

First occurrence of rudists (Bivalvia) from the Coniacian-Santonian limestones of the Saharan platform, southern Tunisia: Description, biostratigraphy and correlation



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ABSTRACT

This study focuses on the description of rudists observed within the Berressef Formation from the Matmata area in the Saharan platform of southern Tunisia. The study of rudists is based on two measured stratigraphic sections and five observation points. It has revealed for the first time the presence of Coniacian-Santonian rudists. Two rudist associations were identified: 1) *Biradiolites angulosus*-*Biradiolites martellii*-*Radiolites trigeri* association (Coniacian) containing *Durania* cf. *arnaudi*, *Bournonia* cf. *gardonica*, *Biradiolites* sp., *Hippurites* sp. and *Apricardia* sp.; and 2) *Radiolites dario*-*Bournonia fascicularis* association (late Coniacian-Santonian) including *Sauvagesia* sp. and *Radiolites* sp. These associations have showed a remarkable similarity with those of central-south of Apennines, Italy. Rudists of the Berressef Formation are mostly elevators in growth position. They present cylindrical to elongated cylindrical shapes and they are organized in isolated individuals, bouquets and clusters. The rudist facies A is mostly represented by rudists in growth position. The facies B consisted of bioclastic limestones rich in rudists fragments, which is considered to have been deposited not far from their original palaeoenvironment.

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1. Introduction

Late Cretaceous rudists are widely exposed in Middle and South of Tunisia, along the north of “North Saharan Flexure”, where the taxonomic rudist studies are mainly focused on the Cenomanian-Turonian, but rarerly on the uppermost Cretaceous (Steuber, 2002; Chikhi-Aouimeur et al., 2006; Chikhi-Aouimeur, 2010). Despite this knowledge, there aren't any rudist descriptions from the Saharan platform, which is located in the southern Tunisia (Fig. 1). Nevertheless, the presence of radiolitid rudists are recently reported to the Coniacian-Campanian formations along the northern escarpment of the Dahar Plateau in southern Tunisia by Khila et al. (2016). This study is focused on the rudists of the Coniacian-Santonian Berressef Formation around Matmata area (South of Tunisia) and investigating the presence of a rich rudist fauna in the north of the Saharan platform (Figs. 1, 2). The study

area is situated in crossroads between Matmata and el Hamma towards Douz. It is bordered to the southeast by Tamazret village, to the west by Douz city, to the north by the Southern Chotts ranges and to the south by the Dahar cliff (Figs. 1, 2).

The aims of this study are mainly to describe the rudist fauna and associations from Matmata area and to compare with those of the Mediterranean Tethys. Indeed, the rudist organization and facies characteristics are also emphasized.

2. Material and methods

The rudist study is based on two measured-stratigraphic sections. These are Bouterfess-I (33°38'39.53"N and 9°42'26.30"E) and Bouterfess-II (33°39'12.53"N and 9°44'57.31"E), which are located in the northwest of Matmata (Fig. 2). Besides, some observations were made on the road from Zraoua to Douz and from Tamazret to Douz (points 1–5 shown in Fig. 2). The coordinates of these points are as follows: 1) 33°37'58.88"N and 9°54'30.348"E, 2) 33°39'18.80"N and 9°44'55.44"E, 3) 33°38'28.20"N and 9°43'42.94"E, 4) 33°36'11.37"N and 9°37'47.19"E and 5) 33°36'03.26"N and 9°36'22.02"E.

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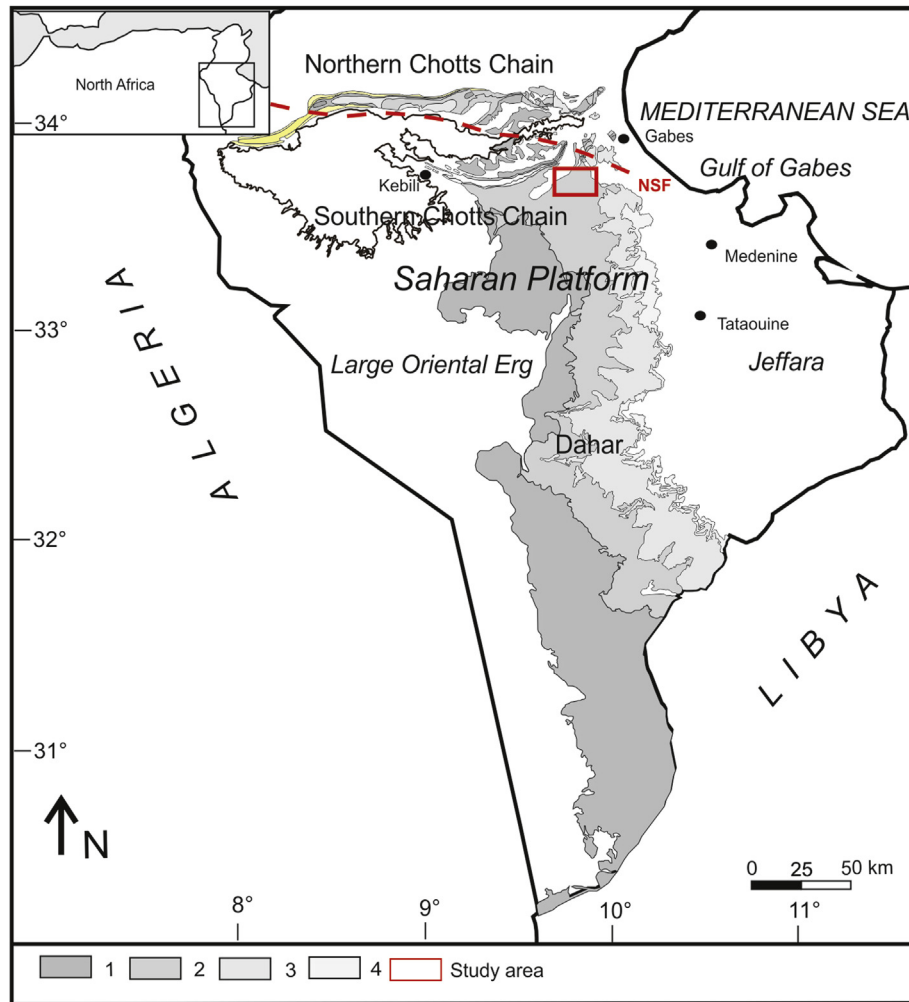


Fig. 1. Simplified geological map of Southern Tunisia (Ben Ayed, 1993) showing the location of the study area. 1. Upper Albian, 2. Cenomanian-Turonian, 3. Coniacian-Santonian, 4. Campanian-Maastrichtian. NSF: North Saharan Flexure (from Gabtni et al., 2005).

Rudists are mostly embedded within the limestones of the Berressef Formation. Dolimitization had affected these levels. Therefore, it was impossible to collect the matrix-free specimens. However, we have benefited of field photos for the description of rudists. We collected 38 limestone samples with rudist and we prepared polished sections for the description of these rudists. These sections have been prepared in the laboratory of the Geology Department, Faculty of Sciences of Gables, University of Gables, Tunisia. We have also collected 14 limestone samples and prepared thin sections for microfossil analysis. Unfortunately, it was observed that the microfossils have mostly been masked due to the dolomitization.

The polished limestone sections and thin sections have been stored in the laboratory of the Geology Department, Faculty of Sciences of Gables, University of Gables.

3. Geological setting and stratigraphy

Dahar Cliff is widely exposed in the southern Tunisia and shows a north-south continuous Mesozoic outcrops extending to the southern border of Tunisia (Fig. 1). Matmata area, in which the two stratigraphic sections were measured, is located in the northern part of Saharan platform and to the south of the North Saharan Flexure (Bouaziz et al., 1989, 2002; Gabtni et al., 2005; Bodin et al.,

2010). This area is bordered to the north by the southern Chotts ranges and to the south by the Dahar Cliff and the eastern Great Erg. It represents a transition between the tabular Saharan platform and the folded atlas field.

The Upper Cretaceous sequences of the Matmata area have recently been investigated by Khila et al. (2016). According to these authors, the correlation of four stratigraphic sections (Bouterfess, Oum Eich, Darbuka, Toual) indicate the presence of Coniacian-Campanian deposits in this area. The Bouterfess section is made by rudist-bearing limestones, cross-stratified carbonates and fossiliferous marls. This latter corresponds to the Berressef Formation by Khila et al. (2016). In this work, we focus on the rudists of the Berressef Formation. The type locality of this formation is located 60 km northeast of the Kebili at Jebel Berressef in the Tebaga Mountains, in the South of the “North Saharan Flexure (NSF)” in southern Tunisia (Ghanmi et al., 1993) (Fig. 1). The Coniacian age of this formation is based on the presence of ostracoda (*Ovocytheridea brevis* Grekoff, *Protobuntonia nummidica* Grekoff, *Brachycythere* aff. *angulata* Grekoff, *Reticulocostata* aff. *tabessaensis* Vivière and other genera) by Ghanmi and Potfaj (1994). The Coniacian-Santonian? age was proposed by Khila et al. (2016) according to the interpretation of ostracoda studies on North Africa, Mali and Congo by Damotte (1995). The Oum Echieh section is consisted by the Berressef Formation which is overlaid by the

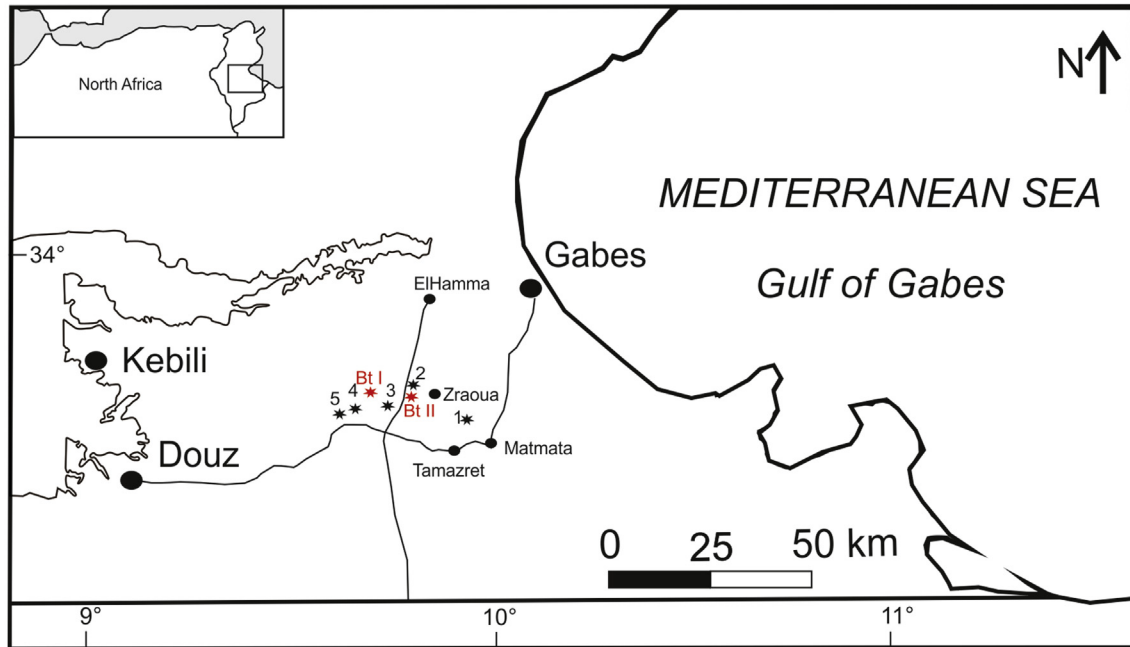


Fig. 2. Map showing the location of the measured stratigraphic sections (red asterisks, Bt-I and Bt-2. Bouterfess sections) and the observation points (black asterisks, 1 to 5). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Campanian Toul formation. However, at the Darbouka and Toul sections this formation is absent. In situ rudists are observed at the top of the Toul section.

Toward the north, in el Hamma region, rudist-bearing Berressef Formation has two equivalents: the Haidoudi and the Maider formations. The Haidoudi Formation is made by bioclastic limestone (grainstone to packstone) and overlaid by the Maider Formation which is formed by clay interbedded with bioclastic limestone (Abbes et al., 1994). In the center of Tunisia, this formation pass to the Aleg Formation, which is predominantly formed by clay and marl interbedded with bioclastic limestone (wackstone) and gypsum (Buroillet, 1956; revised by Fournié, 1978). In the North of Tunisia, the Berressef Formation is equivalent to the Kef Formation, which is composed predominantly by shale, argillaceous limestone, and marl (Buroillet et al., 1954; Buroillet, 1956).

Indeed, we have focused on the rudists within the Berressef Formation in two stratigraphic sections. The Bouterfess-I section is the same section named as Bouterfess section of Khila et al (2016, fig. 7). We measured an additional section (Bouterfess-II section) to observe the lateral evolution of rudist-bearing levels within the Berressef Formation. The lithologic features and rudist levels of these sections are presented below:

3.1. Bouterfess-I section

The Berressef Formation consists mainly of approximately 60-m-thick platform-type carbonates (Fig. 3), in ascending order: (I) a 9-m-thick, beige, bioclastic limestones with rudists (Fig. 4A). Besides, the uppermost part shows rudists in growth position. Echinids and indeterminate mollusks are also present. Dolomitization and bioturbation are usually observed. (II) a 2-m-thick, yellow fossiliferous marlstones with abundant echinids, gastropods and mollusks. (III) a 4-m-thick, beige bioclastic limestones with rudists, echinids and mollusks debris. Dolomitization and bioturbation are usually observed. (IV) a 4-m-thick, beige coarse-grained limestones with cross-stratification grainstone in texture. Dolomitization, mollusk fragments and some benthic foraminifera

(*Cuneolina* gr. *pavonia* d'Orbigny, Miliolidae) are observed. (V) a 8-m-thick, beige limestones (Fig. 4B). The lower 3 m consists of bioclastic limestones showing dolomitization and bioturbation, the upper 5 m comprises mainly in situ rudists, as well as gastropods and echinids. (VI) a 6-m-thick, beige coarse-grained limestones with cross-stratification grainstone in texture. Some benthic foraminifera (*Nezzazatinella* cf. *N. picardi* (Henson), *Cuneolina* gr. *pavonia* d'Orbigny) and mollusk fragments are observed. (VII) a 8-m-thick, beige limestones with rudists and gastropods (Fig. 4C). The middle bed 1-m-thick is about limestones with stromatolites (Fig. 4D, E). (VIII) a 16-m-thick, beige coarse-grained limestones with cross-stratification grainstone in texture (Fig. 4F–H). Some benthic foraminifera (*Nezzazatinella* cf. *N. picardi* (Henson), *Cuneolina* gr. *pavonia* d'Orbigny, Miliolidae) and mollusk fragments are observed. (IX) a 6-m-thick, successions of beige of bioclastic limestones with mainly rudist fragments and echinids and limestones with rudists in growth position. (X) a 7-m-thick, beige limestones with in situ rudists, gastropods and other bivalves.

Rudist fauna consists mainly of radiolites of Coniacian-Santonian age: *Biradiolites angulosus* (d'Orbigny, 1842a), *Biradiolites martellii* (Parona, 1911), *Radiolites trigeri* (Coquand, 1859), *Durania* cf. *arnaudi* (Choffat, 1891), *Bournonia* cf. *gardonica* (Toucas, 1907), *Radiolites dario* (Catullo, 1834) and *Bournonia fascicularis* (Pirona, 1869) are determined. Hippuritids and the requieniid *Apriscardia* are very rare. The distribution of rudists is presented in Fig. 3.

3.2. Bouterfess-II section

This section is 47 m thick and consists from bottom to top of (I) a 5-m-thick, beige limestones with in situ rudists. The bioclastic limestones with rudists debris are very rare. (II) a 12-m-thick, alternation of yellow fossiliferous marlstones with echinids, gastropods and mollusks and beige bioturbated bioclastic limestones with rudist debris. (III) a 10-m-thick, beige coarse-grained limestones with cross-stratification grainstone in texture. Some miliolids can be observed. (IV) a 8-m-thick, beige limestones with in situ rudists towards the middle and upper parts. (V) a 6-m-thick,

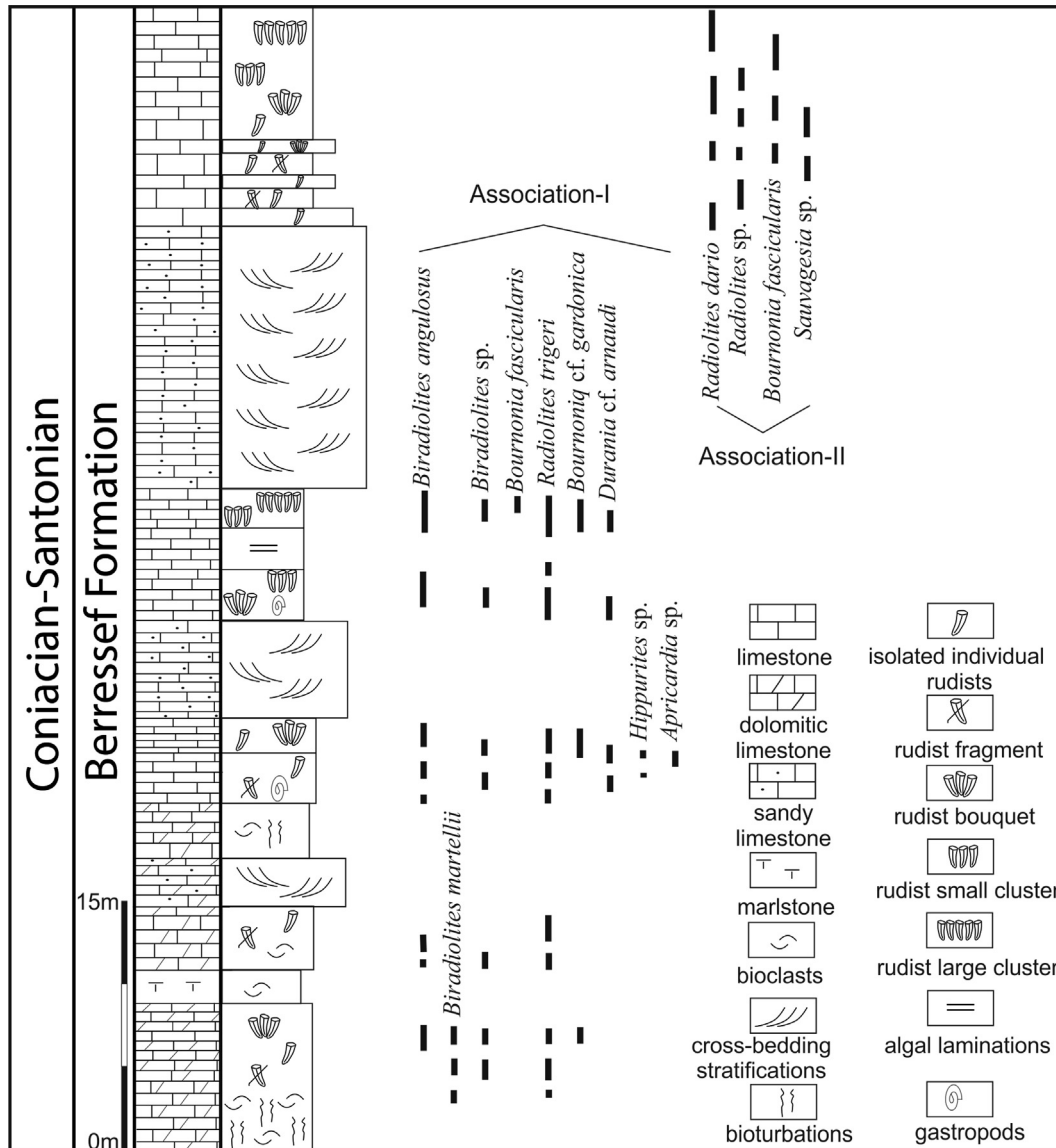


Fig. 3. Bouterfess-I measured stratigraphic section showing rudist distributions and associations.

succession of beige limestones with in situ gastropods and rudists, with bioclastic limestones. (VI) a 6-m-thick, beige limestones with in situ rudists (Fig. 5).

The rudist fauna consists mainly of radiolitids suggesting a Coniacian age: *Biradiolites angulosus* (d'Orbigny, 1842a), *Biradiolites martellii* (Parona, 1911), *Radiolites trigeri* (Coquand, 1859), *Durania cf. arnaudi* (Choffat, 1891), *Bournonia cf. gardonica* (Toucas, 1907) and *Bournonia fascicularis* (Pirona, 1869). Hippuritids are very rare. The distribution of rudists is shown in Fig. 5.

4. Systematic palaeontology

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

Abbreviations: LV, left valve; RV, right valve; Ab, anterior radial band; Pb, posterior radial band; Ib, interband; P1, first pillar; P2, second pillar; L, ligamental ridge; am, anterior myophore; pm, posterior myophore; at, anterior tooth; pt, posterior tooth; bc, body cavity; ol, outer shell layer; il, inner shell layer.

Class Bivalvia Linnaeus, 1758

Order Hippuritida Newell, 1965

Suborder Radiolitidina Skelton, 2013a

Superfamily: Radiolitoidea d'Orbigny, 1847

Family Radiolitidae d'Orbigny, 1847

Genus *Biradiolites* d'Orbigny, 1850

Type species. *Biradiolites canaliculatus* d'Orbigny, 1850

Biradiolites angulosus(d'Orbigny, 1842a)

Fig. 6A–L

1850 *Biradiolites angulosa*, d'Orbigny, p. 233, pl.574, figs.7–11.

1902 *Biradiolites angulosus*, Douvillé, p. 473.

2002 *Biradiolites angulosus*, Steuber (see Web Catalogue of the Hippuritoidea (rudist bivalves) for complete synonym list).

2004 *Biradiolites angulosus*, Cestari and Pons, p. 175–192, figs. 9c, 12c.

2007 *Biradiolites angulosus*, Korbar, p. 141, figs. 10, 11.

2007 *Biradiolites angulosus*, Macé-Bordy, p. 97, fig. 8c, g.

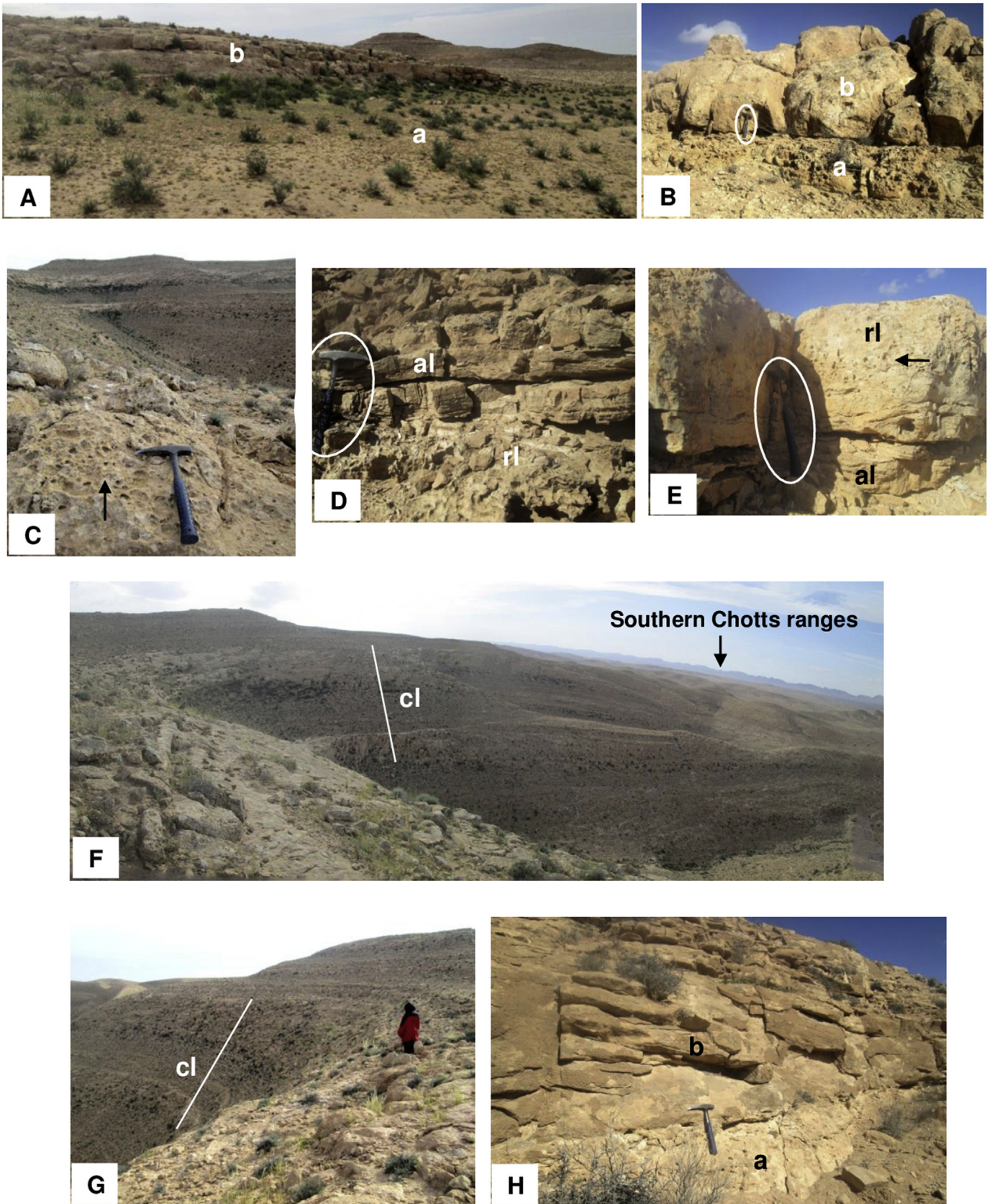


Fig. 4. Field photographs of Besserref Formation, see for details to Bouterfess-I measured-stratigraphic section in text. A. the base of the section showing the bioclastic limestones (a) following well-stratified rudist-bearing limestones (b). B. the bioturbated limestones (a) overlying the massive, limestones with rudists (b), scale is hammer. C. the panoramic view of the rudist-bearing limestones. Note abundant rudists sections at the base of the limestone level (arrow), scale is hammer. D and E. the algal laminated limestones (al) between two rudist-bearing limestones (rl), black arrow indicates the rudist sections, scale is hammer. F and G. the panoramic views of the coarse-grained limestones with cross-stratification (cl) over the rudist-bearing limestones. Note in far the South Chotts ranges in figure F. H. the close view of the relationship between the rudist-bearing limestones (a) and coarse-grained limestones with oblique stratification (b), scale is hammer.

2006 *Biradiolites angulosus*, Chikhi-Aouimeur et al., section Jebel Chemsi, fig. 1.

2008 *Biradiolites angulosus*, Cestari, p. 89–93, figs. 76–78.

2009 *Biradiolites angulosus*, Gil et al., p. 523–538, figs. 5b, d, 6a–c. (*Biradiolites canaliculatus* according to Garcia-Hidalgo et al., 2012, fig. 9E).

Material. Many transverse and radial sections from the isolated individuals, bouquets and clusters. Besides 12 polished sections of the RV.

Description. The RV is cylindrical-elongated in shape, 20–25 mm in length. The transverse section of the valve is mainly sub-squared, rarely ovaloid and round. The cells of the ol are not clearly preserved, but some transverse sections present non-compact structure with continuous radial ridges on the growth lamellae (Pons and Vicens, 2008) around the dorsal and dorsa-posterior parts of the valve (Fig. 6A–C, H–K). The ribs (5–7) present variable shapes more or less developed. The radial bands are flat, but protruding and slightly concave. The Vb is always more wide than the Pb. The ol becomes thick in some transverse sections, especially the ventral one (Fig. 6A, C, I, J). The Ib is represented by a very developed rib limited by grooves. The L is absent. The radiolitiform myocardial apparatus is preserved in some transverse sections as well as radial sections (Fig. 6I–L). The myophores get closer to the inner margin and the mp appears wider than ma.

Discussion. Morphologic variabilities of the radial bands and size of the specimens show close similarities with sections presented in the Trieste Karst sector (Italy) by Caffau and Pleničar (1996) and Caffau et al. (1998). In the study area, all species are represented by small transverse section as presented in central-southern Apennines, Puglia and Trieste in Italy (Caffau and Pleničar, 1996; Caffau et al., 1998; Pleničar and Jurkovšek, 1998; Cestari and Pons, 2004; Cestari, 2008). The lectotype from Pons (France) and the specimens from Beotia (central Greece) are larger than those described by Macé-Bordy (2007) and Steuber (1999), respectively.

Biradiolites martellii (Parona, 1911)

Fig. 6M–T

1911 *Durania martellii*, Parona, p. 386, text-figs. 1, 2.

1966 *Durania martellii*, Torre, p. 15, pl. 5, fig. 1a, b.

1972 *Biradiolites martellii*, Pejović, p. 118, pls.1, 2, text-fig.1 (copy Parona, 1911).

1992 *Durania martellii*, Peza, p. 297, pl. 2, fig. 3.

1995 *Durania* (= *Biradiolites*) *martellii*, Cestari and Sartorio, p. 134, 135.

1996 *Milovanovicia martellii*, Laviano and Pejović, p. 93–96, figs. 1–6.

1999 *Durania martellii*, Steuber, p. 56–60, pl. 1, figs. 1, 2, 4, 7, pl. 2, figs. 1–3.

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

2004 *Biradiolites martellii*, Cestari and Pons, p. 175–192, fig. 12d.

2008 *Biradiolites martellii*, Cestari, p. 93–98, figs. 79–81.

Material. Many transverse and radial sections from the bouquets, clusters and isolated individuals. Three polished sections of the RV are also observed.

Description. The RV is cylindrical and cylindroconical, nearly 30 mm long. The transverse section of the valve is dorsa-ventrally elongated and shows 5–6 sharp rib sections separated with deep grooves. The Vb and Pb are flat, but slightly concave, and between them is more than quarter of the valve circumference. The radial bands are separated by two prominent ribs of Ib. The ol seems to be compact, but some transverse sections have the polygonal cells around the ribs (Fig. 6M, N, Q). The natural radial sections show steeply inclined growth lamellae and some preserved tabulae

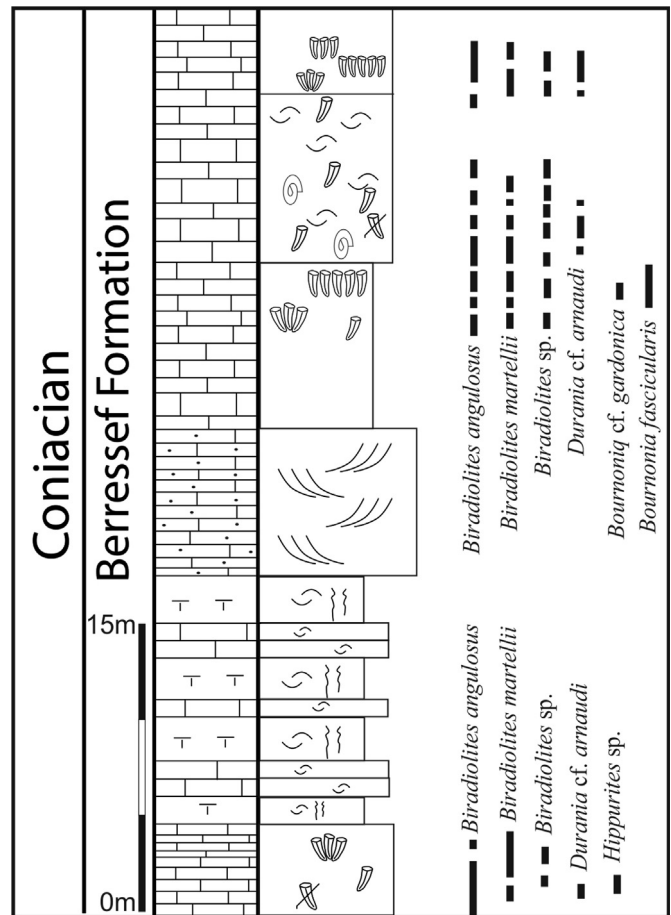


Fig. 5. Bouterfess-II measured-stratigraphic section showing the rudist distributions (for more explanations see Fig. 3).

(Fig. 6S). The L is absent and the myocardial apparatus is not preserved.

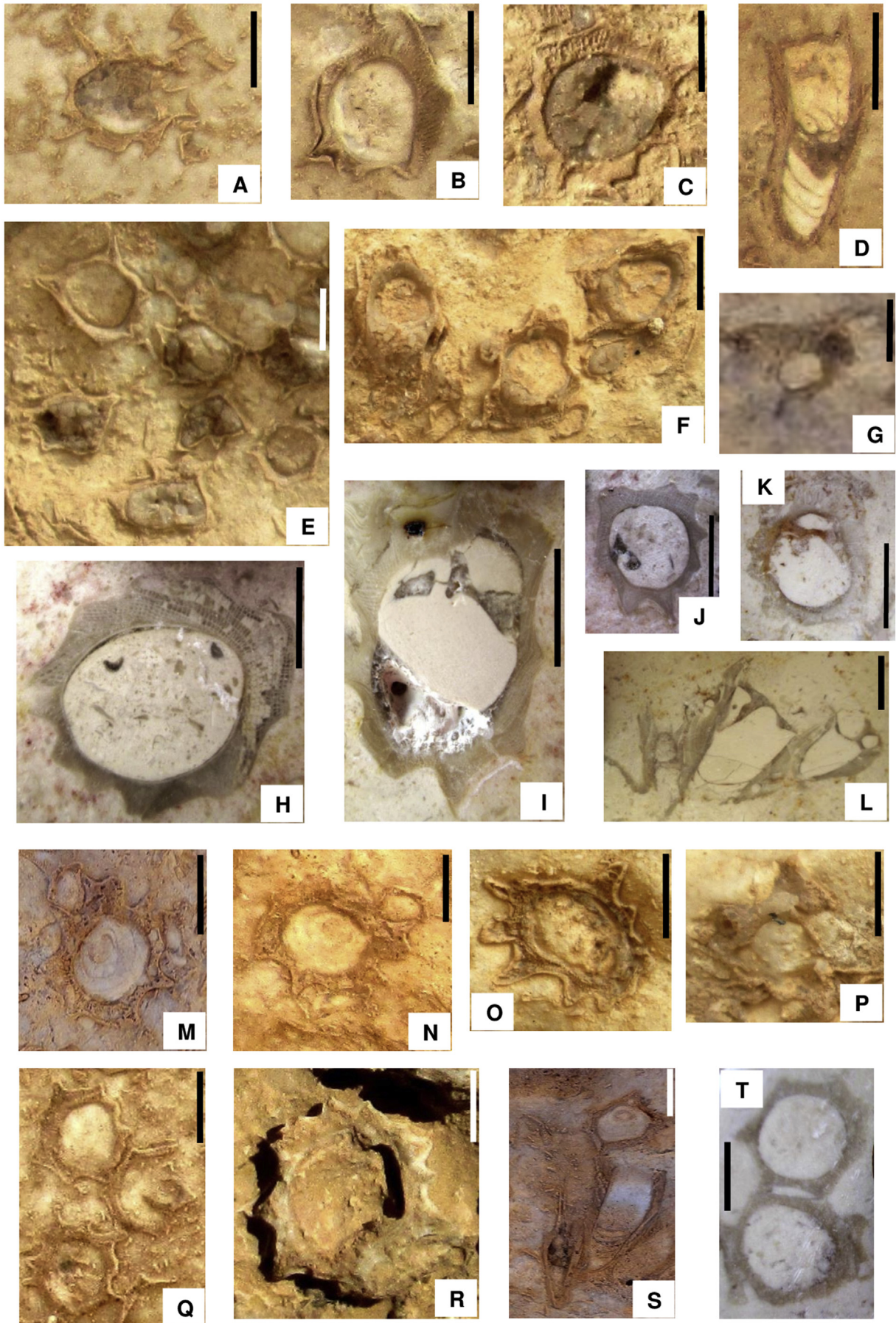
Discussion. Although this species was described under the name of *Durania Douvillé, 1908* by Parona (1911), it was transferred to *Milovanovicia Pořak, 1967* by Laviano and Pejović (1996), it was subsequently replaced by *Biradiolites d'Orbigny, 1850* or preserved the name of *Durania* by different authors. One of the species of *Milovanovicia*, *M. dobrunensis Sliškoivić, 1975* was proposed as a synonymous of this species by Steuber (1999), this time all species of the *Milovanovicia* was described by Pořak (1967) and Sliškoivić (1975, 1984) and also *Durania martellii* are replaced by *Biradiolites martellii* by Cestari (2008). The studied sections show similarities with text-fig. 2 of Parona (1911), but they are accepted here as *Biradiolites martellii* due to the radial bands characters. Our sections can also be compared with figure 80A of Cestari (2008). However, the debatable approaches as summarized above show that taxonomic problem seems to be continued for this species.

Biradiolites sp.

Fig. 7A–D

Material. The transverse, oblique and radial sections from seven polished sections and some field views.

Description. The transverse sections of the RV show postero-anterior elongation and contain up to three sharp ribs slightly separated, but large grooves in the ventral side (Fig. 7A–D). The dorsal side of the valve is smooth, but two or three slightly developed ribs can be preserved. The structure of the ol is non-compact



structure at the inner part, but the cells are elongated towards to outer part of the shell layer (Fig. 7B, D). The L is absent and the myocardinal apparatus is not preserved.

Discussion. Although these sections present ribbed ventral part of the valve, it is impossible to define the radial bands, so species can not be described. They may be compared by shape and position of the radial ribs in the ventral part of the valve with *Biradiolites acuticostatus* (d'Orbigny, 1842b) specimens described in South-Central Pyrenees, Spain by Santiago (2014, p. 160, fig. 100).

Genus *Bournonia* Fischer, 1887

Type species. *Sphaerulites bournoni* Des Moulins, 1826

Bournonia fascicularis (Pirone, 1869)

Fig. 7E–I

1869 *Radiolites fascicularis*, Pirone, p. 424, pl. 23, figs. 6–12.

1907 *Agria fascicularis*, Toucas, p. 22, pl. 1, figs. 13–14.

1932 *Eoradiolites fascicularis*, Kühn, p. 112.

1951 *Agria fascicularis*, Pejović, p. 99, pl. 1, figs. 1–2.

1972 *Eoradiolites fascicularis*, Campobasso, p. 438, pl. 7, fig. 1.

1995 *Bournonia fascicularis*, Cestari and Sartorio, p. 40, 137.

2004 *Bournonia fascicularis*, Cestari and Pons, p. 175–192, figs. 4c, f, 5f, 6e, 12b.

2008 *Bournonia fascicularis*, Cestari, p. 101–104, figs. 84–86.

2012 *Bournonia fascicularis*, Cestari and Laviano, p. 285, fig. 8d.

2012 *Bournonia fascicularis*, Pons, J.M. description in Garcia-Hidalgo et al., p. 273, fig. 9B.

Material. Many transverse and radial sections of the RV of the isolated individuals, bouquets and clusters. Five limestone samples containing sections of the species are also observed.

Description. The RV is cylindroconical and elongated cylindrical, its maximum length is 40 mm. The surface of the valve is smooth, but some not-protruding longitudinal ribs and slightly inclined growth lamellae can be observed. The Vb, Pb and Ib are concaves delimited by protruding longitudinal ribs. They occupy one third or more of the circumference. The ol seems to be compact structure (Fig. 7E–G). The L is absent and the myocardinal apparatus is not preserved. Only one individual presents partially a flat LV (Fig. 7H).

Discussion. The shape of RV and especially the concave Vb, Pb and Ib show typical characteristics of species described from Italy (Pirone, 1869; Cestari and Sartorio, 1995; Cestari, 2008). However, the radial bands are not close together in some specimens, so they may be compared with those of Cestari (2008, fig. 85A, B) and Garcia-Hidalgo et al (2012, fig. 9B).

Bournonia cf. gardonica (Toucas, 1907)

Fig. 7J–M

1907 *Agria gardonica*, Toucas, p. 26, pl. 2, figs. 6–10.

1926 *Bournonia*, Parona, p. 34.

1966 *Bournonia gardonica*, Pamouktchiev, p. 32, text-fig. 1.

1972 *Bournonia gardonica*, Campobasso, text-figs. 1–6 (copy Toucas, 1907)

1981 *Bournonia gardonica*, Pamouktchiev, p. 196, pl. 81, fig. 4 (copy Pamouktchiev, 1966).

2002 *Bournonia gardonica*, Gil et al., p. 245–256, figs. 3b, e–g, 4a–e, 5a–e, 6a–d.

2004 *Bournonia gardonica*, Cestari and Pons, p. 186, fig. 9d.

2008 *Bournonia excavata*, Cestari, p. 101, fig. 83 (copy Cestari and Pons, 2004).

2012 *Bournonia gardonica*, Cestari and Laviano, p. 280, fig. 3.

2012 *Bournonia gardonica*, Pons, J.M. description in Garcia-Hidalgo et al., p. 273, fig. 9A (copy Gil et al., 2002, fig. 4a).

Material. Many densely packed RV within the cluster not allowing to obtain loose specimens. Beside the transverse sections of three isolated RV from the field views and three polished sections.

Description. The RV seems to be cylindro-conical on the edge of its monotypic cluster (Fig. 7J). The transverse section of the valve is rectangular or sub-rectangular showing the rounded structure of the radial ribs, but rare, and also protruding radial bands separated by groove of the Ib. The ol is thin and show the non-compact structure (Fig. 7K–M), but the compact structure can be developed at the outermost margin of the ol (Fig. 7M). The L is absent and the myocardinal apparatus is not preserved.

Discussion. The transverse section and the structure of the radial bands of the RV show close similarities with *Bournonia gardonica* specimens described from the southern margin of the Sistema Central (Spain) by Gil et al. (2002).

Genus *Radiolites* Lamarck, 1801

Type species. *Ostracites angeioides* Lapeirouse, 1781

Radiolites trigeri (Coquand, 1859)

Fig. 7N–R

1859 *Sphaerulites trigeri*, Coquand, p. 972.

1904 *Praeradiolites trigeri*, Douvillé, p. 245, pl. 36, fig. 6.

1908 *Radiolites trigeri*, Toucas, p. 74, pl. 14, figs. 1–7.

2002 *Radiolites trigeri*, Steuber (see Web Catalogue of the Hippuritoidea (rudist bivalves) for complete synonym list).

2004 *Radiolites trigeri*, Cestari and Pons, fig. 12e–g.

2005 *Radiolites trigeri*, Cestari, pl. 1, figs. 1–6.

2006 *Radiolites trigeri*, Chikhi-Aouimeur et al., section Jebel BenYounès, figs. 1–3.

2008 *Radiolites trigeri*, Cestari, p. 142–145, figs. 116–120.

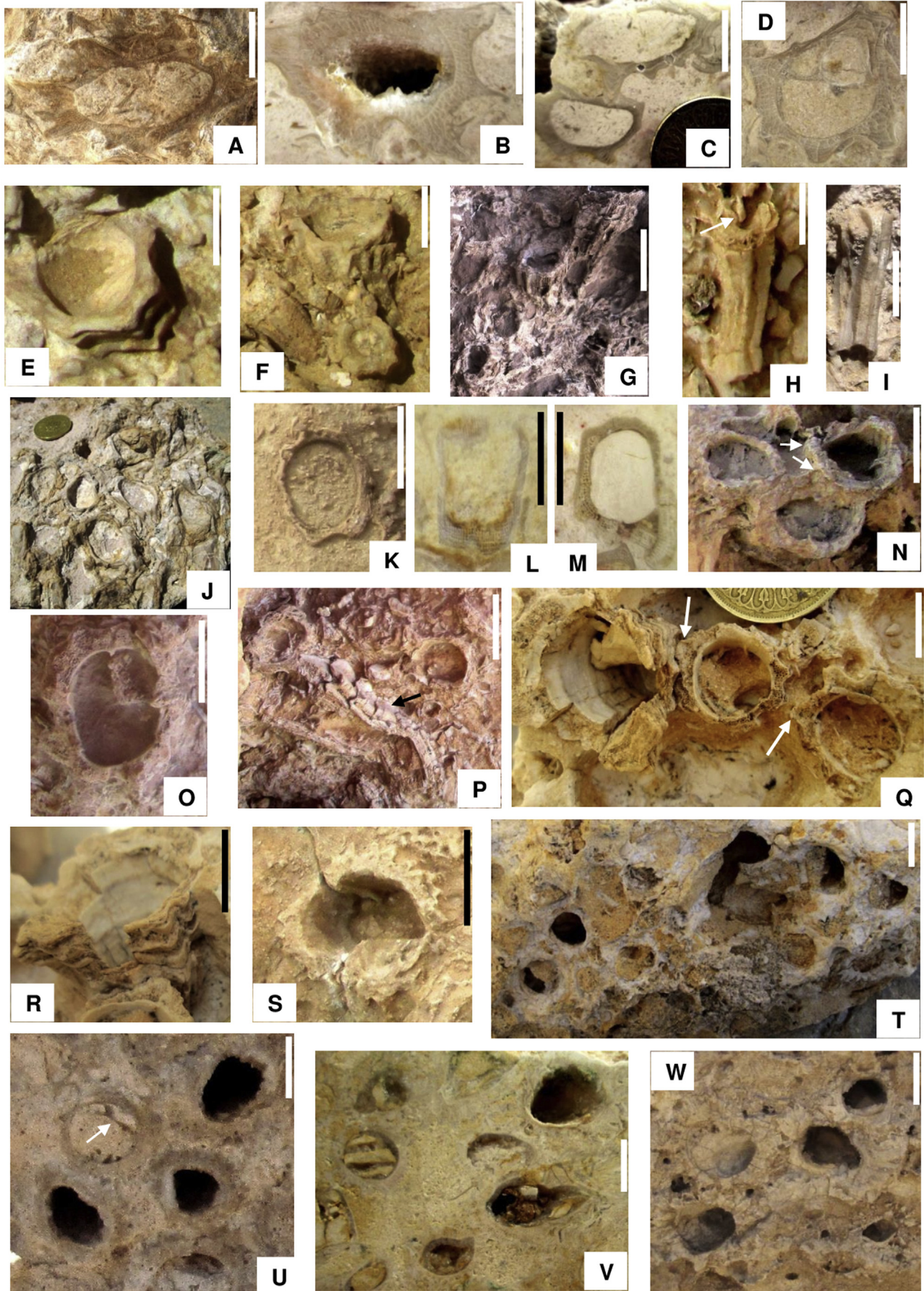
2012 *Radiolites trigeri*, Cestari and Laviano, p. 283, fig. 6.

Material. Many RV from the isolated individuals, bouquets and clusters. Besides six limestone samples with rudists and some polished sections.

Description. The RV is cylindro-conical, 20–30 mm in length. The valve is ornamented with rounded ribs that are interrupted by very marked growth lamellae showing regular cycles (Fig. 7P, R). The Vb and Pb are flat, slightly concave, have nearly same width and separated by narrow but protruding rib of the Ib. The transverse section of the valve is generally subovaloid and elongated in direction dorsa-ventral. However the small forms show sub-rounded sections. The ol is very thick in dorsal side than postero-ventral one and its non-compact structure can be observed in the natural radial and transverse sections of the valve (Fig. 7O–Q). The L is short and triangular. The myocardinal apparatus is not preserved in all sections due to dissolution of il and bc.

Discussion. The ornamentation of the valve and the shape of the radial bands of the studied sections show typical characteristics of

Fig. 6. Rudists of the Berressef Formation: A–L. *Biradiolites angulosus* (d'Orbigny, 1842a). A–G. the field views, H–L. the polished sections, in order to sample nos: Gd-244, Gd-243, Gd-242, Gd-210, Gd-246. A–F from Bouterfess-II section, G from the observation point 1, H–L from Bouterfess-I section. D and L. the radial sections, others the transverse sections of the RV. Note the morphologic variabilities of the radial bands and size of the specimens in transverse sections. The cellular structure of the ol in A–C and H–K, the myocardinal apparatus in I–L and the tabulae in D and L can be observed. L partially presents the myocardinal apparatus in radial sections of small bouquet consisting of three specimens. Scale bar is 10 mm. M–T. *Biradiolites martellii* (Parona, 1911). M–S. the field views, T. the polished section, sample no: Gd-241. M and R from the observation point 1, N–P from Bouterfess-I section, Q and T from Bouterfess-II section, R from the observation point 3. M–R and T. the transverse sections of the RV. S. one transverse and three radial sections of the RV from small bouquet. The tabulae can be observed in the middle specimen. Scale bar is 10 mm.



the species. The Ib of the studied sections is larger than the specimens described from Istria-Croatia by Polšak (1967, pl. 41, figs. 1–5).

Radiolites dario (Catullo, 1834)

Fig. 7S–W

- 1834 *Hippurites dilatatus*, Catullo, p. 17, pl. 2, fig. 1.
 1834 *Sphaerulites da-rio*, Catullo, p. 15, pl. 1, figs. 3, 4.
 1892 *Radiolites da Rio*, Futterer, p. 99, pl. 9, fig. 3.
 2002 *Radiolites dario*, Steuber (see Web Catalogue of the Hippuritoidea (rudist bivalves) for complete synonym list).
 2004 *Radiolites dario*, Cestari and Pons, fig. 4b, c, e.
 2005 *Radiolites dario*, Cestari, figs. 1–3.
 2007 *Radiolites dario*, Cestari and Pons, fig. 4d, e.
 2008 *Radiolites dario*, Cestari, p. 131–141, figs. 107–113.
 2012 *Radiolites dario*, Cestari and Laviano, p. 285, fig. 8a, b.

Material. Many transverse and radial sections from bouquets and clusters. Beside three limestone samples containing the section of this species and three polished sections are observed.

Description. The bouquet of this species presents cylindrical or cylindro-conical RV with 30 mm maximum length. The transverse section is nearly circular having a diameter ranging from 8 mm to 10 mm and the ornamentation of the valve consists of up to ten acute ribs separating by deep furrows. The Vb and Pb are flat, but slightly concave and the Ib is represented by a deep groove. The ol is 3–5 mm thick and shows mostly compact structure (Fig. 7S–W), but some cellular structure seems to be preserved. The L is small, triangular, but it is long (3–4 mm) with an enlarged top in some sections. The myocardial apparatus is only observed in one single section and the at and the ma seem to be more developed than the pt and the pm (Fig. 7U).

Discussion. The features of the ornamentation, the radial bands and the shape of the transverse sections of our specimens show clear similarities with those of *Radiolites dario* described from Italy by Cestari (1992, 2008) and Cestari and Pons (2007).

Radiolites sp.

Fig. 8A, B

Description. About ten sub-oval transverse sections of the RV show ten to twelve small developed ribs, the thin ol and the triangular L. The ol is non-compact structure with polygonal cells, but some elongated cells with very thin compact structure developed at the outermost part of the ol. It is impossible to describe the species due to the radial bands can not be clearly defined. However, these sections may be compared with *Radiolites dario* due to the organization of the ribs.

Genus *Durania* Douvillé, 1908

Type species. *Hippurites cornupastoris* Des Moulins, 1826

Durania cf. arnaudi (Choffat, 1891)

Fig. 8C–H

1891 *Biradiolites runaensis*, variété évasée, Choffat, p. 214.

1898 *Biradiolites Arnaudi*, Douvillé, p. 140.

1902 *Biradiolites Arnaudi*, Choffat, p. 138, 171, pl. 6, pl. 7, figs. 10–17.

1910 *Durania Arnaudi*, Douvillé, p. 50, pl. 3, fig. 1.

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

2006 *Durania arnaudi*, Chikhi-Aouimeur et al., section Jebel Chems, fig. 5.

2010 *Durania arnaudi*, Chikhi-Aouimeur, p. 142, fig. 132 1–4.

Material. Many transverse sections from the isolated individuals, bouquets and clusters. Four limestone samples are also collected from the polished sections.

Description. The transverse section of the RV is circular or sub-circular, the ol is less thick (max. 3 mm) in the ventral part than other parts of the valve. The inner margin of the ol is subcircular and its diameter is a smaller than the outer margin. The Vb and Pb are flat and the Ib is slightly bulge, but narrow. It is not clear to observe but the Ib seems to have only one single rib. The L is not developed, and the myocardial apparatus is not preserved.

Discussion. The narrow Vb, Pb and slightly developed narrow Ib of our transverse sections may be compared with those of *Durania arnaudi* described by Toucas (1909), Polšak (1967), Douvillé (1910), Chikhi-Aouimeur et al. (2006) and Chikhi-Aouimeur (2010). But, the specimens appear to be small compared to other descriptions of the species.

Genus *Sauvagesia* Choffat, 1886

Type species. *Sphaerulites sharpei* Bayle, 1857

?*Sauvagesia* sp.

Fig. 8I

Description. Some transverse sections of the RV has a thick ol, small and triangular L. The sections of the ribs seem to be regular, very close to each other and not acute. But, it is not possible to observe the typical ols cellular structure and also RVs ornamentation consisting of regular longitudinal ribs and furrows because of the absence of the matrix-free specimens.

Family Hippuritidae Gray, 1848

Genus *Hippurites* Lamarck, 1801

Type species. *Hippurites bioculatus* Lamarck, 1801

Hippurites sp.

Fig. 8J–L

Description. Some transverse sections of the RV are remarkably small, maximum diameter 5–6 mm (Fig. 8J, L). But, two sections seem to be larger than 10 mm (Fig. 8K). The L is long and probably round at its top, the P1 and P2 are slightly pinched or open at the base in some sections (Fig. 8J, L). Some of the others show only the L or both the L and the P1 (Fig. 8K). It is impossible to describe the species of the genus due to the very small sections.

Fig. 7. Rudists of the Berressef Formation: A–D. *Biradiolites* sp., the transverse sections of the RV showing the ribbed ventral part and cellular structure of ol. A. Bouterfess-I section, field view. B–D. Bouterfess-II section, the polished sections, in order to sample nos: Gd-230, Gd-245, Gd-229. E–I. *Bournonia fascicularis* (Pirona, 1869), field views, in growth positions. E–G from Bouterfess-I and H and I from Bouterfess-II sections. E. the transverse view of the RV showing the concave radial bands and slightly inclined growth lamellae. F. three individuals showing the concave radial bands and the ornamentation of the RV. G. six individuals showing the structure of the radial bands and natural transverse sections from a bouquet. H and I. the ventral side the RV presenting the radial bands. The LV is partially preserved in H (arrow). J–M. *Bournonia cf. gardonica* (Toucas, 1907). J and K field photos from the Bouterfess-I section, L and M polished sections from the Bouterfess-II section, in order to sample nos: Gd-225 and Gd-226. J presents a general view from the small cluster and K and M show the transverse sections of the RV. Note the cellular structure of the ol and the groove of Ib separating the radial bands. N–R. *Radiolites trigeri* (Coquand, 1859), field views. N–P from the Bouterfess-I, Q and R from the Bouterfess-II sections. N. three individuals from a bouquet showing the small, the triangle L, the protruding Ib (arrows) and the rounded ribs. O. the transverse section of the RV showing the slightly concave Vb and Pb and bulge lb. L is small and triangle, the cellular structure of the ol is partially observed in the dorsa-ventral side of the valve. P. the transverse and radial sections of the RV. The cellular structure of the ol can be preserved in these sections. Note the lamellae are very marked and show regular cycles in the surface of the valve (arrow). Q. three transverse sections of the RV showing the polygonal cellular structure of the ol. Note small L and the bulge lb (arrows). R. the cylindro-conical RV presenting well-marked regular lamellae. S–W. *Radiolites dario* (Catullo, 1834). S–U and W from the field and V from the polished section of sample no. Gd-222. The transverse sections of the RV showing the structure of ribs and the L. The myocardial apparatus can be preserved in figure U (arrow). Scale bars present 10 mm.

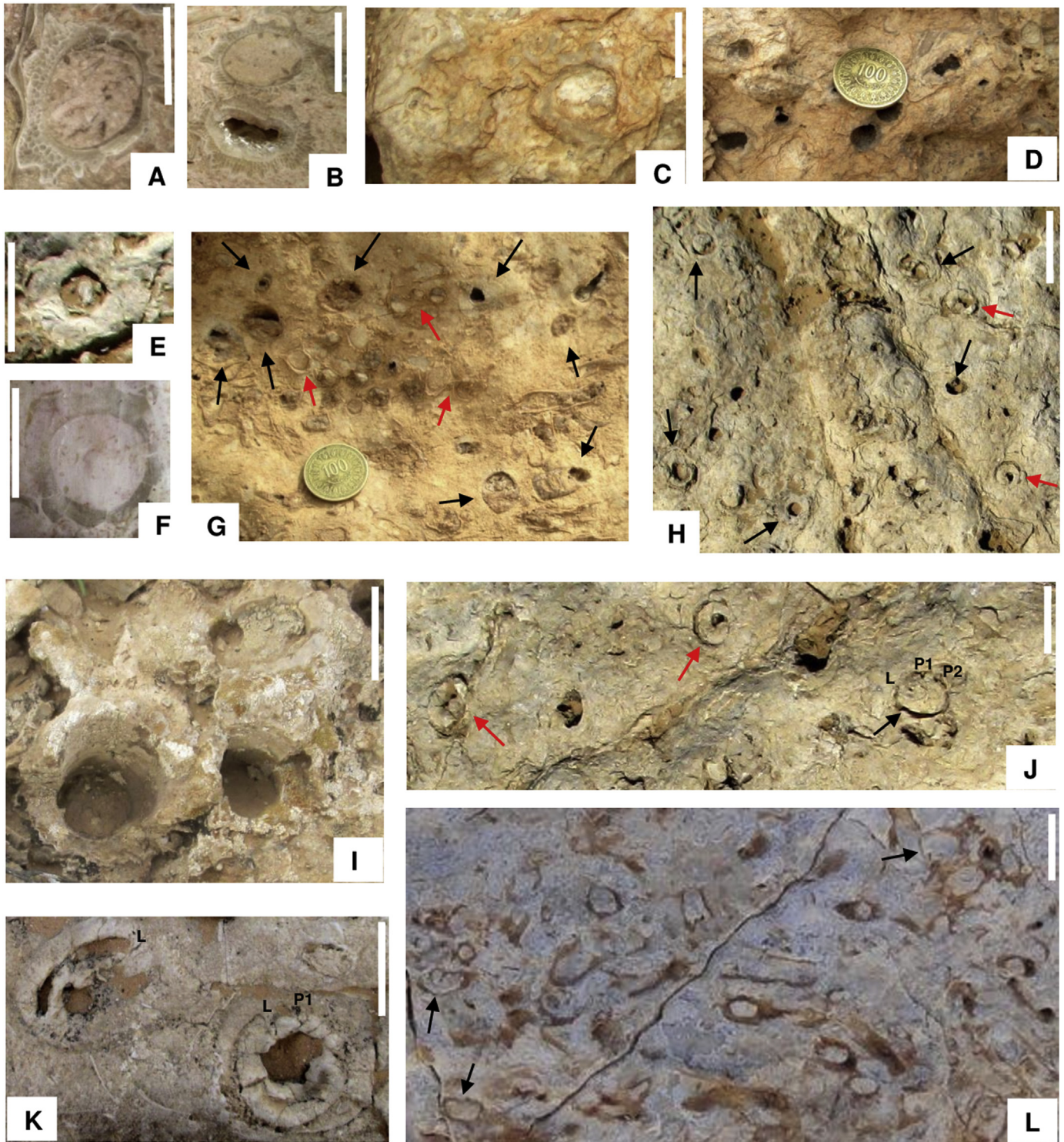


Fig. 8. Rudists of the Berressef Formation: A and B. *Radiolites* sp., the Bouterfess-I section, the polished sections, in order to samples nos: Gd-217, Gd-219. C–H. *Durania* cf. *arnaudi* (Choffat, 1891). C, D, E, from the field view of bouquet showing the natural transverse sections, the ol is thick, the radial bands are flat and lb is slightly protruding. C and D from the Bouterfess-II section, E from the Bouterfess-I section. F. the polished section of the RV from the Bouterfess-II section, sample no: Gd-240. G. many small transverse sections of the RV (black arrows) associated with *Biradiolites angulosus* (red arrows), the field view from the Bouterfess-I section. H. small transverse sections of the RV (black arrows) associated with *Apricardia* sp. (red arrows), the field view from the observation point no 4. I. *?Sauvagesia* sp., three transverse views from the Bouterfess-I section, the field view. J–L. *Hippurites* sp., the field views. J. the transverse section of the RV (black arrow) associated with *Apricardia* sp. (red arrows) from the Bouterfess-I section. K. two transverse sections of the RV. The triangle L and the slightly pinched P1 can be observed, the Bouterfess-II section. L. some transverse sections of the RV (arrows) associated with *Biradiolites angulosus*, the field view from the Bouterfess-I section. Scale bars present 10 mm, the diameter of coin at D and G is 20 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

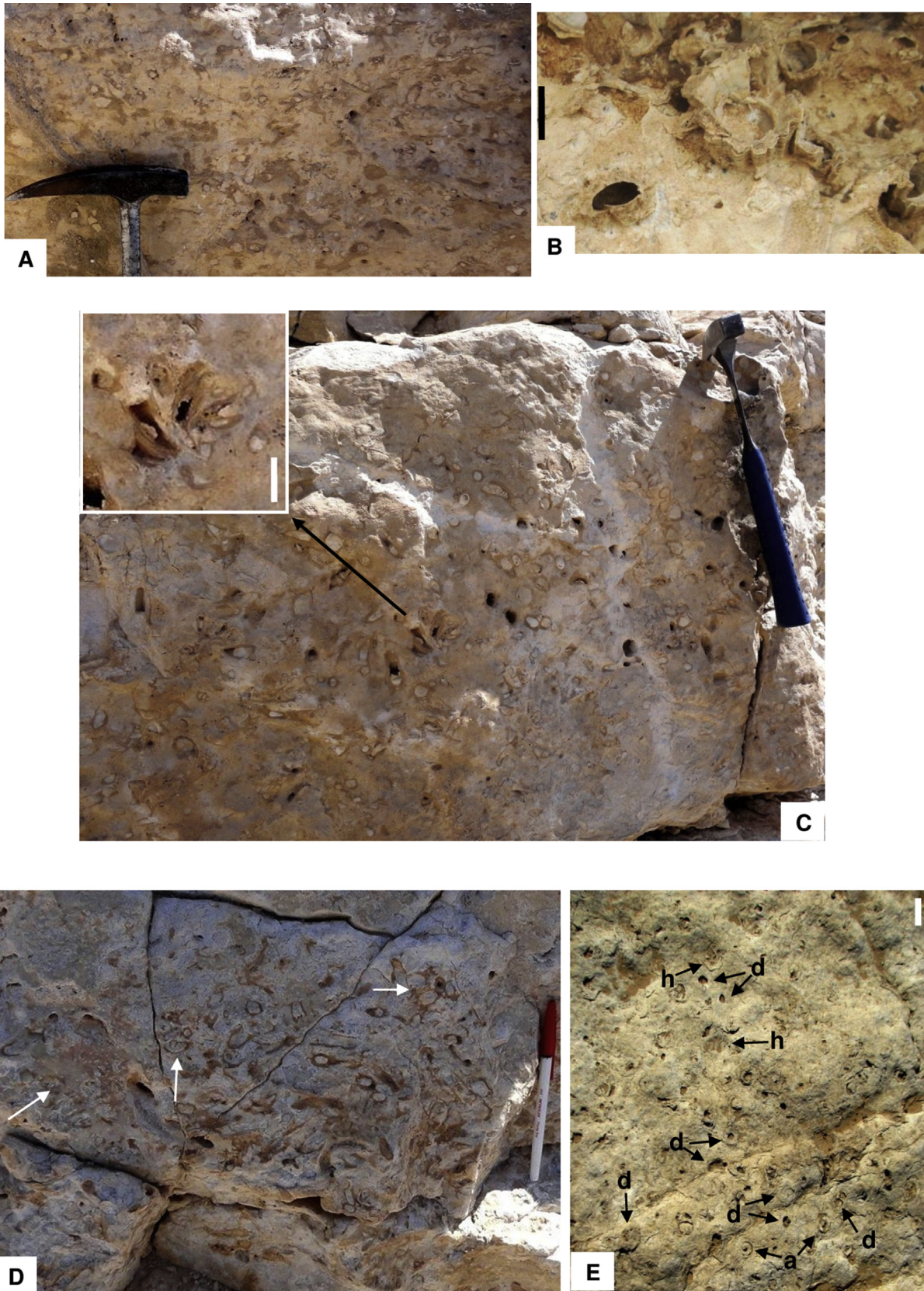


Fig. 9. Field photos showing the limestones with isolated individuals. A. a limestone bed consisting completely of *Biradiolites angulosus* showing the transverse sections, sometimes slightly oblique, and radial sections with tabulae of the RV, Bouterfess-I section, scale is hammer. B. isolated individuals of *Radiolites trigeri* showing in growth position, Bouterfess-I section, scale bar is 10 mm. C. a limestone bed consisting completely of *Biradiolites martellii* showing the transverse and radial sections with tabulae of the RV, scale is hammer. Note the bouquet as shown the enlarged in the top left of the figure, scale bar indicates 10 mm, Bouterfess-II section. D. a limestone bed consisting mainly of *Biradiolites angulosus*, but it contains some *Hippurites* sp. (arrows), Bouterfess-II section, scale is pencil (25 mm). E. the upper surface of limestone showing isolated individuals containing of three species, *Durania* cf. *araudi* (d), *Apricardia* sp. (a) and *Hippurites* sp. (h), the observation point no. 4, scale bar is 10 mm.

Suborder Requiieniidina Skelton, 2013a

Superfamily Requienioidea Kutassy, 1934

Family Requieniidae Douvillé, 1915

Genus *Apricardia* Guéranger, 1853

Type species. *Caprotina carinata* d'Orbigny, 1842b

***Apricardia* sp.**

Fig. 8H, J

Description. Some isolated individuals are very small, 7–8 mm in length. They show strongly coiled LV and conical, but slightly capuloid or operculiform RV. The trace of the myophore plate seems to be present in the LV. Other characters cannot be observed. Our individuals may be compared with *Apricardia* sp. reported to Spain by Garcia-Hidalgo et al (2012, p. 277, fig. 9H).

5. Biostratigraphy

The carbonate sequences of the study area have no characteristic microfossils. We could found *Cuneolina* gr. *pavonia* d'Orbigny, *Nezzazatinella* cf. *N. picardi* (Henson) and Miliolidae, indeterminate dasycladacean algae and Bryozoa suggesting an Albian-Maastrichtian age. However, the study of rudist associations from the Saharan platform and their comparison with those of Mediterranean Tethys, allow the better determination of the age of the Late Cretaceous carbonates.

5.1. Rudist associations

Two rudist associations were distinguished as follows:

5.1.1. *Biradiolites angulosus*-*Biradiolites martellii*-*Radiolites trigeri* association

This association is characterized by the abundance of *Biradiolites angulosus* (d'Orbigny, 1842a) and *Biradiolites martellii* (Parona, 1911). *Radiolites trigeri* (Coquand, 1859) is also abundant, but it is only found in the Bouterfess section-I. *Durania* cf. *arnaudi* (Choffat, 1891) is mainly observed in the middle and upper parts of the association. *Bournonia fascicularis* (Pirone, 1869) is found together with *Radiolites trigeri* in the uppermost part of Bouterfess section-I. *Bournonia* cf. *gardonica* (Toucas, 1907) is very rare and dispersed throughout the section. The fragments of *Biradiolites* sp. are widely present in this association. *Hippurites* sp. and *Apricardia* sp. are very rare.

Rudist species show the same distribution of those present in the northern side of the Mediterranean Tethys: *B. angulosus* has been described from the Turonian-Coniacian sequences of France and Italy and the upper Turonian of Serbia and Greece (Steuber, 2002). Nevertheless, it has been noted from the Coniacian of the central-southern Apennines by Cestari and Sartorio (1995) and Cestari and Pons (2004) or upper Turonian-Coniacian by Cestari (2008) and Cestari and Laviano (2012). *B. martellii* has been observed in the Coniacian-Santonian or Santonian-Campanian of Italy, Bosnia-Herzegovina, Croatia and Slovenia (Steuber, 2002). Also, it was presented in the Coniacian and upper Turonian-Coniacian of the central-southern Apennines by Cestari and Sartorio (1995), Cestari and Pons (2004) and Cestari (2008), Cestari and Laviano (2012), respectively. This species has been described from the middle Coniacian of Greece by Steuber (1999). *R. trigeri* shows mainly in the middle-upper Turonian of France, Italy, Croatia and Serbia (Steuber, 2002), but also found in the upper Turonian-Coniacian and Coniacian of Italy and Croatia (Steuber, 2002; Cestari and Pons, 2004; Cestari, 2008; Cestari and Laviano, 2012). *D. arnaudi* has been mostly reported to the Turonian of

France, Italy, Bosnia-Herzegovina, Croatia, Slovenia and Serbia. However, it has been presented from the Coniacian of Italy by Cestari and Sartorio (1995), Cestari and Pons (2004) and upper Turonian-Coniacian by Cestari (2008) and Cestari and Laviano (2012). *B. gardonica* is mainly described from the Coniacian of France (Toucas, 1907) and Spain (Garcia-Hidalgo et al., 2012). It was reported from the Coniacian and upper Turonian-Coniacian of Apennines, Italy by Cestari and Pons (2004) and Cestari and Laviano (2012), respectively.

B. martellii was first described in the southern side of the Mediterranean Tethys, where *B. angulosus* and *R. trigeri* have shown limited distribution from the middle Turonian of Gafsa region, southern Tunisia (Razgallah et al., 1994; Chikhi-Aouimeur et al., 2006) and from the Cenomanian and Turonian of Libya and Tunisia, respectively. *D. arnaudi* has more wide distribution compared to other species, such as in the Turonian of Algeria, Tunisia and Egypt (Steuber, 2002).

5.1.2. *Radiolites dario*-*Bournonia fascicularis* association

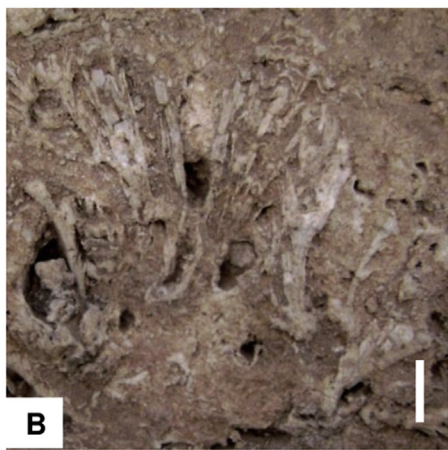
Bouterfess-I section presents this association comprising *Radiolites dario* (Catullo, 1834) and *Bournonia fascicularis* (Pirone, 1869). The fragments of *Sauvagesia* sp. and *Radiolites* sp. are also observed.

R. dario has shown a wide distribution in the upper Coniacian-Santonian, Santonian and Santonian-Campanian of Italy (Steuber, 2002). It was also reported to the upper Santonian of Slovenia (Pleničar and Jurkovsek, 1999). *R. dario* and *B. fascicularis* is well described together from the Santonian (Cestari and Pons, 2004), Coniacian-Santonian (Cestari, 2008) or upper Coniacian-Santonian (Cestari and Laviano, 2012) in the central-southern Apennines. *B. fascicularis* is also described from the Coniacian of France (Toucas, 1907) and Spain (Garcia-Hidalgo et al., 2012).

6. Correlation

Rudist-bearing limestones, cross-stratified carbonates and fossiliferous marlstones of the studied area were assigned to the Berressef Formation by Khila et al. (2016). The studied rudists suggest a Coniacian-Santonian age of the formation, as previous studies (Khila et al., 2016; Khila et al., 2017).

The rudist species of the first association were described in the both sides of the Mediterranean Tethys: from Spain to Greece in the European side and from Algeria to Egypt in the African side. The rudist species of the second association were only observed in France, Spain and Italy. The two rudist associations present a remarkable similarity with CO and SA rudist assemblages determined from the middle-southern Apennines of Italy by Cestari and Pons (2004), Cestari (2008) and Cestari and Laviano (2012). Rudist distribution of Bouterfess-I section has showed similarities with Trentinara and Capaccio Vecchio sections of the Cilento area, Apennines studied by Cestari and Pons (2004) and Cestari (2008). Bouterfess-II section can be compared with Raia del Pedale section of the same area because of the presence of *B. fascicularis* in the uppermost part of the section and the absence of the *R. dario*. Furthermore, in the first association, the radial bands of *Bournonia* sections show similarities with those of *Bournonia gardonica*, which was described from the CO assemblage in the Apennines. *Sauvagesia tenuicostata* Polšak, 1967 is present in the SA assemblage of the Apennines. Although we found a few *Sauvagesia* sections in the second association, but it is difficult to describe them. Other species of the CO and SA assemblages of the Apennines are present in the two studied associations. Hippuritids are remarkable very scarce and small in the first Coniacian association. This is another similarity with Coniacian rudist associations of Italy and Istria, i.e. the promontory of the African Plate located in these countries today



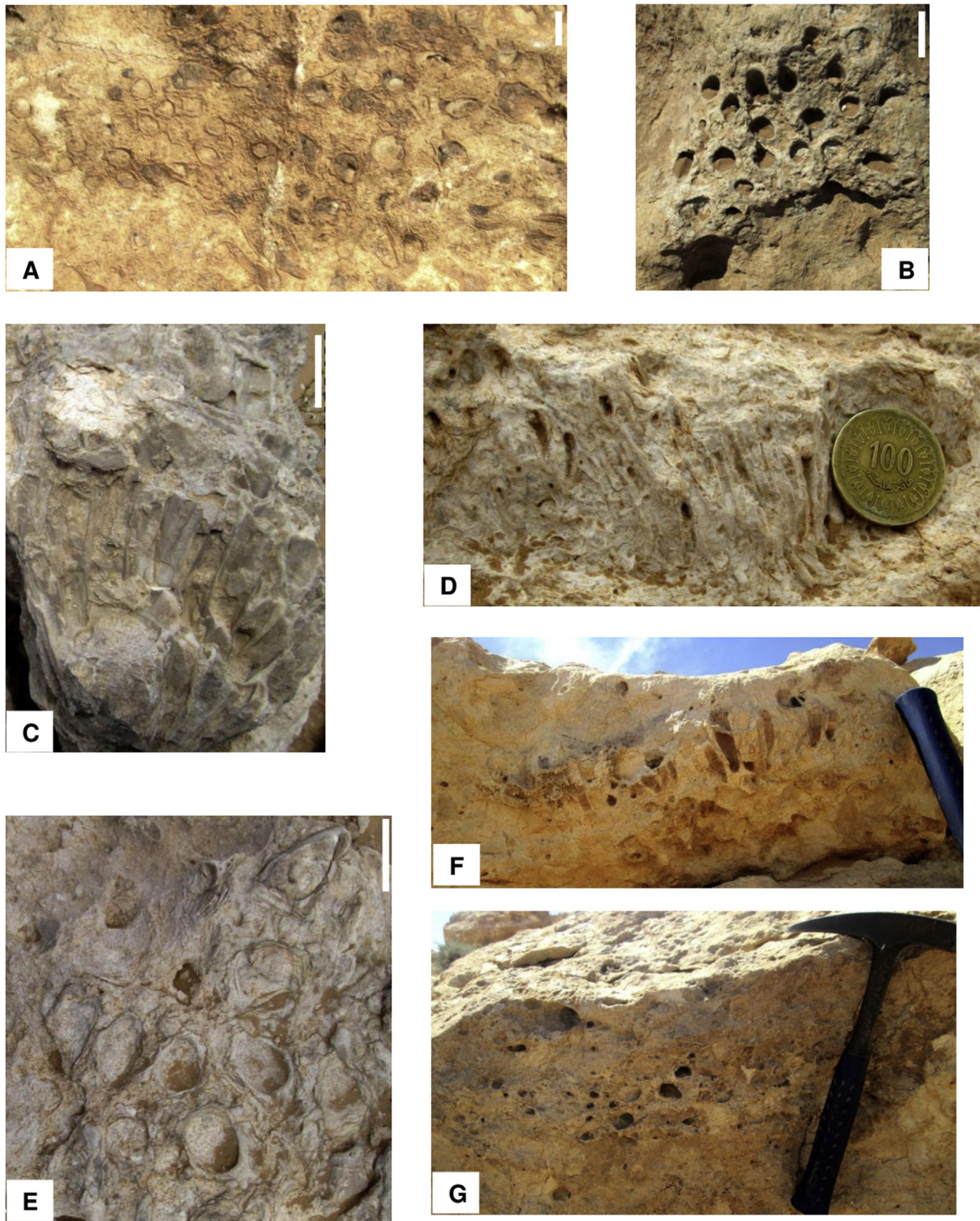


Fig. 11. Field photos showing the rudist clusters. A. a large cluster of *Biradiolites angulosus* showing the transverse sections of the RV, Bouterfess-II section, scale bar indicates 10 mm. B. a small cluster of *Radiolites dario* showing the transverse sections of the right valves, Bouterfess-I section, scale bar indicates 10 mm. C. a small cluster of *Bournonia fascicularis*, in growth position, Bouterfess-II section, scale bar indicates 10 mm. D. a large cluster of *Radiolites dario*, in growth position, Bouterfess-II section, the diameter of coin is 20 mm. E. a small cluster of *Bournonia* cf. *gardonica* showing the transverse sections of the RV, Bouterfess-I section, scale bar indicates 10 mm. F. a large cluster of *Biradiolites martellii*, in growth position, truncating by limestones without rudists, Bouterfess-I section, scale is hammer. G. a large cluster of *Radiolites dario*, Bouterfess-II section, scale is hammer.

Fig. 10. Field photos showing the rudist bouquets. A. two bouquets of *Biradiolites angulosus*. The transvers and radial sections of the right valves can be also observed, in growth position, Bouterfess-I section, scale is hammer. B. *Bournonia fascicularis* bouquet showing the interskeletal porosity, in growth position, Bouterfess-II section, scale bar is 10 mm. C. *Radiolites dario* bouquet, in growth position, Bouterfess-I section, scale is hammer. D. a thick limestone layer consists of the many *Radiolites trigeri* bouquet (arrows), in growth position, Bouterfess-I section, scale is hammer.

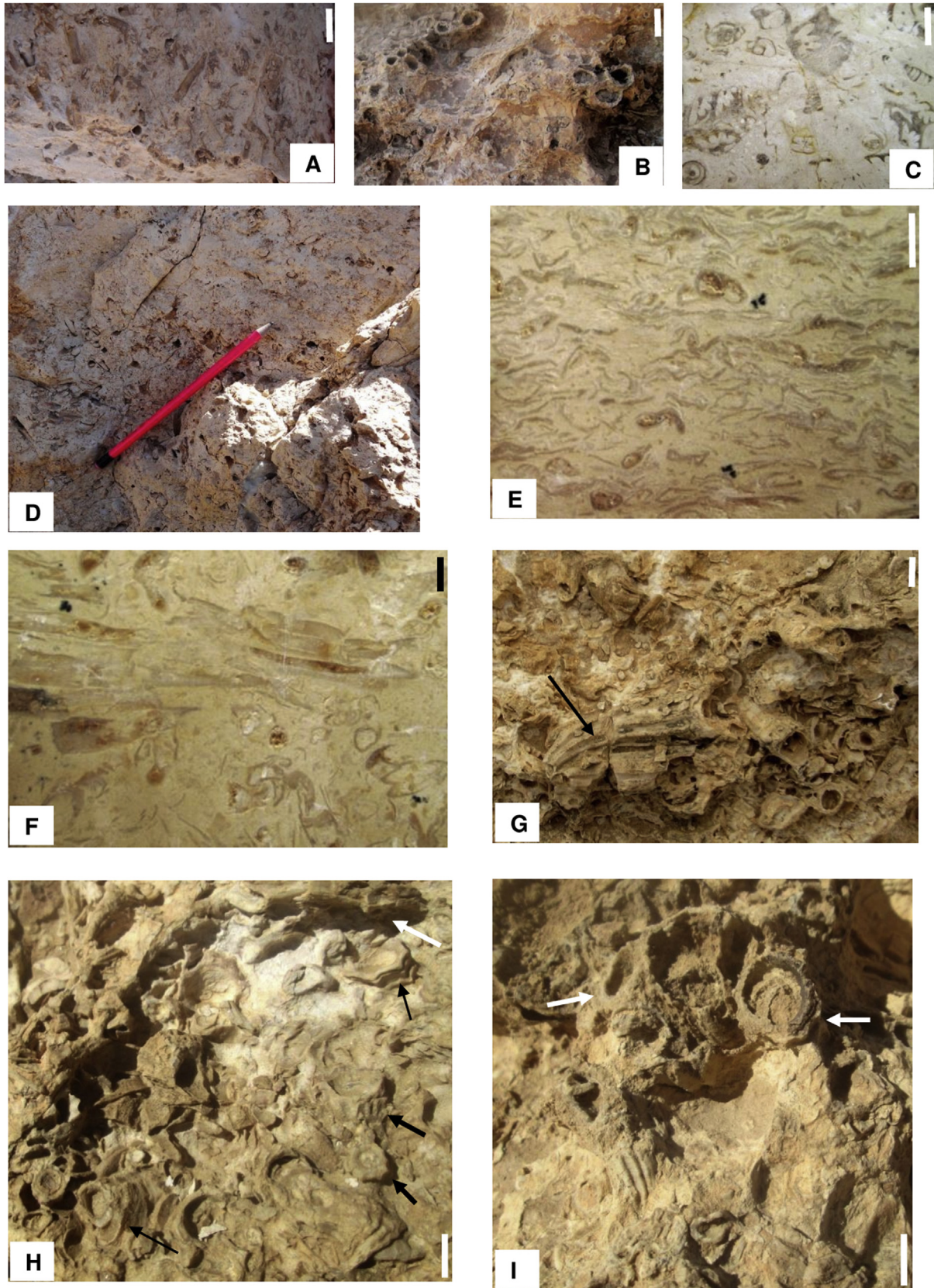


Fig. 12. Field photographs (A, B, D–I) and the polished section (C, E, F) showing the Facies A (Figs. A–C) and B (Figs. D–I). A. the scattered isolated individuals of *Biradiolites angulosus*, Bouterfess-I section, scale bar indicates 10 mm. B. the monotypic bouquets and clusters of *Radioites dario*, Bouterfess-I section, scale bar indicates 10 mm. C. the gastropod-bearing limestone with rare rudist sections, sample no. Gd. 238, Bouterfess-II section, scale bar indicates 10 mm. D. the general view of the bioclastic limestones with rudist fragments, Bouterfess-I section, scale is pencil (200 mm). E. the oriented rudist fragments of the bioclastic limestones, sample no. Gd. 225, Bouterfess-II section, scale bar

(‘Apulian Plate of some authors’), while other northern Mediterranean associations of this age have quite diverse, large hippuritids (Steuber and Löser, 2000, fig. 16).

The age of CO and SA assemblages is slightly different: Cestari and Pons (2004) suggested Coniacian and Santonian ages for CO and SA assemblages, respectively. Nevertheless, Cestari (2008) and Cestari and Laviano (2012) suggested late Turonian-Coniacian for CO and late Coniacian-Santonian for SA. We suggest the Coniacian for the first association and the late Coniacian-Santonian for the second association.

In Tunisia, the studies of the Late Cretaceous rudists are mainly located on the north of “North Saharan Flexure (NSF)”, where the rudist descriptions were mainly focused on the Cenomanian-Turonian species (Steuber, 2002; Chikhi-Aouimeur et al., 2006). The Coniacian to Maastrichtian age of these rudists is based on stratigraphic and sedimentological studies. The taxonomic descriptions are very rare (Steuber, 2002). To the south of NSF around the Saharan platform, only the upper Cenomanian species *Praeradiolites biskarensis* (Coquand, 1880), is described by Berizzi and Busson (1971), around Kebili area (Fig. 1). This study has revealed the presence of rudist assemblages suggesting a Coniacian-Santonian age. Only, three species of the first association, *B. angulosus*, *R. trigeri* and *D. arnaudi*, but *B. martellii* and *B. gardonica*, have been figured from the lower-middle Turonian of Gafsa region by Chikhi-Aouimeur et al. (2006). This area is located nearly 70 km northeast of the study area, in the northeast of the “NSF”. However, these authors have attributed the early-late Turonian age to rudist level integrated ammonites, benthic and planktonic foraminifera and ostracoda data, which are absent in our study area.

7. Rudist organisation and facies

Rudists are abundantly represented in the Berressef Formation in the study area. Gastropods, echinids, dacyladacean algae, ostracods and non-rudist bivalves are rarely observed in the formation. Only, a gastropod-bearing limestone is found within the upper part of the sequence. The organisation and facies characteristics of the rudists are presented as follow:

7.1. Rudist organisation

Three morphotypes (i.e., elevators, clingers, recumbents) were recognised basing on to the stability and growth position of rudists by Skelton and Gili (2002). Rudists of the Berressef Formation are mostly in growth position as elevators. The growth position and the cylindrical to elongated cylindrical shapes of the elevator rudists formed “bouquets” and “clusters”, as well as isolated individuals, in the study area. Gili et al. (1995) suggested that these rudist structures developed in a low energy, shallow marine setting.

7.1.1. Isolated individuals

The rudist-bearing limestones of the Berressef Formation present the isolated individuals of *B. angulosus*, *B. martellii*, *R. trigeri*, *B. fascicularis*, *D. cf. arnaudi*, *Apricardia* sp. and *Hippurites* sp. Mostly the transverse sections, sometimes slightly oblique, and radial sections with tabulae of the right valves and also small bouquets can be observed in almost every layer of the limestones consisting

completely of the single species of the isolated individuals (Fig. 9A–C). But, the limestones containing two or three species of isolated individuals together are present in the middle and uppermost parts of the sequence (Fig. 9D, E).

7.1.2. Bouquet elevators

Many bouquets of *B. angulosus*, *B. martellii*, *R. trigeri*, *R. dario* and *B. fascicularis* are widely dispersed in two associations. Some limestone levels show only one bouquet of these species, however other levels present two or more bouquets (Fig. 10A–D). The bouquets consist mainly of 4 or 5 individuals. Nevertheless more individuals could be found (9–10).

7.1.3. Cluster elevators

It is observed in the middle and upper parts of the Berressef Formation. *B. angulosus*, *B. martellii*, *R. dario*, *B. fascicularis* and *B. cf. gardonica* are the main elevators forming small and large clusters (Fig. 11). Small ones consist of 6–10 individuals and they are widely exposed in the sequence than large ones. The latter contain up to 20 individuals. The clusters are often truncated by limestones without rudists.

7.2. Rudist facies

Two main rudist facies were defined according to their preservation characteristics in the study area as follows:

7.2.1. Facies A

This facies is mainly characterized by rudists in growth position, which are widely present in the region. Rudist-bearing limestones are formed by isolated individuals and monotypic bouquets and clusters (Fig. 12A, B). The rudist clusters don’t show the sedimentary bodies such as mound, bioherms, patch reefs etc. as observed in the Cretaceous carbonate platforms. The isolated individuals are mostly scattered, while the rudist bouquets and clusters are mostly densely-packed within the limestones. The limestones with rudists are interbedded with laminated algal limestones, frequently truncated by coarse-grained limestones with cross-stratification. The isolated individuals can be also found in the gastropod-bearing limestones where gastropods are present in transverse and radial sections (Fig. 12C). Some rudists fragments are rarely observed in some rudist bouquets and clusters due to the increase of energy.

7.2.2. Facies B

This facies correspond to limestone rich in rudists fragments, which are scattered or abundant in the bioclastic limestones (Fig. 12D–F). The bioclastic limestones rarely comprise very thin (30–40-mm-thick) oriented rudist fragments (Fig. 12E, F). The fragments of the bioclastic limestones are belonging to all radiolite species. Some bioclastic limestones contain the determinable rudist sections and the fragments of their bouquet (Fig. 12G–I). Indeed, it is possible to observe the preserved rudist sections in the bioclastic limestones. These data indicate that the development of the currents, the waves may be the storms in the environment causing the fragmentation, the transportation and the accumulation of the rudist valves. The rudist accumulations could be considered deposited not far from their original environment due to the presence of rudist limestone positions which are generally capped

indicates 10 mm. F. the bioclastic limestones with oriented rudist fragments and the transverse and radial sections of *Biradiolites angulosus*, sample no. Gd. 225, Bouterfess-II section, scale bar indicates 10 mm. G. the bioclastic limestones composed of totally *Radiolites dario* specimens. Note the randomly organisation, the presence of the determinable sections and a bouquet fragment of species (arrow), Bouterfess-I section, scale bar indicates 10 mm. H. the bioclastic limestones consist completely of *Bournonia fascicularis* fragments. Note some determinable sections (black arrows) and a bouquet fragment of species (white arrow), Bouterfess-I section, scale bar indicates 10 mm. I. the bioclastic limestones composed of *Radiolites trigeri* fragments derived from the bouquets and/or clusters of this species. Note some determinable sections (white arrows) and compare with previous figure. Bouterfess-II section, scale bar indicates 10 mm.

the cross-stratification, coarse-grained limestones (i.e. shallowing-upward sequences of Khila et al., 2016).

The rudist organisation and facies characteristics of the studied area can be compared with those of Upper Cretaceous sequences, which are widely present in the Mediterranean Tethys.

8. Conclusions

The Coniacian-Santonian rudists are first described from the Berressef Formation in the Saharan platform in Southern Tunisia. The rudist study was based on two measured-stratigraphic sections and five observation points in the Matmata area, which is located between the Southern Chotts ranges and the Dahar cliff. The Berressef Formation characterized by the presence of the rudist-bearing limestones which systemically capped by the coarse-grained limestones with cross-stratification of subaqueous dunes.

Two main rudist associations are examined within the Berressef Formation: 1) *Biradiolites angulosus*-*Biradiolites martellii*-*Radiolites trigeri* association (Coniacian). *Durania* cf. *arnaudi*, *Bournonia* cf. *gardonica*, *Biradiolites* sp., *Hippurites* sp. and *Apricardia* sp. are also found in this association. 2) *Radiolites dario*-*Bournonia fascicularis* association (late Coniacian-Santonian). This association is mainly characterised with two species, *Sauvagesia* sp. and *Radiolites* sp. which are very scarce.

In fact, the rudist species of these associations show usually individual distribution in the western and middle of the Mediterranean Tethys. However, two associations described here present a remarkable similarity with CO and SA rudist assemblages of Apennines, Italy.

Isolated individuals, bouquets and clusters constructed by elevator rudists are observed in the rudist-bearing limestones. Two rudist facies A and B are defined according to their preservation characteristics. The rudists in original growth position in the rudist-bearing limestones consist of isolated individuals and also monotypic bouquets and clusters (Facies A). The accumulation of rudist fragments within the bioclastic limestones is considered not far from their original palaeoenvironment (Facies B).

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