Rev. bras. paleontol. 18(1):3-20, Janeiro/Abril 2015
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doi: 10.4072/rbp.2015.1.01

BENTHIC FORAMINIFERA AND OSTRACODA FROM THE DALICHAI FORMATION (AALENIAN–BAJOCIAN) AT TELMA-DAREH, ALBORZ MOUNTAINS, NORTHERN IRAN

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ABSTRACT – Aalenian-Bajocian benthic foraminiferal and ostracode assemblages of the Dalichai Formation (lithologic unit III) at Telma-Dareh, Alborz Mountains (northern Iran) are presented herein. Twenty-four foraminiferal taxa were identified, with the genera *Reinholdella*, *Epistomina* and *Lenticulina* as the dominant taxa. The dominance of r-selected strategists among foraminifera suggests the occurrence of stressing paleoenvironmental conditions, probably related to bottom-water oxygen levels, during the deposition of the studied strata. The foraminiferal assemblages studied herein are similar to other Boreal ones in paleobiogeographic terms. The ostracode assemblages present low abundance, low species richness and poor preservation, which did not allow any identification at species level. A possible record of *Majungaella* is briefly discussed due to its paleozoogeographic significance. *Cytherella*, *Paracypris* and *Pontocyprella* are the richest genera with two species each.

Key words: benthic foraminifera, ostracodes, Dalichai Formation, Alborz Mountains, Iran.

RESUMO – Assembleias de foraminíferos bentônicos e ostracodes do intervalo Aaleniano-Bajociano correspondentes à Formação Dalichai (unidade litológica III), em Telma-Dareh, Montanhas Alborz (norte do Irã) são aqui apresentadas. Vinte e quarto táxons de foraminíferos bentônicos foram identificados, sendo os gêneros *Reinholdella*, *Epistomina* e *Lenticulina* dominantes. O predomínio de estrategistas-r entre os foraminíferos sugere a ocorrência de condições ambientais estressantes durante a deposição destes estratos, provavelmente relacionadas aos níveis de oxigênio nas águas de fundo. As assembleias de foraminíferos aqui estudadas são similares a outras descritas para o domínio Boreal. As assembleias de ostracodes apresentam espécimes mal preservados, baixa abundância e baixa riqueza. Um possível registro de *Majungaella* é brevemente discutido devido ao seu significado paleozoogeográfico. *Cytherella*, *Paracypris* e *Pontocyprella* são os gêneros mais ricos com duas espécies registradas cada.

Palavras-chave: foraminíferos bentônicos, ostracodes, Formação Dalichai, Montanhas Alborz, Irã.

INTRODUCTION

Studies describing benthic foraminifera from the Middle Jurassic of Iran are patchy in literature. For instance, Kalantari (1969), studying the Middle Jurassic-Cretaceous succession of the Koppet-Dagh region (northeast Iran), reported the occurrence of the genera *Ammobaculites*, *Astacolus*, *Citharina*, *Lenticulina*, and *Pseudoglandulina* from Bajocian strata. Boroumand *et al*. (2010) briefly reported the occurrence of benthic foraminifera in a section of the Alborz Mountains. That study focused on the biostratigraphy of the Dalichai Formation in the Talu section, northern Iran, based on ammonites, foraminifera and dinoflagellates. Those authors suggested a Bathonian-Callovian age for the foraminiferal assemblages including *Lenticulina* sp., *Globigerina jurassica*, *Nodosaria* sp. and *Involutina* sp. Concerning ostracodes, there are no published studies from the Dalichai Formation, though Middle Jurassic ostracodes are fairly well known in Europe, North/Northeast Africa and Southeast Asia (*e.g*. Bate, 2009; Gomez & Arias, 2010; Andreu *et al*., 2012).

The main objective of this work is to present the results of a taxonomic study of benthic foraminifera and ostracodes from the lithostratigraphic unit III of an already described section of the Dalichai Formation (Parent *et al*., 2013; Aalenian-Bajocian, Middle Jurassic), Alborz Mountains, northern Iran, and their possible relation to other faunas previously studied.

GEOLOGICAL SETTING

The studied section (36°12'34"N/53°45'33"E) is located near Telma-Dareh, Alborz Mountains, northern Iran (Figure 1). In the Alborz Mountains, the mid-Cimmerian unconformity separates Jurassic strata deposited during two tectonic-sedimentary cycles (Aghanabati, 2004; Fürsich *et al*., 2009a,b). Lagoonal, fluvial and nearshore siliciclastic deposits compose the first cycle (ranging in age from Carnian to Aalenian). The second cycle (ranging in age from Aalenian/Bajocian to Oxfordian) presents sedimentary rocks deposited in marine settings (Fürsich *et al*., 2009b; Parent *et al*., 2013), including the Dalichai and Lar formations (Seyed-Emami *et al*., 2005).

In the study area, the Dalichai Formation presents a total thickness of 114 m, composed dominantly of marly limestones, marlstones and limestones. Parent *et al*. (2013) divided the Dalichai Formation into five lithostratigraphic units (I-V), suggesting an Aalenian-Bajocian age for the succession, based on their ammonites and belemnites. The present study is focused on the 29 m thick unit III, which is composed of gray to greenish marlstones with gypsum and calcareous sideritic concretions (Figure 2). Given to the undoubted occurrence of lower-middle Aalenian ammonites within the unit II and possibly upper Bajocian ammonites within the unit IV, Parent *et al.* (2013) suggested an Aalenian age for the lower ~10 m of the unit III, which is characterized by the belemnites *Brevibelus breviformis* and *Holcobelus* cf. *H. munieri*. The upper part of the unit III remained undifferentiated as late Aalenian to early Bajocian in age.

MATERIAL AND METHODS

Twenty-nine marlstone samples (Tables 1, 2) were analyzed. During chemical treatment, approximately 60 g of dried rock were crushed and soaked in 200 mL of hydrogen peroxide solution (H_2O_2), at a concentration of 29%, for 24 hours. Resultant residues were washed over sieve meshes of 63, 150, and >250 µm. The total amounts of benthic foraminifera and ostracodes were handpicked under stereomicroscope from each grain-size fraction. Selected specimens were imaged with scanning electron microscope (SEM - Zeiss Evo 40) and Zeiss Discovery V20 stereomicroscope (only foraminifera), using multidimensional acquisition with extended focus (software AxioVision 4.8).

Since most samples studied herein did not yield a minimum of 300 benthic foraminiferal/ostracode specimens, quantitative paleoecological analyses were not performed, except for some simple general indexes, such as benthic

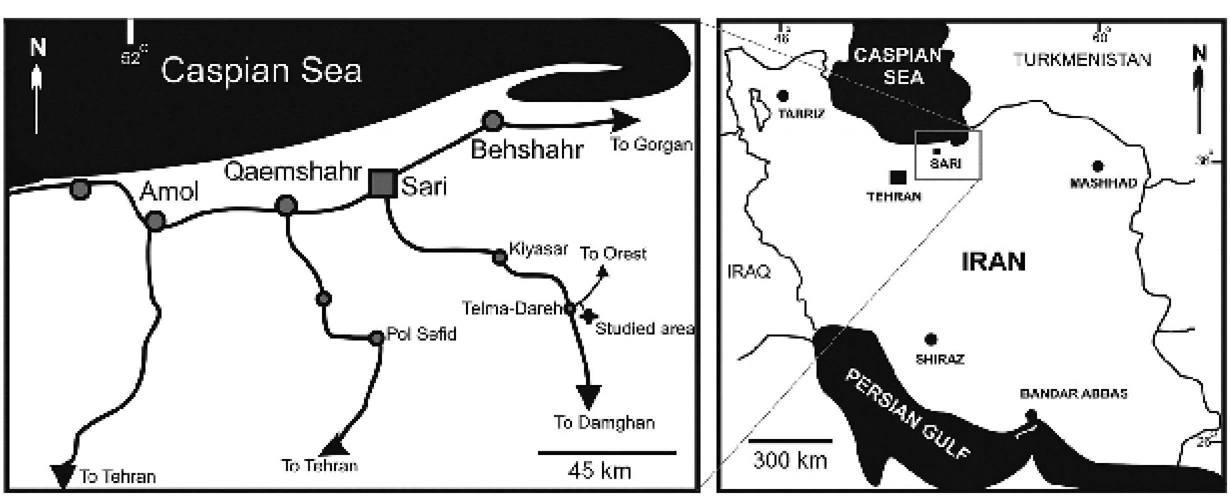

Figure 1. Location map of the studied section.

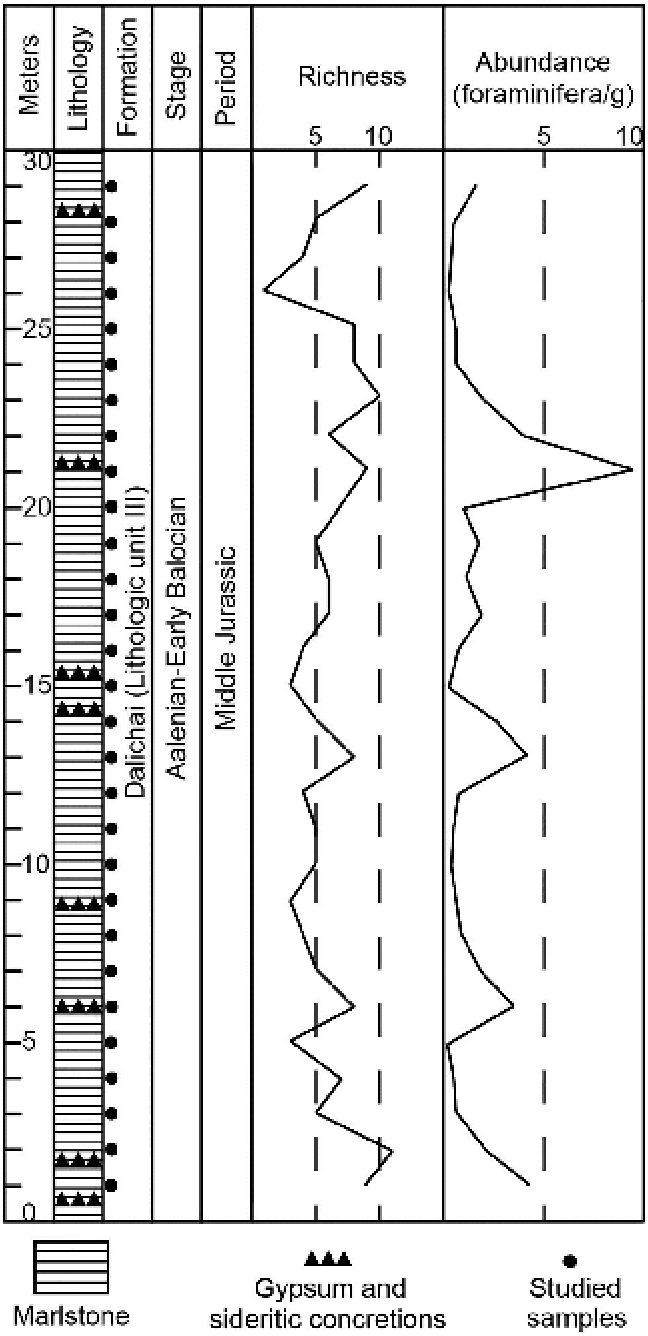

Figure 2. Studied stratigraphic section within the Dalichai Formation with benthic foraminiferal richness (number of occurring species in a single sample) and abundance (foraminifera/g). Stratigraphy after Parent *et al.* (2013).

foraminiferal species richness (number of species occurring in a single sample) and benthic foraminiferal total abundance. The specimens figured are stored in the collections of the Museu de História Geológica do Rio Grande do Sul, Universidade do Vale do Rio dos Sinos (UNISINOS), Brazil, under the curatorial numbers ULVG-11439 to 11481 and 11505.

Morphological abbreviations for ostracodes. C, carapace; **CC**, carapace cast; **h**, height; **l**, length; **w**, width.

SYSTEMATIC PALEONTOLOGY

Foraminifera

Relevant references to understand the applied species concepts and the original descriptions are given in the synonyms lists. Suprageneric classification follows Loeblich & Tappan (1987) as modified by Loeblich & Tappan (1992), for calcareous benthic foraminifera, and Kaminski (2014), for agglutinated taxa.

Class FORAMINIFERA d'Orbigny, 1826
Order ASTRORHIZIDA Lankester, 1885
Suborder ASTRORHIZINA Lankester, 1885
Family RHABDAMMIDAE Brady, 1884

Bathysiphon Sars, 1872

Bathysiphon sp.
(Figures 3A-B)

Figured specimen. ULVG 11439.
Description. Elongate, unbranched, tubular test, agglutinated of fine-grained material; has both ends opened and a slightly flattened inner cavity.

Order AMMODISCIDA Mikhalevich, 1980
Suborder AMMODISCINA Mikhalevich, 1980
Family AMMODISCIDAE Reuss, 1862

Ammodiscus Reuss, 1826

Ammodiscus sp.
(Figures 3C-D)

Figured specimen. ULVG 11440.
Description. Small finely agglutinated test. A globular proloculus is followed by an undivided planispirally coiled second chamber. Each whorl of the second chamber is tightly appressed against the preceding one.
Remarks. Poor preservation hampers a more precise identification.

Tolypammina Rhumbler, 1895

Tolypammina? sp.
(Figure 3K)

Figured specimen. ULVG 11441.
Description. Test attached and finely agglutinated. It consists of an undivided semitubular chamber that winds irregularly over the attachment surface.
Remarks. Since it is not possible to observe the proloculus in the studied specimen, its identification remains tentative. The view presented in Figure 3K corresponds to the attachment surface.

Order SCHLUMBERGERINIDA Mikhalevich, 1980
Suborder SCHLUMBERGERININA Mikhalevich, 1980
Family RZEHAKINIDAE Cushman, 1933

Table 1. Counts of benthic foraminiferal taxa from Dalichai Formation. **Abbreviations: G**, gastropod; **H**, holoturies; **B**, bivalve mollusks; **Bq**, braquiopod; **E**, echinoid.

Sample (m)	*Lenticulina* sp. 2	*Lenticulina* sp. 1	*Reinholdella* sp.	*Epistomina*? sp.	*Astacolus dorbignyi*	*Astacolus* sp. 4	*Lenticulina* sp. 3	*Astacolus*? sp. 1	*Nodosaria fontinensis*	*Bathysiphon* sp.	*Saracenaria* sp.	*Eoguttulina liassica*	*Citharina clathrata*	*Astacolus* sp. 3	*Tolypammina*? sp.	*Miliammina*? sp.	*Lenticulina muensteri*	*Ammodiscus* sp.	*Pseudonodosaria vulgata*	*Astacolus*? sp. 2	*Vaginulinidae*? indet.	*Ammomarginulina* sp.	*Planularia* sp.	*Grigelis apheilolocula*	Other microfossils
29	1	4	98		2			4		5						1				1				1	G,H,B,
28			13		1			2		6			1												G,H,B
27		2	6							12													1		G
26										15															G,B
25	1		16		3							3	1			4		2					1		G,B,Br,Bq
24			15	8	2	1			1	6											1	1			G,B
23	6	3	74	23	8			1		1						2	1				1				G,E
22		4	193	40	3		2			1															G,H
21	17		442	39		2		1		4							1	2		1					G,H,B
20	5	3	40				2	1			4			1											G,H,B,Br
19	14		116							2								1	1						G,H
18	9	1	61	5							1							1							G,H,B,Br
17		3	98	17	1						1						2								G,H
16	6	4	38		3																				Br,H,
15	2	1	12																						G,H,B,E
14	20	5	136		2					1															G,H,B
13	8	3	205							1	3		3		1	1									G,H,B
12	10	4	24	1																					H
11	10	4	9	2										2											H
10	7	4	5							5				1											G,H
9		1	43							1															G,H
8	1		30					1		21															G,H,E
7	10	4	118	3				1																	G,H,B
6	4	5	200	17	1		2	3					1												G,H,E,B
5	6		3							4															G,E,B
4	1		14	2	1			2		2			3												G
3	3		36	2			2			2															G.B
2	6	1	84	2	3		9	3	1	12	1	1													G,E,B
1	2	4	217	14	1	2	2	2																	G,H,E

Miliammina Heron-Allen & Earland, 1930

Miliammina sp.
(Figures 3E-F)

Figured specimen. ULVG 11442.
Description. Test very finely agglutinated, elongate ovate, with narrow chambers probably arranged in a "quinqueloculine" coiling. Aperture is terminal, on a short neck.
Remarks. Poor preservation does not enable more precise identification.

Order LITUOLIDA Lankester, 1885
Suborder LITUOLINA Lankester, 1885
Family LITUOLIDAE de Blainville, 1827

Ammomarginulina Wiesner, 1931

Ammomarginulina sp.
(Figures 3G-J)

Figured specimen. ULVG 11443.
Description. Test agglutinated of medium-sized particles, roughly finished, elongate and compressed. Early stage weakly planispirally coiled, followed by an uncoiled stage with curved and depressed sutures. Chambers of the latter stage are wider than high. Aperture terminal and rounded.

Order LAGENIDA Lankester, 1885
Family NODOSARIDAE Ehrenberg, 1838

Table 2. Counts of ostracode species from Dalichai Formation.

Sample (m)	*Progonocythere*? sp.	*Cytheropterina* sp.	Gen. *et* sp. indet. 1	Gen. *et* sp. indet. 2	*Pontocyprella* sp. 2	*Ektyphocythere* sp.	*Eocytheridea* sp.	*Paracypris* sp. 1	*Cytherella* sp. 1	*Cardobairdia* sp.	*Polycope* sp.	*Paracypris* sp. 2	Gen. *et* sp. indet. 3	*Cytherella* sp. 2	*Pontocyprella* sp. 1	*Monoceratina* sp.	*Majungaella*? sp.	Broken/juveniles
29		1															1	6
28																		3
27											1				2	1		
26													1	1				
25							1			1								4
24												2						4
23	1																	
22																		1
21			1				1	2		1	2							
20		1	1						4	1								
19	1								5									2
18			1							1								1
17																		1
16																		
15									1									
14							2		2									
13	4		5						2									1
12			1					2										6
11			1															5
10	1																	
9																		
8																		
7	1		1				2											7
6						1	1											
5																		
4						1												1
3					1													
2	1																	
1	2	2	1	1														3

Grigelis Mikhalevich, 1981

Grigelis apheilolocula (Tappan, 1955)
(Figures 3L-M)

1955 *Nodosaria apheilolocula* Tappan, p. 68.
1984 *Nodosaria apheilolocula* Tappan. Riegraf *et al.*, p. 681, pl. 5, fig. 130.
2001 *Grigelis apheilolocula* (Tappan). Nagy, p. 342, pl. 2, fig. 1.

Figured specimen. ULVG 11444.
Remarks. This species, usually recovered as unilocular specimens, was likely part of a bigger and delicate multiserial form, as originally stated by Tappan (1955).

Stratigraphic range. Sinemurian to Callovian (Jurassic; Nagy *et al.*, 2001; Riegraf *et al.*, 1984).

Nodosaria Lamarck, 1812

Nodosaria fontinensis Terquem, 1870
(Figures 3P-Q)

1870 *Nodosaria fontinensis* Terquem, p. 353, pl. 26, figs. 1-5.
2008 *Nodosaria fontinensis* Terquem. Canales & Henriques, pl. I, fig. 15.

Figured specimen. ULVG 11445.
Remarks. This species is characterized by its uniserial and straight test. Chambers tend to be slightly higher than wide

and increase regularly and slowly in size as added. Sutures are horizontal, straight and depressed. The surface is covered by about six longitudinal ribs (in lateral view), which are constricted where they cross the sutures. Aperture is terminal and simple.
Stratigraphic range. Jurassic (Terquem, 1870; Canales & Henriques, 2008).

Pseudonodosaria Boomgaart, 1949

Pseudonodosaria vulgata (Bornemann, 1854)
(Figures 3N-O)

1854 *Glandulina vulgata* Bornemann, p. 31, pl. 2, figs. 1-2.
2013 *Pseudonodosaria vulgata* Bornemann. Canales & Henriques, p. 190, fig. 3.21.

Figured specimen. ULVG 11446.
Remarks. This species is characterized by its uniserial-straight test of conical shape. Chambers are wider than high, initially strongly overlapping and increasing rapidly in size. Sutures are horizontal, straight and slightly depressed. The last chamber tends to be somewhat inflated and comprises about two-thirds of the test's length. Aperture radial and terminal.
Stratigraphic range. Lower to middle Jurassic (Bornemann, 1854; Canales & Henriques, 2013).

Family VAGINULIDAE Reuss, 1860

Lenticulina Lamarck, 1804

Lenticulina muensteri (Roemer, 1839)
(Figures 4I-L)

1839 *Robulina muensteri* Roemer, p. 48, pl. 20, figs. 29a,b.
2013 *Lenticulina muensteri* (Roemer). Canales & Henriques, p. 191, fig. 4.4.

Figured specimen. ULVG 11447.
Remarks. This species is characterized by its planispiral, lenticular and biumbonate test. There are 10 to 15 broad and low chambers in the last whorl. Sutures curved to sigmoidal, not expressed externally. Periphery is carinate, bearing a thick keel. Aperture radial at a neck-like projection of the last chamber.
Stratigraphic range. Middle Aalenian to Albian (Jendryka-Fuglewics, 1975; Holbourn & Kaminski, 1997; Canales & Henriques, 2013).

Lenticulina sp. 1
(Figures 4E-H)

Figured specimen. ULVG 11448.
Description. Planispiral, lenticular and biumbonate test, with oval peripheral outline. It presents 12 to 14 broad and low chambers in the last whorl, which increase moderately in size as added. Sutures curved, not pronounced externally. Periphery carinate, bearing a keel. Aperture radiate at the dorsal angle of the last chamber.
Remarks. It differs from *Lenticulina muensteri* by not having sigmoidal sutures and presenting a faster growth rate.

Lenticulina sp. 2
(Figures 3R-U)

Figured specimen. ULVG 11449.
Description. Planispiral, lenticular and biumbonate test, with circular peripheral outline. About 11 broad and low chambers appear in the last whorl, increasing slowly in size as added. Sutures curved, slightly elevated externally. Periphery carinate, bearing a thick keel. Aperture radiate at the dorsal angle of the last chamber.
Remarks. This species differs from *Lenticulina* sp. 1 by having fewer chambers in the last whorl that increase slower in size and slightly elevated sutures.

Lenticulina sp. 3
(Figures 4A-D)

Figured specimen. ULVG 11450.
Description. Planispiral, lenticular and biumbonate test, with ovate peripheral outline. About 10 broad and low chambers occur in the last whorl, with a slight tendency to uncoil and a moderate growth rate. Sutures curved to sigmoidal, slightly elevated externally. Periphery carinate. Aperture radiate at the dorsal angle.

Saracenaria Defrance, 1824

Saracenaria sp.
(Figures 4M-O)

Figured specimen. ULVG 11451.
Description. Planispiral test with seven chambers in the last whorl, tendency to uncoil and flaring; triangular in section, with a broad and flat apertural face. Sutures curved and elevated. Dorsal margin carinate. Aperture radial at the dorsal angle.

Astacolus de Montfort, 1808

Astacolus dorbignyi (Roemer, 1839)
(Figures 4T-U; 5A-B)

1839 *Peneroplis dorbignii* Roemer, p. 47, pl. 20, fig. 31.
2013 *Lenticulina dorbigyi* (Roemer). Canales & Henriques, p. 192, fig. 4.9.

Figured specimen. ULVG 11452.
Remarks. This species is characterized by an initially planispirally-coiled test that later uncoils to a uniserial arched stage (last 1-4 chambers). The surface is covered by a reticulated ornamentation that results from the intersections of the elevated sutures with about nine longitudinal ribs. Aperture is radial at the dorsal angle.

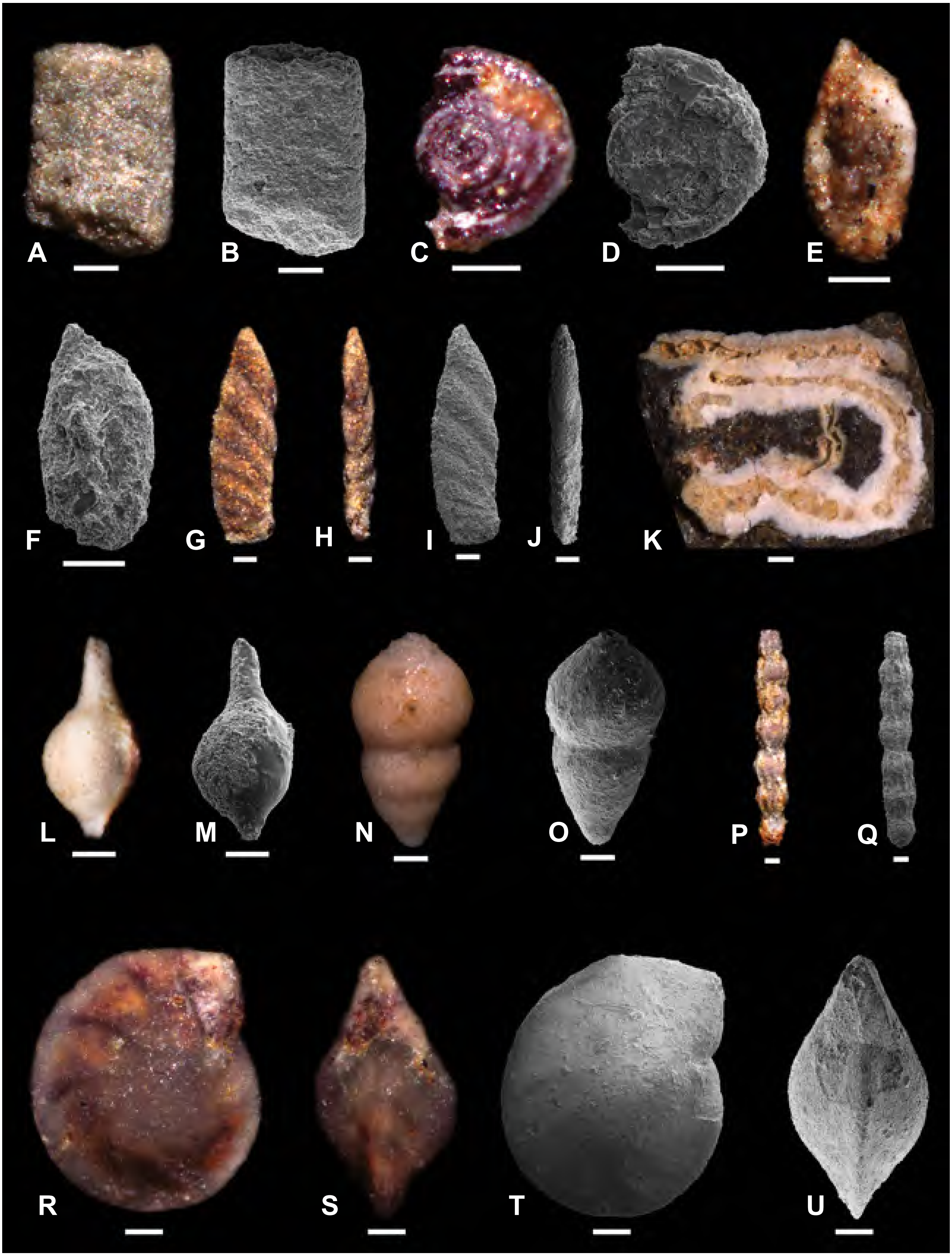

Figure 3. Optical and scanning electron micrographs of benthic foraminifera recovered from the Dalichai Formation, Iran. **A-B**, *Bathysiphon* sp. (13 m); **C-D**, *Ammodiscus* sp. (25 m); **E-F**, *Miliammina* sp. (25 m); **G-J**, *Ammomarginulina* sp. (24 m); **K**, *Tolypammina*? sp. (13 m); **L-M**, *Grigelis apheilolocula* (24 m); **N-O**, *Pseudonodosaria vulgata* (19 m); **P-Q**, *Nodosaria fontinensis* (24 m); **R-U**, *Lenticulina* sp. 2 (13 m). Scale bars = 100 µm.

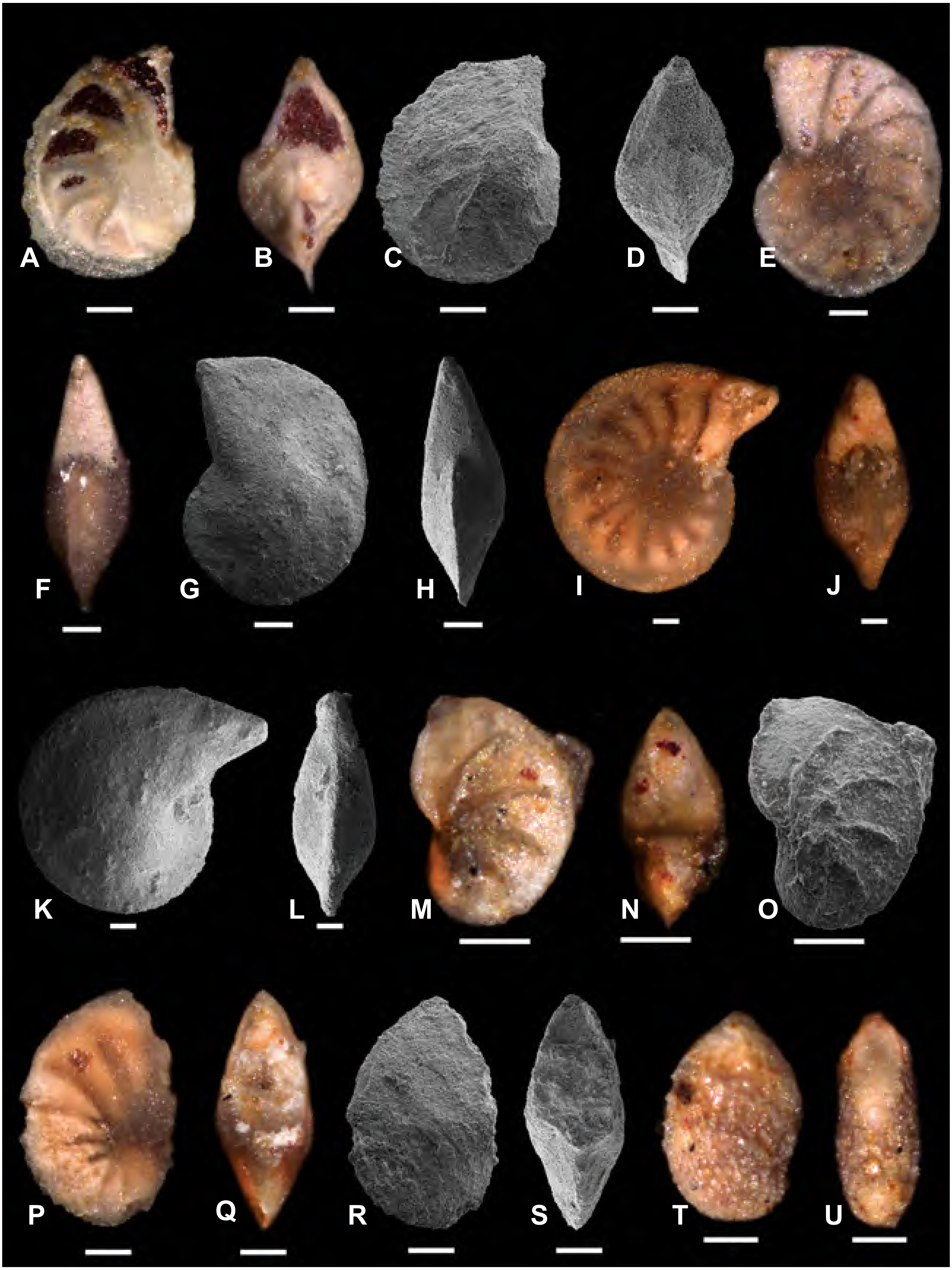

Figure 4. Optical and scanning electron micrographs of benthic foraminifera recovered from the Dalichai Formation, Iran. **A-D**, *Lenticulina* sp. 3 (22 m); **E-H**, *Lenticulina* sp. 1; **I-L**, *Lenticulina muensteri* (23 m); **M-O**, *Saracenaria* sp. (13 m); **P-S**, *Astacolus* sp. 4 (24 m); **T-U**, *Astacolus dorbignyi* (28 m). Scale bars = 100 μm.

Stratigraphic range. Lower to middle Jurassic (Bejjaji *et al*., 2010; Canales & Henriques, 2013).

Astacolus sp. 1
(Figures 5C-F)

Figured specimen. ULVG 11453.
Description. Test elongate in outline, flattened; chambers usually numbering eight, broad and low. Early stage coiled, later becoming uncoiled, with a curved axis. Sutures curved to sigmoidal; periphery rounded. Aperture at the dorsal angle, probably radiate.
Remarks. All specimens recovered in this study have the last chamber broken.

Astacolus sp. 2
(Figures 5G-J)

Figured specimen. ULVG 11454.
Description. Test elongate in outline, slightly flattened; chambers broader than high. Early stage coiled, later becoming uncoiled, with a slightly curved axis. Sutures curved; periphery broadly rounded. Aperture at the dorsal angle, and radiate.
Remarks. This species differs from *Astacolus* sp. 1 by having a broadly rounded periphery and higher chamber in the uncoiled stage.

Astacolus sp. 3
(Figures 5K-M)

Figured specimen. ULVG 11455.
Description. Test elongate in outline, strongly flattened; chambers broader than high. Early stage distinctively coiled; latter stage becomes uncoiled, with a slightly curved axis. Sutures sigmoidal; periphery acute. Aperture at the dorsal angle, and radiate.
Remarks. This species differs from *Astacolus* sp. 1 and *Astacolus* sp. 2 by having a more acute periphery and broader chamber in the uncoiled stage.

Astacolus sp. 4
(Figures 4P-S)

Figured specimen. ULVG 11456.
Description. Planispiral test with tendency to uncoil and flaring; lenticular in section, with a narrow apertural face. Sutures curved and not pronounced externally. Dorsal margin carinate. Aperture probably radial at the dorsal angle.
Remarks. Poor preservation does not enable a more precise identification. It differs from the previous species of *Astacolus* recorded in this study by having a narrower apertural face.

Citharina d'Orbigny, 1839

Citharina clathrata (Terquem, 1864)
(Figures 5N-Q)

1864 *Marginulina longuemari* var. *clathrata* Terquem, p. 402, pl. 8, figs. 16, 19.
1978 *Citharina clathrata* (Terquem). Bhalla & Abbas, p. 176, pl. 5, fig. 8; pl. 9, figs. 1-5.
2008 *Citharina clathrata* (Terquem). Canales & Henriques, p. 176, pl. 3, fig. 7.

Figured specimen. ULVG 11457.
Remarks. This species is characterized by having a flaring test with about nine chambers, wider than high, in the arched uniserial stage. About five longitudinal ribs cover the surface and the aperture is radial at the dorsal angle.
Stratigraphic range. Lower to middle Jurassic (Bhalla & Abbas, 1978).

Planularia Defrance, 1826

Planularia sp.
(Figures 5V-Y)

Figured specimen. ULVG 11458.
Description. Test flared, broadly ovate, and strongly compressed. Early stage partially coiled, later becoming uncoiled. Chambers are broader than high. Sutures curved and flush. Surface smooth. Aperture radiate at the dorsal angle.
Remarks. This species differs from *Planularia madagascariensis* Espitalié & Sigal, 1963 by having more depressed sutures and fewer chambers in the final stage and from *P. complanata* (Reuss, 1845) by having a straight dorsal margin and more depressed sutures.

Vaginulinidae? indet.
(Figures 5R-U)

Figured specimen. ULVG 11459.
Description. Planispiral form, with ten chambers in the last forming whorl. Sutures curved backwards. Peripheral margin keeled. Chambers are wider than high, increasing moderately in size as added. Aperture probably terminal at the dorsal angle.
Remarks. Poor preservation of the recovered specimens hampers more precise identification.

Family POLYMORPHINIDAE d'Orbigny, 1839

Eoguttulina Cushman & Ozawa, 1930

Eoguttulina liassica (Strickland, 1846)
(Figures 6A-B)

1846 *Polymorphina liassica* Strickland, p. 31, fig. 6.
2013 *Eoguttulina liassica* (Strickland). Canales & Henriques, p. 195, fig. 8, fig. 5.7.

Figured specimen. ULVG 11460.
Remarks. This species is characterized by having an elongate test, rounded in section. Elongate chambers are somewhat

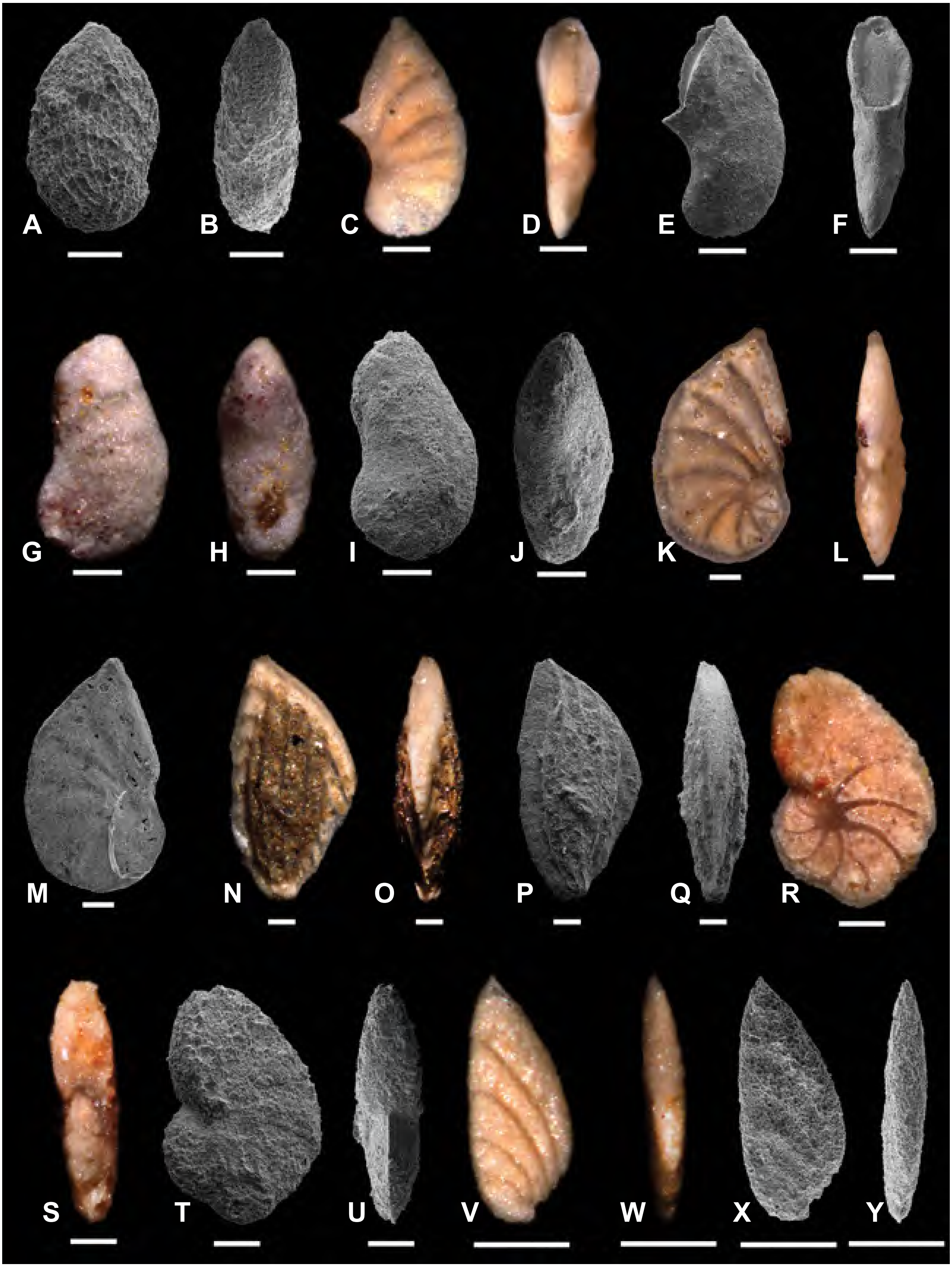

Figure 5. Optical and scanning electron micrographs of benthic foraminifera recovered from the Dalichai Formation, Iran. **A-B**, *Astacolus dorbignyi* (28 m); **C-F**, *Astacolus* sp. 1 (28 m); **G-J**, *Astacolus* sp. 2 (29 m); **K-M**, *Astacolus* sp. 3 (11 m); **N-Q**, *Citharina clathrata* (13 m); **R-U**, Vaginulinidae? indet. (24 m); **V-Y**, *Planularia* sp. (27 m). Scale bars = 100 μm.

inflated and probably added in planes less than 90° apart. Sutures are slightly depressed and the aperture is terminal.
Stratigraphic range. Lower to middle Jurassic (Strickland, 1846; Canales & Henriques, 2013).

Order ROBERTINIDA Mikhalevich, 1980
Family EPISTOMINIDAE Wedekind, 1937

Reinholdella Brotzen, 1948

Reinholdella sp.
(Figures 6C-F)

Figured specimen. ULVG 11461.
Description. Trochospiral biconvex test. Slightly curved internal partitions can be seen within the chambers in umbilical view. Sutures slightly curved and probably limbate on the spiral side; radial and depressed on the umbilical side. Periphery rounded. Aperture interiomarginal.
Remarks. Most of the recovered specimens occur as casts, hampering a more precise identification.

Epistomina Terquem, 1883

Epistomina? sp.
(Figures 6H-L)

Figured specimen. ULVG 11462.
Description. Trochospiral biconvex test. Slightly curved internal partitions can be seen within the chambers in umbilical view. Sutures slightly curved and probably limbate on both sides. Periphery keeled. Aperture probably lateromarginal.
Remarks. It differs from *Reinholdella* sp. by having a peripheral keel, sutures slightly curved on both sides, and a probable lateromarginal aperture. Most of the recovered specimens occur as casts, hampering a more precise identification.

Ostracodes

The suprageneric taxonomic framework here adopted follows basically Liebau (2005). The species that could not be assigned to any genus or family are referred as “Gen. *et* sp. indet.” and grouped as Podocopida indeterminate.

Subclass OSTRACODA Latreille, 1802
Order PLATYCOPIDA Sars, 1866
Family CYTHERELLIDAE Sars, 1866

Cytherella Jones, 1849

Cytherella sp. 1
(Figures 7A-B)

Figured specimens. ULVG 11463 (sample 13 m) LV, l: 0.54 mm, h: 0.30 mm; ULVG 11464 (sample 19 m) RV, l: 0.56 mm, h: 0.34 mm.
Remarks. This species is characterized by a conspicuous pit in the median part of the carapace. This feature, seen also in other Jurassic species of the genus, such as *Cytherella knysnaensis* Dingle & Klinger, 1972 (South Africa) seems to be related to the adductor muscle insertion area.

Cytherella sp. 2
(Figures 7C-D)

Figured specimens. ULVG 11465 female C, l: 0.50 mm, h: 0.28 mm, w: 0.20 mm (broken). Sample 26 m.
Remarks. Though the carapace is broken in the anterodorsal region, it clearly differs from *Cytherella* sp. 1 in the lateral outline. Brood pouches are easily seen, especially in dorsal view.

Order PODOCOPIDA Sars, 1866
Suborder CYPRIDOCOPINA Jones, 1901
Family CANDONIDAE Daday, 1900

Paracypris Sars, 1866

Paracypris sp. 1
(Figure 7E)

Figured specimen. ULVG 11466 C, l: 0.66 mm, h: 0.28 mm, w: 0.18 mm. Sample 12 m.
Remark. This carapace is deformed at the posterior region.

Paracypris sp. 2
(Figures 7F-G)

Figured specimen. ULVG 11467 C, l: 0.58 mm, h: 0.26 mm, w: 0.2 mm. Sample 24 m.
Remark. *Paracypris* sp. 2 differs from *Paracypris* sp. 1 by the outline of both the dorsal and ventral margins.

Pontocyprella Mandelstam, 1955

Pontocyprella sp. 1
(Figures 7H-J)

Figured specimens. ULVG 11471 CC, l: 0.6 mm, h: 0.28 mm, w: 0.18 mm; ULVG 11472 C, l: 0.62 mm, h: 0.3 mm, w: 0.20 mm. Sample 27 m.
Remarks. The identification of these species in *Pontocyprella* is based on the carapace outline and on the overlap of the LV on the RV. Moreover, though some studies (*e.g.* Holden, 1976) tentatively record *Pontocyprella* in Cenozoic, most part of the occurrences of the genus are either in Jurassic or Early Cretaceous deposits (*e.g.* Oertli, 1974; Witte *et al*., 1992; Beher *et al*., 2010). Since the figured specimens are casts, no precise comparison could be done to other formally described or merely recorded species.

Pontocyprella sp. 2
(Figures 7K-L; 8O)

Figured specimen. ULVG 11473 CC, l: 0.54 mm, h: 0.26 mm, w: 0.2 mm. Sample 3 m.

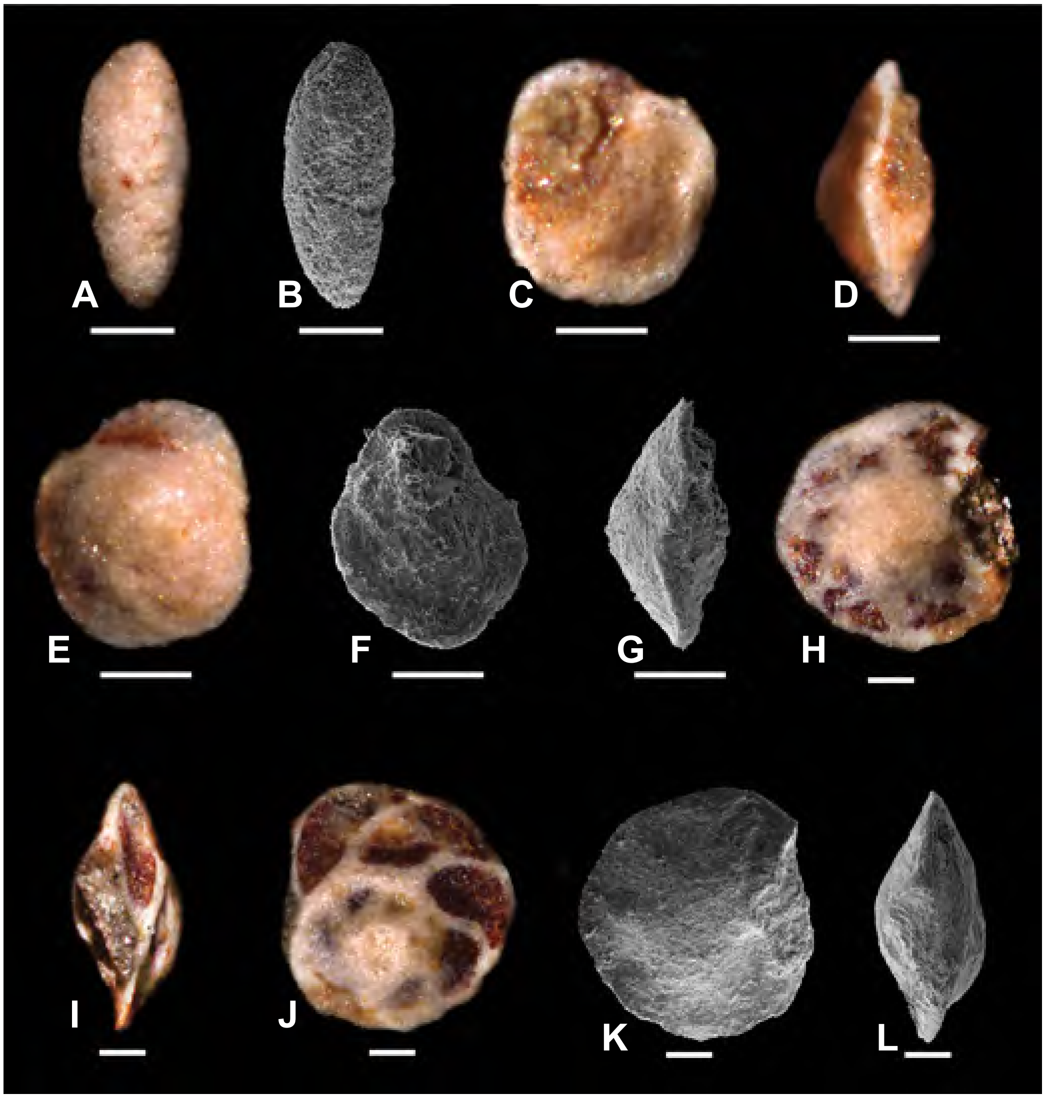

Figure 6. Optical and scanning electron micrographs of benthic foraminifera recovered from the Dalichai Formation, Iran. **A-B**, *Eoguttulina liassica* (25 m); **C-F**, *Reinholdella* sp. (14 m); **H-L**, *Epistomina*? sp. (13 m). Scale bars = 100 μm.

Remark. *Pontocyprella* sp. 2 differs from the previous species in the outline of the dorsal margin, which is less convex.

Suborder CYTHEROCOPINA Gründel, 1967
Family BYTHOCYTHERIDAE Sars, 1926

Monoceratina Roth, 1928

Monoceratina sp.
(Figures 7M-O)

Figured specimen. ULVG 11468 CC, l: 0.38 mm, h: 0.26 mm, w: 0.2 mm. Sample 27 m.
Remark. Though this species is represented in this study by a single carapace cast, it clearly demonstrates the straight dorsal margin and the lateral expansions typical of the genus.

Family PROGONOCYTHERIDAE Sylvester-Bradley, 1948

Majungaella Grèkoff, 1963

Majungaella? sp.
(Figures 7P-R)

Figured specimen. ULVG 11469 C, l: 0.50 mm, h: 0.30 mm, w: 0.32 mm. Sample 29 m.
Remarks. This fossil is tentatively identified as a species of *Majungaella* based on the carapace shape and the presence of concentric ribs in the ventrolateral area. However, its chronostratigraphic and paleobiogeographic occurrences do not fit into *Majungaella* characterization (see "Results and Discussion").

Progonocythere Sylvester-Bradley, 1948

Progonocythere? sp.
(Figure 8A)

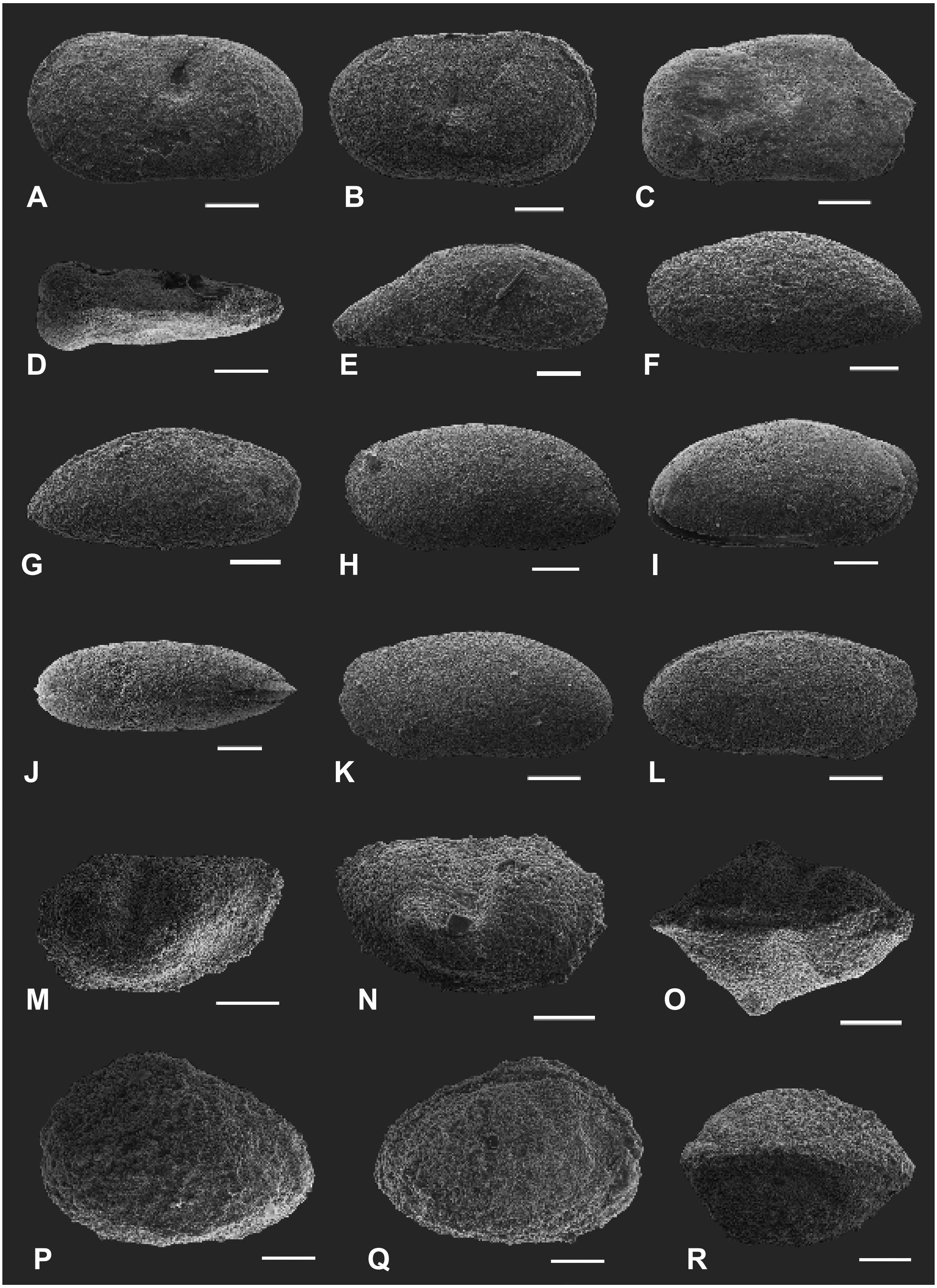

Figure 7. Scanning electron micrographs of ostracodes from Dalichai Formation. **A-B**, *Cytherella* sp. 1, **A**, LV, ULVG 11463; **B**, RV, ULVG 11464. **C-D**, *Cytherella* sp. 2, **C**, C, ULVG 11465, right lateral view; **D**, same specimen dorsal view. **E**, *Paracypris* sp. 1, C, ULVG 11466, right lateral view. **F-G**, *Paracypris* sp. 2, **F**, C, ULVG 11467, left lateral view; **G**, same specimen right lateral view. **H-J**, *Pontocyprella* sp. 1, **H**, CC, ULVG 11471, left lateral view; **I**, same specimen right lateral view; **J**, C, ULVG 11472, dorsal view. **K-L**, *Pontocyprella* sp. 2, **K**, CC, ULVG 11473, left lateral view; **L**, same specimen right lateral view. **M-O**, *Monoceratina* sp., **M**, CC, ULVG 11468, left lateral view; **N**, same specimen right lateral view; **O**, same specimen dorsal view. **P-R**, *Majungaella*? sp., **P**, C, ULVG 11469, left lateral view; **Q**, same specimen right lateral view; **R**, same specimen dorsal view. Scale bars = 100 µm.

Figured specimen. ULVG 11470 RV, l: 0.56 mm, h: 0.21 mm. Sample 1 m.

Family CYTHERIDAE Baird, 1850

Ektyphocythere Bate, 1963

Ektyphocythere sp.
(Figures 8B-C)

Figured specimen. ULVG 11474 C, l: 0.54 mm, h: 0.28 mm, w: 0.3 mm (broken). Sample 4 m.
Remarks. The studied specimen is seriously damaged and a significative portion of the posterodorsal area of the carapace is broken. The remaining of the carapace, however, preserves important diagnostic characteristics of the genus, such as the reticulated surface, the anteromarginal depression followed by a marginal rib and the ventrolateral inflation.

Family CYTHERURIDAE Müller, 1894

Cytheropterina Mandelstam, 1956

Cytheropterina sp.
(Figure 8D)

Figured specimen. ULVG 11475 RV, l: 0.44 mm, h: 0.24 mm (broken). Sample 1 m.
Remarks. The specimen is broken at the anterior cardinal angle.

Family SIGILLIDAE Mandelstam, 1960

Cardobairdia Bold, 1960

Cardobairdia sp.
(Figures 8E-G)

Figured specimens. ULVG 11476 (sample 18 m) male C, l: 0.44 mm, h: 0.24 mm, w: 0.2 mm. ULVG 11505 (sample 25 m) female C, l: 0.44 mm; h: 0.26 mm; w: 0.22 mm.
Remarks. This species has conspicuous sexual dimorphism, being the females significantly wider at posterior region.

Family CYTHERIDEIDAE Sars, 1925

Eocytheridea Bate, 1963

Eocytheridea sp.
(Figure 8H)

Figured specimen. ULVG 11477 RV, l: 0.42 mm, h: 0.2 mm. Sample 6 m.

PODOCOPIDA Indeterminate

Gen. *et* sp. indet. 1
(Figures 8I-K)

Figured specimen. ULVG 11478 C, l: 0.54 mm, h: 0.24 mm, w: 0.16 mm. Sample 11 m.
Remarks. The generic status of the present specimen could not be reached satisfactorily. Gen. *et* sp. indet. 1 is similar to *Monoceratina*? *amigdaliformis* Blaszyc, 1967 described for the Middle Bathonian of Poland. The dimensions of the adult males figured in that study (l: 0.50 mm, h: 0.20 mm, w: 0.18 mm) are also compatible with the specimen here studied. However, the carapace does not present the lateral extension typical of *Monoceratina*. The outline of this fossil, particularly in dorsal view, is also similar to the *Eocytheridea*? *erugata* Bate, 1964, but the holotype of the latter is significantly bigger (l: 0.67 mm, h: 0.33 mm, w: 0.29 mm) reinforcing the hypothesis that they are not co-specific.

Gen. *et* sp. indet. 2
(Figure 8L)

Figured specimen. ULVG 11479 RV, l: 0.42 mm, h: 0.22 mm (broken). Sample 1 m.
Remarks. The specimen is broken at the anteroventral region.

Gen. *et* sp. indet. 3
(Figures 8M-N)

Figured specimen. ULVG 11480 C, l: 0.5 mm, h: 0.24 mm, w: 0.08 mm. Sample 26 m.
Remarks. The specimen figured is laterally compressed.

Order HALOCYPRIDIDA Skogsberg, 1920
Suborder HALOCYPRIDINA Skogsberg, 1920

Polycope Sars, 1866

Polycope sp.
(Figures 8P-Q)

Figured specimen. ULVG 11481 C, l: 0.36 mm, h: 0.3 mm, w: 0.2 mm. Sample 21 m.

RESULTS AND DISCUSSION

Foraminifera

Benthic foraminiferal abundance varies from 0.2 to 9.4 specimens/g of residue, while species richness varies between 1 and 11 species identified in a single sample (Table 1; Figure 2). Benthic foraminiferal abundance and species richness seem to present a positive correlation throughout the studied interval (Figure 2). A total of 2,965 specimens were identified and assigned to 24 taxa (Table 1). *Reinholdella* sp. and *Epistomina*? sp. are dominant in the studied assemblages, occurring both as complete specimens and casts. These species are followed in abundance by several others assigned do the genus *Lenticulina*, and the agglutinated taxon *Bathysiphon* sp.; the remaining species compose the background assemblages.

The abundant occurrence of foraminiferal casts throughout the studied section suggests that preservation is poor and that

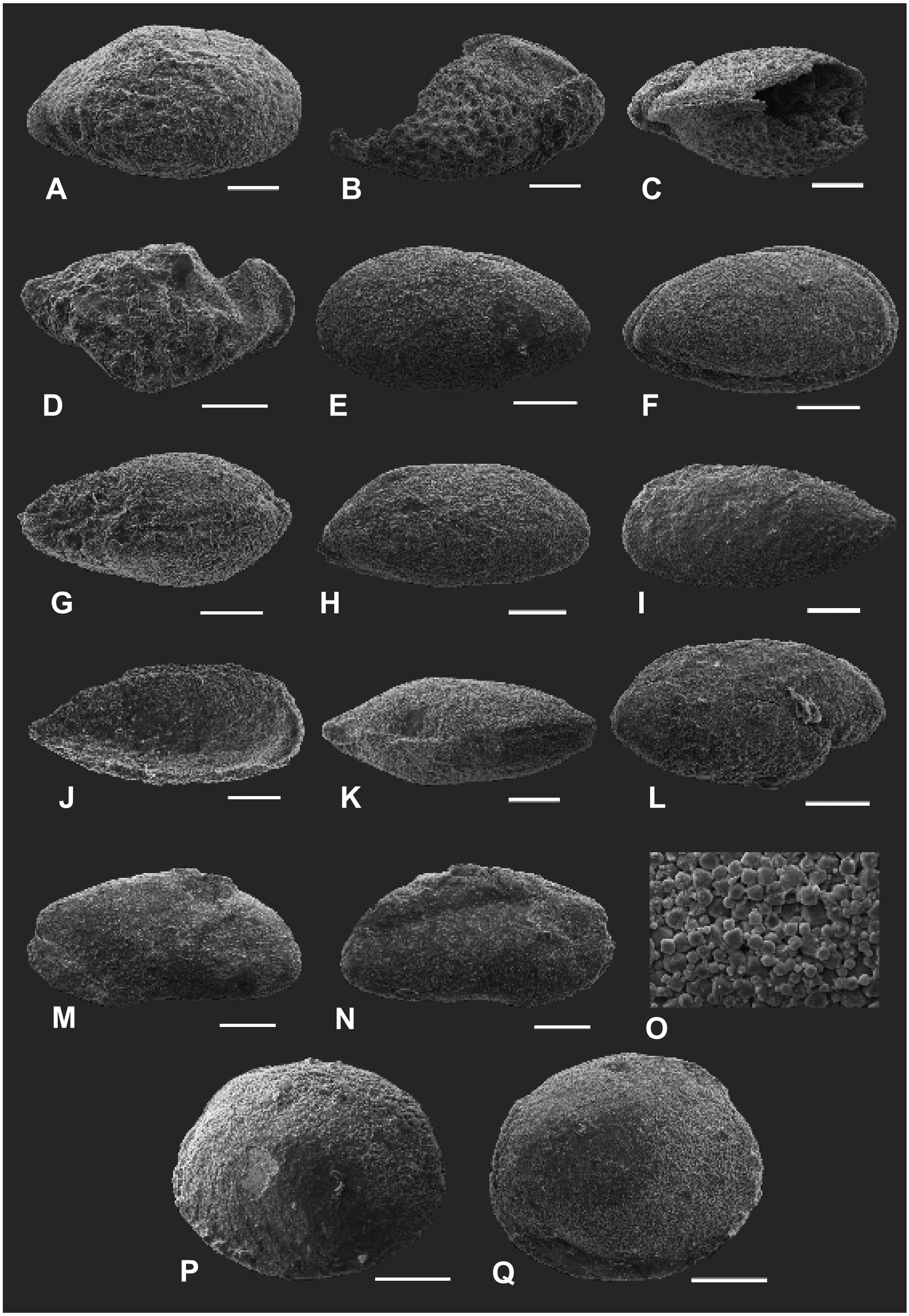

Figure 8. Scanning electron micrographs of ostracodes from Dalichai Formation. **A**, *Progonocythere*? sp., RV, ULVG 11470. **B-C**, *Ektyphocythere* sp., **B**, C, ULVG 11474, right lateral view; **C**, same specimen dorsal view. **D**, *Cytheropterina* sp., RV, ULVG 11475. **E-G**, *Cairdobairdia* sp., **E**, male C, ULVG 11476, left lateral view; **F**, same specimen right lateral view; **G**, female C, ULVG 11505, dorsal view. **H**, *Eocytheridea* sp., RV, ULVG 11477. **I-K,** Gen. *et* sp. indet. 1, **I**, C, ULVG 11478, left lateral view; **J**, same specimen right lateral view; **K**, same specimen dorsal view. **L**, Gen. *et* sp. indet. 2, RV, ULVG 11479. **M-N**, Gen. *et* sp. indet. 3, **M**, C, ULVG 11480, left lateral view; **N**, same specimen right lateral view. **O**, *Pontocyprella* sp. 2, CC, ULVG 11471, surface detail. **P-Q**, *Polycope* sp., **P**, C, ULVG 11481, left lateral view; **Q**, same specimen right lateral view. Scale bars = 100 μm.

the assemblages described herein may be not representative of the original biocoenosis. Therefore, several species were left in open nomenclature. Other fossil groups recovered from the residues used in the micropaleontological survey were gastropods, brachiopods, undifferentiated echinoderms, bivalves, and bryozoans (Table 1). The total number of benthic foraminiferal specimens identified in the present study is significant when compared to other faunas from comparable time intervals, such as those described by Reolid *et al.* (2012), in which about 2,120 specimens were recovered from 22 samples (with 0.5 kg of residue analyzed), and Canales & Henriques (2008), in which 5411 specimens were recovered from 28 samples (with 0.3 kg of residue analyzed).

In general terms, it can be suggested that r-selected strategists, such as species of *Reinholdella* and *Epistomina*, which are characteristic of oxygen-depleted environments (Sagasti & Ballent, 2002; Ballent *et al*., 2006; Reolid *et al.*, 2012), dominate the studied assemblages, with special emphasis to *Reinholdella* sp. (Table 1). Species of *Lenticulina*, the second most abundant genus in the studied samples, are also considered r-selected generalists being characteristic of environments with moderate levels of dissolved oxygen (Bernhard, 1986; Koutsoukos *et al*., 1990; Canales & Henriques, 2008; Reolid *et al*., 2012). This dominance of r-selected strategists suggests the occurrence of stressing paleoenvironmental conditions (*cf*. Reolid *et al*., 2012), probably related to bottom-water oxygen levels.

Representatives of the suborder Robertinina (*Reinholdella*, *Epistomina*) are supposed to have thrived in outer shelf (for the genus *Epistomina*) or even deeper (for the genus *Reinholdella*) marine environments during the Jurassic (*e.g.* Koutsoukos *et al*., 1990; Sagasti & Ballent, 2002; Ballent *et al*., 2006). Therefore, the dominance of *Reinholdella* and forms tentatively assigned to *Epistomina* in the studied samples suggests the occurrence of at least outer shelf paleodepths throughout the studied section.

The occurrence of benthic foraminiferal species with reported Aalenian-Bajocian occurrences (see the systematic paleontology section above) within the studied section supports the undifferentiated late Aalenian-early Bajocian age suggested by Parent *et al*. (2013) for the lithologic unit III of the Dalichai Formation.

Similarities at genus and species level can be detected when the fauna described herein is compared to Aalenian-Bajocian faunas described in Europe (*e.g.* Reolid *et al*., 2008, 2010). For instance, the species *Astacolus dorbignyi*, *Nodosaria fontinensis*, *Pseudonodosaria vulgata*, *Lenticulina muensteri*, *Citharina clathrata* and *Eoguttulina liassica* occur in the Aalenian-Bajocian GSSP of the Murtinheira section, west Portugal (Canales & Henriques, 2008, 2013). Canales & Henriques (2013) suggested that Aalenian-Bajocian benthic foraminifera from the Murtinheira section are typical of the Boreal Realm. This paleozoogeographic similarity contrasts to some degree to the data of Parent *et al*. (2013). These authors suggested a Tethyan-Submediterranean affinity for the ammonite fauna of the Dalichai Formation, but a Subboreal-Submediterranean affinity for the belemnite fauna.

Ostracoda

Despite the low abundance (116 specimens), ostracodes are present in most part of the studied section, except in samples 8 m and 9 m (Table 2). The assemblages are characterized by low richness (17 species) and poor preservation, with specimens broken, abraded, recrystallized (see Figure 8O) or preserved as casts, not presenting, therefore, the morphological features necessary for species identification. Casts with similar aspect were recorded by Swain & Brown (1972), who described them as being composed of calcite crystals. Besides those preservational constraints, some specimens could be identified in the following genera: *Cardobairdia* (1 sp.), *Cytherella* (2 spp.), *Cytheropterina* (1 sp.), *Ektyphocythere* (1 sp.), *Eocytheridea* (1 sp.), *Pontocyprella* (2 spp.), *Majungaella*? (1 sp.), *Paracypris* (2 spp.) and *Polycope* (1 sp.).

Though the species *Progonocythere* sp., Gen. *et* sp. indet. 1 and *Cytherella* sp. 1 are fairly abundant, most taxa are either scarce or represented by a single specimen. The poor taxonomic results achieved preclude, therefore, detailed ecological interpretations and paleozoogeographical interpretations. The genera *Monoceratina*, *Ektyphocythere*, *Polycope*, *Cardobairdia* and *Paracypris* are common elements in Middle Jurassic boreal assemblages (*e.g*. Olempska & Blaszyc, 2001; Arias *et al*., 2009; Bate, 2009). However, the complexity of this subject is discussed by Tesakova *et al.* (2008), who in their study on Bathonian ostracodes from Poland, comment that the high endemism of the Middle Jurassic ostracodes from Europe characterizes distinct bioprovinces. The processes of dispersal among these bioprovinces are not enough understood at the moment, demanding improvement on the taxonomic knowledge (Tesakova *et al*., 2008).

The imbalance between the data from the fairly well studied European assemblages and this preliminary study on Middle Jurassic of Iran do not allow accurate paleozoogeographic remarks for Dalichai Formation ostracodes. However, the possible occurrence of *Majungaella* Grekoff, a typical gondwanide genus, has especial importance. It is broadly accepted by ostracodologists that this genus originated somewhere in the region of India, Madagascar and East Africa during the Bathonian (Ballent *et al*., 1998; Piovesan *et al*., 2012). Its occurrence in the Dalichai Formation, if confirmed, would constitute the oldest record of *Majungaella*. Moreover, it would be also the first record of the genus outside the Gondwana, which would imply in a new interpretation of its paleobiogeography. The preservation of the single specimen available, however, is not suitable for such remarkable reinterpretation.

A conspicuous change in the assemblages composition and in general abundance is seen in the interval above the sample 15 m. From this level onwards, abundance increases and several taxa such as *Polycope* sp., *Cytherella* sp. 2, *Majungaella*? sp., *Monoceratina* sp., *Cardobairdia* sp., *Paracypris* sp. 2, *Pontocyprella* sp. 1 and Gen. *et* sp. indet. 3 have their first occurrences. The species *Pontocyprella* sp. 2, *Ektyphocythere* sp. and Gen. *et* sp. indet. 2, on the other hand, are represented by only one specimen each and restricted to the lower part of the section. The remaining species occur both in the upper and in the lower parts of the studied section. Faunal turnovers and richness variations usually result from changes in environmental parameters related to the water depth and productivity (*e.g.* oxygen concentration, temperature, bottom composition) and reflect local sea level oscillation and sedimentary input. An additional evidence that this section records environmental reorganization is the occurrence of barren or very poor samples between 15 and 17 m, which represent a faunal threshold.

CONCLUDING REMARKS

Foraminiferal and ostracode assemblages from the studied section of the Dalichai Formation present similar increasing-upward trends in both abundance and richness. Twenty-four benthic foraminiferal taxa were identified within the studied section of the Dalichai Formation. The dominance of r-selected strategists among benthic foraminifera (species assigned to the genera *Reinholdella*, *Epistomina* and *Lenticulina*) suggests stressing paleoenvironmental conditions, probably related to bottom-water oxygen levels. The benthic foraminiferal fauna studied herein is similar to previously described ones ascribed to the Boreal Realm. This is in contrast to the Tethyan-Submediterranean paleozoogeographic affinity of the associated ammonite fauna, but closer to the Subboreal-Submediterranean affinity of the belemnite assemblages of the Dalichai Formation.

Among ostracodes, the genera *Cardobairdia*, *Cytherella*, *Cytheropterina*, *Ektyphocythere*, *Paracypris*, *Polycope* and *Pontocyprella* were identified, besides the possible oldest record of *Majungaella*. A conspicuous faunal turnover is seen among ostracodes between the samples 15 m and 17 m, which might be related to the paleoenvironmental restraints that caused the increased abundance and richness of ostracodes and foraminifera above this level. Ostracod-based paleozoogeographical remarks can not be advanced due to the poorness of the taxonomic data.

ACKNOWLEDGEMENTS

Criticism by M.L. Canales (Universidad Complutense de Madrid) and E.A.M. Koutsoukos (Universität Heidelberg) greatly improved the first version of the manuscript. Comments by A. Caramés (Universidad de Buenos Aires) and an anonymous reviewer are greatly appreciated. M. Goulart (Universidade do Vale do Rio dos Sinos) is thanked for the SEM images.

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Received in June, 2014; accepted in January, 2015.