form, all others having a wider distribution. The majority is also known from the European Faunal Province and only three from the Ethiopian Province.

▪ **Key words:** *brachiopods, taxonomy, Jurassic, Iran*

Zusammenfassung. Vierzehn Brachiopodenarten aus dem Mitteljura des Tabasblocks, östlicher Zentraliran werden beschrieben und illustriert. Sie gehören zu den Gattungen *Dorsoplicathyris, Moeschia, Moisseevia, Conarithyris, Tubithyris, Somalithyris, Arabatia, Daghanirhynchia, Burmirhynchia, Cardinirhynchia, Digonella* und *Aulacothyris.* Von den 12 Gattungen ist lediglich eine endemisch, alle anderen haben eine weitere Verbreitung. Die Mehrheit ist aus der Europäischen Faunenprovinz bekannt, lediglich drei Gattungen treten auch in der Äthiopischen Faunenprovinz auf.

▪ **Schlüsselwörter:** *Brachiopoden, Taxonomie, Jura, Iran*

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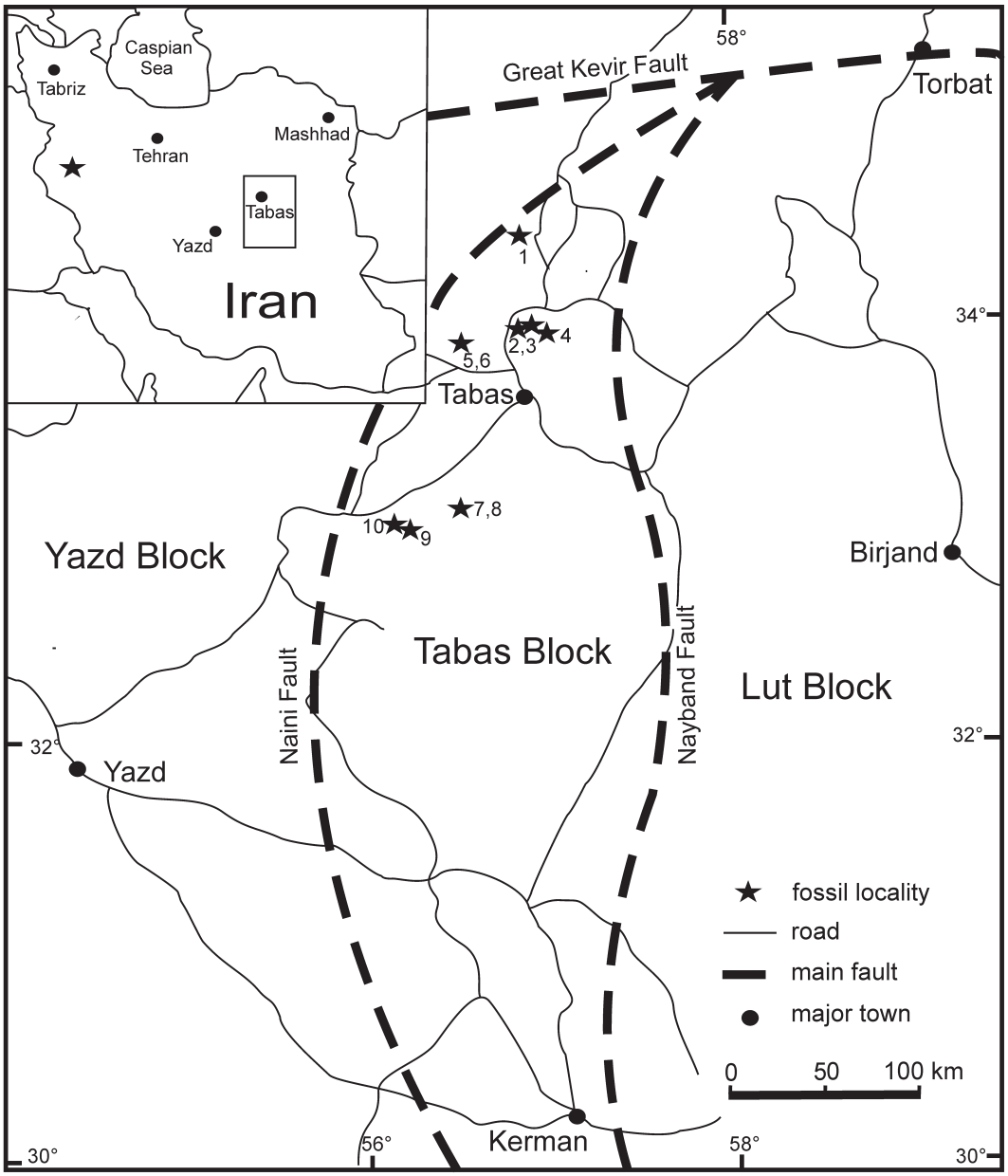
Introduction

The Central-East Iranian Microcontinent (CEIM), which collided with the Turan Plate of Eurasia) towards the end of the Triassic Period (e.g., Saidi et al. 1997; Stampfli & Borel 2002) consists of three blocks called, from West to East, the Yazd, Tabas, and the Lut Block (Text-fig. 1). Jurassic strata occur on all three blocks but the sedimentary succession on the Tabas Block is the most complete and extensive one. An overview of the Jurassic stratigraphy and facies development of the Tabas Block has recently been given by Wilmsen et al. (2009). The Jurassic sedimentary succession ranges from siliciclastics to carbonates and environments from epicontinental basins to carbonate platforms and a variety of non-marine settings such as coal swamps and flood plains. In the several 1000-m-thick succession fossils are distributed very unevenly and thin layers crowded with fossils may alternate with tens or even hundreds of metres of sediments which are devoid of macro- and microfossils. Due to excellent exposures and beds that often can be traced for tens of metres laterally, it is possible to obtain comprehensive collections of the macrofauna. In the past, the biostratigraphically important ammonites were at the focus of investigations (e.g. Seyed-Emami 1971; Seyed-Emami et al. 1991), but recently also elements of the benthic macrofauna (corals: Flügel 1966; Pandey & Fürsich 2003; bivalves: Fürsich & Pan 2014). The benthic macrofauna is dominated by bivalves followed by corals, sponges, gastropods, and brachiopods.

So far, the only record of Jurassic brachiopods from Iran is that by Adabi & Ager (1997), who described the genera *Moeschia*, *Urallela*, and *Torquirhynchia* from the Upper Jurassic Mozduran Formation of the Koppeh Dagh, northeastern Iran, and regarded the fauna as belonging to the Boreal Province having an 'Extra-Alpine' affinity with a notable absence of Ethiopian taxa. Adabi & Ager (1997) assigned a Kimmeridgian –Tithonian age to the assemblage, and although they mentioned the absence of typical European taxa they concluded that Iran was part of the European plate. Recently, Baeza-Carratala & Sepehriannasab (2014) described a latest Toarcian brachiopod assemblage from the Laluk Mountain of Central Iran. The assemblage is paucispecific, which is typical of the brachiopod records from this interval, and consists of *Homoeorhynchia sepahanensis* Baeza-Carratala & Sepehriannasab, as the dominant taxon with *Globirhynchia subobsoleta* (Davidson), *Pseudogibbirhynchia* sp., *Tetrarhynchiidae* sp. indet., *Monsardithyris*? aff. *haresfieldensis* (Davidson), and *Zeilleria* cf. *leckenbyi* (Walker in Davidson) as accessory faunal elements. Interestingly, the fauna has a global distribution except the new species of the rhynchonellid *Homoeorhynchia*. Apparently, the Iranian brachiopod occurrences during the Early – Middle Jurassic transition and in the Late Jurassic show influences of the NW European palaeobiogeographic province as has been traditionally held (Adabi & Ager 1997), but the presence of cosmopolitan taxa points to homogenization of biochoremas and, consequently, a less clear provinciality of the brachiopod faunas in the late Toarcian-earliest Aalenian (Baeza-Carratala & Sepehriannasab 2014).



Text-fig. 1. Localities on the northern Tabas Block from which Jurassic brachiopods have been collected. 1: N of Kalshaneh; 2: S of Kuh-e-Bagh-e-Vang; 3: SE of Robat-e-Dahaneh; 4: Kharavan-pain; 5: Kuh-e-Echellon area; 6: W of Kuh-e-Echellon; 7: Parvadeh area; 8: a few km N of Shurabi, Parvadeh area; 9: Kamar-e-Mehdi area; 10: 84 km SW of Tabas. (See Table 1 for co-ordinates.)

In the present study, 14 species belonging to 12 brachiopod genera are described and illustrated from the Tabas Block as part of an attempt to document the Jurassic benthic macrofauna. Among the 14 species only one is an endemic form; the others are all cosmopolitan taxa, the majority of them present in the European Province but three also occurring in the Ethiopian Province. Ager (1986) suggested the presence of Mesozoic sea-mounts to explain brachiopod distribution on both sides of the wide Neotethys.

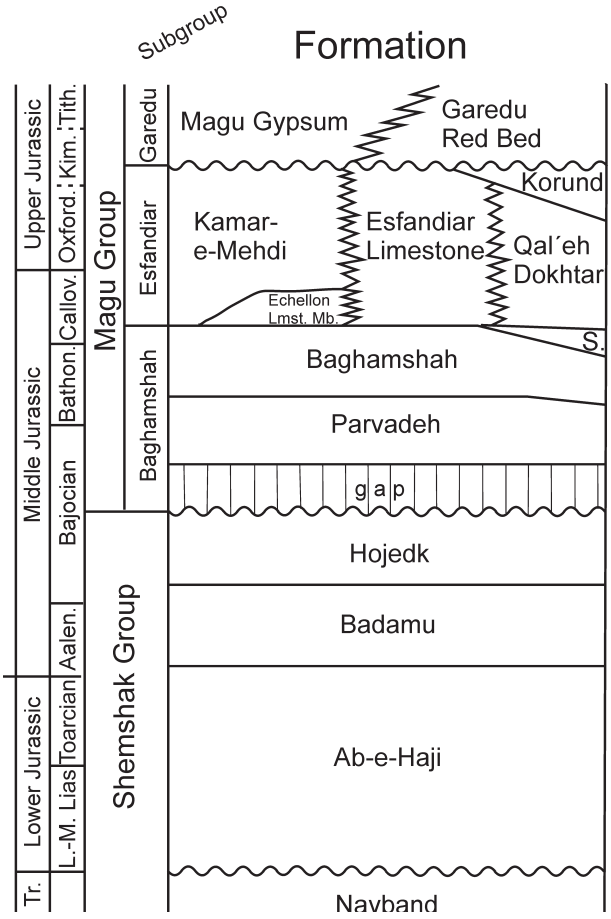
The specimens have been collected during extensive field work in the Tabas Block during the years 1996–2003. In addition, a sample from the Parvadeh Formation S of Sankhast, north-eastern Iran (co-ordinates: N37° 00'11", E56°55'06") has been included. Although situated north of the Tabas Block, the Parvadeh Formation of that area is very similar to that further south.

Stratigraphy

The brachiopods span the time slice Bajocian to Oxfordian and belong to the siliciclastic Hojedk Formation (Bajocian), the siliciclastic to calcareous Parvadeh Formation (Upper Bajocian–Lower Bathonian), the marly-silty Baghamshah Formation (Bathonian to Lower Callovian), and the calcareous-marly Kamar-e-Mehdi Formation (Callovian–Oxfordian), in particular from its basal Echellon Limestone Member (Callovian) (Text-fig.

Tab. 1. Localities of Jurassic brachiopods from the northern Tabas Block, east-central Iran. For position on the map see Text-fig. 1.

	Locality	Lithostratigraphy	co-ordinates
1	N of Kalshaneh	Echellon Limestone Mb.	N 34° 07, E 56° 49‘
2	S of Kuh-e-Bag-e Vang	Echellon Limestone Mb.	N 33° 56‘ 54“, E 56° 47‘ 05“
3	SE of Robat-e-Dahaneh	Echellon Limestone Mb.	N 33° 55‘ 56“, E 56° 49‘ 17“
4	Kharavan-pain (Shotori Mts.)	top Hojedk Fm.	N 33° 47‘ 52“, E 56° 02‘ 29“
5	Kuh-e-Echellon area	Baghamshah Fm.	N 33° 44‘, E 56° 32‘
6	W of Kuh-e-Echellon	top Baghamshah Fm., Echellon Limestone Mb.	N 33° 44‘ 34“, E 56° 30‘ 55“
7	Parvadeh area (a) Parvadeh area (b)	Parvadeh Fm. Parvadeh Fm.	N 33° 00‘ 03“, E 56° 46‘ 58“ N 32° 59‘ 46“, E 56° 45‘ 35“
8	a few km N of Shurabi, Parvadeh area	Parvadeh Fm.	
9	Kamar-e-Mehdi area	Parvadeh Fm. Kamar-e-Mehdi Fm.	N 33° 02‘, E 56° 26‘
10	84 km SW of Tabas	Parvadeh Fm.	
11	S of Sankhast	Parvadeh Fm.	N 37° 00‘ 11“, E 56° 55‘ 06“



Text-fig. 2. Lithostratigraphic framework of the Jurassic rocks of the northern Tabas Block (after Wilmsen et al. 2009). S.: Sikhor Formation; Tr.: Upper Triassic; Bath.: Bathonian; Kim.: Kimmeridgian; Tith.: Tithonian.

2). Most of the specimens have been collected from the northern part of the Tabas Block. For position of the localities see Fig. 1 and Table 2.

Taxonomy

The material is housed in the collections of the Bayerische Staatssammlung für Paläontologie und Geologie in Munich under the prefix BSPG 2013VI.

Order Terebratulida Waagen, 1883
Suborder Terebratulidina Waagen, 1883
Superfamily Loboidothyridoidea Makridin, 1964
Family Lissajousithyrididae Cooper, 1983
Subfamily Lissajousithyridinae Cooper, 1983
Genus *Dorsoplicathyris* Alméras, 1971

Type species. *Terebratula dorsoplicata* (Suess, MS), Deslongchamps (1859).

Remarks. The genus is an important component of the brachiopod fauna of western Europe and Asia in the Bathonian and Callovian (Vörös 2004). Williams et al. (2006) included three more genera in *Dorsoplicathyris*, *Pentithyris* (Cooper, 1983), *Stenorina* (Cooper, 1989), and *Tanyothyris* (Cooper, 1989) all characterised by elongate sub-pentagonal, ventri-biconvex shells with uniplicate to incipiently sulciplicate anterior commissure. Thus the geologic range of the genus is extended to the Oxfordian and the genus includes also the small-sized rectimarginate to incipiently sulciplicate *D. symmetrica* (Cooper). Corroy (1932) described *T. dorsoplicata* (Suess) from the Lower Callovian of France which was, however, not included by Alméras (1971) when describing *Dorsoplicathyris*. Vörös (2004), in contrast, was of the

Tab. 2. Mean size parameters of *Dorsoplicathyris dorsoplicata* (Suess in Deslongchamps, 1856) from four lithostratigraphic units. Ranges are given in brackets. N: number of specimens.

Formation	N	Length	Width	Thickness	Fold Width	Fold Height
Kamar-e-Mehdi (Echellon Limestone Member)	19	35.23 (26.7-46.18)	27.53 (20.25-34.06)	19.71 (14.7-25.12)	20.23 (13.9-26.9)	6.81 (3.6-8.89)
Baghamshah	11	32.4 (26.48-40.46)	26.5 (23.32-35.01)	17.8 (13.21-21.99)	15.9 (11.82-20.8)	7.2 (2.89-10.67)
Parvadeh	27	29.57 (21.81-39.57)	23.85 (16.99-30.6)	16.09 (11.03-19.96)	16.88 (11.13-23.0)	7.02 (4.07-9.6)
basal Parvadeh	3	29.4	22.06	15	16.3	5.03

opinion that they might belong to *Dorsoplicathyris*. The specimens of Corroy (1932: pl. 29, figs. 4-6) have a rectimarginate anterior commissure and the shell shape and outline is identical with *Dorsoplicathyris* and, in our opinion, the specimens belong to *D. dorsoplicata*.

Interestingly, in Iran *Dorsoplicathyris* existed for a long time span, from the Hojedk Formation (Bajocian) to the Echellon Limestone Member of the Kamar-e-Mehdi Formation (Callovian). The specimens vary in size and anterior margin but all belong to a single species, *D. dorsoplicata*.

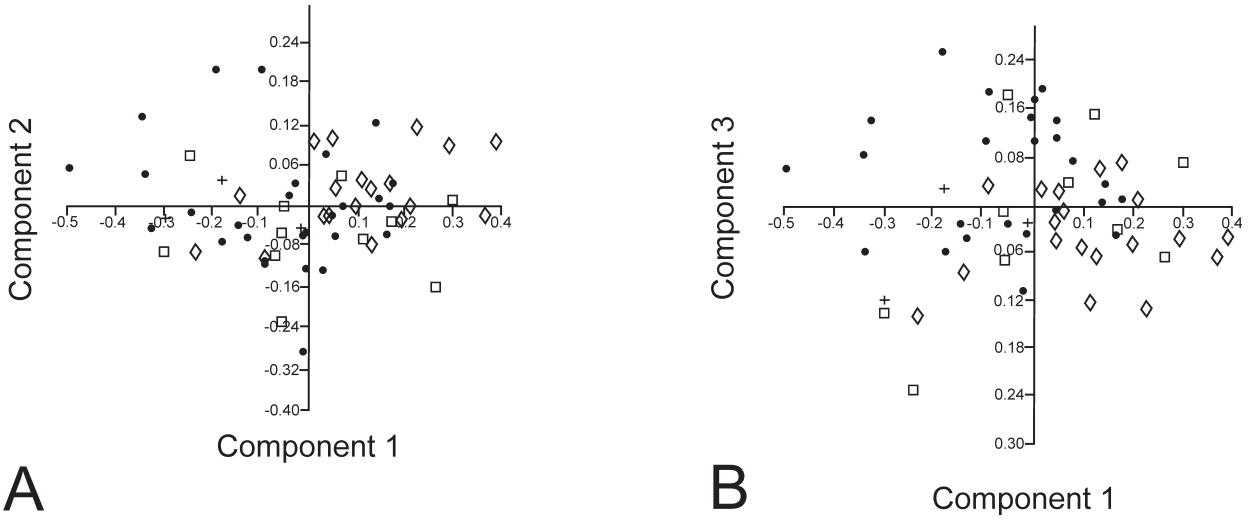
Dorsoplicathyris dorsoplicata
(Suess in Deslongchamps, 1859)

Pl. 1, Figs. 1-4

1859 *Terebratula dorsoplicata* (Suess, MS) – Deslongchamps: 17 (partim), pl. 1, figs. 5-7, 9-11, 13-14, 16-18 (non figs. 8, 12, 15).
1932 *Terebratula dorsoplicata* (Suess) – Corroy: 216, pl. 29, figs. 4-6.
1998 *Dorsoplicathyris dorsoplicata* (Deslongchamps 1856) – Alméras & Elmi: 49, pl. 4, fig. 3.
2004 *Dorsoplicathyris dorsoplicata* (Suess in Deslongchamps, 1856) – Vörös: 22, figs. 3, 6-8.

Material. One hundred-and-two specimens; 11 specimens from the basal Parvadeh Formation 7 km NNW of Khorow-pain (BSPG 2013VI 5), but mostly deformed (only three measured for statistics); 26 specimens from the Parvadeh Formation of Parvadeh area (b) (BSPG 2013VI 1-3, 6-8) and S of Sankhast, 9 specimens from the Baghamshah Formation at Kuh-e-Echellon, 28 specimens from the Echellon Limestone Member SE of Robat-e-Dahaneh (BSPG 2013VI 4, 12), only 11 of which with both valves preserved, and 40 specimens (19 measurable) from the Echellon Limestone Member S of Kuh-e-Bagh-e-Vang (BSPG 2013VI 4, 11, 13-14).

Description. Shell medium to large, the maximum length, width, and thickness being 46.18 mm, 35.01 mm, and 25.12 mm, respectively. Outline of adult shells elongated-oval to sub-pentagonal but sub-circular to semi-elliptical in earlier ontogeny. Position of maximum width generally in the anterior third of the length; ventri-biconvex. Lateral commissure straight at first then taking a gentle curve towards the ventral valve after the middle. Anterior commissure mostly uniplicate, but also broadly sulciplicate in some specimens. In the juvenile to intermediate stage (till L ~25 mm) the commissure is



Text-fig. 3. Scatter plot of principal component scores of *Dorsoplicathyris* from Iran. A. PC1 X PC2. B. PC1 X PC3. Plus symbol: specimens from the Hojedk Formation; solid circles: specimens from the Parvadeh Formation; squares: specimens from the Baghamshah Formation; diamonds: specimens from the Echellon Limestone Member.

Tab. 3. Principal component analysis of the *Dorsoplicathyris* population showing the eigenvalue (EV), percentage of variance explained by the component axes (PCT. VAR), and the loadings on the first three components. L: length of the shell; W: width; T: thickness; PMW: position of maximum width; PMT: position of maximum thickness; PW: plication width; PH: plication height. F: diameter of foramen; DV(L): Length of dorsal valve.

Components	EV	PCT. VAR	L	W	T	PMW	PMT	F	PW	PH	DV (L)
1	.035	57.5	0.335	0.235	0.346	0.290	0.231	0.322	0.366	0.484	0.323
2	.012	20.37	-0.213	-0.218	-0.177	-0.194	-0.199	-0.2	0.041	0.841	-0.22
3	.006	9.55	0.117	0.035	0.158	0.231	0.115	-0.91	0.247	0.051	0.093

rectimarginate. Beak sub-erect to erect and arising from a broad base, foramen circular, medium-sized, permesothyridid, beak ridges blunt.

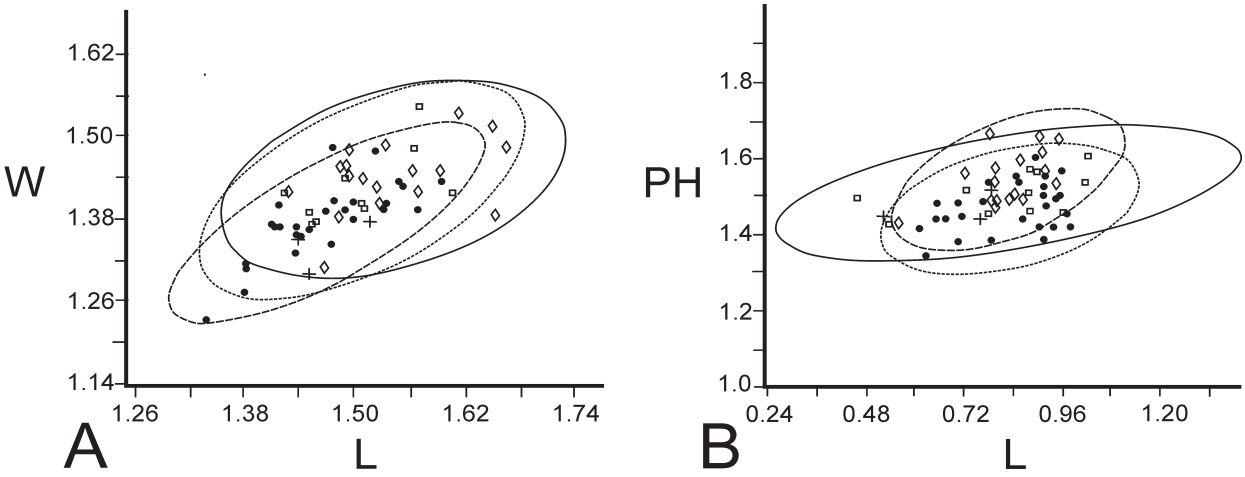
Ventral valve generally of uniform convexity except for the anterior third (to fifth) which is flattened to form a shallow sulcus that extends as a tongue to produce a uniplicate anterior margin, occasionally with a slight median indentation, to form a sulciplicate anterior commissure.

Dorsal valve somewhat flat with its maximum convexity in the posterior part, the umbonal region being occasionally swollen; anterior third with a very low incipient fold, in some specimens consisting of two plicae divided by a sinus near the margin.

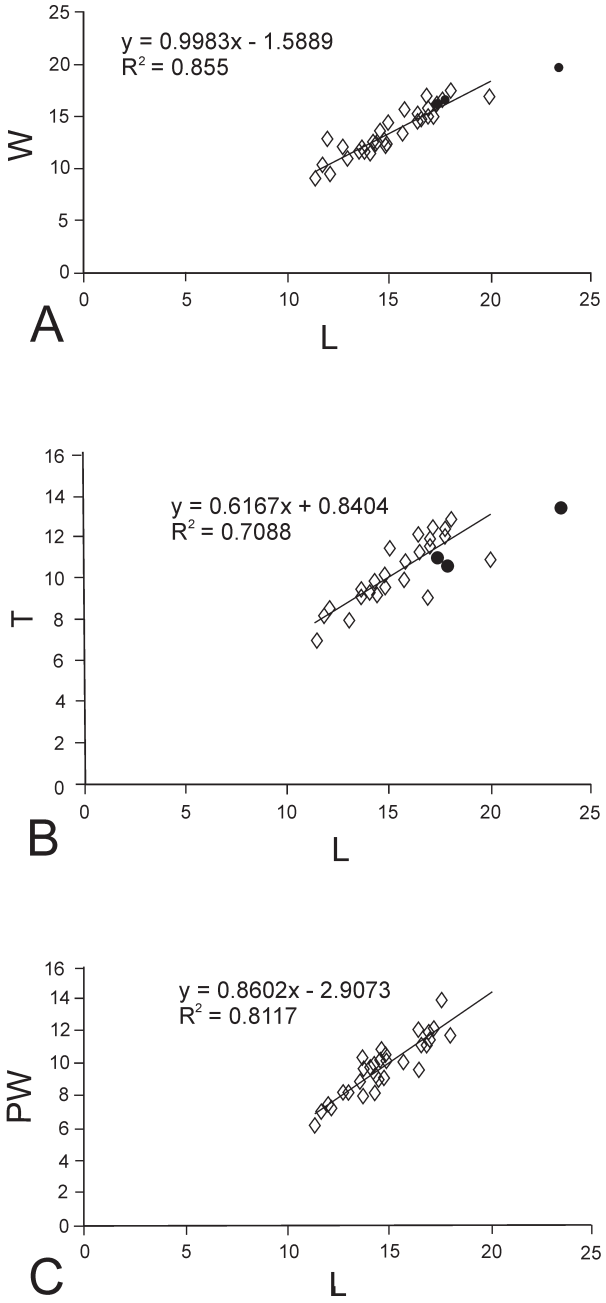
Remarks. *D. dorsoplicata*, the type species of the genus, has been recorded in western Europe and Asia from the Bathonian to Callovian (Cooper 1983; Vörös 2004). The studied material comes from the top of the Bajocian and continues to the Callovian. The material from the Upper Bajocian part of the Parvadeh Formation is slightly deformed and consists of relatively few specimens but in the higher part of the Parvadeh Formation, in the Baghamshah and in the basal Kamar-e-Mehdi Formation (Echellon Limestone Member) the number of specimens is larger. The mean size parameters of the *D. dorsoplicata* population in the four lithostratigraphic units are listed in Table 2.

The *Dorsoplicathyris dorsoplicata* assemblages of Iran span a considerable geological interval of about 5 m.y., from the Late Bajocian to Late Callovian. A Principle Component Analysis (PCA) was performed with the total assemblage, separating the specimens from the different formations in order to see whether any morphological discontinuities were present. Nine morphological parameters were measured in all specimens; shell length, dorsal valve length, width, thickness, position of maximum width, position of maximum thickness, foramen diameter, plication width, and plication height, and the raw data were log-transformed and then subjected to a PCA using PAST.

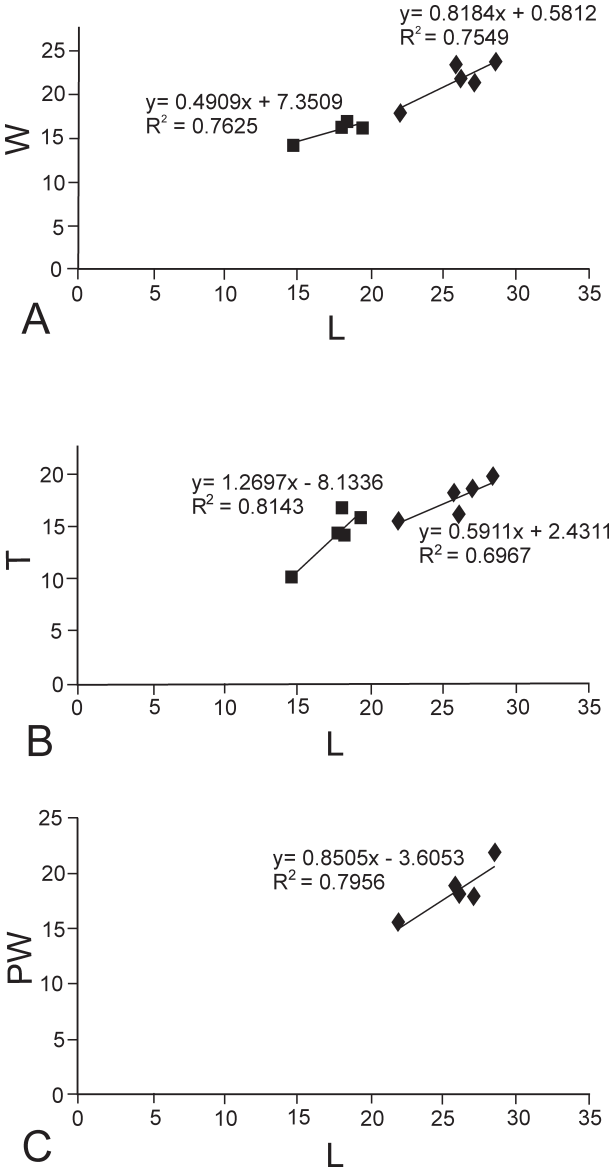
The first three components account for about 90% of the variability (Table 3), and PC1-PC2 and PC2-PC3 plots (Text-fig. 3) show a uniform scatter without any separation into clusters, which indicates the presence of a single species with a wide range of variation. The mean size of *D. dorsoplicata* shows an increase from the Parvadeh Formation to the Echellon Limestone Member. PC1 has a maximum loading on plication height and plication width (Table 3). Bivariate plots after log transformation of Length-Width and Length-Plication Height (Text-fig. 4) do not show any separation between groups and have an uniform scatter ascertaining that the populations from the Parvadeh Formation to the Echellon Limestone Member represent a single species.



Text-fig. 4. Bivariate scatter plots of Length (L) –Width (W) (A) and Length (L) – Plication height (PH) (B), with 95% probability ellipse of the *Dorsoplicathyris dorsoplicata* assemblage from Iran showing variation in size but uniform clustering with plication height. Plus symbol: specimens from the Hojedk Formation; solid circles: specimens from the Parvadeh Formation; squares: specimens from the Baghamshah Formation; diamonds: specimens from the Echellon Limestone Member.



Text-fig. 5. Bivariate scatter plots of (A) Length (L) –Width (W), (B) Length (L) –Thickness (T), and (C) Length (L) – Plication Width (PW) of *Tubithyris agapae* from Iran (diamonds). A comparison with three specimens of T. agapae from North Africa (dots) (Alméras & Faure, 2008) reveals the close correspondence of the populations.



Text-fig. 6. Bivariate scatter plots of (A) Length (L) –Width (W), (B) Length (L) – Thickness (T), and Length (L) – Plication Width (PW) (C) of *Conarothyris arabica* from Iran. A comparison with *C. arabica* from Saudi Arabia (Alméras et al., 2010) reveals close correspondence of the trend lines. Solid diamonds and squares denote the Iran and the Arabian specimens, respectively.

Vörös (2004) described *D. dorsoplicata* from the Upper Bathonian of Villany; they are of smaller size than the present populations from Iran and show incipient biplication. *D. dorsoplicata* (Corroy) from the Lower Callovian of France resembles the rectimarginate specimens of Iran. The assemblages from Iran are characterised by abundant forms with a uniplicate to incipiently sulciplicate anterior commissure.

Alméras & Elmi (1998) described *D. dorsoplicata* from the Middle Callovian of France, which is also pentagonal, uniplicate, and similar in size to the *Dorsoplicathyris* specimens from the Bathonian Baghamshah Formation.

Family Postepithyrididae Tchorszhevsky, 1974
Subfamily Postepithyridinae Tchorszhevsky, 1974
Genus *Moeschia* Boullier, 1976

Type species. *Terebratula alata* Rollet (1972).

Remarks. *Moeschia* is a common genus in the Upper Jurassic of France, Switzerland, Poland, and Romania. Adabi & Ager (1997) recorded it from the Mozduran Formation of the Koppeh Dagh (NE Iran). Cooper (1983) noted some similarity in the general aspect of the genus with *Dorsoplicathyris,* and the present study shows

Tab. 4. Mean shell parameters of *Tubithyris agapae* (de Gregorio, 1886) from the Parvadeh Formation of Iran compared with data from Algeria and Morocco from Alméras & Faure (2008). Given are mean values and ranges in brackets. N: number of specimens; L: length; W: width; T: thickness; PMW: position of maximum width; PMT: position of maximum thickness; PW: plication width; PH: plication height.

Locality	Reference	N	L	W	T	PMW	PW	PH
Iran	present study	45	15.45 (11.4–23.4)	13.82 (9.1–20)	10.43 (7.0–13.5)	10.21 (7.92–12.98)	9.77 (6.1–13.82)	3.09 (1.63–4.85)
Middle Atlas	Alméras & Faure (2008)	45	12.9 (9.3–18.3)	11.9 (8.4–16.4)	7.6 (5.0–11.8)	7.5 (5.0–10.8)	—	—
central High Atlas	Alméras & Faure (2008)	131	15,1 (10.2–9.6)	13.6 (8.7–18.1)	8.0 (5.3–11.5)	—	—	—

that the two genera co-occur in the Echellon Limestone Member and exhibit similarities in the beak and the circular, medium-sized, permesothyridid foramen. *Moeschia* is similar in shell shape and anterior margin to *Colosia*, Cooper, 1983 from the Kimmeridgian of Europe. In fact, the type species of *Colosia*, *Terebratula zieteni,* was originally placed by Boullier (1976) in *Moeschia,* but it is smaller. This similarity was also noted by Adabi & Ager (1997), but they mistakenly mentioned the species as *Loboidothyris zieteni,* which had been designated as the type species of the genus *Colosia* by Cooper (1983).

Moeschia alata (Rollet, 1972)

Pl. 1, Figs. 5-6

1972 *Terebratula alata* n. sp. – Rollet: 24, pl. 1, figs. 2-10; pl. 2, figs. 1-3 (=*Terebratula rollieri* auct. pars).

Material. Four adult specimens and 4 juveniles from the Echellon Limestone Member S of Kuh-e Bagh-e Vang (BSPG 2013VI 14-16).

Description. Moderately large, rounded-pentagonal shell, sub-circular in earlier ontogeny, attaining a maximum length of 35.43 mm, a width of 30.84 mm, and a thickness of 16.59 mm. Valves planoconvex or occasionally slightly biconvex and having a characteristically truncated anterior margin. Lateral commissure straight or gently curved and abruptly truncated beyond the position of maximum width to form the uniplication. The truncation becomes more prominent in the adult stage.

Beak short, sub-erect to occasionally incurved, massive; beak ridges rounded; foramen circular to oval, medium-sized, marginate and mesothyrid. Shell surface smooth.

Dorsal valve plane to weakly convex, umbonal area slightly swollen in some specimens; position of maximum width at the middle in earlier ontogeny but moving slightly to the anterior end in adult shells. Anterior margin plicated, in juvenile shells anterior commissure rectimarginate.

Ventral valve convex, in the anterior third the shell projects as a linguiform extension that increases in late ontogeny.

Remarks. Adabi & Ager (1997) described *M. subsella* from the Mozduran Formation of NE Iran. Their specimens are slightly larger, planoconvex and biconvex and have a weakly biplicate anterior commissure. Makridin (1964) described *M. subsella* from the Upper Oxfordian of the Russian Platform, which are also biplicate and weakly biconvex. *M. alata* from the Oxfordian of the Jura, France, described by Boullier (1976), is similar to the Iran specimens except that the present specimens are slightly smaller in size.

Genus *Moisseevia* Makridin, 1964

Type species. *Moisseevia sokolovi* Makridin, 1964.

Remarks. The genus is present in the Upper Jurassic of the Russian Platform, Caucausus, Crimea, and western Europe. Not much is known about the loop. As the present material from Iran is slightly deformed and may have undergone replacement, internal studies were not carried out. Apart from the type species *M. sokolovi* there are no other species in the genus.

Moisseevia sokolovi Makridin, 1964

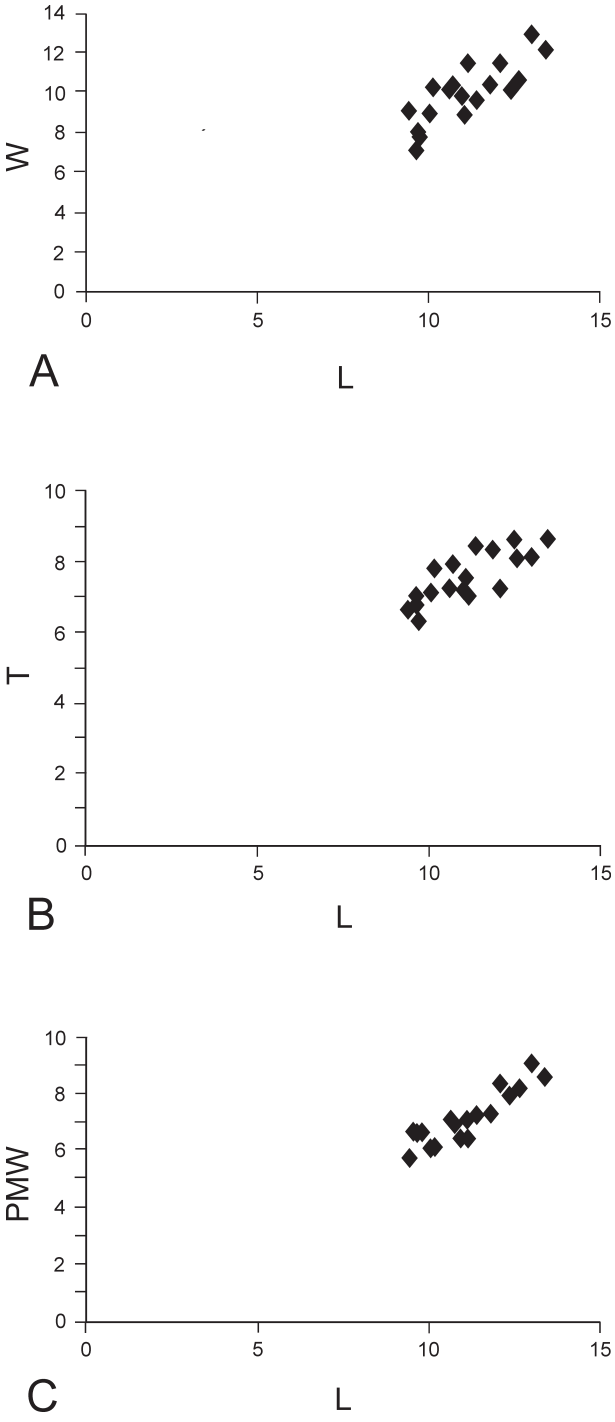
Pl. 1, Fig. 7

1964 *Moisseevia sokolovi* n. sp. – Makridin: 244; pl. 16, figs. 3,4.

Material. Six slightly deformed specimens from the Echellon Limestone Member S of Kuh-e-Bagh-e-Vang and SE of Robat-e-Dahaneh (BSPG2013VI 17-18).

Description. Medium in size, attaining a maximum length of 27.25 mm, a width of 25.1 mm, and a thickness of 16.27 mm. Shell sub-circular to elongated-oval, weakly biconvex. Lateral commissure gently curved and anterior commissure weakly plicated to rectimarginate. Beak strongly incurved in the adult stage but weakly incurved to sub-erect in earlier ontogeny. Foramen small, circular, mesothyrid, with weakly developed beak ridges.

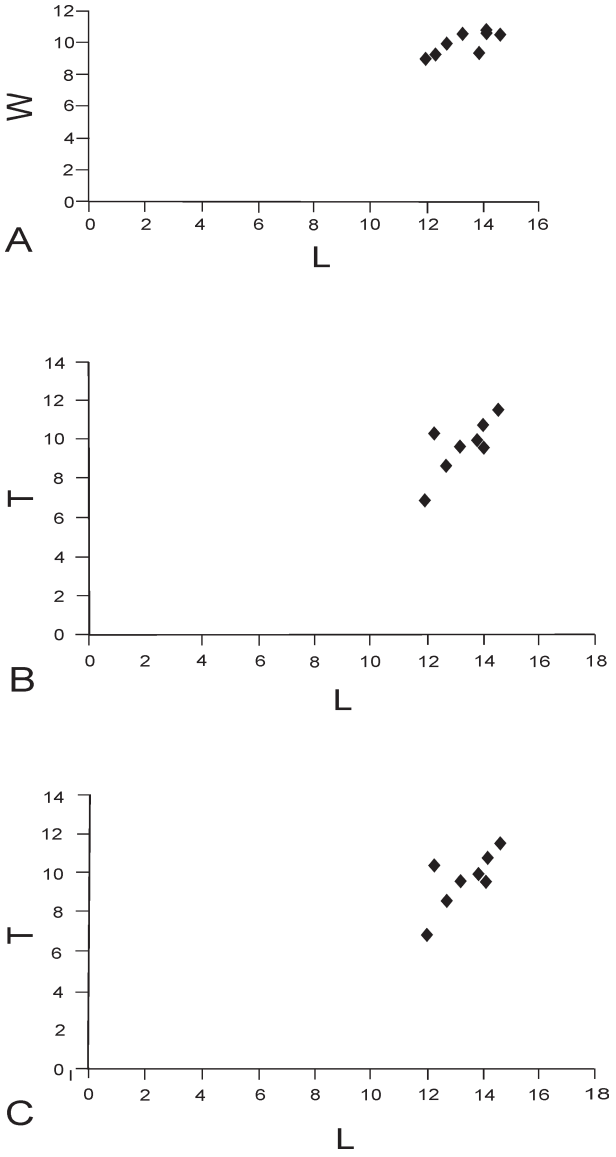
Dorsal valve weakly convex and occasionally plane, especially in young specimens; anterior margin having a wide, usually faintly developed plica or rectimarginate. Ventral valve strongly convex; anterior margin occasionally faintly extended to form the uniplicate commissure



Text-fig. 7. Bivariate scatter plots of (A) Length (L) –Width (W), (B) Length (L) – Thickness (T), and (C) Length (L) – Position of maximum width (PMW) of *Aulacothyris cucullata* from Iran.

or remaining straight. Surface smooth except for growth lines.

Remarks. *M. sokolovi* has been described by Makridin (1964) from the Oxfordian of Russia. The present material from Iran is similar except for its slightly smaller size and mesothyrid foramen.



Text-fig. 8. Bivariate scatter plots of (A) Length (L) –Width (W), (B) Length (L) – Thickness (T), and (C) Length (L) – Position of maximum width (PMW) of *Digonella* sp. from Iran.

Family Lobothyrididae Makridin, 1964
Subfamily Lophrothyridinae Cooper, 1983
Genus *Tubithyris* Buckman, 1918

Type species. *Terebratula wrighti* Davidson, 1854.

Remarks. The genus, originally described by Buckman (1918) from the Bajocian of England, has a wide geographic distribution and has also been recorded in Bajocian-Bathonian strata of France, Switzerland, Italy, Morocco, Egypt, Algeria, Kenya, Turkmenia, and Saudi Arabia. Alméras et al. (2010) described four species from the Bajocian-Bathonian of Arabia, *T. chouberti* Rousselle, 1965, *T. wylliei* (Weir, 1929), *T. aethiopica* (Weir, 1929), and *T. jurayfahiensis* Alméras, Cougnon, Énay & Mangold, 2010, differentiated mainly on the basis of the valve convexity, shell outline, and commissure. The ontogeny of *T. jurayfahiensis* shows a sub-circular, rectimarginate juvenile stage to sub-circular pentagonal sulciplicate adult stage (Alméras et al. 2010**:** pl.

Tab. 5. Shell parameters of *Conarothyris arabica* (Cooper, 1989) from Iran compared with other *Conarothyris* species. Given are mean values and ranges in brackets. N: number of specimens; L: length; W: width; T: thickness; PMW: position of maximum width; PMT: position of maximum thickness; PW: plication width; PH: plication height.

Reference	N	L	W	T	PMW	PMT	PW	PH	L/W	L/T
***Conarothyris* species**										
C .arabica (present work)	5	25.94 (21.96-28.58)	21.81 (18.07-23.82)	17.76 (15.75-19.92)	16.55	12.56	18.46	8.55	1.18	1.46
C. arabica of Alméras et al. (2010)	5	18.42	16.7	14.53	11.6				1.1	1.27
C. opima Cooper, 1983		25.52	21.52	18.5					1.19	1.38
C. roussellae Alméras & Moulan, 1988		16.8	15.64	12.91					1.3	1.30

10, figs. 5-11**)** but there are some specimens (pl. 10, figs. 7, 8) that have a uniplicate stage and an almost straight lateral commissure at an increased length (adult stage). *Loboidothyris* (?) *jubaensis* Weir (1930: 47, pl. 5, figs. 11, 14), which has been synonymised with *T. jurayfahiensis* by Alméras et al. (2010), when observed carefully, shows a more pronounced biplication than is characteristic of *Tubithyris*. Alméras & Faure (2008) also described four species, *T. chouberti, T. whatleyensis*, *T. wrighti,* and *T. agapae*, from the Bajocian-Bathonian of Morocco and Algeria, the last being present in the Parvadeh Formation of Iran.

Tubithyris agapae (de Gregorio, 1886)

Pl. 1, Fig. 8

1886 *Terebratula agapae* n. sp. – de Gregorio: 17, pl. 2, fig. 38.
1965 *Charltonithyris*? sp. – Rousselle: 79, pl. 8, figs. 11-14.
2008 *Tubithyris agapae* de Gregorio – Alméras & Faure: 698, pl. 12, fig. 16, pl. 13, figs. 3-4.

Material. Fourty-nine specimens from the Parvadeh Formation of the Parvadeh area (a) (BSPG2013VI 26), Parvadeh area (b) (BSPG2013VI 27, 29) and N of Shurabi (BSPG2013VI 25).

Description. Small, globular, with sub-circular shell outline and strongly biconvex valves with sub-equal convexity. Maximum size dimensions: length 23.4 mm, width 20 mm, and thickness 13.5 mm. Shell width less variable during ontogeny than shell thickness. Position of maximum width and thickness mostly at mid-valve or slightly posterior of it. Lateral commissure nearly straight, and anterior commissure rectimarginate to uniplicate. Beak short, sub-erect and mostly in contact with the dorsal umbo obscuring the symphytium. Foramen small, mesothyrid to sub-mesothyrid, beak ridges subangular.

Dorsal valve slightly swollen near the umbo, convexity slightly lower than that of the ventral valve, forming a broad plica restricted to the anterior margin, occasionally rectimarginate. The uniplication never attains much height (at most 4.85 mm) and the plica is broad and circular (mean: 9.77 mm, maximum: 13.82 mm). Of the 45 specimens measured nine had a plication height of less than 1 mm or a straight commissure. The plication height is not correlatable with shell length as the maximum plication height (4.85 mm) is attained by a specimen with a length of 16. 64 mm. Ventral valve slightly projected to form a linguiform extension, which is variable but never very long.

Remarks. *T. agapae* is characterised by a small size (Table 4). The population from Iran is comparable in size to the assemblages from the Middle and High Atlas of Morocco and Algeria (Alméras & Faure 2008: tables 46-47). A bivariate scatter plot of Length-Width and Length-Thickness (Text-fig. 5) of *T. agapae* from Iran together with the three specimens of Alméras & Faure (2008) revealed a good correlation and show an allometric increase of the plication width during ontogeny. *T. agapae* is easily differentiated from *T. wrightii* (Davidson, 1854) by its low uniplicate anterior commissure which is rectimarginate during early ontogeny (Alméras & Faure 2008: pl. 12, figs. 15,16, pl. 13, figs. 1-4).

Family Postepithyrididae Tchorszhevsky, 1974
Genus *Conarothyris* Cooper, 1983

Type species. *Conarothyris opima* Cooper, 1983.

Conarothyris arabica (Cooper, 1989)

Pl. 1, Fig. 9

1989 *Toxonelasma arabicum* nov. sp. – Cooper: 96, pl. 24, figs. 17-23.
2010 *Conarothyris arabicum* (Cooper) – Alméras et al.: 81, pl. 12, figs. 11-12.

Material. Five specimens from the Parvadeh Formation of the Parvadeh area (b) (BSPG2013VI 19-21).

Description. Medium-sized specimens attaining up to 28.58 mm in length, 23.82 mm in width, and 19.92 mm in thickness, with length slightly greater than width

Tab. 6. Shell parameters of *Arabatia africana* (Weir, 1929) from Iran compared with data from Saudi Arabia. Given are mean values and ranges in brackets. N: number of specimens; L: length; W: width; T: thickness; PMW: position of maximum width; PW: plication width; PH: plication height.

Reference	N	L	W	T	PMW	PW	PH
present work	3	35.5 (29.51-39.8)	26.75 (23.37-29.45)	23.33 (18.75-25.76)	24.55 (20.51-26.21)	16.94 (16.28-17.47)	8.21 (6.62-10.14)
Alméras et al. (2010)	11	29.1 (19.1-38.8)	24.1 (17.3-30.5)	18.6 (14.2-26.5)	18.5 (13.4-25)	9.2 (6.7-13.5)	3.7 (1.5-6.5)

(mean L/W=1.18). Outline rounded sub-pentagonal, valves unequally biconvex. Position of maximum width lying anteriorly to the middle, and maximum thickness in the posterior third of the valve. Lateral commissure gently curved at first and then forming an angle near the anterior margin. Anterior commissure biplicate, the plications divided by a shallow sinus. Beak short, rounded, sub-erect to erect with a large circular foramen. Shell smooth with fine commarginal and radial lines.

Dorsal valve unequally convex in side view, bulging near the umbo; in anterior view forming a strongly arched dome with sloping sides. At one-third of shell length from the anterior margin, two narrow ridges develop, separated by a furrow that forms the biplicate anterior margin. The plica is short and rounded (mean PW: 18.46, PH:8.55), plication length and height correlates with size. Ventral valve strongly and uniformly convex in side view; anterior third projected like a tongue with a median ridge corresponding to the median sinus in the dorsal anterior margin.

Remarks. The specimens from Iran are larger in size than the population from Saudi Arabia and also have a more globular dorsal valve (L/T is greater in the population from Iran). The L-W and L-T plots of *C. arabica* from the two areas reveal good correlation and matching of the trendlines (Text-fig. 6). Shell width, thickness, and plication width show an allometric increase during ontogeny (Text-fig. 6).

C. arabica is similar in size to the type species *C. opima*, but differs in shell outline and anterior plication. The shell parameters are comparable (Table 5) but *C. arabica* has a sharper outline and more angular plication in contrast to the rounded sub-pentagonal outline and rounded plication of *C. opima*. The position of maximum width is also more anterior in the latter. *C. roussellae* Alméras & Moulan 1988 is much smaller in size (Table 5). Another *Conarothyris* species, *C. eudesiana* (Buckman in Davidson, 1884) from the Lower Bajocian of Algeria (Alméras & Faure 2008), is a much smaller but strongly biplicate form.

Genus *Somalithyris* Muir-Wood, 1935

Type species. *Somalithyris macfaydeni* Muir-Wood, 1935.

Somalithyris subcircularis Cooper, 1989

Pl. 1, Figs. 10-11

1989 *Somalithyris subcircularis* n. sp. – Cooper 1989: 89, pl. 29, figs. 8-14.

Material. Two specimens from the Echellon Limestone Member W of Kuh-e-Echellon (BSPG2013VI 23) and SE of Robat-e-Dahaneh (BSPG2013VI 24).

Description. Shell large (L: 36.47 mm, W: 31.61 mm, T: 20.61 mm), sub-circular to rounded-oval, biconvex. Position of maximum width slightly anterior to the middle in adults, lateral commissure with a wide curve, anterior commissure rectimarginate to marginally sulciplicate. Beak short, erect with a large base, foramen fairly large (F: 3.92 mm), mesothyrid.

Dorsal valve weakly convex, convexity increasing during ontogeny, younger shell nearly planoconvex, broadly arched with rounded sides in anterior view; anterior commissure forming a wide, indistinct fold; rectimarginate in early ontogeny.

Ventral valve moderately convex, slightly more so near umbo; valve swollen in the umbonal area up to the mesial region then flattening anteriorly; tongue short.

Remarks. The species differs from other somalithyrids by its larger size and circular valve outline. The anterior plication is also much less developed in *S. subcircularis*. The Arabian assemblage is slightly smaller in size and the anterior plication is more developed. Due to the paucity of specimen in the present collection a statistical comparison was not possible. The present material is from the Callovian whereas the material from Saudi Arabia is Kimmeridgian in age.

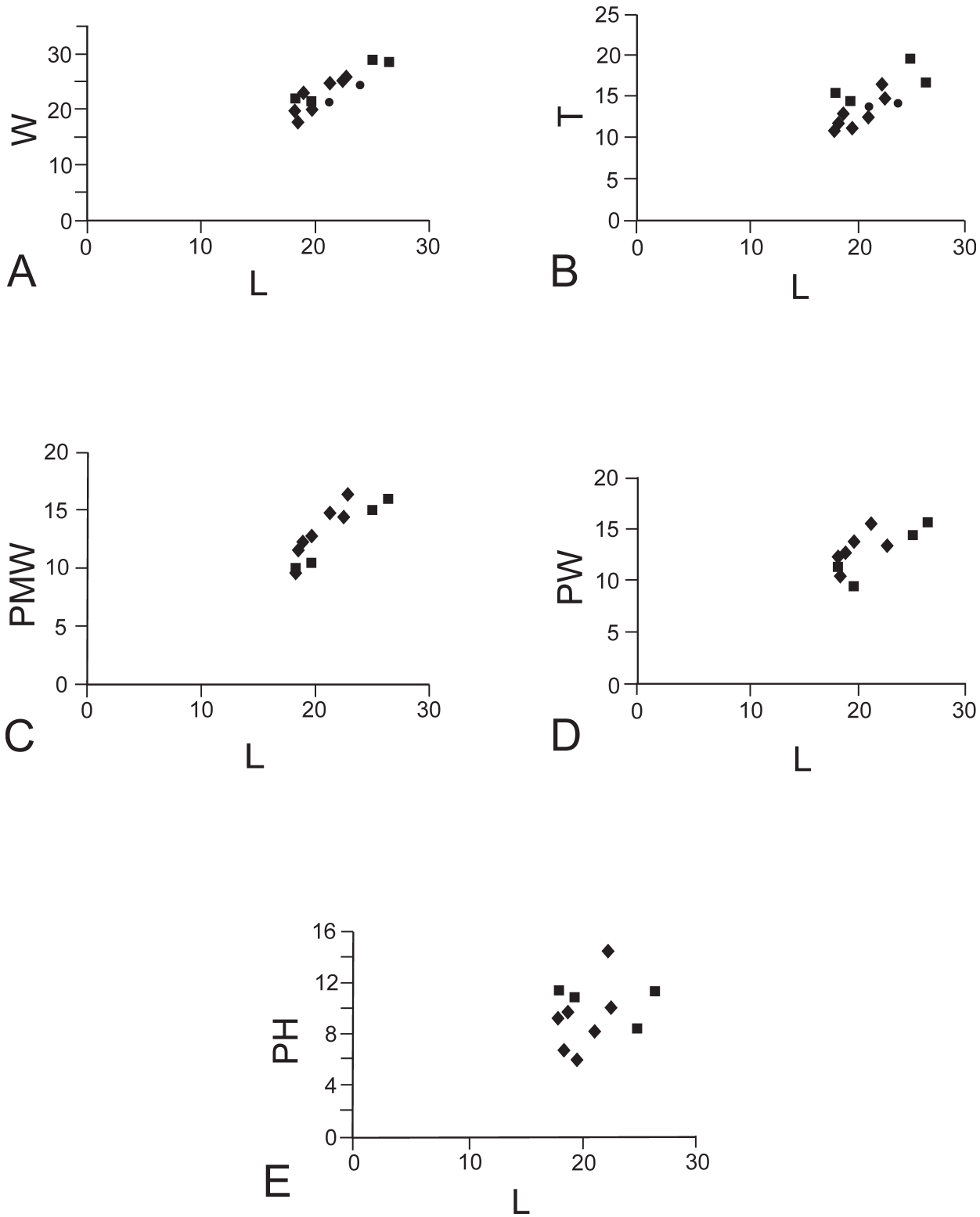
Family Loboidothyrididae Makridin, 1964
SubfamilyLoboidothyridinae Makridin, 1964
Genus *Arabatia* Cooper, 1989

Type species. *Arabiata concava* Cooper, 1989.

Arabatia africana (Weir, 1929)

Pl. 1, Figs. 12-13

1929 *Charltonithyris africana* n. sp. – Weir: 43, pl. 5, fig. 3.
1929 *Charltonithyris africana* Weir, var. –Weir: 43, pl. 5, fig. 4 [= miniaturised form].
1935 *Charltonithyris? africana* Weir – Muir-Wood: 116; text-fig. 15.
2010 *Arabatia africana* (Weir) – Alméras et al.: 63, pl. 7, figs. 4-7.



Text-fig. 9. Bivariate scatter plots of (A) Length (L) – Width (W), (B) Length (L) – Thickness (T), (C) Length (L) – Plication Width (PW), and (D) Length (L) – Plication Height (PH) of *Cardinirhynchia surrecta* from Iran (diamonds), *C. surrecta* (squares), and *C. rotundata* (dots). The data for the latter two species are from Seiffert (1963).

Material. Five specimens from the Echellon Limestone Member, 2 from W of Kuh-e-Echellon (BSPG2013 VI 30), 3 from S of Kuh-e-Bagh-e-Vang (BSPG2013 VI 31, 32). One specimen slightly deformed and all specimens slightly broken near the beak except one.

Description. Shell moderately large, maximum shell dimensions 39.31 mm (length), 29.45 mm (width), and 25.76 mm (thickness) (mean values: L: 35.67, W: 26.75, T: 23.33). Shell sub-pentagonal, unequally biconvex; position of maximum width anterior of the middle, maximum thickness in the posterior third. Lateral commis-

sure forming a wide curve in the beginning that takes an angular bend, not very sharp, near the anterior. Anterior commissure uniplicate to sulciplicate with moderately sharp plications divided by a shallow sinus (mean PW: 21.83, PH: 10.14) . Beak broadly rounded, massive, moderately incurved; foramen large, symphytium hidden. Surface with growth lines and radial striae.

Dorsal valve less convex than the ventral valve, convexity increasing during ontogeny; just after the mid-length the valve is raised into a fold, bordered generally by two moderately sharp, diverging plicae separated by a shallow sinus, but in some specimens the plications are not developed thereby an uniplicate commissure is formed.

Ventral valve strongly convex, the anterior part extended as a linguiform projection. Occasionally an inconspicuous median ridge is present near the margin, corresponding to the dorsal median sinus.

Remarks. The type species *A. concava* differs from *A. africana* in its triangular outline, anteriorly shifted position of maximum width, widely sulciplicate commissure, and posterior flattening of the dorsal valve. The Iran assemblage is larger in size than the *A. africana* from Arabia described by Alméras et al. (2010), and the plica is also slightly larger than in the Arabian specimens from Jubaland (Table 6), but the ratio between plica-height and width is similar; 0.48 in Iran and 0.39 in Arabia (Alméras et al. 2010). The Jubaland specimens are also smaller in size and the holotype is an immature specimen (Alméras et al. 2010). The species exhibits some similarity with the genus *Bihenithyris* as was also noted by Cooper (1989) when describing the genus *Arabatia*. He, however, differentiated it on the basis of the pentagonal shell outline and the narrow, widely divergent adductor muscle scars of *Bihenithyris*. *A. africana* also shares a similar sub-pentagonal outline but can be differentiated by the convexity of the dorsal valve which is almost flat in *Bihenithyris*. The adductor muscle scar as seen in one of the specimens from Iran is long, narrow, and diverges at a very low angle.

Ectyphoria inflata Cooper, 1989, which was included by Alméras et al. (2010) in the present species, is more sphaeroidal and has a distinct sulcate dorsal umbo and carinated ventral umbo which is never seen in *A. africana.*

Suborder Terebratellidina Muir-Wood, 1955
Superfamily Zeillerioidea Allan, 1940
Family Zeilleriidae Allan, 1940
Subfamily Zelleriinae Allan, 1940
Genus *Aulacothyris* Douvillé, 1879

Type species. *Aulacothyris resupinata* (J. Sowerby, 1816).

Aulacothyris cucullata Buckman, 1910

Pl. 2, Figs. 1-2

1910 *Aulacothyris cucullata* n. sp. – Buckman: 102, pl. 12, figs. 1, 2.
1936 *Aulacothyris cucullata* Buckman – Muir Wood: 105, pl. 2, fig. 1a-c, text-fig. 4c.

Material. Twenty-two specimens from the Parvadeh Formation a few km N of Shurabi (Parvadeh area) (7 specimens; BSPG2013VI 36) and 15 specimens from the Parvadeh area (a) and (b) (BSPG2013VI 33-35, 37).

Description. Shell small, with a mean length of 11.17 mm, width of 10.1 mm, and thickness of 7.67 mm. Outline sub-rounded, elliptical to sub-pentagonal in adults and sub-circular in early ontogeny; position of maximum width at the middle or shifted slightly anteriorly. Ventral valve strongly convex, dorsal valve weakly convex to plane in the posterior and concave in the anterior half. Lateral margin curved, convex; anterior margin unisulcate. The dorsal valve is thinly sulcate posteriorly, near the umbo, the sulcus becoming prominent near the anterior margin. It runs mesially dividing the valve into two halves; it is a faint line in juveniles, but becomes prominent in adults and disappears in the anterior third forming the sulcus which is broad and shallow. The pedicle valve has a sharp carina that forms a low median fold with gently sloping sides. Beak narrow, incurved, beak ridges long and sharp, palintrope well developed; foramen small, permesothyrid.

Remarks. The specimens from Iran come from the Bathonian and the L-W, L-T and L-PMW plots show a homogeneous scatter (Text-fig. 7). *A. resupinata* (J. Sowerby, 1816), the type species, is a common Liassic species found in the Pliensbachian of England and France and has been recorded in the Lower Jurassic of Spain, Slovakia, and Turkey. It shows a wide range of morphological variation but is restricted to the Liassic. Ager (1959) and Ager et al. (1980) described *A.* cf. *resupinata* from the Liassic of Turkey. These specimens, which are slightly smaller, have a smaller dorsal fold and do not have the sharp groove in the dorsal valve. The specimens from Iran also do not have the 'sharp groove', characteristic of *A. resupinata*, but have a faint posterior dorsal sinus that enlarges to form a conspicuous dorsal sinus near the commissure. This character has been noted in a little known aulacothyrid, *A. cucullata,* from the Bathonian of England (Muir Wood 1936). It is a small form, comparable in size to the present population, characterised by a similar type of folding in the carinate ventral valve and also with a small dorsal sinus. The umbonal character is also similar, both characterised by a small umbo and foramen and long, sharp beak ridges. Muir Wood (1936), however, expressed doubts regarding the generic assignment because *A. resupinata* is a middle Liassis species, but she also states that the species is similar to other aulacothyrids, such as *A. meriani* (Oppel, 1858) and *A. bernardiana* (d'Orbigny, 1850). The *Aulacothyris* clade is in a state of flux and includes species from the Middle Triassic to Upper Jurassic. It is in needs of serious revision.

Tab. 7. Shell parameters of *Digonella* sp. from Iran. Given are mean values and ranges (in brackets). N: number of specimens; L: length; W: width; T: thickness; PMW: position of maximum width

N	L	W	T	PMW	L/W	L/T	L/PMW
8	13.36 (11.98-14.6)	9.86 (8.2-10.85)	9.69 (6.87-11.56	11.29 (9.95-12.69	1.35	1.38	1.18

Suborder Terebratellidina Muir-Wood, 1955
Superfamily Zeillerioidea Allan, 1940
Family Zeilleriidae Allan, 1940
Subfamily Zelleriinae Allan, 1940

Genus *Digonella* Muir Wood, 1934

Type species. *Digonella digona* (J. Sowerby, 1815).

Digonella sp. A

Pl. 2, Figs. 3-4

Material. Eleven specimens; 4 from the Kamar-e-Mehdi Formation of the Kamar-e-Mehdi area (BSPG2013VI 38-40), 3 from the Echellon Limestrone Member W of Kuh-e-Echellon (BSPG2013VI 41), and 4 from the uppermost Baghamshah Formation of the Kamar-e-Mehdi area (BSPG2013VI 42).

Diagnosis. Small trigonal *Digonella* with low dorsal valve thickness and strongly convex ventral valve bearing a sharp carina.

Description. Shell small (mean L: 13.36 mm, W: 9.86 mm, T: 9.69 mm), outline elongated, trigonal to subtrigonal in adults but sub-oval in juveniles; valve thickness differing much between the two valves. Ventral valve strongly convex, arched, dorsal valve thin, weakly convex in the posterior part and slightly concave in the anterior; position of maximum width near the anterior margin (L/PMW: 1.18) (Table 7, Fig. 8). Shell sulco-carinate in early ontogeny. Lateral commissure curved, anterolateral extremities with angular carina. Anterior commissure straight or slightly arched dorsally. Occasionally, a small sulcus is present medially, forming a short biplication. Ventral valve strongly carinated in the posterior fourth and arched in the middle bordered by two carinae with sharply sloping sides. Dorsal umbo flattened, ventral umbo gently curved, beak slender, sub-erect to slightly incurved, with short, angular beak ridges. Foramen small, permesothyrid.

Remarks. *Digonella* sp. A is readily distinguished from other *Digonella* species by its much smaller size and the nature of valve convexity. Though only few specimens are available they appear in three stratigraphic units, from the Bathonian to Callovian, without showing any difference in size. Variability is shown regarding the dorsal valve convexity and the anterior commissure.

The type species, *D. digona* (J. Sowerby, 1815), is of medium size and the dorsal valve is more convex (Muir Wood 1934) and thus slightly differs from the present specimens. Corroy (1932) described *Zeilleria digona*, a paper that has not been mentioned by Muir Wood (1934) when erecting the genus, which has a similar shell outline, convexity, commissure and also the presence of an angular carina in the anterolateral extremities and thus should belong to *D. digona*. The species is not restricted to the Upper Bathonian but a few specimens have been found also in the Lower Callovian. Feldman et al. (2001) described *D. boylani* from the Upper Callovian of Israel, which is more biconvex and the position of maximum width is at the middle unlike in *D. digona* and the Iranian taxon. But in both *D. boylani* and the species from Iran, the width is nearly equal to thickness.

Superfamily Hemithiridoidea Rzhonsnitskaia, 1956
Family Tetrarhynchiidae Ager, 1965
Subfamily Gibbirhynchiinae Mancenido et al., 2002

Genus *Burmirhynchia* Buckman, 1918

Type species. *Burmirhynchia gutta* Buckman, 1918.

Burmirhynchia athiensis Rousselle, 1965

Pl. 2, Figs. 5-6

pars 1965 *Burmirhynchia* ? *termierae* n. sp. – Rousselle: 37, pl. 1, figs. 6-9, 11-18, pl. 2, figs. 1-8 only (see Almèras et al. 2010 for details).
1965 *Burmirhynchia* ? *termierae athiensis* n. subsp. – Rousselle: 48, pl. 3, figs. 1-5, 8-13.
2007 *Burmirhynchia athiensis* Rousselle – Alméras et al.: 8, fig. 5 (12-14).
2010 *Burmirhynchia athiensis* Rousselle – Alméras et al.: 32, pl. 3, figs. 1-6.

Material. 42 specimens from the top Hojedk Formation near Kharavan-pain (BSPG2013VI 48-50) and 2 broken valves from the Parvadeh Formation N of Shurabi (BSPG2013VI 51); 12 measured for statistics.

Description. Shell small, rounded-triangular in outline, sub-circular in early ontogeny; strongly dorsi-biconvex, position of maximum width slightly anterior of the midpoint. Valve margins broadly rounded; lateral commissure slightly oblique, anterior commissure uniplicate. Beak long, sharply pointed, erect to slightly incurved; foramen elliptical, medium-sized, with marginal rim. Costae strong, moderately angular, closely spaced.

Dorsal valve strongly convex, valve thick, swollen, roundly arched with steep sides in anterior profile; dorsal fold poorly defined, attaining strength near the anterior margin with variable height.

Ventral valve weakly convex, median sulcus starting from mid-valve, shallow, extended as a linguiform projection in the dorsal margin.

Tab. 8. Shell parameters of *Burmirhynchia athiensis* Rousselle, 1965 and *B. parva* (Cooper, 1989) from Iran compared with data from Saudi Arabia. Given are mean values with ranges in brackets. N: number of specimens; L: length; W: width; T: thickness; PMW: position of maximum width; PW: plication width; PH: plication heigh

Locality	Reference	N	L	W	T	PMW	L/W	PW	PH
Iran	present study	7	20.31 (18.19-22.7)	22.73 (17.82-25.83)	13.20 (10.86-16.44)	13.12 (9.47-16.32)	0.89	12.90 (10.58-15.6)	9.81 (6.15-14.59)
Saudi Arabia	Cooper (1989)	4	22.33 (18.2-26.5)	25.25 (21.5-29)	16.5 (14.4-19.6)		0.88	12.8 (9.5-15.8)	10.63 (8.5-11.5)
Sinai	Feldman et al. (2012)	2	22.55	23.3	14.35		0.97		

Remarks. Alméras et al. (2010) clubbed the genus *Eurysites* (Cooper, 1989) with this species, though it has a rounded triangular outline and much fewer costae, because according to them the genus was similar to *B. termierae* s.s., internally. But the internal characters such as dental lamellae and septalium show a wide range of variation in *Burmirhynchia* (compare Shi & Grant 1993: 61, figs. 38-43; Cooper 1989: figs. 17-18; Alméras et al. 2010: fig. H.t. 4). Alméras et al. (2010) also commented that the "genus *Burmirhynchia* corresponds to all forms having early uniplicate stage", which is also a character noted in the ontogeny of the majority of the rhynchonellids that have a strongly uniplicate adult stage. Shi & Grant (1993) suggested that the *B. termierae* and *B. preathiensis* groups may belong to *Baeorhynchia* Cooper, 1989, but the latter is a smaller form with more strongly developed plication and closely spaced costae than the present specimens. The assemblage from Iran exhibits variability in valve thickness and beak incurvature. It is similar to the *B. athiensis* from Saudi Arabia described by Alméras et al. (2010), except being slightly smaller in size, with more costae and occasionally a broader beak angle (Table 8). It differs from *B. parva* (Cooper, 1989), which is also present in Iran, mainly in the shell outline, beak and number of costae.

Burmirhynchia parva (Cooper, 1989)

Pl. 2, Figs. 7-8

1989 *Gibbirhynchia parva* n. sp. – Cooper: 36, pl. 9, figs. 37-42.
2010 *Burmirhynchia parva* (Cooper, 1989) – Alméras et al.: 39, pl. 4, figs.1-4.

Material. Ten specimens from the top Hojdek Formation near Kharavan-pain (BSPG2013VI 54) and the Parvadeh Formation of the Parvadeh area (b) and N of Shurabi (BSPG2013VI 52-53, 55).

Description. Shell small, sub-circular, dorsi-biconvex, sphaeroidal, position of maximum width and thickness almost at mid-valve. Lateral commissure oblique, anterior commissure uniplicate. Beak small, sharp, erect, foramen small. Numerous costae with slightly rounded crest, numbering 25-30 in each valve.

Dorsal valve strongly convex, bulging in lateral profile, rounded-arched in anterior profile, fold poorly defined, seen only at the anterior commissure. Ventral valve weakly convex, sulcus shallow, prominent only at the anterior margin.

Remarks. The specimens from Iran are mostly similar to the population from Arabia described by Cooper (1989) and Alméras et al. (2010). Compared to the Iran specimens, the specimen figured by Cooper (1989) has a slightly deeper sulcus and weakly incurved beak (Cooper 1989: pl. 9, figs. 38-42). The specimens from Iran co-occur with *B. athiensis* in the Hojedk and Parvadeh formations but can be readily differentiated by their smaller size, the sphaeroidal shape, and an ornamentation pattern that is denser and less angular.

Superfamily Hemithyridoidea Rzhonsnitskaia, 1956

Family Cyclothyrididae Makridin, 1955

Subfamily Cardinirhynchiinae Makridin, 1964

Genus *Cardinirhynchia* Buckman, 1918

Type species. *Cardinirhynchia acuticosta* (Hehl, 1832).

Cardinirhynchia surrecta Seiffert, 1963

Pl. 2, Fig. 9

1963 *Cardinirhynchia surrecta* n. sp. – Seiffert; 166, pl. 10, fig. 3.
1963 *Cardinirhynchia rotundata* n. sp. – Seiffert; 166, pl. 10, fig. 4.

Material. Twelve specimens, 11 from the Parvadeh Formation of the Kamar-e-Mehdi area (BSPG2013VI 56-57) and 1 from the basal Baghamshah Formation at N 33° 04' 11", E 56° 28' 06" (BSPG2013VI 58). Seven specimens could be used for statistics.

Description. Shell medium-sized (maximum values: L: 25.75, W: 33.24, T: 15.85), wider than long, low valve thickness, equi-biconvex to dorsi-biconvex with subcircular outline. Position of maximum width posterior of middle or at the middle of the shell. Hinge line nearly straight and long, beak erect to sub-erect, foramen of medium size.

Dorsal valve weakly to moderately convex, with a wide and straight posterior margin, broadening at the lateral flanks. Anterior commissure incipiently uniplicate, plica broad and with low height. Ventral valve weakly convex,

Tab. 9. Shell parameters of *Daghanirhynchia anguloscostata* Cooper, 1989 from Iran compared with data from Saudi Arabia and Sinai. Given are mean values with ranges in brackets. N: number of specimens; L: length; W: width; T: thickness; PMW: position of maximum width; PW: plication width; PH: plication height.

Species/ locality	Reference	N	L	W	T	PMW	PW	PH
B. athiensis Iran	Present study	12	18.72 (15.4-22.0)	18.45 (15.8-21.7)	11.68 (9-17.2)	11.93 (9.8-14)	10.41 (8.5-12.3)	5.44 (2.7-8.9)
B. athiensis S. Arabia	Alméras et al. 2010	36	16.3 (10.3-23.2)	15.6 (9.8-21.8)	11.0 (6.1-18.7)	11.3 (7.4-16.7)	9.6 (4.8-14.5)	5.2 (2.0-10.3)
B. parva Iran	Present study	7	15.83 (13.5-17.3)	15.67 (12-17.6)	11.74 (10.04-13.9)	10.44 (8.3-12.35)	9.12 (7.8-10.01)	4.67 (4.1-5.7)
B. parva S. Arabia	Alméras et al. 2010	26	13.1 (8.3-20)	13.6 (7.8-19)	11 (5.4-18.2)	8.6 (5.8-13)	8.1 (4-11.2)	6.2 (2.4-10.8)

with a shallow sulcus forming at the median part and with the flanks curving slightly towards the dorsal valve. Tongue slightly projected at the anterior commissure.

Coarsely costate throughout, costae sharp and angular, in some specimens incipient spines can be seen at intersection points with growth lamellae.

Remarks. The specimens from the Parvadeh and Baghamshah formations are similar to *Cardinirhynchia surrecta* and *C. rotundata* described from the Bifurkaten-Oolith, Middle Jurassic, by Seiffert (1963). A bivariate scatter plot of L, W, and T of the present specimens and of the holotype of Seiffert (1963) reveals good correlation (Text-fig. 9). The width of the plication is not related to ontogenetic size increase but the plication height shows an allometric increase with growth (Text-fig. 9C, D). The two species *C. surrecta* and *C. rotundata* have similar outline, valve convexity, and umbo and were differentiated by Seiffert on the basis of a slight difference in ornamentation, *C. surrecta* having slightly rounded costae and *C. rotundata* having angular costae. The assemblage from Iran varies with respect to the plication and valve convexity. Intermediate variants indicate that it belongs to a single species. Therefore, *C. surrecta* and *C. rotundata* are clubbed in a single species, with *C. surrecta* having line priority.

Subfamily Tetrarhynchiinae Ager, 1965

Genus *Daghanirhynchia* Muir-Wood, 1935

Type species. *Daghanirhynchia daghaniensis* Muir Wood, 1935.

Daghanirhynchia angulocostata Cooper, 1989

Pl. 2, Fig. 10

1989 *Daghanirhynchia angulocostata* n. sp. – Cooper: 26, pl. 6, figs. 1-19, pl. 7, figs. 44-53, pl. 11, figs. 16-21, text-figs. 13, 14.

Material. Six specimens, four from the Parvadeh Formation S of Sankhast (BSPG2013VI 43-44) and the Kamar-e-Mehdi area (BSPG2013VI 45), and one each from the top Baghamshah Formation at Kuh-e-Echellon (BSPG2013VI 46) and the Echellon Limestone Member W of Kuh-e-Echellon (BSPG2013VI 47).

Description. Shell moderately large, widely triangular, L/W <1 especially in the adult stage, position of maximum width generally in the anterior third. Dorso-biconvex with low valve thickness, maximum thickness slightly posterior of mid-length. Lateral commissure straight in the beginning, then curving toward the ventral valve. Anterolateral extremities narrowly rounded; anterior margin broadly rounded, anterior commissure uniplicate, strength of plication variable ontogenetically and intraspecifically. Beak narrow, rising from a broad base and sub-erect. Foramen medium-sized, circular, beak ridges short, poorly developed. Costae strong, angular, 14-18 in each valve.

Ventral valve weakly convex and broadly sulcate in anterior profile. Sulcus originating slightly posterior of mid-valve, widening anteriorly, variable in depth, with 4-6 costae, flanks bordering sulcus narrow, gently curved. Dorsal valve moderately convex, broadly arched in anterior view. At about mid-length, valve sides flex down to form a low fold that gains height at the plane of commissure, carrying 4-5 costae.

Remarks. The specimens are similar to *D. angulocostata* from Saudi Arabia described by Cooper (1989) in shape, shell outline, beak, and ornamentation but there is some difference regarding the dorsal valve convexity, which is reflected in the difference in valve thickness, i.e., that of the specimens from Iran, especially those from the Parvadeh Formation (Table 9), is distinctly less. The Arabian specimens, too, show variation in dorsal valve convexity, e.g., the paratype USNM380498a (Cooper 1989: pl. 6, figs. 1-5) agrees well with the material from Iran. *D. angulocostata* from Sinai described by Feldman et al. (2012) is similar to the present population in overall shell parameters. The shell parameters such as width, thickness, position of maximum width, and plication width of *Daghanirhynchia angulocostata* from Iran and Arabia show an allometric increase during ontogeny but plication height does not show any correlation with length

(Fig. 10). Though there are only a few specimens, the overlap of the specimens from the two areas is obvious in the scatter plots.

Alméras et al. (2010), while describing *D. daghaniensis* from Saudi Arabia, included a part of the *D. angulocostata* of Cooper (1989: pl. 7, figs. 44-53) in *D. daghaniensis* but we feel that the shell parameters and the shape and outline agree with other specimens of *D. angulocostata* as figured by Cooper and that *D. daghaniensis* has a thicker and erect beak and a more costate shell (Alméras et al. 2010: pl. 5, figs. 16,17,19, table17).

Stefanini (1925) described *Rhynchonella* [=*Daghanirhynchia*?] *huddlestoni* Rollier and *Rhynchonella* [=*Daghanirhynchia*?] *hadramautensis* from Hisn Baqirdan, Arabia, which are similar to *D. angulocostata* as was also noted by Cooper (1989). The slight differences in the shell parameters are well within the intra-specific variation.

The *D. angulocostata* population from Iran shares some common characters with *Cryptorhynchia karuna* from the Middle Bathonian of Kutch especially regarding the valve convexity and the beak, both having a short sub-erect beak and weakly biconvex valves. The coarse, angular costae, occasionally spinose when intersected by growth lamellae, are also similar to the ornamentation pattern of *Cryptorhynchia*.

Acknowledgements

DM is thankful to the Director General, Geological Survey of India, for permission to carry out the work and to Dr. S. Shome, Director Palaeontology, GSI, for his valuable comments and suggestions. The photographic work has been carried out by Lisa Egger. Help received from Wagih Ayoub-Hannaa, Erlangen, while preparing the plates, is gratefully acknowledged. FTF acknowledges joint fieldwork with K. Seyed-Emami and M.R. Majidifard (Tehran), B. Senowbari-Daryan (Erlangen), and M. Wilmsen (Dresden).

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Plate 1. Terebratulids from the Middle Jurassic of Iran. All figures in natural size.

Figs. 1-4. *Dorsoplicathyris dorsoplicata* (Suess in Deslongchamps, 1856) from the Parvadeh Formation and Echellon Limestone Member. 1. BSPG 2013VI 1 from the Parvadeh area (b); a: dorsal view, b: lateral view, c: anterior view, d: ventral view. 2. BSPG 2013VI 2 from the Parvadeh area (b); a: dorsal view, b: lateral view, c: anterior view, d: ventral view. 3. BSPG 2013VI 3 from the Parvadeh area (b); a: dorsal view, b: lateral view, c: anterior view. 4. BSPG 2013VI 4 from the Echellon Limestone Member SE of Robat-e-Dahaneh; a: dorsal view, b: lateral view, c: anterior view.

Figs. 5-6. *Moeschia alata* (Rollet, 1972) from the Echellon Limestone Member S of Kuh-e-Bagh-e-Vang. 5. BSPG 2013VI 14; a: dorsal view, b: lateral view, c: anterior view, d: ventral view. 6. Juvenile specimen BSPG 2013VI 15; a: dorsal view, b: lateral view, c: anterior view.

Fig. 7. *Moisseevia sokolovi* Makridin, 1964. BSPG2013VI 17 from the Echellon Limestone Member SE of Robat-e-Dahaneh; a: dorsal view, b: lateral view, c: anterior view.

Fig. 8. *Tubithyris agapae* (de Gregorio, 1886). BSPG 2013VI 25, from the Parvadeh Formation N of Shurabi; a: dorsal view, b: lateral view, c: anterior view, d: ventral view.

Fig. 9. *Conarothyris arabica* (Cooper, 1989). BSPG2013VI 19 from the Parvadeh Formation of the Parvadeh area (b); a: dorsal view, b: lateral view, c: anterior view, d: ventral view.

Figs. 10-11. *Somalithyris subcircularis* Cooper, 1989 from the Echellon Limestone Member W of Kuh-e-Echellon. 10. BSPG 2013VI 23; a: dorsal view, b: lateral view, c: anterior view. 11. BSPG 2013 VI 24; a: dorsal view, b: lateral view, c: anterior view.

Figs. 12-13. *Arabatia africana* (Weir, 1929) from the Echellon Limestone Member W of Kuh-e-Echellon. 12. BSPG 2013VI 30; a: dorsal view, b: lateral view, c: anterior view, d: ventral view. 13. BSPG 2013VI 32; a: dorsal view, b: lateral view, c: anterior view.

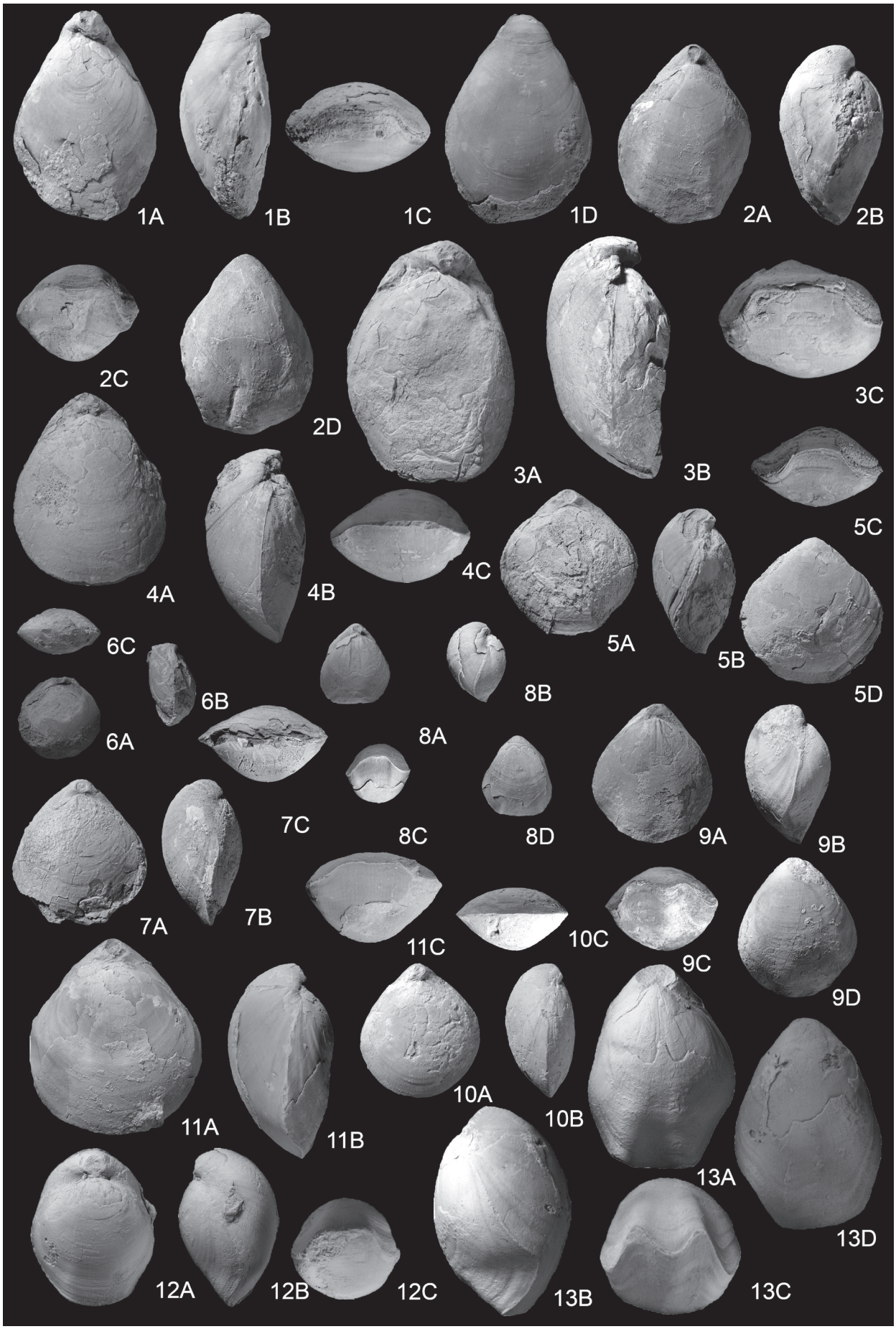
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Plate 2. Middle Jurassic Brachiopods from the Middle Jurassic of Iran. All figures X2.

Figs. 1-2. *Aulacothyris cucullata* Buckman, 1910 from the Parvadeh Formation of the Parvadeh area (a). 1. BSPG 2013VI 34; a: dorsal view, b: lateral view, c: anterior view, d: ventral view. 2. BSPG 2013VI 33; a: dorsal view, b: lateral view, c: anterior view.

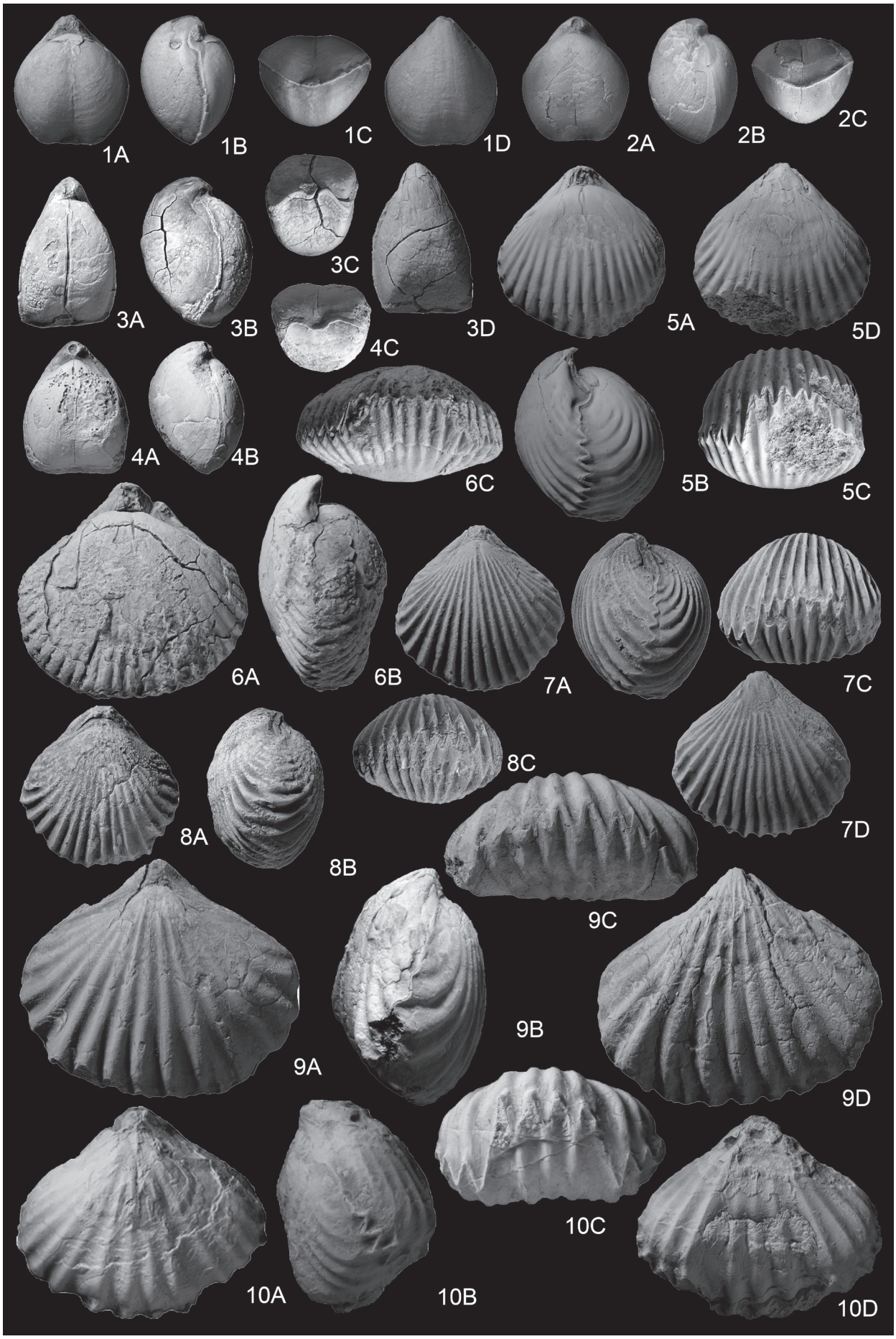
Figs. 3-4. *Digonella* sp. A from the Kamar-e-Mehdi Formation of the Kamar-e-Mehdi area. 3. BSPG 2013VI 38; a: dorsal view, b: lateral view, c: anterior view, d: ventral view. 4. BSPG 2013VI 39; a: dorsal view, b: lateral view, c: anterior view.

Figs. 5-6. *Burmirhynchia athiensis* Rousselle, 1965 from the top Hojedk Formation near Kharavan-pain. 5. BSPG 2013VI 49; a: dorsal view, b: lateral view, c: anterior view, d: ventral view. 6. BSPG 2013VI 48; a: dorsal view, b: lateral view, c: anterior view.

Figs. 7-8. *Burmirhynchia parva* (Cooper, 1989) from the Parvadeh Formation of the Parvadeh area (b). 7. BSPG 2013VI 52; a: dorsal view, b: lateral view, c: anterior view, d: ventral view. 8. BSPG 2013VI 53; a: dorsal view, b: lateral view, c: anterior view.

Fig. 9. *Cardinirhynchia surrecta* Seiffert, 1963 from the Parvadeh Formation of the Kamar-e-Mehdi area, BSPG 2013VI 56; a: dorsal view, b: lateral view, c: anterior view, d: ventral view.

Fig. 10. *Daghanirhynchia angulocostata* from the Parvadeh Formation S of Sankhast, BSPG 2013 VI 43; a: dorsal view, b: lateral view, c: anterior view, d: ventral view.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