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New record of *Durania cornupastoris* (rudist) from the Campanian of the Aruma Formation, Riyadh, Saudi Arabia: Description and biogeographic remarks

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ABSTRACT

A Radiolitidae (rudist, bivalvia), *Durania cornupastoris* (Des Moulins) is a well-known species defined as an index fossil from the Turonian (mostly middle-upper) deposits in the Mediterranean Tethys and also in the USA. This study includes new rudist materials and well-preserved samples of the species from the Campanian Khanasir Limestone Member of the Aruma Formation outcropping around the Riyadh (Saudi Arabia) region. *Durania cornupastoris* is characterized by the many finely ribbed, generally flat, sometimes slightly or pronounced concave posterior and ventral radial bands and bulge interband with thick costae similar to the external ornament of the rest of the right valve surface. The width of the radial bands are variable. A comparison of the species with the well-known *Durania* species such as *Durania arnaudi* (Choffat), *Durania gaensis* (Dacqué) and *Durania apula* Parona is considered. The broadening of the stratigraphic range up to the Campanian and biogeographic distribution into the eastern part of the Arabo-African plate of the species are also emphasized.

1. Introduction

The rudists from the Campanian Khanasir Limestone Member of the Aruma Formation of central Saudi Arabia were firstly described by El-Asa'ad (1983a, b, 1987). Then a new canaliculate rudist bivalve *Eodictyoptychus* was defined by Skelton and El-Asa'ad (1992). The presence of *Durania cornupastoris* (Des Moulins) in this area was reported by Skelton in Cobban et al. (1991, p. D6) in his detailed description of the species from the samples in cluster of the Turonian (middle) Greenhorn Limestone in Colorado (USA). El-Asa'ad (1991, p. 153) also mentioned that "The rudistid reefal limestone yields an abundant Campanian rudist fauna; these comprise *Dictyoptychus morgani*. *Durania cornupastoris*, *D. gaensis* and *Biradiolites lumbricalis*" in his study on the Late Cretaceous Ammonites from central Saudi Arabia. Although these papers suggest significant data, in preparation, on the Campanian *Durania cornupastoris* and rudist material from central Saudi Arabia, the detailed descriptions of the species are not well documented until today from this area.

The new rudist material from the Khanasir Limestone Member of the Aruma Formation of central Saudi Arabia allowed us to describe the specimens of *Durania cornupastoris* and to compare with the some well-known *Durania* species recorded from the same area, Arabian-African plate and northern side of the Mediterranean Tethys. The geographic and stratigraphic broadening of the species are also emphasized.

2. Material and methods

Durania cornupastoris samples were collected from a biostrome, 2 m thick, caps the Khanasir Limestone Member in Khashm Buwaibiyat and Khashm Tawqi to the northeast of Riyadh (Figs. 1–3): 1) Khashm Buwaibiyat on the dipslope surfaces neighboring the crest of the escarpment, on either side of the road which runs NNE to Rumhiyah, at the intersection of latitude 25° 12′ 12″ N and longitude 46° 49′ 27″ E; 2) Khashm Tawqi to the northwest of Khashm Buwaibiyat at the intersection of latitude 25°

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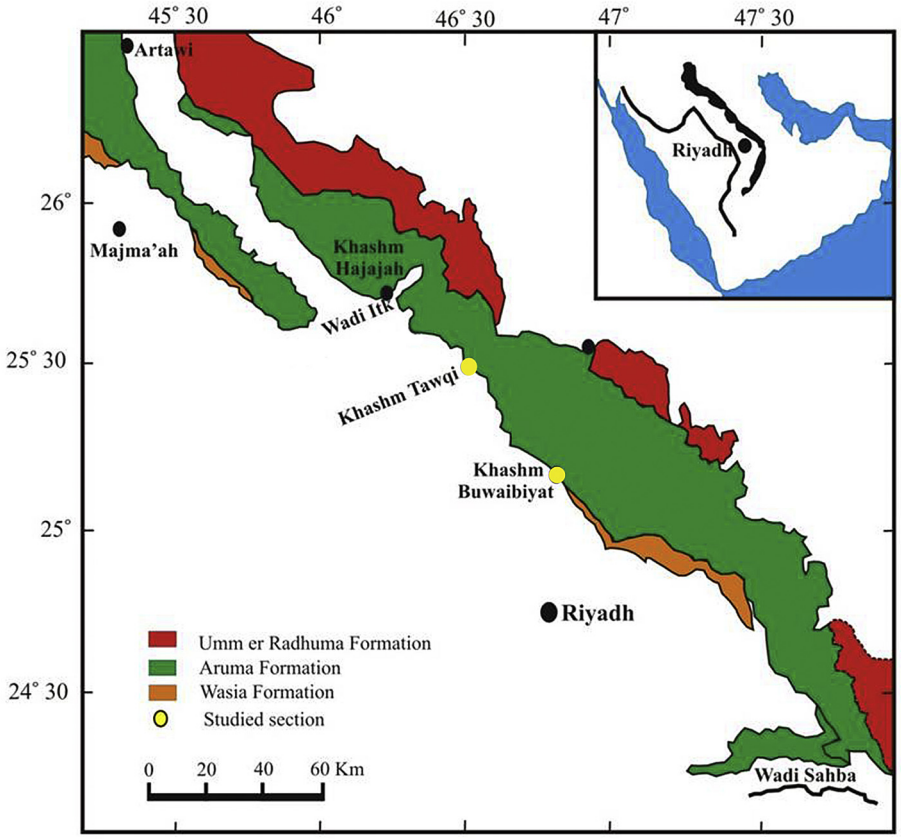

Fig. 1. Geological map (simplified after Gameil and El-Sorogy, 2015) showing the studied localities.

27′ 11″ N and longitude 46° 30′ 08″ E, where the same biostromal horizon crops out on the slopes and gullies beside the road which cuts through which the escarpment there. Three both valves nos MGD-CSc-KSU 18, 22 and 35 from Khashm Buwaibiyat, nine RV nos MGD-CSc-KSU 12, 17, 19, 20, 21, 26, 30, 31 and 32 from Khashm Tawqi and eleven RV nos MGD-CSc-KSU 13, 14, 16, 23, 24, 25, 27, 28, 29, 33 and 34 from Khashm Buwaibiyat. The transverse sections of the rudist specimens were prepared in the laboratories of King Saud University, Riyadh, Saudi Arabia and Dokuz Eylul University, İzmir, Turkey. The studied specimens are housed in the Dokuz Eylul University and King Saud University collections.

3. Geological setting and stratigraphy

The Mesozoic sequence of central Saudi Arabia dips very gently towards the Aruma basin to the east forming a series of extensive westward-facing escarpments. Upper Cretaceous strata are exposed along one of these escarpments, and over its eastern dipslope. They form a broadly arcuate outcrop passing to the east of Riyadh (Powers et al., 1966). Steineke and Bramkamp (1952) gave the name "Aruma Formation" to the Upper Cretaceous sequence that outcrops in Central Saudi Arabia (Fig. 1). It was named for its occurrence in the Al'Aramah plateau, a broad upland surface related to the easternmost of the Najd escarpments. The Aruma Formation was subdivided by El-Asa'ad (1977, 1983a, 1983b) into three members, namely the Khanasir Limestone Member, Hajajah Limestone Member and Lina Shale Member. The Khanasir Limestone Member is overlain by the Hajajah Limestone Member and the Lina Shale Member is seen at the top of the sequence. These members were recently restudied in detail by Gameil and El-Sorogy (2015) and Al-Kahtany et al. (2016). The Aruma Formation is underlain by various colored clastic sediments of the Wasia Formation. A distinctive lithologic change from yellow-brown dolomitic shale to gray crystalline *Lockhartia*-bearing dolomite of the Umm er Radhuma Formation is seen at the upper boundary of the formation.

Our study concentrates on the upper most part of the lower Khanasir Limestone Member in Khashm Buwaibiyat and Khashm Tawqi to the northeast of Riyadh. The following is a detailed description of the Khanasir Limestone member, from base to top, in the two studied localities (Figs. 2 and 3):

1. Unfossiliferous, reddish-brown, dark red to brown in parts, granular, sandy dolomite (1.5–3 m) with a few small pebbles and abundant vugs, many filled with white coarsely crystalline calcite. It disconformably overlies the continental Cenomanian siliciclastics of the Wasia Formation (Steineke et al., 1958) with a sharp contact.
2. Calcarenitic, cream-colored, chalky, nodular limestone (16–20 m) with abundant clastic carbonates debris. Nodules are set in a matrix of sandy marl. It is fossiliferous with few gastropod and bivalve molds and echinoids.
3. Molluscan calcarenitic limestone (2–4.5 m) with abundant biostromal rudists, oysters, and large gastropods set in matrix of chalky limestone.

The rudist biostrome forms the top most part of the Khanasir Member. The rudists are apparently single generation, embedded in growth position (autochthonous) with very rare the left valves. This unit is of thin vertical extent (2–3 m) and a broad lateral extent (about 400 km, El-Asa'ad, 1987). He stated that it does not maintain the same thickness on its whole lateral extent. It is well developed

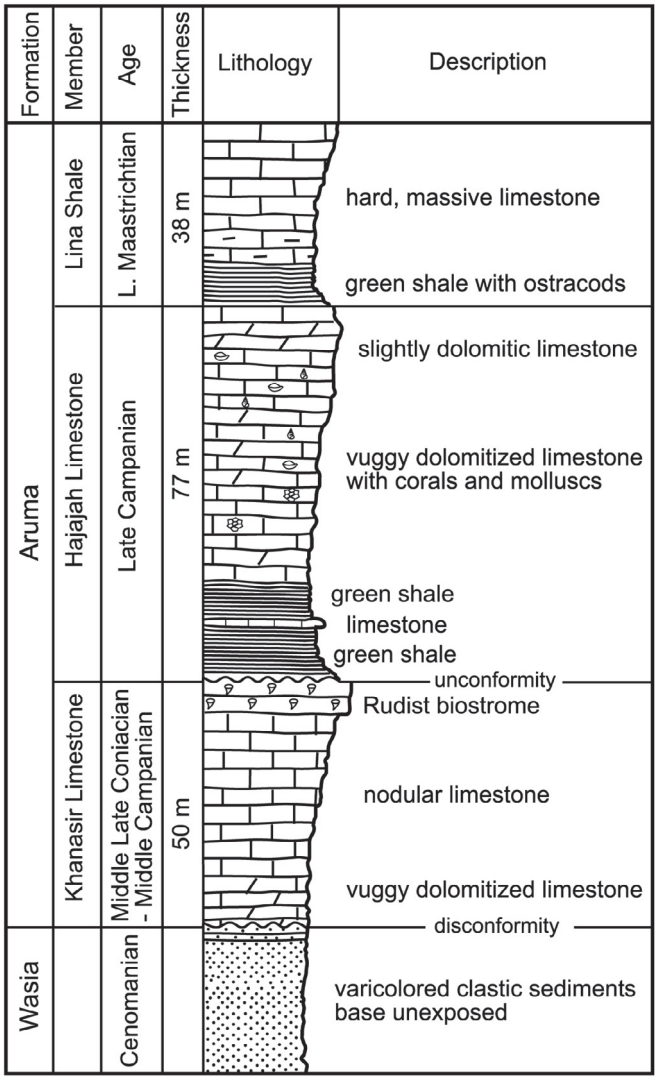

Fig. 2. Generalized stratigraphic section showing the formations of the studied area. *Durania* specimens were collected from the rudist biostrome of the Khanasir Limestone Member of the Aruma Formation.

at Khashm Hajajah, Khashm Khanasir and Khashm Buwaibiyat areas while at Wadi Sahba and Majmáah areas, remnants of this unit remain below an erosional surface. The rudist biostrome is overlain by bioclastic wackestones to floatstones with abundant dacycladacean algae, larger foraminifers, few gastropod and bivalve molds and badly preserved echinoids (Al-Kahtany et al., 2016). This provided the suitable hardground for the rudists' growing. The rudist species which built up the biostromal limestone unit were of large, very thick and barrel or cylindroconical right valves with small attachment bases (Fig. 3). Fossils of scattered individuals were mainly right valves lying on one side, while those of aggregative forms were found in upright position.

3.1. Age of the Aruma Formation

In the basis of its foraminiferal content, the Campanian to Maastrichtian age was attributed to the Aruma Formation by Powers et al. (1966) and by Powers (1968). The lowermost beds of the Aruma Formation (Khanasir Limestone Member) could be as old as Santonian. The lower beds contain *Meandropsina vidali* Schlumberger, a form originally described from the Santonian of Spain (Powers et al., 1966). However, the uppermost occurrence of this form in the Saudi Arabia overlaps the range of *Monolepidorbis sanctae-pelagiae* Astre, a Campanian form likewise originally described from Spain (Powers et al., 1966). The middle part of the Aruma Formation (Hajajah Limestone Member) presents a problem as it contains beds which fall below the level of the definitely lowermost Maastrichtian foraminifera and above the level of the definitely uppermost Campanian foraminifera (Powers et al., 1966). Immediately overlying this anomalous interval are beds which carry abundant occurrences of *Orbitoides gensacicus* (Leymerie) and *Omphalocyclus macroporus* (Lamarck), both are good Maastrichtian markers with a very wide distribution in Europe (Hardenbol et al., 1998). However, Morris and Skelton (1995) reported the benthic foraminifers (*Omphalocyclus*) from a level below the Campanian transgressive sequence with rudists on the top of the ophiolites in the United Arab Emirates. The strontiom-isotope stratigraphy (SIS) based on the rudist shells from Apulia (Italia) and SE Anatolia (Turkey) by Schlüter et al. (2008) and Steuber et al. (2009), respectively, showed the presence the larger benthic foraminifera such as *Omphalocyclus macroporus* and *Orbitoides apiculatus* in the late Campanian rudist formations. Özcan (2007) presented also the revision of the stratigraphical ranges of larger benthic foraminifera in his morphometric analysis of the genus *Omphalocyclus* in the Late Cretaceous of Turkey.

El-Asa'ad (1983b) recognized nine faunal zones representing the Coniacian–Maastrichtian in the outcrops of the Aruma Formation. Among them, the following four faunal zones were recorded in Khanasir Limestone Member, from base to top: The *Tissotia* Assemblage Zone (Coniacian), the *Lopha/Ostrea* Assemblage Zone (Santonian), the *Sphaerulites/Biradiolites* Assemblage Zone = *Durania* Assemblage Zone (Santonian) and the *Cardium/Protocardia* Assemblage Zone = The *Monolepidorbis sanctae-pelagiae/Orbitoides tissoti* Local Range Zone (Campanian). Also El-Asa'ad (1983b) identified two larger foraminifers from the top of the Khanasir Limestone Member, just below the olive, green shale unit (the lowermost part of the Hajajah Limestone Member), these are *Monolepidorbis sanctae-pelagiae* Astre and *Orbitoides tissoti* Schlumberger. He stated that, the first species has been recorded by different authors from the Campanian of Organya, Spain, while the second species has been recorded from the Campanian of Algeria, Tunisia, France, and West Pakistan.

In his study on Late Cretaceous Ammonites from Central Saudi Arabia, El-Asa'ad (1991) identified eight ammonite species from the Khanasir Limestone Member and the overlying Hajajah Limestone Member, these are: *Pachydesmoceras* sp., *Pachydiscus (Pachydiscus) launayi* (de Grossouvre), *Metatissotia* cf. *ewaldi* (Von Buch), *Hemitissotia turzoi* Karrenberg, *H. Arumaensis* El Asa'ad, *Manambolites amardi* Collignon and Roman, *Libycoceras chargense* Blankenhorn and *Libycoceras* sp. According to these ammonite species, the Khanasir Limestone Member is dated as Middle-Late Coniacian to Middle Campanian and the overlying Hajajah Limestone Member is Late Campanian in age (Skelton and El-Asa'ad 1992).

4. Systematic palaeontology

The classification scheme and terminology for rudist higher taxa used follows Skelton (2013a,b).

Abbreviations: LV, left valve; RV, right valve; Vb, ventral radial band; Pb, posterior radial band; Ib, interband; ol, outer (calcitic) shell layer.

Class Bivalvia Linnaeus, 1758.
Order Hippuritida Newell, 1965.
Suborder Radiolitidina Skelton, 2013a
Superfamily Radiolitoidea! d'Orbigny, 1847.

Fig. 3. Field photos showing the rudist biostrome of the Khanasir Limestone Member. (a) general view of the Khanasir Limestone Member showing the nodular limestones and the rudist biostrome (red arrow) in its uppermost part, Khashm Buwaibiyat; (b) close view of the rudist biostrome consisting mainly of *Durania* specimens in life position, scale is hammer, Khashm Buwaibiyat; (c) the rudist biostrome, note very low dipping, Khashm Tawqi. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Family Radiolitidae d'Orbigny, 1847.
Genus *Durania* Douvillé, 1908.
Type species *Hippurites cornupastoris* Des Moulins, 1826

Durania cornupastoris (Des Moulins, 1826)
1826 *Hippurites cornupastoris* Des Moulins, p. 141, pl. X, figs. 1–2.
1850 *Biradiolites cornupastoris* Des Moulins, p. 231, pl. 573, figs.

1–6.

1909 *Sauvagesia cornupastoris* Des Moulins, Toucas, p. 94, pl.18, figs. 8–9, text-figs. 61–63.

1911a *Durania cornupastoris* (Des Moulins), Parona, p. 289, text-fig. 6.

1966 *Sauvagesia cornupastoris* (Des Moulins), Pamouktchiev, p. 36, pl. 5, figs. 2 and 3.

1967 *Durania cornupastoris* (Des Moulins), Polšak, p. 91, 194, pls. 18–21, pl. 56, fig. 3, pl. 58, figs. 1–5, text-fig. 25.

1987 *Durania* cf. *apulus* Parona, El'As'aad, p. 59, 60, pl. I, fig. 2, pl. III, figs. 1 and 2, pl. IV, figs. 1 and 2).

1991 *Durania cornupastoris* (Des Moulins), Cobban et al., D3-8, pls.1–3, text-fig. 1.

2002 *Durania cornupastoris* (Des Moulins), Steuber (see Web Catalogue of the Hippuritoidea (rudist bivalves) for complete synonym list).

2003 *Durania cornupastoris* (Des Moulins), El-Sabbagh and El-Hedeny, p. 247, pl.1, figs. 1–4.

2007 *Durania cornupastoris* (Des Moulins), Macé-Bordy, p. 101, fig. 3A.

2010 *Durania cornupastoris* (Des Moulins), Chikhi-Aouimeur, p. 139–141, figs. 130 and 131.

4.1. Description

The RV is elongated conical slightly curved towards the ventral part or robust cylindrical and cylindro-conical ornamented with salient, regular longitudinal 2–4 mm width ribs and furrows. Some ribs represent downfolds of the funnel plates and the furrows upfolds. The conical specimens attain up to 170 mm in lenght, the cylindrical 140 mm and the cylindro-conical 95 mm, and having a diameter of up to 110 mm, however it reaches up to 140 mm in a single cylindrical specimen (Table 1). The radial bands are generally flat or slightly to pronounced concave in shape, characterized by many finely ribbed ornamentation. They have variable width, but the Vb is always more wider than Pb. The Vb reaches 30 mm width, other 28 mm. The Ib is bulge with three to seven sailent ribs similar to those of the valve surface, and separates the radial bands. Its width is variable, but less than that of the radial bands.

The transverse section of the RV is circular or subcircular, the ol is more thick (max. 50 mm) in the dorsal part than ventral part and consists of thin-walled, very small polygonal cell. The inner margin of the ol is subcircular and its diameter is a little or more of two-thirds that of the outer margin. But the smaller, approximately one-half or little diameter of the inner margin is observed in some specimens showing the radial and bifurcate vascular impressions (Figs 4E, F and 6D). The radial sections of the valve show the continuous and rarely discontinuties of cell floors (Fig. 6F) as observed in radiolitids (Amico, 1977, 1978; Pons and Vicens, 2008). The ligamentary ridge is not developed, and the cardinal apparatus can not be preserved. (see Fig. 5).

The LV is preserved in some of the specimens. It is very smooth and consists of very thin, compact calcite. The thin calcitic LV rim entirely covered the inner rim of RV (Fig. 4D).

4.2. Discussion and remarks

Our material are characterized by the many finely ribbed, generally flat, sometimes slightly or pronounced concave posterior and ventral radial bands and bulge interband with thick costae similar to the external ornament of the rest of the right valve surface, so we identified it as *Durania cornupastoris* (Des Moulins). Their radial bands may be compared with those of *Durania arnaudi* (Choffat); but it has narrow, slightly bulge Ib with only one to rarely three costae (Toucas, 1909; Polšak, 1967; Douvillé, 1913). The existence of many descriptive studies on *D. arnaudi* (see Steuber, 2002 for references) may show to support its taxonomic status, but Douvillé (1910) indicated that *D. arnaudi* is "a simple variety of *D. cornupastoris*". The present study agrees with the indications of Skelton in Cobban et al. (1991) and Steuber (1999) showing clearly the presence of the problems on the species assignment of the genus and it needs a revisional study.

The radial bands and RVs ornamentation of some of our specimens show similarities with neotype of the species proposed by Macé-Bordy (2007, Fig. 3A).

The broad Ib and the shape of the Vb and Pb of our specimens

Table 1
Measurements (in mm) on the RV specimens of *Durania cornupastoris* from the Campanian of Khanasir Limestone Member of Aruma Formation.

Sample no	Height of RV	Shape of RV	Diameter	Pb			Ib			Vb		
				Width	No. of ribs	Shape	Width	No. of ribs	Shape	Width	No. of ribs	Shape
12	70	cyl	80 × 60	18	14	flat	16	?4	bulge	20	18	flat
13	120	cyl.con	70	20	22	flat	18	?3	bulge	24	26	flat
14	80	cyl	65	13	6	flat	12	6	flat	22	?10	flat
16	130	con	80	15	10	flat	10	4	bulge	20	–	?flat
17	150	con	80	25	8	flat	18	4	bulge	28	?14	cnc
18	80	con	68	13	8	flat	10	?3	bulge	15	–	cnc
19	170	con	85	22	?15	flat	17	?3	bulge	25	?13	flat
20	65	con	70	14	9	cnc	12	3	bulge	18	–	flat
21	45	con	82	23	–	cnc	14	–	bulge	25	–	flat
22	120	cyl.con	90	20	?8	flat	18	4	bulge	25	–	flat
23	60	cyl.con	95	20	–	flat	19	3–4	bulge	26	12	cnc
24	180	cyl	140	25	11	flat	23	5–6	bulge	30	16	cnc
25	175	cyl	–	28	22	cnc	18	5–7	bulge	?30	?10	flat
26	110	con	95	–	–	–	–	–	–	–	–	–
27	70	cyl	65	20	?10	flat	18	4	bulge	25	?	flat
28	60	cyl	–	–	10	flat	15	–	bulge	–	–	–
29	110	cyl	–	22	12	cnc	20	5–6	bulge	–	–	–
30	145	cyl.con	–	18	–	flat	15	?4	bulge	–	–	–
31	90	cyl	110	?22	–	flat	20	5	bulge	?25	–	flat
32	100	con	110	?20	–	flat	18	–	bulge	20	?8	flat
33	90	cyl	–	–	–	–	–	–	–	–	–	–
34	75	cyl	–	–	–	–	18	–	bulge	20	6	flat
35	110	con	97	20	?8	flat	16	7	bulge	22	?8	flat

cyl: cylindirical, cylcon:cylindro-conical, con: conical, cnv: convex, cnc: concave.

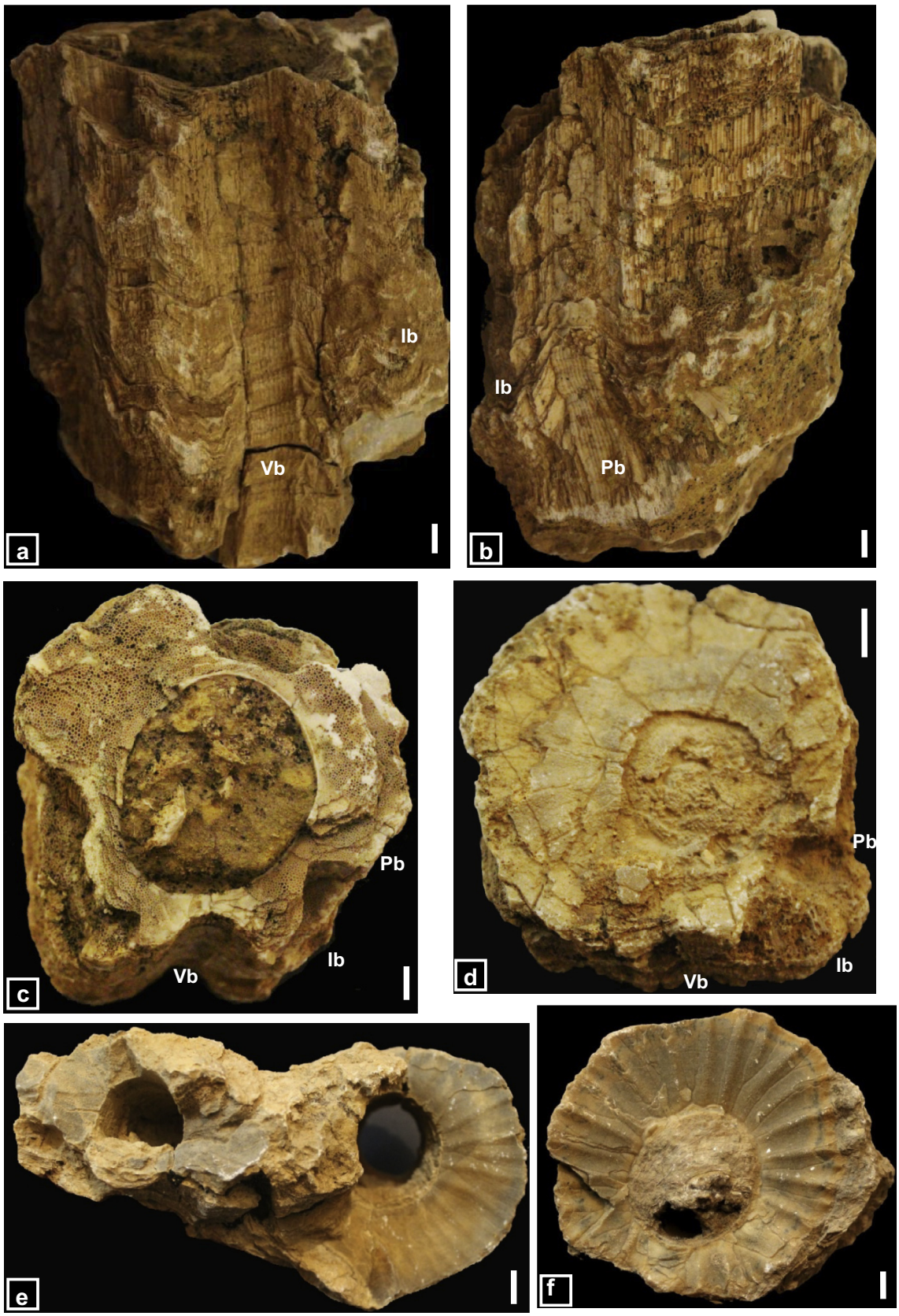

Fig. 4. *Durania cornupastoris* (Des Moulins). (a–c) sample no: MGD-CSc-KSU 24, (a) RV showing the fine ribbed, concave Vb and bulge Ib. (b) RV showing the fine ribbed, flat Pb and bulge Ib; (c) the naturel transverse section view of the RV, note concave Vb, bulge Ib and flat Pb. The polygonal cells can be clearly seen all parts of the ol; (d) the top view of the LV. Note thin calcitic LV rim covered the inner rim of RV. The Vb is slightly concave, Ib bulge and Pb flat, sample no: MGD-CSc-KSU 18; (e) the top view of two conjoined RV, sample no: MGD-CSc-KSU 20; (f) the naturel transverse section of the RV showing the bifurcating, radiating vascular impressions on the inner valve rims. Compare with the previous figure. sample no: MGD-CSc-KSU 21. Scale bar is 10 mm.

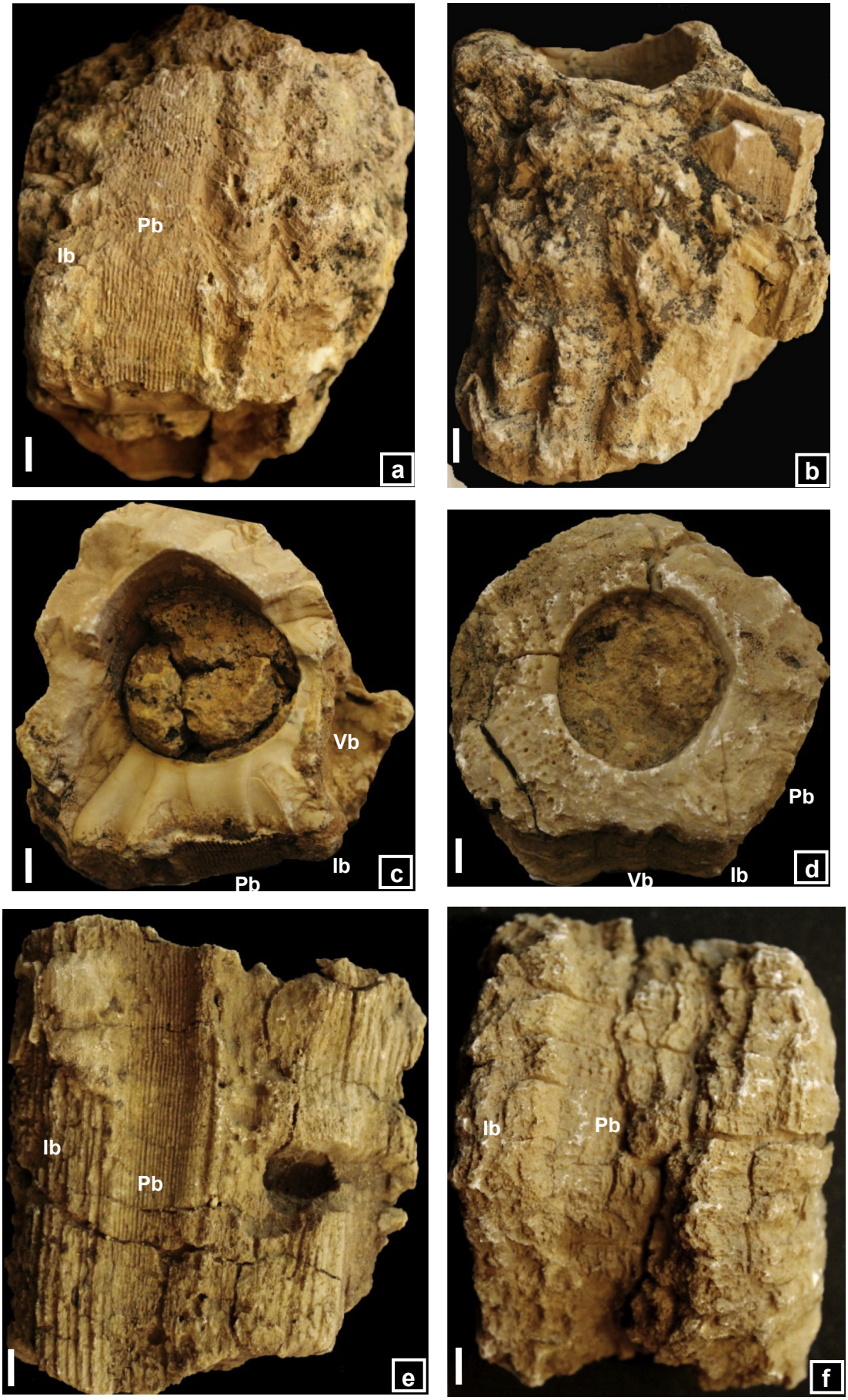

Fig. 5. *Durania cornupastoris* (Des Moulins). (a–c) sample no: MGD-CSc-KSU 13, (a) RV showing the many finely ribbed Pb and narrow Ib; (b) RV, dorsa-ventral side showing thick, saillent costae and furrows. Note the downfolds of the funnel plates and the furrows upfolds; (c) the view of the lower part of the RV. The Vb and Pb are flat, but Ib is very narrow and slightly bulge. The Pb is partly eroded; (d) the naturel transverse section view of the RV, note slightly conical Vb, flat Pb, and very narrow and slightly bulge Ib, sample no: MGD-CSc-KSU 23; (e) RV showing the finely ribbed and concave Pb and the bulge Ib consists many of costae showing resemblances to those in the dorsa-posterior part of the valve, sample no: MGD-CSc-KSU 25; (f) RV showing the finely ribbed and concave Pb but partially eroded and the bulge Ib, sample no: MGD-CSc-KSU 29. Scale bar is 10 mm.

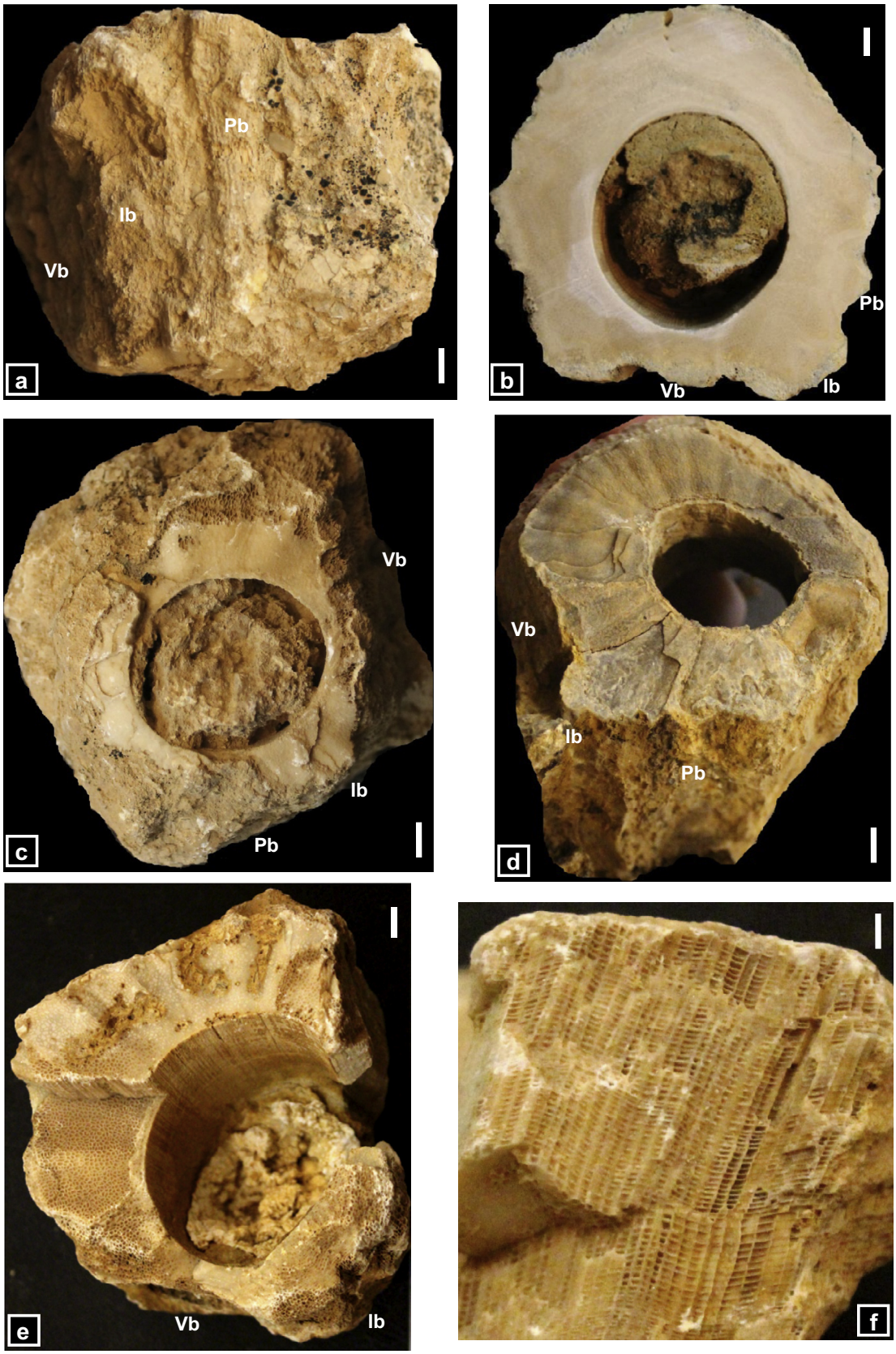

Fig. 6. *Durania cornupastoris* (Des Moulins). (a–c) sample no: MGD-CSc-KSU 12, (a) RV showing the fine ribbed Pb and bulge Ib; (b) the transverse section of the RV passing 10 mm below from uppermost part of the valve, commissure unkown; (c) the view of the lower part of the RV. The Vb and Pb are flat, but Ib is very narrow and slightly bulge. Note the reduction of the radial bands and compare with those of previous figure; (d) RV showing the slightly concave Vb, narrow but bulge Ib and flat Pb. Compare the radiating vascular impressions on the inner valve rims with Fig. 4e and f, sample no: MGD-CSc-KSU 17; (e) the natural transverse section of the RV showing the cellular ol, sample no: MGD-CSc-KSU 31; (f) same specimen, the radial section showing the continuous and discontinuties of cell floors. Scale bar is 10 mm.

may be compared with Istrian specimens described by Polšak (1967), however they are longer than the latter.

Our specimens show remarkable similarities with those of Algerian described by Chikhi-Aouimeur (2010) by the different shape of the RV and the radial bands.

The ornemantation of the RV and the shape of the Pb of our specimens show some similarities with those of *Durania gaensis* (Dacqué), but the latter is characterized by the depressed Vb and differs from the Riyadh specimens.

The radial bands and ornemantation of the RV of our specimens show clear similarities with the descriptions of El-Asa'ad (1987, pl. I, Fig. 2, pl. III, Figs. 1 and 2, pl. IV, Figs. 1 and 2) as *Durania* cf. *apulus* Parona. However, *D. apula* has a very narrow Pb with three fine ribs and Vb with four, but Ib is very wide, four times larger than others and it has five sailent ribs according to its original description and figure (Parona, 1900, p.21, pl.III Fig. 1). So, El-As'aad's specimens differ from *D. apula* and close to *D. cornupastoris*. If, we follow Parona's description, it needs a revisional study of all specimens described until today as *D. apula* having a very wide, finely ribbed radial bands from Italy, Greece, Oman and Saudi Arabia (see Steuber, 2002).

5. Geographic and stratigraphic distribution

The type locality of *Durania cornupastoris* is Pyles-Dordogne in France (Toucas, 1908; Macé-Bordy, 2007). It shows a widespread distribution in the middle-upper Turonian of France such as Aude, Bouches-du-Rhône, Charente, Dordogne, Loire-Atlantique, Maine-et-Loire, Sarthe and Vaucluse (Toucas, 1907, 1908, 1909; Fabre, 1940; Bilotte, 1985). It shows the same vast distribution in the middle-upper Turonian of Italy: Abruzzo, Campania, Ancona and Puglia (Parona, 1911a, b, 1926; Carannante et al., 2000), in Crotia: islands of Adriatic Sea, Dalmatia, Istra and external Dinarides (Toucas, 1909; Polšak, 1967; Polšak and Mamuzic, 1969) as well as in Bosnia-Herzegovina: Kladanj, Mostar (Slišković, 1968, 1975), in Bulgaria: Kazanlak (Pamouktchiev, 1966) and in Serbia: Pocuta (Pejović, 1957). These knowledges indicate that *Durania cornupastoris* is widespread in the middle-upper Turonian of the northern side of the Mediterranean Tethys, although it is reported from the upper Cenomanian of Portugal (Toucas, 1908; Berthou et al., 1979; Bilotte, 1985).

The previous studies suggest that *Durania cornupastoris* was mainly described from the upper Turonian of Algeria in the southern side of the Mediterranean Tethys. It has widespread occurrences in Algeria, from which it was described from various localities of Algeria such as Si Mesinoudin by Toucas (1909), Aumale from conjoint two specimens (see Chikhi-Aouimeur, 2010, p. 153, fig. 144, 2, 3), one of them belongs to *Lapeirousia aumalensis* Douvillé (*Lapeirousella aumalensis* according to Steuber, 1999, p. 74) by Douvillé (1915) and Aurès from well-preserved RV by Chikhi-Aouimeur (2010). Our knowledge about the Tunisian specimens is very limited, for example, it was reported, but without given references, by Sanchez (1981) and also by Pervinquière (1912, p. 322) as *Radiolites* cf. *cornupastoris*. *Durania cornupastoris* was described from the upper Turonian of Abu Roash by El-Sabbagh and El-Hedeny (2003). We agree this description, however it was included to *Durania arnaudi* (Choffat) by Aly et al. (2005). *Durania cornupastoris* was also described from Gabal Yelleg by Hamama (2010) in Egypt, but it is very difficult to compare due to the data incompleteness on the shape of the radial structures. Same author was also described *Durania arnaudi* showing the similarity with Abu Roash *Durania cornupastoris* specimens of El-Sabbagh and El-Hedeny (2003).

Although the widespread distribution of *D. cornupastoris* in the Mediterranean Tethys, it has been only described until today from the New World in the middle Turonian of Colorado (USA) by Skelton in Cobban et al. (1991).

The presentation of *D. cornupastoris* from Saudi Arabia provides extending of its geographic distribution into the eastern part of the Arabo-African plate and also stratigraphic range up to the Campanian.

6. Conclusions

The Aruma Formation is distributed in NW-SE direction around Riyadh (Saudi Arabia) and consists of three members, namely from bottom to top, the Khanasir Limestone Member, the Hajajah Limestone Member, and the Lina Shale Member. The rudist biostrome, approximately 2 m thick, is placed in the uppermost part of the Khanasir Limestone Member and consists mainly of *Durania* specimens.

Durania cornupastoris (Des Moulins) was described for the first time from the rudist biostrome of the Khanasir Limestone Member at Khashm Buwaibiyat and Khashm Tawqi localities to the northeast of Riyadh.

Our specimens showed different shape of the RV such as conical, cylindrical and cylindroconical ornamented with sailent costae. The Vb and Pb are flattish to slightly or pronounced concave and characterized by finely ribbed costae, the first is always wider than the other and the Ib is bulge with many thick costae similar to those of the RV surface. The Ib is wider than Pb.

The shape of the RV and the features of the radial bands of the specimens show clear similarities with those of Algeria and differ from *Durania arnaudi* (Choffat) by very wide and bulge Ib with more costae, from *Durania gaensis* (Dacqué) by flat or slightly concave Vb and from *Durania apula* Parona by very wide radial bands.

The present new record of *Durania cornupastoris* in the Campanian of the Khanasir Limestone Member of the Aruma Formation suggests broadening in its geographic distribution towards the eastern part of the Arabo-African plate and also the stratigraphic range up to Campanian.

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References

Aly, M.F., Saber, S.G., Abdel-Gawad, G.I., Ferieg, Y.F., 2005. Cenomanian-Turonian rudist buildups of northern Sinai, Egypt. Egypt. J. Paleontol. 5, 253–286.
Al-Kahtany, Kh, El-Sorogy, A.S., Youssef, M., 2016. Stratigraphy and depositional environments of the upper Cretaceous Aruma Formation, Central Saudi Arabia. Arabian J. Geosci. 9, 330.
Amico, S., 1977. Etude de la structure du test des rudistes. Applications a la systematique a la paléobiologieet a la paléoécologie de cegroupe. Ph. D. Thesis. Université de Provence, Aix-Marseille. I (Unpublished), 90 p.
Amico, S., 1978. Recherch sur la structure du test des Radiolitidae. Travaux du Laboratoire de géologie Hist. de paléontologie 8, 131.
Berthou, P.Y., Ferreira Soaresi, A., Lauverjat, J., 1979. Mid Cretaceous events, Iberian field conference 77, guide I, Partie Portugal. Cuad. Geol. Ibérica 5, 31–124.
Bilotte, M., 1985. Le Crétacé supérieur des plates-formes est-pyrénéenes. Strata 2 (5), 438.
Carannante, G., Ruberti, D., Sirna, G., 2000. Upper Cretaceous ramp limestones from the Sorrento Peninsula (southern Apennines, Italy): micro- and macrofossil associations and their significance in the depositional sequences. Sediment. Geol. 132, 89–123.
Chikhi-Aouimeur, F., 2010. L'Algerié a Travers Son Patrimoine Paléontologique. Les Rudistes. Sarl Baosem, 269 p.
Cobban, W.A., Skelton, P.W., Kennedy, W.J., 1991. Occurrence of the Rudistid *Durania*

cornupastoris (Des Moulins, 1826) in the Upper Cretaceous Greenhorn Limestone in Colorado. United States Geological Survey Bulletin, pp. D1–D8, 1985.
Des Moulins, C., 1826. Essai sur les *Sphérulites* qui existent dans les collections de M.M.F. Jouannet, membre de l'Académie royale des Sciences, belle Lettreseta Arts de Bordeaux, et Charles Des Moulins. Bull. d'histoire Nat. la Société Linn. Bordx. 1, 148–303.
Douvillé, H., 1908. Sur la classification des radiolitidés. Bull. Soc. Géol. Fr. 4, 308–310.
Douvillé, H., 1910. Etudes sur les rudistes. Rudistes de Sicile, d'Algérie, d'Egypte, du Liban et de la Perse. Mémoires la Société géologique Fr. 41, 83.
Douvillé, H., 1913. Description des rudistes de l'Egypte. Mémoires présentés à l'Institut égyptien 6, 237–256.
Douvillé, H., 1915. Les premiers Lapeirousia. Compte rendu sommaire des séances de la Société géologique de France, pp. 25–27.
El-Asa'ad, G.M.A., 1977. A Contribution to the Geology of the Aruma Formation in Central Saudi Arabia. Ph.D. Thesis. Mansoura University, Egypt (Unpublished), 384 p.
El-Asa'ad, G.M.A., 1983a. Lithostratigraphy of the Aruma Formation in Central Saudi Arabia. In: Proceedings of the 1st Jordanian Geological Conference, Special Publication, vol. 1, pp. 72–86.
El-Asa'ad, G.M.A., 1983b. Bio- and chronostratigraphy of the Aruma Formation in Central Saudi Arabia. In: Proceedings of the 1st Jordanian Geological Conference, Special Publication, vol. 1, pp. 87–111.
El-Asa'ad, G.M.A., 1987. Rudist faunas from the late Cretaceous of central Saudi Arabia. J. Coll. Sci. 18, 53–71. King Saud University.
El-Asa'ad, G.M.A., 1991. Late Cretaceous Ammonites from Central Saudi Arabia, vol. 3. Journal of King Saud University, pp. 135–158.
El-Sabbagh, A.M., El-Hedeny, M.M., 2003. Upper Turonian Radiolitidae (Rudist Bivalves) from the *Actaeonella* series, El-Hassana Dome, Abu Roash, Egypt. Egypt. J. Paleontol. 3, 243–269.
Fabre, S., 1940. Le Crétacé supérieur de la Basse-Provence occidentale (1:) Cénomanien et Turonien. Ann. la Fac. Sci. Marseille 2, 1–355.
Gameil, M., El-Sorogy, A.S., 2015. Gastropods from the Campanian–Maastrichtian Aruma Formation, Central Saudi Arabia. J. Afr. Earth Sci. 103, 128–139.
Hamama, H., 2010. Morphology and wall structure of some Turonian rudists (Bivalvia, Hippuritoida) of Gabal Yelleg, Northern Sinai, Egypt. J. Am. Sci. 6 (12), 1682–1701.
Hardenbol, J., Thierry, J., Farley, M.B., de Jacquin, T., Graciansky, P.C., Vail, P.R., 1998. Cretaceous biochronostratigraphy. In: de Graciansky, P.C., Hardenbol, J., Jacquin, T., Vail, P.R. (Eds.), Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. Society for Sedimentary Geology (SEPM), Special Publication, vol. 60, pp. 3–13.
Linnaeus, C., 1758. Systema Naturae, tenth ed., vol. 1, p. 824 Holmiae (Salvius).
Macé-Bordy, J., 2007. Révision des rudistes crétacés (Bivalvia) de la *Paléontologie française* d'Alcide d'Orbigny. Ann. de. Paléontol. 93, 67–105.
Morris, N.J., Skelton, P.W., 1995. Late Campanian–Maastrichtian rudists from the United Arab Emirates - Oman border region. Bulletin of the British Museum (natural History). Geol. Ser. 51, 277–305.
Newell, N.D., 1965. Classification of the Bivalvia. Am. Mus. Novitates 2206, 1–25.
Orbigny, A.de, 1847. Considérations zoologiques et géologiques sur les brachiopodes. Ann. des Sci. Naturelles Zoologie Biol. Animale 3, 241–270.
Özcan, E., 2007. Morphometric analysis of the genus *Omphalocyclus* from the Late Cretaceous of Turkey: new data on its stratigraphic distribution in Mediterranean Tethys and description of two new taxa. Cretac. Res. 28, 621–641.
Pamouktchiev, A., 1966. La faune de rudistes du village Borouchtitza, Balkan central (III). Annu. de l'Université de Sofia Kliment Ohridski Fac. de Geol. Geogr. Livre 1 Géologie 59, 23–42.
Parona, C.F., 1900. Sopra alcune rudiste senoniane dell'Appennino meridionale. Mem. dell'Accademia delle Sci. Torino Cl. Sci. Fis. Mat. Nat. 50, 1–23.
Parona, C.F., 1911a. Nuovi studii sulle rudiste dell'Appennino (radiolitidi). Accad. delle Sci. Torino 62, 273–293, 62, 273–293.
Parona, C.F., 1911b. Sulla presenza del Turoniano nel Monte Coneropresso Ancona. Soc. Geol. Ital. 30, 108–112.
Parona, C.F., 1926. Fauna a rudiste, ed una sua nuova forma, di Villa Vallelonga in Abruzzo. Accad. delle Sci. Torino 61, 743–748.
Pejović, D., 1957. Geologie und Tektonik der weiteren Umgebung von Pocuta (Westserbien) mitbesonderer Berücksichtung der Biostratigraphie der oberkretazischen Bildungen. GeoloskiInstitut "Jovan Zujovic". Poseb. Izd. 8, 147p.
Pervinquière, L., 1912. Etudes de paléontologietunisienne, II. Gastropodes et lamellibranches des terrains crétacés. Ordre des Pachyodontes 297–328.
Polšak, A., 1967. Macrofaune crétacée de l'Istrie méridionale (Yougoslavie). Palaeontol. Jugosl. 8, 1–219.
Polšak, A., Mamuzic, P., 1969. Les nouveaux gisements de rudistes dans le Crétacé supérieur des Dinarides externes. Geolski Vjesn. 22, 229–245.
Pons, J.M., Vicens, E., 2008. The structure of the outer shell layer in radiolitid rudists, a morphoconstructional approach. Lethaia 41, 219–234.
Powers, R.W., 1968. Lexique stratigraphie international 3, Asie. Commission de Stratigraphie. Centre National de la Recherche Scientifique, Paris, 10bl, 180 p.
Powers, R.W., Ramirez, L.F., Redmond, C.D., Elberg, E.L., 1966. Geology of the Arabian Peninsula, sedimentary geology of Saudi Arabia. In: U. S. Geological Survey Professional Paper, 560-D, 147 p.
Sanchez, V., 1981. Hippuritidae y Radiolitidae (Bivalvia). Catálogo de especies, vol. 15. Universidad Autónoma de Barcelona, 228 p.
Schlüter, M., Steuber, T., Parente, M., 2008. Chronostratigraphy of Campanian–Maastrichtian platform carbonates and rudist associations of Salento (Apulia, Italy). Cretac. Res. 29, 100–114.
Skelton, P.W., 2013a. Rudist classification for the revised Bivalvia volumes of the 'Treatise on invertebrate paleontology'. Caribb. J. Earth Sci. 45, 9–33.
Skelton, P.W., 2013b. Rudist classification: nomenclatural correction of 'Suborder Radiolitidina Skelton, 2013' to 'Suborder Hippuritidina Newell, 1965'. Caribb. J. Earth Sci. 45, 34.
Skelton, P.W., El-Asa'ad, G.M.A., 1992. A new canaliculate rudist bivalve from the Aruma Formation of Central Saudi Arabia. Geol. Romana 28, 105–117.
Slišković, T., 1968. Biostratigraphie du Crétacé supérieur de Herzégovine méridionale. République Social. Bosnie Herzégovine 7, 5–66.
Slišković, T., 1975. Recherches plus récentes sur les couches crétacées de la Bosnie orientale. Wissen mitt. des bosnisch herzegowinischen Landesmus. C. 4–5, 49–58.
Steineke, M., Bramkamp, R.A., 1952. Stratigraphic introduction. In: Arkell, W.J. (Ed.), Jurassic Ammonites from Jebel Tuwaiq, Central Arabia. Philosophical Transactions of the Royal Society of London, vol. 633, pp. 241–313.
Steineke, M., Bramkamp, R.A., Sander, N.J., 1958. Stratigraphic relations of Arabian Jurassic oil. In: Habitat of Oil, American Association of Petroleum Geologists, pp. 1294–1329.
Steuber, T., 1999. Cretaceous rudists of Boeotia, central Greece. Special Pap. Palaeontol. 61, 1–229.
Steuber, T., 2002. Web Catalogue of the Hippuritoidea (Rudist bivalves). http://www.paleotax.de/rudists/index.htm.
Steuber, T., Özer, S., Schlüter, M., Sarı, B., 2009. Description of *Paracaprinula syriaca* Piveteau (Hippuritoidea, Plagioptychidae) and a revised age of ophiolite obduction on the African-Arabian plate in southeastern Turkey. Cretac. Res. 30, 41–48.
Toucas, A., 1907. Etudes sur la classification et l'évolution des radiolitidés: *Agria* and *Praeradiolites*. Mémoires de la Société géologique de France. Paléontologie 36, 1–46.
Toucas, A., 1908. Etudes sur la classification et l'évolution des radiolitidés: *Sphaerulites* and *Radiolites*. Mémoires de la Société géologique de France. Paléontologie 36, 47–78.
Toucas, A., 1909. Etudes sur la classification et l'évolution des radiolitidés: *Sauvagesia* and *Biradiolites*. Mémoires de la Société géologique de France. Paléontologie 36, 79–132.