Journal of African Earth Sciences 97 (2014) 161–172

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

Marine benthic invertebrates of the upper Jurassic Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah, central Saudi Arabia

Abdelbaset S. El-Sorogy [a,b,*], Khaled M. Al-Kahtany [a], Hesham M. El-Asmar [c]

[a] Geology and Geophysics Department, College of Science, King Saud University, Saudi Arabia
[b] Geology Department, Faculty of Science, Zagazig University, Egypt
[c] Consultant, Vice Rectorate for Education and Academic Affairs, King Saud University, Saudi Arabia

ARTICLE INFO

Article history:
Received 5 August 2013
Received in revised form 29 March 2014
Accepted 4 April 2014
Available online 24 April 2014

Keywords:
Invertebrates
Jurassic
Saudi Arabia
Tuwaiq Mountain Limestone

ABSTRACT

26 species belong to 24 genera and 16 families have been described and illustrated from the Callovian Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah, central Saudi Arabia. 10 of the identified species belong to scleractinian corals, 7 to brachiopods, 4 to bivalves, 4 to gastropods and one to cephalopods. *Actinastraea pseudominima*, *Thamnasteria nicoleti*, *Enallocoenia crassoramosa*, *Collignonastraea* cf. *grossouvrei*, *Burmirhynchia jirbaensis*, *Pholadomya* (*Bucardiomya*) *somaliensis*, *Pseudomelania* (*Rhabdoconcha*) *raabi* and *Nautilus giganteus* are believed to be recorded for the first time from the Jurassic rocks of central Arabia. The identified species have close affinity to Tethyan faunas known from parts in Asia, Africa and Europe. They indicated shoaling of the sea floor persisted throughout the deposition of the Tuwaiq Mountain Limestone, in water depth ranging from 20 to 30 m. The low diversity of invertebrates in the studied section may attribute to paleoenvironmental conditions prevailed during the Callovian age as high rate of sedimentation.

1. Introduction

Studies on Jurassic invertebrates such as scleractinian corals, bivalves and gastropods of central Saudi Arabia are very few, unlike others such as brachiopods and cephalopods. In his study on Callovian corals in central Saudi Arabia, El-Asa'ad (1989) stated that, a broad shallow sea deposited very extensive bioclastic limestones and calcarenites, rich in silicified corals and stromatoporoids during upper middle-upper Callovian. The upper part of these limestones forms an extensive coral biostrome extending for more than 1000 km in central Saudi Arabia and locally includes bioherms.

The earliest development of a coral-bearing carbonate in central Saudi Arabia took place during of the deposition of the upper Tuwaiq Mountain Limestone (Late Callovian). An extensive sheet of coral bearing, dense, pure aphanitic limestone (25–40 m thick) caps the Tuwaiq Mountain Limestone. The main target of the present work is to identify the Callovian marine invertebrates of the Tuwaiq Mountain Limestone at Khashm Al-Qaddiyah area, central Saudi Arabia (Fig. 1) and document their paleoecological aspects.

1.1. Materials and methods

Two field trips were carried out to Khashm Al-Qaddiyah area in order to measure section and collect fossils. All fossils are stored in the Museum of the Geology and Geophysics Department, College of Science, King Saud University. Distribution data of the identified fossil materials have been collected from previously published articles and mostly from the Paleobiology Database (http://paleodb.org). Abbreviations used for measurements are: *d*, diameter of calices; c–c, nearest distance between calicular centers; Ns, number of septa; *L*, length of bivalve and brachiopod shell; *W*, width of bivalve and brachiopod shell; *T*, thickness of bivalve and brachiopod shell; SH, height of the gastropod shell; AH, aperture height; MD, maximum diameter.

2. Geological setting and stratigraphy

The Jurassic succession in Saudi Arabia is represented by the Shaqra Group, which is subdivided into seven formations. These are from older to younger: Marrat, Dhruma, Tuwaiq Mountain Limestone, Hanifa, Jubaila, Arab and Hith formations. Jurassic outcrops in central Saudi Arabia are arranged in a convex arc hinged in Al-Riyadh region with the horns of the arc oriented to the northwest and to the south. The total outcrop length is in excess of 1000 km and the width nowhere exceeds 85 km. The greatest

* Corresponding author at: Geology and Geophysics Department, College of Science, King Saud University, Saudi Arabia. Tel.: +966 540325046.
E-mail address: asmohamed@ksu.edu.sa (A.S. El-Sorogy).

http://dx.doi.org/10.1016/j.jafrearsci.2014.04.004
1464-343X/

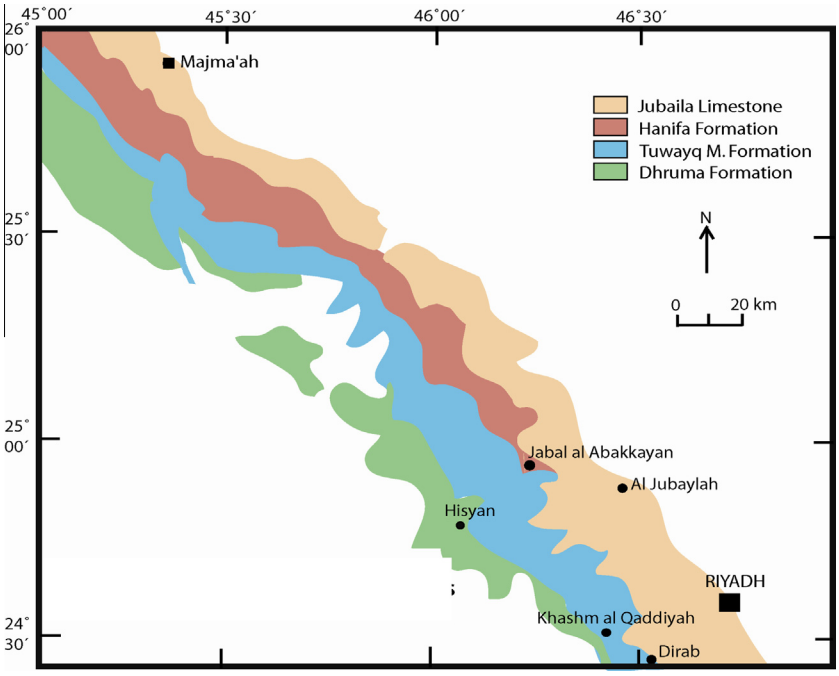

Fig. 1. Location map of the study area.

outcrop width and thickness (1100 m thick) are in the Al-Riyadh region. This represents the area closest to the open sea domain of the Tethys which was located to the north-east of Riyadh, mostly underling the present day Arabian Gulf (El-Asa'ad, 1989).

The lithostratigraphy of the Tuwaiq Mountain Limestone has been described by Arkell (1952), Steineke et al. (1958), Powers et al. (1966), Powers (1968), Vaslet et al. (1991), Le Nindre et al. (1990), Al-Husseini (1997), Sharland et al. (2001) and Hughes (2004, 2006). The Tuwaiq Mountain Limestone is named after Jabal Tuwaiq, the spectacular, nearly parallel sequence of west-facing scarps developed in the Jurassic rocks of central Arabia. It forms the largest and most persistent of these escarpments and, as such, constitutes the backbone of Jabal Tuwaiq.

The thickness of The Tuwaiq Mountain Limestone reaches a maximum of between 200 and 250 m in the Darb al-Hijaz (type locality) to Wadi Nisah (lat. 24°15′N) area and thins uniformly away from this region to the north and to the south, where it becomes 45–60 m thick at its northern and southern extremities. The lower Tuwaiq Mountain Limestone comprises a series of fine grained, fairly clayey limestone intercalated with beds of brown calarenites and white bioturbated nodular limestone. The Middle Tuwaiq Mountain Limestone comprises a monotonous assemblage of fine-grained or gravelly bioclastic limestones, relatively bioturbated and clayey, containing isolated colonies. The Upper Tuwaiq Mountain Limestone consists of very extensive bioclastic limestone and calcarenite, rich in silicified corals and stromatoporoids which give rise to reef forms with bioherms in the middle of the basin.

At Khashm Al-Qaddiyah section, the Tuwaiq Mountain Limestone attains about 190 m thick of mostly shallow-marine lagoon carbonates (Figs. 2 and 3). It is composed at the lower part of yellowish green marls with gypsum veinlets intercalated with thin fossiliferous limestones. The middle part of the section is a limestone succession topped by conglomeratic limestone with abundant silicified corals. The upper part of the section is a massive bedded, chalky limestone intercalated with chert layers and lenses. The upper most 25–40 m thick of coral bearing, bioturbated limestone caps the Tuwaiq Mountain Limestone.

In the studied section, no Dhruma/Tuwaiq boundary is observed as the base of the section is covered. The upper boundary of the Tuwaiq Mountain Limestone with the overlying Hanifa Formation is unconformable and is taken at the change from light-colored, massive, resistant, coral-bearing aphanitic limestone below to brown, soft, thin-bedded, non-coral-bearing and calcarenitic limestone above.

3. Systematic paleontology

3.1. Corals

Class Anthozoa Ehrenberg, 1834
Subclass Zoantharia Blainville, 1830
Order Scleractinia Bourne, 1900
Suborder Astrocoeniina Vaughan and Wells, 1943
Family Actinastraeidae Alloiteau, 1952
Genus *Actinastrea* d'Orbigny, 1849
Type species: *Astrea goldfussi* d'Orbigny, 1849 [= *Astrea geminata* Goldfuss, 1826].

Actinastraea pseudominima (Koby, 1897)
(Fig. 4A and B)
1897 *Astrocoenia pseudominima* Koby: 59, pl. 15, figs. 4, 4a.
1998 *Actinastraea* aff. *pseudominima* (Koby) – Morycowa and Masse: 738, pl. 10, fig. 2.
2003 *Actinastraea* aff. *pseudominima* (Koby) – Baron-Szabo et al.: 201, pl. 36, figs. 5, 6.
2007 *Actinastraea pseudominima* (Koby) – Pandey et al.: 9, pl. 1, figs. 1, 2.

Material: One moderately preserved corallum.

Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: *d* = 1.5–3.5 mm, c–c = 1.7–3.2 mm, Ns = 13–24.

Description: Corallum colonial, small, encrusting, cerioid. Budding intracalicular. Calices outline subcircular to polygonal. Septa compact, occasionally anastomosing, arranged in three cycles, inner margins of primary septa (up to 8 septa) fused in the center. Wall septoparathecal. Columella well developed.

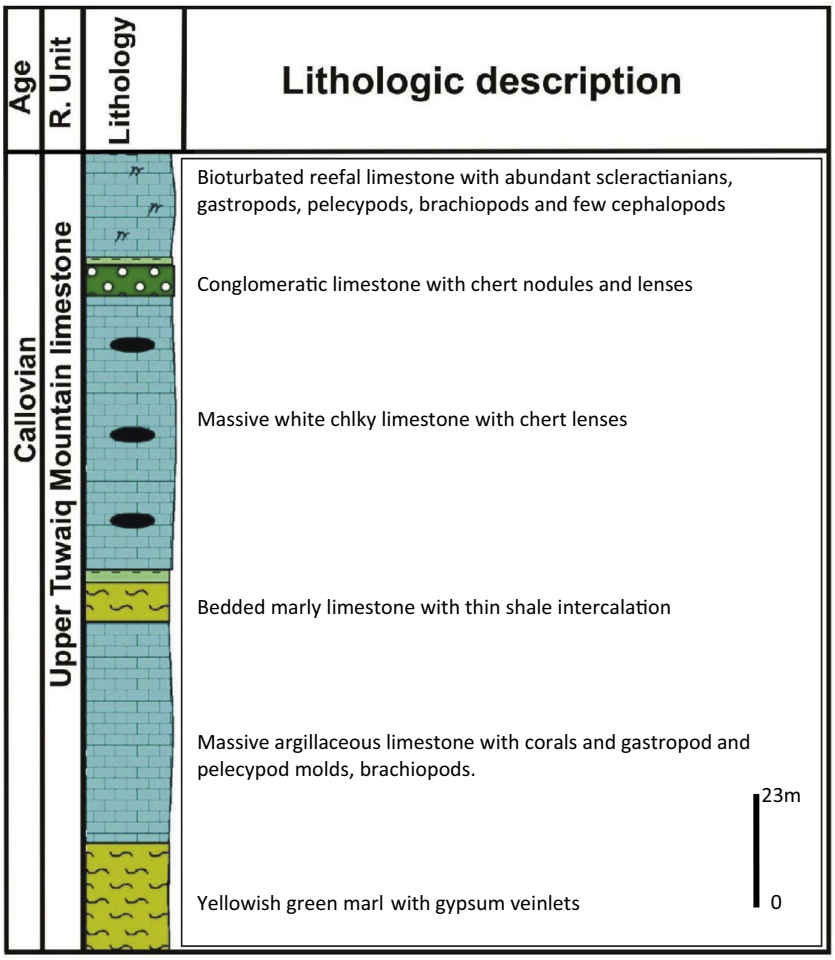

Fig. 2. Lithology and faunal content of the Tuwaiq Mountain Limestone at Khashm Al-Qaddiyah section.

Fig. 3. Exposed Tuwaiq Mountain Limestone at Khashm Al-Qaddiyah, west of Riyadh.

Distribution: Lower Cretaceous of Iran and France.

Family Thamnastcriidae Reuss, 1864

Genus *Thamnasteria* Lesauvage, 1823

Type species: *Thamnasteria concinna* (Goldfuss, 1826)

Thamnasteria nicoleti Koby, 1897

(Fig. 4C and D)

1897 *Thamnasteria nicoleti* Koby: 374, pl. 103, fig. 1.

1964 *Thamnasteria nicoleti* Koby – Beauvais: 214, pl. 25, fig. 6, pl. 27, fig. 3.

1993 *Thamnasteria nicoleti* Koby – Pandey and Fursich: 25, pl. 6, figs. 10, 13, text-fig. 16.

Material: Two badly preserved specimens.

Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: d = 4–5 mm, c–c = 6–9 mm, Ns = 40–51.

Description: Corallum encrusting, thamnasterioid, corallites small. Calices superficial, with prominent central calicular pit. Septa thin, with tiny granulae along the sides. Septa short to long, perforated and confluent with those of adjoining corallites. Columella trabecular. Epitheca present.

Distribution: Jurassic of France, Greece, India and Switzerland.

Family Isastreidae Alloiteau, 1952

Genus *Isastrea* Milne Edwards and Haime, 1851

Type species: *Astrea helianthoides* Goldfuss, 1826

Isastrea hemisphaerica Gregory, 1900

(Fig. 4E and F)

1900 *Isastraea hemisphaerica* Gregory: 127, pl. 16, figs. 2–4.

1993 *Isastraea hemisphaerica* Gregory – Pandey and Fursich: 18, pl. 11, fig. 10.

2014 *Isastraea hemisphaerica* Gregory – El-Sorogy and Al-Kahtany: figs. 4/C, D.

Material: 7 moderately preserved corolla.

Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

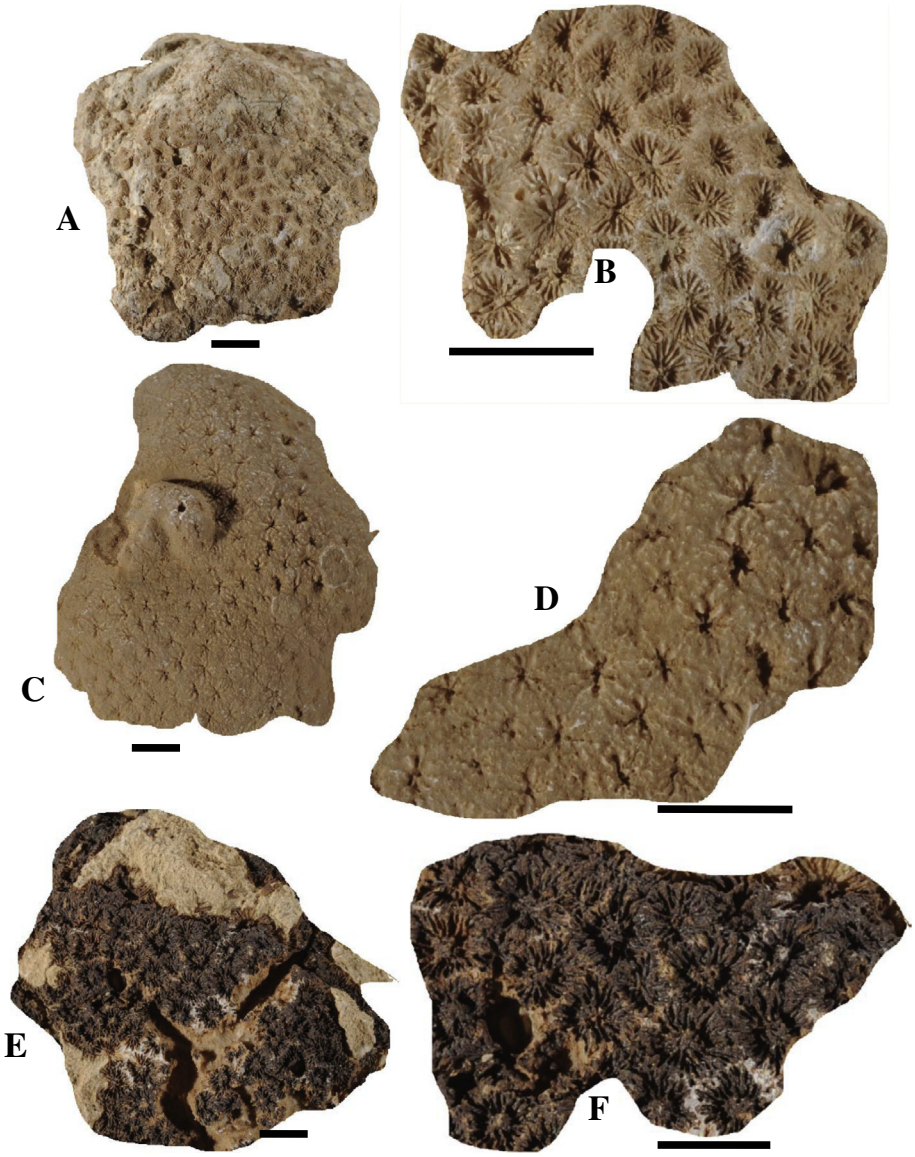

Fig. 4. (A and B) *Actinastraea pseudominima* (Koby, 1897). (A) Calicular view showing a cerioid corallum and polygonal outlines of the calices. (B) Close up view of a small part of the same colony showing compact, occasionally anastomosing septa. (C and D) *Thamnasteria nicoleti* Koby 1887. (C) Calicular view showing a thamnasterioid corallum with superficial calices. (D) Close up view of the same with prominent central calicular pit, with short to long and confluent septa with those of adjoining corallites. (E and F) *Isastrea hemisphaerica* Gregory, 1900. (E) Calicular view showing a cerioid corallum and polygonal outlines of the calices. (F) Close up view of the same showing anastomosing septa at the inner edge and pseudocolumella due to reaching the first and second cycles with corallites centers. Scale bar = 1 cm.

Dimensions: *d* = 3.3–6.2 mm, c–c = 4.5–7.2 mm, Ns = 40–50.

Description: Corallum massive. Corallites cerioid, polygonal in outline. Calices distinct, moderately deep, mostly monocentric, rarely dicentric. Septa compact, thick, covered with granules and spinules. Septa arranged in at least four cycles, anastomosing at the inner edges. Septa of the first and second cycles nearly reaching the center, occasionally forming a pseudocolumella. Third and fourth cycles extent from the corallites wall to about one third of the corallites diameter. Septa non-confluent with those of adjacent corallites. Wall septothecal.

Remarks: The diameters of corallites in the present specimens agree with specimens of Pandey and Fürsich (1993) and are smaller (3.3–6.2 mm) than those of Gregory (8 mm).

Distribution: Jurassic of Chile, India and Saudi Arabia.

Genus *Enallocoenia* D'Orbigny, 1849

Type species: *Astrea crasso-ramosa* Michelin, 1840

Enallocoenia crassoramosa (Michelin, 1843)

(Fig. 5A and B)

1843 *Astrea crasso-ramosa* Michelin: 109, pl. 25, fig. 2.

2003 *Enallocoenia crassoramosa* (Michelin) – Pandey and Fürsich: 13, pl. 2, fig. 7.

2007 *Enallocoenia crassoramosa* (Michelin) – Pandey et al.: 10, pl. 2, figs. 2/a, b, pl. 3, figs. 1/a, b, 2/a, b.

Material: Three well preserved fragments.

Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: *d* = 2.5–3.5 mm, c–c = 2.2–3.3 mm, Ns = 12–24.

Description: Corallum cerioid with a moderately large attachment area. Calices small, distinct, moderately deep, polygonal in outline. Septa compact, moderately thick, few in number, thickest at the periphery and thinning towards the center, non-anastomosing to rarely anastomosing, non-confluent, arranged in three cycles; the larger ones (numbering 6–12) nearly reaching the center, occasionally joined to the columella. Septa of second cycle

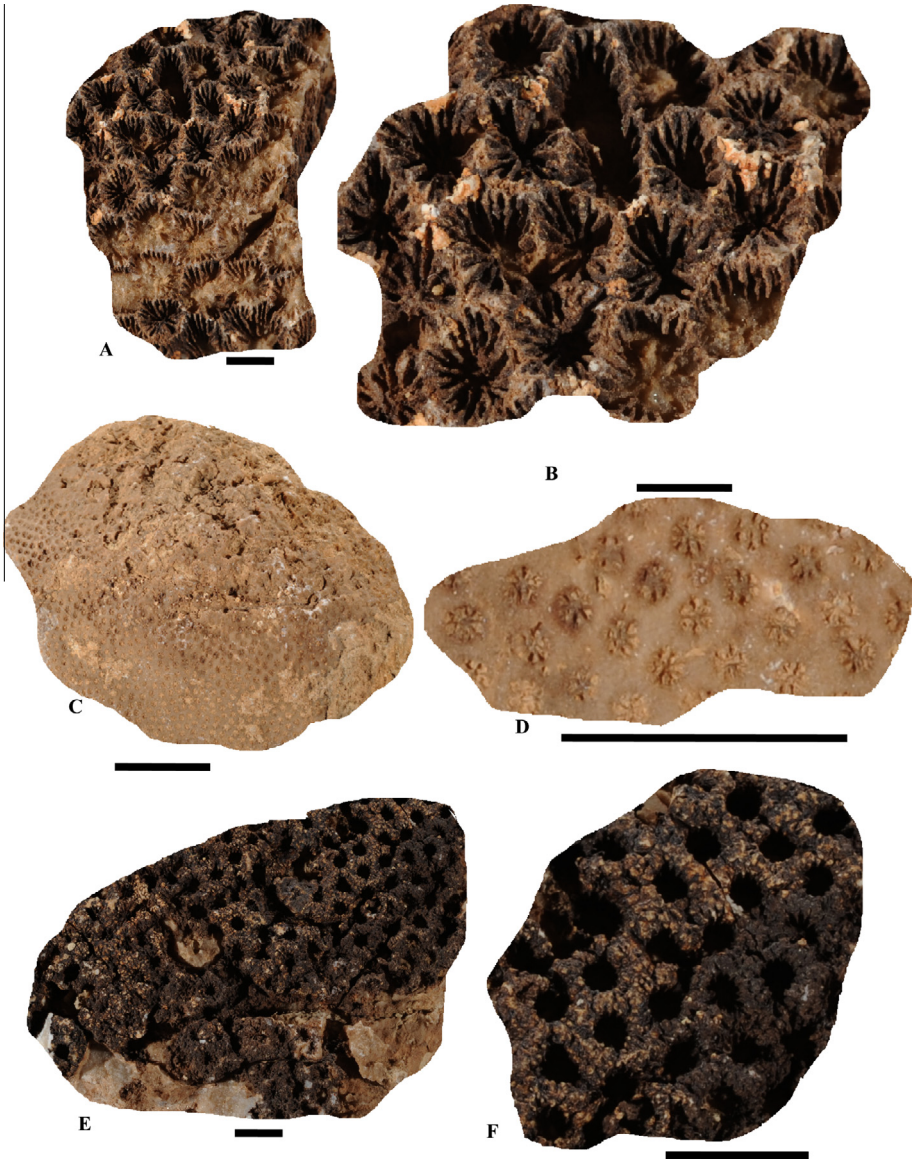

Fig. 5. (A and B) *Enallocoenia crassoramosa* (Michelin, 1843). (A) Calicular view showing a cerioid corallum with subpolygonal corallities. (B) Close-up view showing non-anastomosing septa with occasionally bulging inner edges and septoparathecal wall. (C and D) *Stylina regularis* Fromentel, 1867. (C) Side view showing plocoid colony. (D) Close-up view showing columella thickened by inner edges of first cycle of septa and costae. (E and F) *Cryptocoenia wegeneri* Pandey and Fürsich, 1993. (E) Calicular view showing a plocoid corallum with circular corallites. (F) Enlarged of the same showing subconfluent septocostae and absent columella. Scale bar = 1 cm.

shorter and those of third cycle rudimentary or very short. Lateral surfaces ornamented with very fine granules and spinules. Dissepiments common. Wall thin, septoparathecal. Columella small, distinct, trabecular.

Remarks: The specimens are fragmentary. It seems that the rare cases of anastomosing septa are early stages of intracalicular budding. The morphological features and dimensions match with those of *Enallocoenia crassoramosa* (Michelin) described by earlier worker from the Jurassic.

Distribution: Jurassic of India and Lower Cretaceous of Iran.

Suborder Stylinina Alloiteau, 1952

Family Stylinidae ÓOrbigny, 1851

Genus *Stylina* Lamarck, 1816

Type species: *Stylina echinulata* Lamarck, 1816

Stylina kachensis Gregory, 1900

(Fig. 5C and D)

1900 *Stylina kachensis* Gregory: 56, pl. 12, Figs. 1–17, pl.13. Figs. 1–7.

1993 *Stylina kachensis* Gregory – Pandey and Fürsich: 9, pl. 1, Figs. 3–5, text-fig. 7.

2014 *Stylina kachensis* Gregory – El-Sorogy and Al-Khahtany: fig. 3/K, L.

Material: One badly preserved specimen.

Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: d = 1.2–3.1 mm, c–c = 1.4–3.0 mm, Ns = 12.

Description: Corallum hemispherical. Corallites plocoid, slightly projecting beyond the corallum. Corallite wall septothecal. Calices shallow to moderately deep and circular in plain view. Septa well developed, primaries may or may not meet the columella, secondaries short and do not reach the columella. Vesicular and tabular endothecal dissepiments common. Costae well developed, joining with those of the adjoining corallites. Columella styliform, mostly prominent.

Remarks: The present species differs from *Stylina delabechii* Milne Edwards and Haime (1851) in that, the latter is characterized

by projecting calices, more septa and more prominent and confluent costae.

Distribution: Jurassic of Chile, India and Iran.

Genus *Cryptocoenia* d'Orbigny, 1847

Type species: *Aslrea alveolala* Goldfoss, 1826.

Cryptocoenia wegeneri Pandey and Fürsich, 1993

(Fig. 5E and F)

1900 *Stylina kachensis* Gregory: 58, pl. 13, fig. 6.

1993 *Cryptocoenia wegeneri* Pandey and Fürsich: 10, pl. 5, figs. 4, 6, 9, text fig. 8.

2014 *Cryptocoenia wegeneri* Pandey and Fürsich – El-Sorogy and Al-Kahtany: figs. 4/A, B.

Material: Five badly preserved fragments.

Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: *d* = 2.5–4 mm, c–c = 3.5–4.5 mm, Ns = 6–12

Description: Corallum plocoid. Corallites circular, bounded by septotheca and parathecal wall. Coenosteum composed of thin, more or less horizontal exotheca. Septa few in numbers, thick, hexamerally arranged. Tabular and vesicular endothecal dissepiments present. Columella absent.

Distribution: Jurassic of India and Iran, Saudi Arabia.

Family Kobyastraeidae Roniewicz, 1970

Genus *kobyastrea* Roniewicz, 1970

Type species: *Thamanastrea lomontiana* Etallon, 1864

Kobyastraea lomontiana (Etallon, 1864)

(Fig. 6A and B)

1864 *Thamanastrea lomontiana* Etallon: 399, pl. 56, fig. 14.

1897 *Thamanastrea lomontiana* Etallon – koby: 366, pl. 98, fig. 4.

1970 *Kobyastraea Lomontiana* (Etallon) – Roniewicz:140, pl. 1, figs. 1, 2, pl. 2, fig. 1, pl. 3, fig. 4.

1975 *Kobyastraea Lomontiana* (Etallon) – Turnšek:15, 10, fig. 3.

1985 *Kobyastraea Lomontiana* (Etallon) – Rosendahl, 68, pl. 2, fig, 9.

1991 *Kobyastraea Lomontiana* (Etallon) – El-Asa'ad: 282, pl. 4, fig. 1/a–c.

2011 *Kobyastraea Lomontiana* (Etallon) – Kiessing et al.: 206, fig. 9/E, F.

2014 *Kobyastraea Lomontiana* (Etallon) – El-Sorogy and Al-Kahtany: figs. 6/C, D.

Material: Two moderately preserved specimens.

Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: *d* = 3.3–7.1 mm, c–c = 3.2–6.3 mm, Ns = 36.

Description: Corallum massive and thamnasterioid with shallow, dense calices. Extracalicular and rarely intratentacular budding. Septa confluent from one corallite center to another, 3–4 cycles. Septa of the first cycle long and reach the columella, the second cycle shorter and thinner, the third one join the second by their inner ends. Horizontal and large endothecal dissepiments. The wall synapticulothecal and incomplete. Columella is small, styliform and sometimes slightly flattened.

Distribution: Jurassic of Azerbaijan, Croatia, the Czech Republic, Ethiopia, Portugal, Saudi Arabia, Switzerland, Uzbekistan, Saudi Arabia.

Suborder Microsolenina Morycowa and Roniewicz, 1995

Family Latomeandridae Alloiteau, 1952

Genus *Ovalastraea* d'Orbigny, 1900

Type species: *Astra caryophilloides* Goldfuss, 1826

Ovalastraea caryophilloides (Goldfuss, 1826)

(Fig. 6C and D)

1943 *Ovalastraea caryophilloides* Goldfuss–Vaughan and Wells: 120, pl. 10, fig. 17.

1964 *Ovalastraea caryophilloides* Goldfuss – Beauvais: 259, pl. 38, fig. 3.

1989 *Ovalastraea caryophilloides* Goldfuss – El-As'ad: 677, pl. 78, figs. 4–9.

Material: Seven moderately preserved specimens.

Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: *d* = 5–14 mm, c–c = 4–12 mm, Ns = 50–60.

Description: Corallum massive, plocoid. Lower surface without epitheca. Corallum surface moderately convex. Mono- to tricentric, circular to subpolygonal corallites, united by costae and perithecal dissepiments. Septa in 4–5 cycles, meet the axial region at their inner ends. 5–20 short septa join the long ones at their inner margins. Septa bifurcate at the corallite margins and spread as exothecal costae. Columella trabecular or spongy.

Distribution: Jurassic to Cretaceous of Spain. Jurassic of the Czech Republic, France, Georgia, Germany, Poland, Portugal, the Russian Federation and Spain.

Genus *Collignonastraea* Alloiteau, 1958

Type spccies: *Comoserisjumarense radiata* Gregory, 1900

Collignonastraea jumarensis (Gregory, 1900)

(Fig. 6E and F)

1900 *Comoseris plana* Gregory: 160. pl. 20, figs. 6–8.

1978 *Collignonastraea jumarensis* (Gregory) – Beauvais: 65, pl. 6, fig. 4.

2003 *Collignonastraea jumarensis* (Gregory) – Pandey and Fürsich: 39, pl. 10, figs. 5, 6, 8–13, 15, 16.

2014 *Collignonastraea jumarensis* (Gregory) – El-Sorogy and Al-Kahtany: figs. 5/A, B, C.

Material: Two moderately preserved specimens.

Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: *d* = 2.4–6.8 mm, c–c = 2.2–6.0 mm.

Description: Corallum low, meandroid. Calices distinct, bounded by synapticulotheca along the collines. Septa thin, dense, with pointed to rounded granules along the sides. Synapticulae and dissepiments common. Columella either not visible on the calicular surface or with trabecular-like appearance. Primary collines radiate from the central corallite. With increasing size, secondary and tertiary collines either branch from primaries or independently develop towards the periphery.

Distribution: Jurassic of China, India, Iran and Jordan, Saudi Arabia.

Collignonastraea grossouvrei Beauvais, 1972

(Fig. 7A and B)

1972 *Collignonastraea grossouvrei* Beauvais: 48, pl. E, fig. 3.

2011 *Collignonastraea* cf. *grossouvrei* Beauvais – Kiessing et al.: 206, fig. 9/C, D.

Material: One moderately preserved corallum.

Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: *d* = 3.8–11.8 mm, c–c = 3.9–7.2 mm.

Description: Corallum meandroid, formed by intracalicular linear budding. Valleys sinuous, wide, with mostly one, rarely two series of calice centers. Valleys divide into two towards the periphery. Septa subcompact, distal margin with fine, acute to obtuse denticles. Collines prominent, tectiform to tholiform. Septa thin and numerous, mostly non-nastomosing.

Remarks: The morphological characters and dimensions, particularly septal density match *Collignonastraea grossouvrei* Beauvais (1972).

Distribution: Jurassic of Ethiopia, France, and the United Kingdom.

3.2. Brachiopods

Superfamily Rhynchonellacea Gray, 1848

Family Rhynchonellidae Gray, 1848

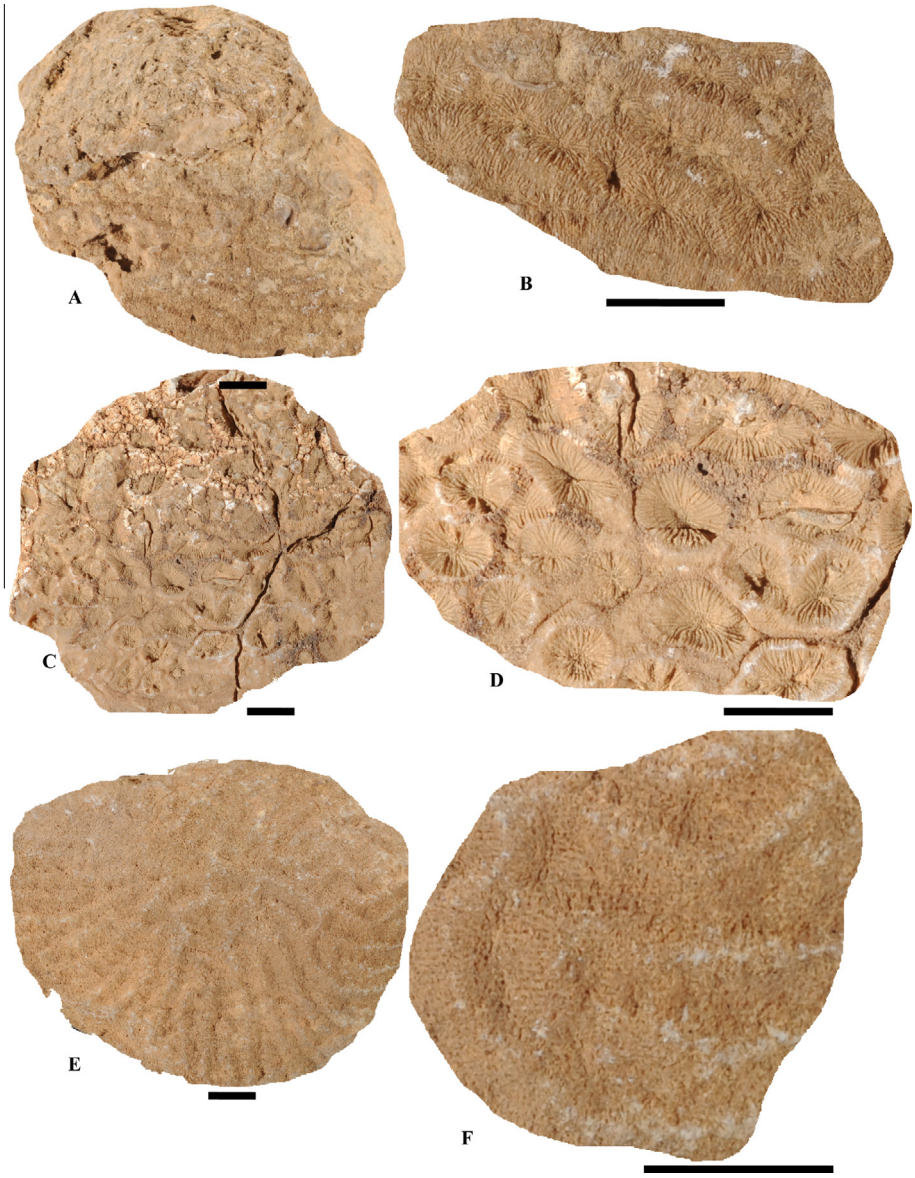

Fig. 6. (A and B) *Kobyastraea lomontiana* (Etallon, 1864). (A) Calicular surface showing massive and thamnasterioid corallum with shallow and dense calices. (B) Close up view of the same showing confluent septa from one corallite center to other, septa of the first cycle reach the Columella. (C and D) *Ovalastraea caryophilloides* (Goldfuss, 1826). (C) Calicular view showing massive, plocoid corallum with circular ovate, elongate or subpolygonal corallites. (D) Close up view of the same showing Mono- to tricentric corallites, united by costae and perthecal dissepiments, Septa meet the axial region at their inner ends. (E and F) *Collignonastraea jumarensis* (Gregory 1900). (E) Calicular view showing low, meandroid corallum with subcircular to subelliptical corallites, secondary and tertiary collines either branch from primaries or independently develop towards the periphery. (F) Enlarged part of the same showing synapticulotheca along the collines and thin, dense septa. Scale bar = 1 cm.

Genus *Burmirhynchia* Buckman, 1918

Type species: *Burmirhynchia jirbaensis* Muir-Wood, 1935.

Burmirhynchia jirbaensis Muir-Wood, 1935

(Fig. 7C)

1935 *Burmirhynchia jirbaensis* Muir-Wood: 91, pl. 8, fig. 3/a, c.

2001 *Burmirhynchia jirbaensis* Muir-Wood – Feldman et al.: 641, pl. 1, figs. 1–6, text-fig. 3.

Material: Two articulated, moderately preserved specimens.

Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: L = 22 mm, W = 22.2 mm, T = 17 mm.

Remarks: The present species is characterized by a slightly inflated umbo with an incurved beak. The median fold on the dorsal valve is more clearly defined, but the anterior margin shows a similar, broadly trapezoidal sulcation of the ventral valve with a broad arched or arcuate anterior commissure.

Distribution: Jurassic of Israel and Somalia.

Baeorhynchia Cooper, 1989

Type species: *Baeorhynchia nucleata* Cooper, 1989

Baeorhynchia nitida Cooper, 1989

(Fig. 7D)

1989 *Baeorhynchia nitida* Cooper: 13, pl. 1, figs. 34–51.

Material: Five articulated moderately preserved specimens.

Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: L = 23 mm, W = 22 mm, T = 18 mm.

Description: Shell of small size, subtriangular, Anterior margin nearly straight to gently rounded, sides narrowly rounded, apical angle acute. Anterior commissure strongly uniplicate. Beak short, low, erect. Foramen small, narrow. Costae narrowly rounded, strong, about 17–25. Ventral valve flatly convex in lateral view, fairly strongly sulcate in anterior view. Dorsal valve gently convex

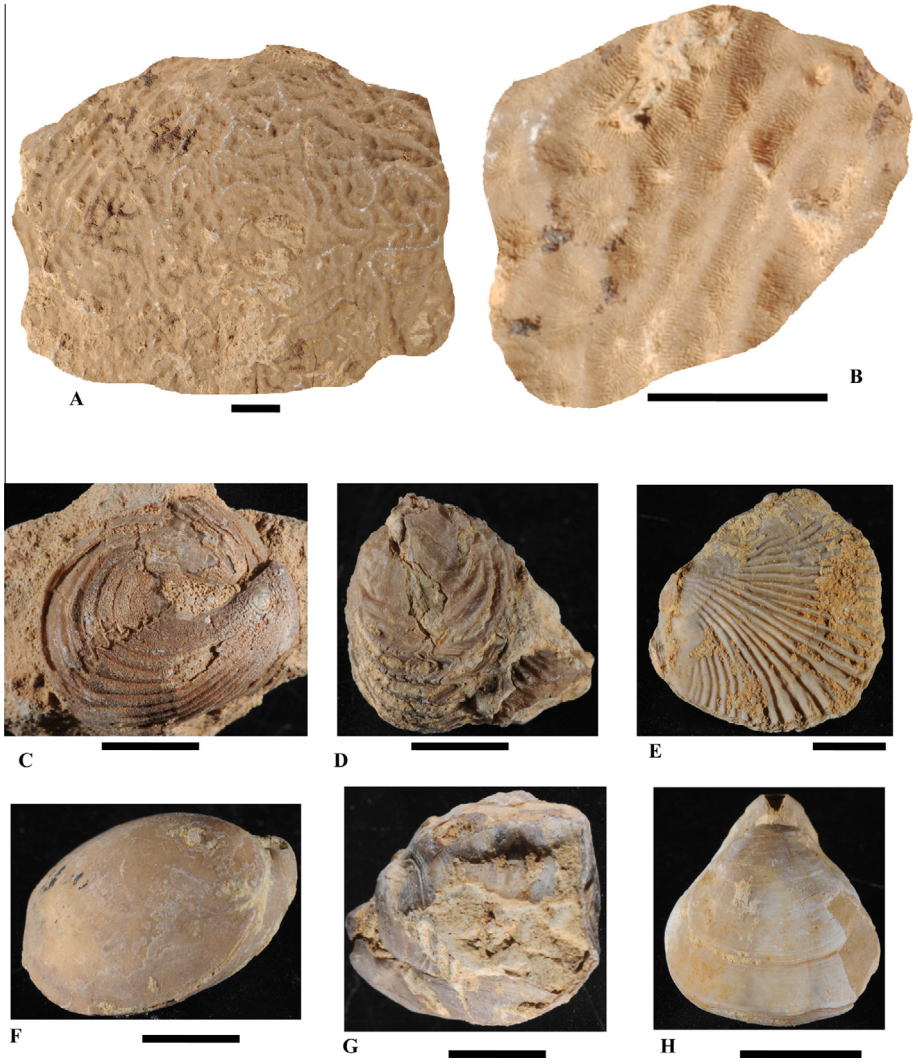

Fig. 7. (A and B) *Collignonastraea grossouvrei* Beauvais 1972. (A) Calicular view showing a meandroid corallum. (B) Close up view of the same showing sinuous valleys with thin subcompact septa. (C) *Burmirhynchia jirbaensis* Muir-Wood, 1935. Side view. (D) *Baeorhynchia nitida* Cooper, 1989. Side view. (E) *Apothyris aberrans* Cooper, 1989. Dorsal view. (F) *Habrobrochus amygdaloideus* Cooper, 1989. Side view. (G) *Apatecosia inornata* Cooper, 1989. Side view. (H) *Bihenithyris mediocostata* Cooper, 1989. Dorsal view. Scale bar = 1 cm.

in lateral view, strongly domed with steep sides in anterior profile. Fold narrowly rounded, originating at midvalve with 4 or 5 costae.

Remarks: This species differs from *Baeorhynchia eleganlula* in having stronger costae and narrower fold. *Baeorhynchia nitida* differs from *B. carinata*, in being larger, wider, and with stronger costae.

Distribution: Jurassic of Saudi Arabia.

Superfamily Zeilleriacea Allan, 1940

Family Eudesiidae Muir-Wood, 1965

Apothyris Cooper, 1989

Type species: *Apothyris aberrans* Cooper, 1989

Apothyris aberrans Cooper, 1989

(Fig. 7E)

1989 *Apothyris aberrans* Cooper: 101, pl. 32, figs. 36–63.

Material: One articulated well preserved specimen.

Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: *L* = 33 mm, *W* = 39 mm, *T* = 11 mm.

Description: Shell of medium size, subrounded to oval, inequivalve, dorsal valve less deep than ventral valve. Beak short, wide. Lateral commissure straight, anterior commissure slightly uniplicate. Costae strong, elevated, narrowly rounded, 12–18. Ventral valve moderately convex in side view, broadly, fairly strongly domed in anterior profile. Umbonal region swollen. Dorsal valve slightly convex in side view, broadly, gently domed in anterior profile.

Distribution: Jurassic of Saudi Arabia.

Superfamily Terebratulacea Gray, 1840

Family Terebratulidae Gray, 1840

Genus *Habrobrochus* Cooper, 1983

Habrobrochus amygdaloideus Cooper, 1989

(Fig. 7F)

1989 *Habrobrochus amygdaloideus* Cooper: 82, pl. 31, figs. 13–21.

Material: Two articulated well preserved specimens.

Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: *L* = 26 mm, *W* = 22 mm, *T* = 16 mm.

Description: Shell of small size, subelliptical, maximum width at anterior, side view biconvex. Hing-line curved. Commissure line simple. Beak large. Dorsal valve slightly convex in side view. Moderately domed with steeply sloping sides in anterior profile. Umbonal and median regions swollen.

Distribution: Jurassic of Saudi Arabia

Apatecosia Cooper, 1983
Type species: *Cererithyris nutiensis* Bague, 1955
Apatecosia inornata Cooper, 1989
(Fig. 7G)
1989 *Apatecosia inornata* Cooper: 69, pl. 20, figs. 1–5.
2001 *Apatecosia inornata* Cooper – Feldman: 643, pl. 1, figs. 16–18.
Material: One articulated and one inarticulated specimens.
Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.
Dimensions: *L* = 25 mm, *W* = 20 mm, *T* = 15.5 mm.
Description: Shell of small size, evenly biconvex, subpentagonal in outline. Umbo massive, beak suberect with rounded or poorly defined beak ridges. The foramen is large and circular. Shell surface with evenly spaced faint concentric growth lines.
Distribution: Jurassic of Israel and Saudi Arabia.
Bihenithyris Muir-Wood, 1935
Type species: *Bihenithyris barrlngtoni* (Muir-Wood, 1935)
Bihenithyris mediocostata Cooper, 1989
(Fig. 7H)
1989 *Bihenithyris mediocostata* Cooper: 76, pl. 23, figs. 9–11.
2001 *Bihenithyris mediocostata* Cooper – Feldman: 644, pl. 1, figs. 19–23.
Material: One articulated well preserved specimen.
Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.
Dimensions: *L* = 25.1 mm, Width = 20.1 mm, *T* = 13.0 mm.
Description: Shell of small size, pentagonal, biconvex. Dorsal valve sometimes less acutely convex than ventral. Umbo massive, suberect, truncated by large circular labiate foramen with distinct mesothyrid beak ridges. Maximum width of shell approximately just anterior to midvalve. Dorsal valve with two well developed folds at the anterior margin.
Remarks: The present species differs from *B. quadrilobata* Cooper, 1989 in its less incurved beak and more pronounced anterolateral extremities.
Distribution: Jurassic of Israel and Saudi Arabia.
Arapsothyris Cooper, 1989
Type species: *Arapsothyris magna* Cooper, 1989.
Arapsothyris magna Cooper, 1989
(Fig. 8A)
1989 *Arapsothyris magna* Cooper: 74, pl. 22, figs. 6–20.
Material: Two articulated badly preserved specimens.
Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.
Dimensions: *L* = 40.1 mm, Width = 46.3 mm, *T* = 21.0 mm.
Description: Shell of medium size, pentagonal. Anterior narrowly, gently rounded, sides narrowly rounded. Anterior commissure sulciplicate. Beak subcarinate, narrow, short, erect. Foramen small. Ventral valve strongly convex in side view, narrowly domed with flattened, long steeply sloping sides in anterior profile. Dorsal valve deceptively convex in side view, broadly concave in anterior profile. Umbo narrowly sulcate. Fold developed at anterior of concave valve, visible in anterior third as pair of broad costae separated by shallow depression.
Remarks: The present species differs from *Terebratula superstes* Douvillé (1916) from the Bathonian of the Sinai Peninsula, Egypt in having a narrower, subcarinate beak, shorter and concave posterolateral margins, maximum width more posterior, and the dorsal valve more deeply concave.
Distribution: Jurassic of Saudi Arabia.

3.3. Bivalves

Class Bivalvia Linné, 1758
Order Ostreoida Ferussac, 1822
Superfamily Ostreoidea Rafinesque, 1815
Family Palaeolophidae Malchus, 1990
Genus *Actinostreon* Bayle, 1878
Type species: *Ostrea solitaria* Sowerby, 1824.
Actinostreon gregareum (Sowerby, 1816)
(Fig. 8B)
1816 *Ostrea gregarea* Sowerby: 19, pl. 111, figs. 1, 3.
1824 *Ostrea solitaria* Sowerby: 105, pl. 468, fig. 1.
1933a *Lopha gregarea* (Sowerby) – Arkell: 183, pl. 22, figs. 5–6, pl. 23, figs. 1–4.
1995 *Actinostreon gregareum* (Sowerby) – Jaitly et al.: 186, pl. 13, fig. 13, pl. 14, figs. 1–5.
1998 *Actinostreon gregareum* (Sowerby) – Holzapfel: 105, pl. 6, figs. 18, 19.
Material: Seven complete specimens.
Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.
Dimensions: *L* = 62 mm, Width = 40 mm, *T* = 15.3 mm.
Description: Shell of medium size, inequivalve and of variable shape. Shell ornamented with more than 10 rounded to sharp, radial plicae that diverge ventrally.
Distribution: Jurassic of China, Ethiopia, France, Germany, India, Japan, Jordan, Kenya, Madagascar, Mexico, Poland, Saudi Arabia, Somalia, Spain, Tanzania and the United Kingdom.
Subclass Anomalodesmata Dall, 1889
Order Pholadomyoida Newell, 1965
Superfamily Pholadomyacea King, 1844
Family Pholadomyidae Gray, 1847
Genus *Pholadomya* Sowerby, 1823
Type species *Lutraria ambigua* Sowerby, 1819
Pholadomya (Bucardiomya) aubryi Douvillé, 1886
(Fig. 8C)
1980 *Pholadomya* (*Bucardiomya*) *aubryi* Douvillé – Hirsch: pl. 7, figs. 12–14.
Material: Six internal moulds.
Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.
Dimensions: *L* = 83 mm, *W* = 36 mm, *T* = 65 mm.
Remarks: Mold of small-size, strongly inflated, triangular to trapezoidal, equivalved and strongly inequilateral. Umbons prominent, recurved and prosogyrate. Anterior margin truncated and the posterior one rounded without siphonal gapes, ventral margin straight.
Distribution: Jurassic of Israel, Ethiopia, Saudi Arabia and Somalia.
Pholadomya (Bucardiomya) somaliensis Cox, 1935
(Fig. 8D)
1935 *Pholadomya* (*Bucardiomya*) *somaliensis* Cox: 192, pl. 2, figs. 1, 2.
1980 *Pholadomya* (*Bucardiomya*) *somaliensis* Cox – Hirsch: pl. 8, figs. 1, 2.
2011 *Pholadomya* (*Bucardiomya*) *somaliensis* Cox – Kiessling et al.: 210, fig. 13Q.
Material: Seven complete internal moulds.
Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.
Dimensions: *L* = 69 mm, *W* = 35 mm, *T* = 49 mm.
Remarks: Mold of large-size, elongated to ovate. Mold ornamented with four strong radial ribs. The surface of ribs is uneven. *Pholadomya* (*Bucardiomya*) *somaliensis* differs from *Pholadomya* (*Bucardiomya*) *lirata* in having more elongated, larger and more pronounced marginal crenulations.
Distribution: Jurassic of Somalia, Ethiopia, Egypt, Yemen and Israel.
Genus *Homomya* Agassiz, 1843
Type species: *Mactra gibbosa* Sowerby, 1813
Homomya vezalayi (D'Archiac, 1843)

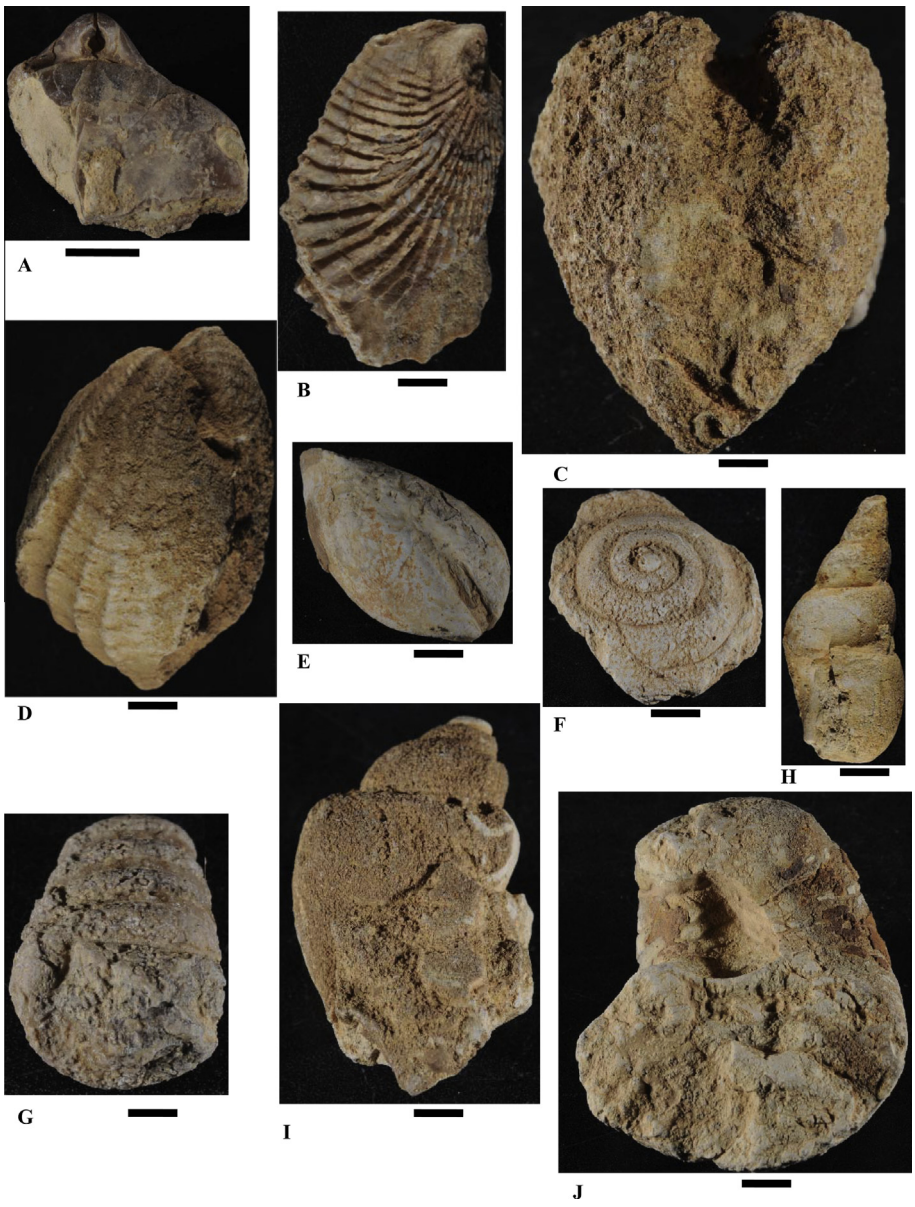

Fig. 8. (A) *Arapsothyris magna* Cooper, 1989. Dorsal view. (B) *Actinostreon gregareum* (Sowerby, 1815). Double-valved original shell. (C) *Pholadomya* (*Bucardiomya*) *aubryi* (Douvillé, 1886). Internal mold of a complete shell. (D) *Pholadomya* (*Bucardiomya*) *somaliensis* Cox, 1935. Internal mold of a complete shell. (E) *Homomya vezalayi* (D'Archiac, 1843). Internal mold of a complete shell. (F) *Kosmomphalus reticulatis* Fischer 2001. Internal mold. (G) *Pseudomelania* (*Rhabdoconcha*) *raabi* Reiner, 1968. Internal mold. (H) *Bathonella scotica* (Tate, 1873). Internal mold. (I) *Purpuroidea perstriata* Cossmann, 1925. Internal mold. (J) *Nautilus giganteus* D'Orbigny, 1843. A fragment of an internal mold. Scale bar = 1 cm.

(Fig. 8E)

1843 *Mya vezalayi* D'Archiac: 370, pl. 25, figs. 4–4b.

1999 *Homomya vezalayi* (D'Archiac) – Ahmed: 34, pl. 7, figs. 6/a, b.

Material: Four complete internal moulds.

Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: *L* = 46 mm, *W* = 22 mm, *T* = 31 mm.

Remarks: Mold large, elongated, equivalve, inequilateral, strongly inflated, umbons rounded and slightly compressed, situated one fifth of mold length from the anterior end.

Distribution: Jurassic of Jordan.

3.4. Gastropods

Class Gastropoda Cuvier, 1797

Superfamily Bellerophontoiacea McCoy, 1852

Family Euomphalidae Knight, 1956

Genus *Kosmomphalus* Fischer, 2001

Kosmomphalus reticulatus Fischer, 2001

(Fig. 8F)

2001 *Kosmomphalus reticulatus* Fischer: 71, pl. 1, figs. 1/a–c

2004 *Kosmomphalus reticulatus* Fischer – Szabó and Jaitly: 21, pl. I, figs. 6–10.

Material: Four complete internal moulds.

Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.

Dimensions: SH = 16 mm, AH = 6 mm, MD = 41 mm.

Remarks: Mold of small size, planispiral. Whorl diameter increases slowly. Whorl side appears flattened and keeled. Shell coil evolutes, ends with dextral aperture.

Distribution: Jurassic of Saudi Arabia and India.

Superfamily Pseudomelanioiacea Fischer, 1886

Family Pseudomelaniidae Fischer, 1886

Genus *Pseudomelania* Pictet and Campiche, 1862

Pseudomelania (Rhabdoconcha) raabi Reiner, 1968
(Fig. 8G)
1999 *Pseudomelania* (*Rhabdoconcha*) *raabi* Reiner–Abdel Gawad and Gameil: 776, pl. 1, figs. 19–21.
1999 *Pseudomelania raabi* Reiner – Khalil: pl. 2, fig. 9.
2001 *Pseudomelania* (*Rhabdoconcha*) *raabi* Reiner–Fischer: 78, pl. 1, fig. 15.
Material: One internal mould.
Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al Giddiyah.
Dimensions: SH = 52 mm, AH = 27 mm, MD = 40 mm.
Remarks: Moderately sized mold. Spire consists of four whorls. Whorls separated by flushed suture.
Distribution: Jurassic of Egypt and Saudi Arabia.
Family Campaniloidea Douvillé, 1904
Genus *Bathonella* Yen, 1948
Bathonella scotica (Tate, 1873)
(Fig. 8H)
1948 *Bathonella scotica* (Tate) – Anderson and Cox: 115, pl. III, figs. 13/a, b, 14.
2001 *Bathonella scotica* (Tate) – Fischer: 79, pl.1, figs. 18–19.
Material: Three internal moulds.
Occurrence: Callovian, middle and upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.
Dimensions: SH = 51 mm, AH = 20 mm, MD = 21 mm.
Remarks: Mold of small size, fusiform in outline. The spire consists of four overlapping whorls with convex outline. Sutures deep. The body whorl is large. Aperture subcircular.
Distribution: Jurassic of Great Britain and Saudi Arabia.
Superfamily Littorinoiacea Children, 1834
Family Purpurinidae Zittel, 1895
Genus *Purpuroidea* Lycett, 1848
Purpuroidea perstriata Cossmann, 1925
(Fig. 8I)
1925 *Purpuroidea perstriata* Cossmann – Douvillé: 316, pl.VII, fig. 5.
2001 *Purpuroidea perstriata* Cossmann – Fischer: 86, pl.3, figs. 6/a, b.
Material: Two internal moulds.
Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al-Qaddiyah.
Dimensions: SH = 71 mm, AH = 46 mm, MD = 46 mm.
Remarks: Mold of conical-ovate in shape, having six whorls. Base slightly convex in outline. Aperture semilunar. Whorls convex, becoming concave near adapical suture. *Purpuroidea perstriata* is distinct from other ones in its ovoid shape and fine ornament.
Distribution: Jurassic of Egypt and Saudi Arabia.

3.5. Cephalopods

Superfamily Stephanocerataceae Perrin Smith, 1913
Family Pachyceratidae Buckman, 1918
Genus *Erymnoceras* Hyatt, 1900
Nautilus giganteus D'Orbigny, 1843
(Fig. 8J)
1916 *Nautilus giganteus* (D'Orbigny) – Douvillé: 70, pl.VIII, fig. 7.
Material: One phragmocone.
Occurrence: Late Callovian, upper Tuwaiq Mountain Limestone, Khashm Al Giddiyah.
Dimensions: Whorl breadth = 72 mm.
Remarks: Mold of medium size. Sutures nautilic, broad. whorl section high, elliptical to rectangular.
Distribution: Oxfordian sediments of Sinai, Egypt.

4. Discussion and conclusions

During the Callovian, a broad shallow sea along the southern flank of the Tethys deposited bioclastic limestones from central Arabia eastwards to Iran and Oman, and southwards across Yemen and Aden. Similar neritic limestones extend north through central Iraq (Powers et al., 1966). In central Saudi Arabia, this broad shallow sea deposited very extensive bioclastic limestones and calcarenites of the Tuwaiq Mountain Limestone (upper middle-upper Callovian), rich in silicified corals and stromatoporoids. The upper part of these limestones forms an extensive coral biostrome extending for more than 1000 km in central Saudi Arabia and locally includes bioherms (El-Asa'ad, 1989).

26 benthic invertebrate species have been identified from the Callovian Tuwaiq Mountain Limestone at Khashm Al-Qaddiyah section. 10 of the identified taxa belong to scleractinian corals, 7 to brachiopods, 4 to bivalves, 4 to gastropods and one cephalopod. *Actinastraea pseudominima*, *Thamnasteria nicoleti*, *Enallocoenia crassoramosa*, *Collignonastraea* cf. *grossouvrei*, *Burmirhynchia jirbaensis*, *Pholadomya* (*Bucardiomya*) *somaliensis*, *Pseudomelania* (*Rhabdoconcha*) *raabi* and *Nautilus giganteus* are believed to be recorded for the first time from the Jurassic rocks of central Arabia. It is being noted that all coral samples are highly affected by diagenetic processes (recrystallization, dolomitization and silicification).

The identified species were previously recorded from the Jurassic rocks of Ethiopia, Somalia, Israel, Jordan, Egypt, the United Kingdom, France, Germany, Czech Republic, Georgia, Greece, India, Switzerland, Poland, Portugal, the Russian Federation and Spain. They also previously recorded from Cretaceous rocks of Bulgaria, China, France, Spain, Georgia, Greece, Iran, Mexico, Poland, Romania, Serbia, Montenegro, Slovenia, USSR and Ukraine.

From the paleoecological point of view, the identified taxa indicated that shoaling of the sea floor persisted throughout the deposition of the formation. It seems that this slow subsidence of the sea floor did not provide adequate space for the buildup of a true reefal barrier system in central Saudi Arabia. A striking feature of the Tuwaiq Mountain Limestone benthic fauna is that a low diversity of species (26 species belong to 24 genera) persisted throughout the development of the formation. This low diversity is the result of interacting factors related to the paleogeographical and the paleoecological conditions of a very shallow platform.

Inadequate (inimical) paleoenvironmental conditions have prevailed during the Callovian as high rate of sedimentation, which caused turbidity and consequently decreased light penetration. Also the muddy facies might lead to unfavorable soft substrate for coral colonies to grow into large sizes. The sediments of the Tuwaiq Mountain Limestone at Khashm Al-Qaddiyah section were laid down in low-energy of a carbonate shelf in the lower part and grades upward into moderate-energy deposits in water ranging from 20 to 30 m, as indicated by abundant corals.

Acknowledgments

The authors would like to extend their sincere appreciation to the Deanship of Scientific Research at King Saud University for its funding of this research through the Research Group No. RGP-360.

References

Abdel-Gawad, G.I., Gameil, M., 1999. Middle Jurassic fauna from El Minshera area, north central Sinai, Egypt. In: Proceeding of 4th International Conference of Geology of the Arab World, Cairo University, pp. 767–789.
Ahmad, F., 1999. Middle Jurassic macroinvertebrates from northwestern Jordan. Beringeria 23, 3–46.
Al-Husseini, M., 1997. Jurassic sequence stratigraphy of the western and southern Arabian Gulf. GeoArabi 2, 361–380.
Anderson, F.W., Cox, I.R., 1948. The "Loch Staffin Beds" of Skye, with a note on the molluscan fauna of the Great Estuarine Series. Proc. R. Philos. Soc. Edinburgh 15 (2), 103–122.
Arkell, W.J., 1932–1933a. A monograph of British Corallian Lamellibranchia. Monogr. Palaeontogr. Soc. Pt. IV(84), 133–180 (1932); Pt. V(85), 181–228 (1933a).

Arkell, W.J., 1952. Jurassic ammonites from jebel Tuwaiq, Central Arabia. Phil. Trans. R. Soc. Lond. B 633 (236), 241–313.
Baron-Szabo, R.C., Hamedani, A., Senowbari-Daryan, B., 2003. Scleractinian corals from Lower Cretaceous deposits north of Esfahan (Central Iran). Facies 48, 199–216.
Beauvais, L., 1964. Etude stratigraphique et paléontologique des formations à madréporaires du Jurassique supérieur du Jura et de l'Est du Bassin de Paris. Mémoir. Soc. Géol. France 100, 1–287.
Beauvais, L., 1972. Contribution a l'etude de la fauna Bathonienne dans la vallce de la Creuse (Indre). Madrcporaires. Ann. Paleontol. (Invertebres) 58, 35–87 (Paris).
Cooper, G.A., 1989. Jurassic brachiopods of Saudi Arabia. Smithson. Contrib. Paleobiol. 65, 1–213.
Cox, L.R., 1935. Jurassic Gastropoda and Lamellibranchiata. In: The Mesozoic Palaeontology of British Somaliland, Pt. II, The Geology and Palaeontology of British Somaliland. Crown Agents for the Colonies, London, pp. 148–197.
D'Archiac, A., 1843. Description géologique du départment de l'Aisne. Mémoir. Soc. Géol. France I (5), 129–419.
Douvillé, H., 1916. Les terrains secondaires dans le massif du Moghara à l'Est de l'isthme de Suez. Mémoir. l'Acad. Sci., Paris IV (2), 1–184.
Douvillé, H., 1925. Le Callovian dans le Massif du Moghara, avec la description des fossils Par M. Cossmann. Bull. Soc. Géol. France, Paris, sér. 4 (25), 303–328.
El-Asa'ad, G.M., 1989. Callovian colonial corals from the Tuwaiq Mountain Limestone of Saudi Arabia. Palaeontol. Assoc. Lond. 32 (3), 675–684.
El-Asa'ad, G.M.A., 1991. Oxfordian hermatypic corals from central Saudi Arabia. Geobios 24 (3), 267–287.
El-Sorogy, A.S., Al-Kahtany, K.M., 2014. Contribution to the scleractinian corals of Hanifa Formation, Upper Jurassic, Jabal al-abakkayn Central Saudi Arabia. Hist. Biol.. http://dx.doi.org/10.1080/08912963.2013.866950.
Etallon, A., 1864. Classe des Polypes. In: Thurmann, J., Etallon, A. (Eds.), Lethea Bruntrutana, ou études paléontologiques et stratigraphiques sur le Jura bernois et, en particulier, sur les en virons de Porrentruy. Neue Denkschriften der allgemeinen Schweitzerischen Gesellschaft für Naturwissenschaften 20, pp. 357–464.
Feldman, H.R., Owen, E.F., Hirsch, F., 2001. Brachiopods from the Jurassic (Callovian) of Hamakhtesh Hagadol (Kurnub Anticline), Southern Israel. Palaeontology 44 (4), 637–658.
Fischer, J.-C., 2001. Jurassic gastropod faunas of central Saudi Arabia. GeoArabia 6 (1), 63–99.
Fromentel, E. De., 1867–1873. Zoophytes, terrain crétacé (7–9). In: ÓOrbigny, A. (Ed.), Paléontologie française, 8, 289–336 (1867); 337–384 (1870); 385–432 (1873); Paris.
Gregory, J.W., 1900. Jurassic fauna of Cutch: the corals. Palaeontol. Indica, Ser. 92, 1–195.
Hirsch, F., 1980. Jurassic bivalves and gastropods from northern Sinai and southern Israel. Israel J. Earth Sci. 28, 128–163.
Holzapfel, S., 1998. PalÖkologie benthischer Faunengemeinschaften und Taxonomie der Bivalven im Jura von Sudtunesien. Beringeria 20, 3–199.
Hughes, G.W., 2004. Middle to Late Jurassic biofacies of Saudi Arabia. Riv. Ital. Paleontol. Stratigr. 110, 173–179.
Hughes, G.W., 2006. Biofacies and palaeoenvironments of the Jurassic Shaqra Group of Saudi Arabia. Volum. Jurassica VI, 33–45.
Jaitly, A.K., Fursich, F.T., Heinze, M., 1995. Contributions to the Jurassic of Kachchh, western India. IV, The bivalve fauna, Pt. I, Subclasses Palaeotaxodonta, Pteriomorphia, and Isofilibranchia. Beringeria 16, 147–257.
Khalil, H., 1999. Biostratigraphy, facies and paleoecology of the Middle Jurassic succession in Gabal El-Minsherah, Northern Sinai, Egypt. Egypt. J. Geol. 43 (2), 203–217.
Kiessling, K., Pandey, D.K., Schemm-Gregory, M., Mewis, H., Aberhan, M., 2011. Marine benthic invertebrates from the Upper Jurassic of northern Ethiopia and their biogeographic affinities. J. Afr. Earth Sci. 59, 195–214.
Koby, F., 1897. Monographie des polypiers crétacés de la Suisse (2). Mémoir. Soc. Paléontol. Suisse 23, 29–62 (Basel).
Le Nindre, Y.-M., Manivit, J., Manivit, H., Vaslet, D., 1990. Stratigraphie sequentielle du Jurassique et du Cretace en Arabie Saoudite. Bull. Soc. Géol. France 8, 1025–1034.
Michelin, H., 1843. Iconographie zoophytologique. déscription par localités et terrains des polypiers fossiles de France et pays environnants. P. Bertrand, Paris, 348pp.
Morycowa, E., Masse, J.P., 1998. Les Scléractiniaires du Barrémien-Aptien inférieur de Provence (SE de la France). Geobios 31, 725–766.
Muir-Wood, H.M., 1935. Jurassic Brachiopoda. In: McFadyen, W.A. et al. (Eds.), The Mesozoic Geology and Paleontology of British Somaliland, vol. 2, pp. 75–147.
Pandey, D.K., Fürsich, F.T., 1993. Contributions to the Jurassic of Kachchh, western India. I. The coral fauna. Beringeria 8, 3–69.
Pandey, D.K., Fürsich, F.T., 2003. Jurassic corals of east-central Iran. Beringeria 32, 1–138.
Pandey, D.K., Fürsich, F.T., Baron-Szabo, R., Wilmsen, M., 2007. Lower Cretaceous corals from the Koppeh Dagh, NE-Iran. Zitteliana 47, 3–52.
Powers, R.W., 1968. Lexique stratigraphie international 3, Asie, fasc. 10bl, Saudi Arabia. C.N.R.S. edit.: 177p.
Powers, R.W., Ramirez, L.F., Redmond, C.D., Elberg Jr., E.L., 1966. Geology of the Arabian Peninsula, sedimentary geology of Saudi Arabia. U.S. Geol. Surv. Prof. Pap., 560, 147 p.
Roniewicz, E., 1970. *Kobyastraea* nov. gen. homeomarphique de *Thamnasteria* Lesauvage, 1823 (Hexacoralla). Act. Pal. Pol. 15 (1), 137–151.
Rosendhal, S. von, 1985. Die Oberjurasische Korallenfazies von Algarve (Süd Portugal). Arab. Instgeol. Palaont., N.F., 82, 1–125.
Sharland, P., Archer, R., Casey, D., Davies, R., Hall, S., Heward, A., Horbury, A., Simmons, M., 2001. Arabian plate sequence stratigraphy: Mesozoic and Cenozoic sequences. GeoArabia, Spec. Publ. 2, 1–371.
Sowerby, J., 1815–1824. The Mineral Conchology of Great Britain. London, J. Sowerby, II, 1–28 (1815), 29–116 (1816), 117–194 (1817), 195–239 (1818); IV, 1–16 (1821), 17–114 (1822), 139–171 (1824).
Steineke, M., Bramkamp, R.A., Sanders, N.J., 1958. Stratigraphic relations of Arabian Jurassic oil. In: Weeks, L.G. (Ed.), Habitat of oil. American Association of Petroleum Geologists, Tulsa, Oklahoma, USA, pp. 1294–1329.
Szabó, J., Anand, K., Jaitly, A., 2004. Contributions to the Jurassic of Kachchh, western India VIII. The gastropod fauna. Part II: Discohelicidae, Neritomorpha, Caenogastropoda. Fragment. Palaeontol. Hungarica 22, 9–26.
Turnšek, D., 1975. Malmian corals from Zolbin, Southwest Croatia. Palaeont. Jugoslavaica 16, 7–23.
Vaslet, D., Al-Muallem, M.S., Maddah, S.S., Brosse, J., Fourniquet, J., Breton, J., Le Nindre, Y., 1991. Explanatory Notes to the Geologic Map of the Ar Riyad Quadrangle, Sheet 24 I, Kingdom of Saudi Arabia. Saudi Arabian Deputy Ministry for Mineral Resources, Jeddah, Geosciences Map, GM-121, pp. 1–54.
Vaughan, T.W., Wells, J.W., 1943. Revision of the suborders, families and genera of the Scleractinia. Geol. Soc. Am. Spec. Pap. 44 (15), 1–363.