Bulletin of MTA (2013) 147: 31-55

Bulletin of the Mineral Research and Exploration

http://bulletin.mta.gov.tr

FIRST DETERMINATION OF RUDISTS (BIVALVIA) FROM NE IRAQ: SYSTEMATIC PALAEONTOLOGY AND PALAEOBIOGEOGRAPHY

Sacit ÖZER[*,a], Kamal Haji KARIM[b] and Dereen Mohamad SADIQ[b]

[a] *Dokuz Eylül University, Engineering Faculty, Geological Engineering Department, 35160 Tınaztepe-Buca Campus, İzmir, Turkey,*
[b] *University of Sulaimani, Department of Geology, Sulaimaniya, IRAQ*

Key words:
Rudists,
Maastrichtian,
systematic palaeontology,
palaebiogeography,
Iraq.

ABSTRACT

The Maastrichtian Aqra Formation around Mawat-Chwarta (Sulaimaniya city) in NE Iraq consists mainly of coarse grained detrital limestone, locally containing terrigenous clastics, and is characterized by abundant rudists in life position. The rudist biostromes are very common in the formation and benthic foraminifers, gastropods and non-rudist bivalves with scarcer echinoderms and solitary corals are associated with the rudists. This first determination of rudists from NE Iraq recognizes the following species, *Dictyoptychus* aff. *morgani*, *Sauvagesia somalica, Hippurites cornucopiae*, *Praeradiolites subtoucasi* and *Lapeirousia jouanneti,* as well as some indeterminable radiolitid sections. This rudist fauna is assigned to the *Hippurites cornucopiae* interval zone indicating a mid to Late Maastrichtian age. *Dictyoptychus* is an endemic rudist genus for the Arabian Plate, to which *Sauvagesia somalica* also seems to be limited. Other determined species are recorded mostly from the central-eastern Mediterranean Tethys, and to a lesser extend from the Arabian Plate. The determination of rudists from NE Iraq fills an important gap in terms of the taxonomic database and palaeobiogeography. The data on the rudist fauna reveals the existence of a shallow marine dispersal route for rudist larvae during the Maastrichtian along the area of the present Zagros fold-thrust belt from SE Turkey across NE Iraq towards SW Iran.

1. Introduction

Our knowledges of the Upper Cretaceous rudists of northern Iraq is limited by the absence of systematic studies. Only one or two genera or species have been documented so far, as follows: *Eoradiolites liratus* Conrad and *Caprinula* sp. were announced by Dubertret (1966) from the Cenomanian beds around Ga'ara and Rutbah (western Iraqi, Syrian Deserts) and some radiolitids and hippuritids were cited from the type area of the Maastrichtian Aqra Formation in northern Iraq by Bellen et al. (1959), Buday (1980), Karim (2004) and Sadiq (2009).

The rudist specimens of the present study were extracted from the three following measured stratigraphic sections of the Aqra Formation in the Mawat-Chwarta area, north-northeast of Sulaimaniya city (Figure 1):

1- Khewata section: West of Khewata village at 6 km south of Mawat town at the intersection of latitude (35° 48' 25.06" N) and longitude (45° 26' 34.35" E).

2- Sura Qalat section: 2km to the northwest of Suraqalat town and 8 km to the south of Mawat town at the intersection of latitude (35° 47' 5.10" N) and longitude (45° 26' 32.50" E).

3- Sherawezha section: 1km west of Sherawezha village at south east of Chwarta town, along the

[*] *Corresponding author: S. ÖZER, sacit.ozer@deu.edu.tr*

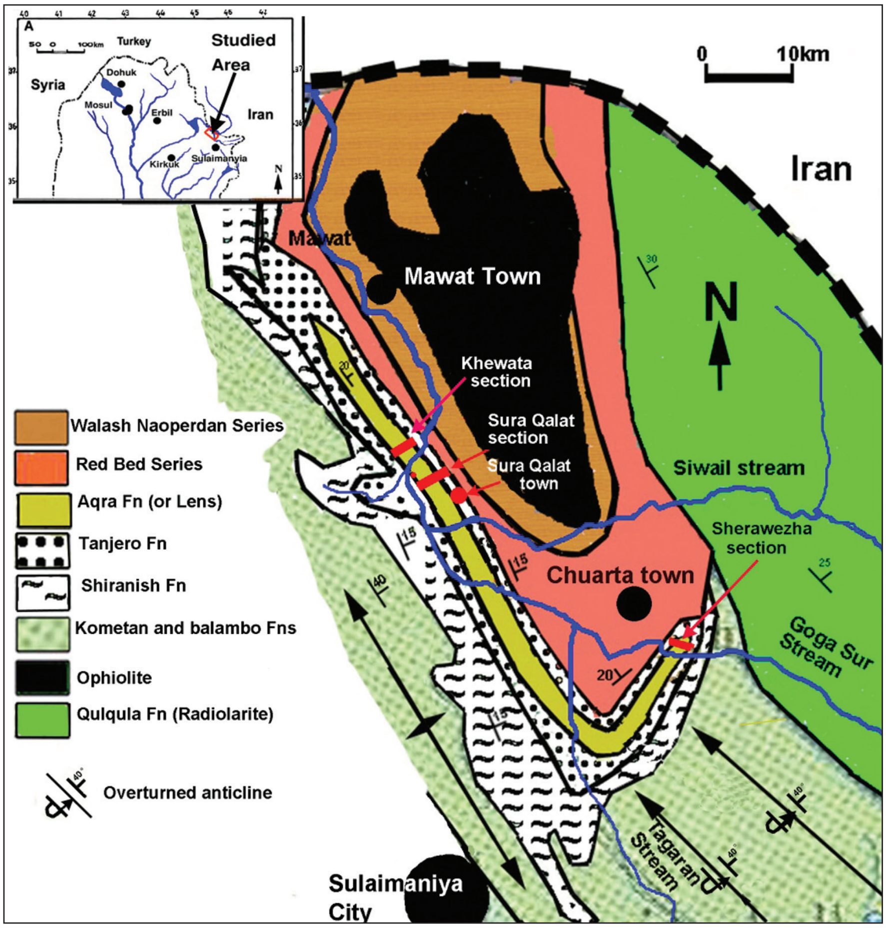

Figure 1- Location map of the studied area (inset top left) and geological map (modified from Maala, 2008 and Sadiq, 2008) showing the measured-stratigraphic sections.

eastern and western banks of the Qalachwallan stream at the intersection of latitude (35° 41′ 21.90″ N) and longitude (45° 36′ 20.63″ E).

The aim of this study is mainly to describe the rudists collected from NE Iraq and also to show their palaeobigeographic importance in the Arabian platform. Isolated rudist specimens are held in the S. Özer collection in Dokuz Eylul University, İzmir, Turkey.

2. Geological Setting And Stratigraphy

The studied area represents the northeastern margin of the Arabian Plate, where the previous Early Cretaceous platform was transformed to a foreland basin during the Late Cretaceous. This transformation was due to either ophiolite obduction (Buday, 1980; Buday and Jassim,1987; Jassim and Goff, 2006) or to the continental collision of the Iranian and Arabian plates (Karim, 2004; Karim and Surdashy, 2006). According to Karim (2005), the Mawat-Chwarta area consists of a large graben which was formed by two transverse normal faults. Geographically, the northern part of the area is occupied by ophiolite (Late Cretaceous) and Naoperdan Series thrust sheets while the northeastern part is covered by the Qulqula Formation (Early Cretaceous). The carbonates of Early and Middle Cretaceous age are exposed in the south and southwest of the study area (Figure 1).

The rudist-bearing Aqra Formation crops out as a narrow L-shaped strip about 35 km wide alongside the Qalachuallan-Mokaba stream (downstream of Goga Sur stream) to the south of Mawat and Chwarta towns (Figure 1). Due to imbrication, overturned synclines and anticlines are recognized and all the strata dip about 25 degrees towards the northeast (Figures 1, 2). The Aqra Formation has two stratigraphic manifestations due to the lateral change of the Tanjero Formation (Buday, 1980; Karim, 2004; Al-Barziniy,

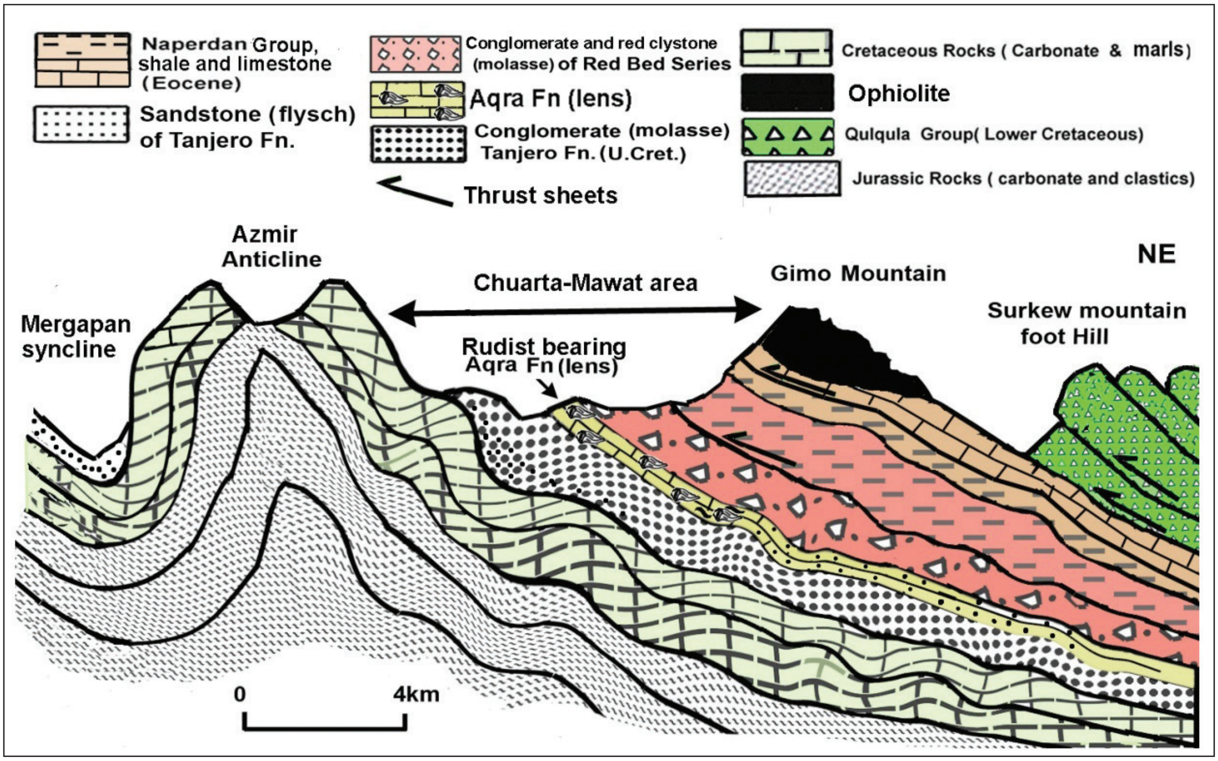

Figure 2- Simplified geological cross section of the studied area (after Karim et al., 2007).

2005; Sadiq, 2009). The first outcrop is located between the Tanjero Formation (Maastrichtian), at its base, and a Red Bed Series (Paleocene) at its top (Figures 2, 4). The second outcrop is located along the southern boundary where the Aqra Formation is located inside the upper part of the Tanjero Formation (Figure 3).

The Tanjero Formation consists mainly of thick successions of gravel conglomerate with a thickness of 20-500m in the northern and eastern part of the studied area (in the proximal part of the Cretaceous foreland basin), whereas it consists of calcareous shale and channelized sandstone and pebbly sandstone in the southern and western part of the studied area.

The Aqra Formation consists mainly of coarse grained detrital limestones, which contains in many places terrigenous clastics, and its thickness varie from 20 m to 150 m. It is characterized by abundant rudists and also benthic foraminifers, gastropods and non-rudist bivalves, the echinoderms and solitary corals are very sparse (Karim, 2004; Sadiq, 2009). The formation is very fossiliferous in the northern part of the studied area (proximal area), but much less so in the southwestern area (outer shelf or distal part). The benthic foraminifera have been determined as as *Orbitoides medius* (d'Archiac), *Omphalocyclus macroporus* (Lamarck) and *Loftusia* sp. and a Maastrichtian age was suggested for the Aqra Formation by Al-Kubaysi (2008), Sadiq (2009) and

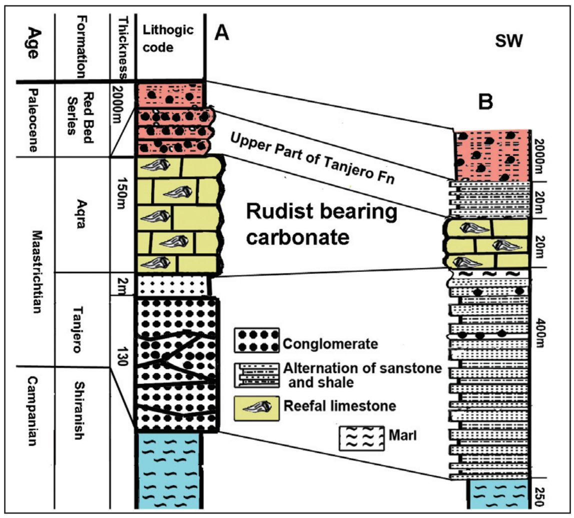

Figure 3- Stratigraphic columns showing the setting of the Aqra Formation in the succession at Mawa-Chuarta area (after Karim et al., 2007). A. The column for the northern boundary of the studied area (Khewata section). B. The column for the southern boundary of the studied area reflecting Suraqalat and Sherawazha sections.

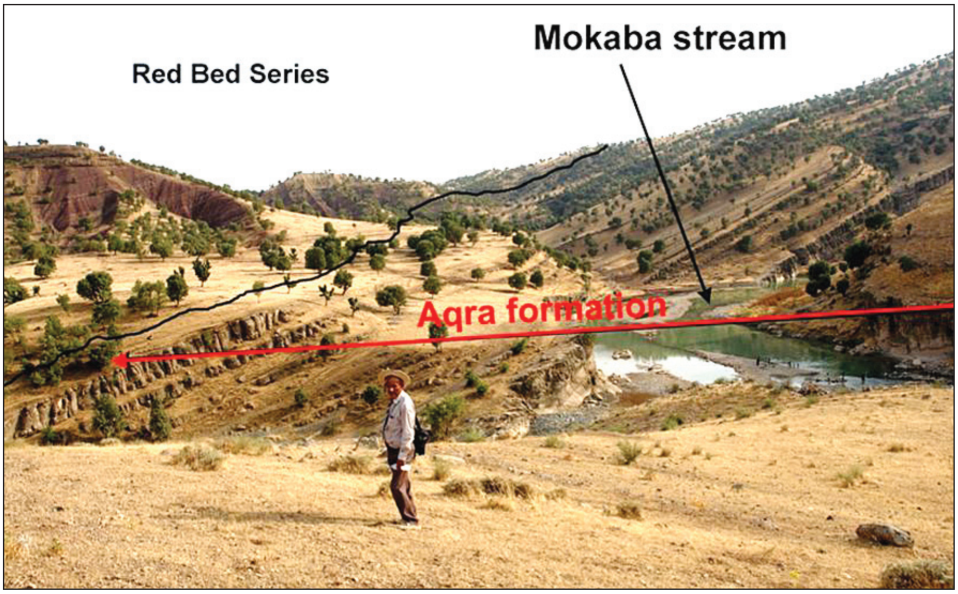

Figure 4- Khewata section showing the relationship of the Aqra Formation with Red Bed Series in the northern boundary of the studied area, looking southeast.

Zebari (2010). The rudists are found life in position in two places along both Suraqalat and Khewata sections, where the *Hippurites cornucopiae* Defrance biostromes are commonly observed (Figure 5).

The Red Bed Series (or Red Bed Group) consist mainly of alternations of thick beds of red claystone, sandstone and conglomerate, Paleocene-Eocene in age (Figures 3, 4).

Figure 5- *Hippurites cornucopiae* biostrome, top view, Sura Qalat section, Aqra Formation.

3. Systematic Palaeontology

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

Abbreviations: LV, left valve; RV, right valve; Ab, anterior radial band; Pb, posterior radial band; Ib, interband; L, ligament ridge; ma, anterior myophore; mp, posterior myophore; at, anterior tooth; pt, posterior tooth; ct, central tooth; ac, accessory cavity; pp, posterior pillar, ap, anterior pillar; Pp, posterior pseudopillar, Ap, anterior pseudopillar; cv, body cavity; ol, outer (calcitic) shell layer; il, inner (originally aragonitic) shell layer; op, outer (celluloprismatic calcitic) shell layer of the RV (in radiolitids).

Class BIVALVIA Linnaeus, 1758

Order : Hippuritida Newell, 1965

Superfamily : Radiolitoidea d'Orbigny, 1847

Family : Trechmannellidae Cox, 1933

Genus : *Dictyoptychus* Douvillé, 1905

Type species: *Polyptychus morgani* Douvillé, 1904

Dictyoptychus aff. *morgani* (Douvillé, 1904)

(plate I, figures A-I)

1904 *Polyptychus Morgani* Douvillé, page 520, text-figures 1, 2.

1933 *Trechmanella morgani* (Douvillé), Cox, page 388.

1995 *Dictyoptychus morgani* (Douvillé), Morris and Skelton, page 282, plate 1, figure 3.

2010*a Dictyoptychus morgani* (Douvillé), Özer, pages 587-592, plates 1-4.

2012 *Dictyoptychus morgani* (Douvillé), Steuber and Schlüter, page 52, figure 10 B.

Material: Three specimens with both valves (Nos. Kh1, Kh2 and Kh3) from Khewata section, and three RV (Nos. Sh6, Sh9 and Sh10) from Sherawezha section.

Description: The LV is depressed conical with dorsally eccentric apex and it has very thin ol, around 1 mm. The longitudinal sections of the radial canals of the il are observed where the ol has been eroded away (Plate I, Figures B, C, D).

The RV is conical to cylindro-conical in shape, slightly curved towards the ventral part and of length varying from 35 mm to 65mm. The surface of the valve is smooth (Plate I, Figure A); however dense and fine growth lamellae can be observed in some specimens (Plate I, Figure E). Two shallow swellings representing Ab and Pb can be observed only in one specimen. The ol of the valve is thick, about 15 mm (Plate I, Figures H, I). Due to the intense sediment infilling, the pallial canals of the il and also the cardinal apparatus are badly preserved. However, the large canal sections can be observed in some specimens (Plate I, Figures G, H). The transverse section too close to commissure of one of the specimens shows also the basal attachement of the myocardinal arc within the LV (Plate I, Figure F). The myophores can be partially observed in the another section of the same specimen, from 10 mm below the precedent, but the individual teeth can not be clearly determined due to the recrystallization. The L is absent.

Discussion: The absence of L, the presence of radial and pallial canals in the il of LV and RV respectively, the greater thickness of the ol in the RV than that of LV, the very simple ornementation of the RV and the shallow structure of the radial bands show that these specimens belong to the Afro-Arabian endemic rudist genus, *Dictyoptychus* (Douvillé, 1904, 1905; Karacabey-Öztemür, 1979; Özer, 1986, 1992 a, b, 2005, 2010 a; Pons et al., 1992; Morris and Skelton, 1995; Skelton and Smith, 2000; Khazaei et al., 2010; Steuber and Schlüter, 2012). *Dictyoptychus* has recently been revised by Özer (2010 a), who showed the variability of the canal shapes and the cardinal apparatus of the RV, and demonstrated that all of the previous determined species such as *D. leesi* (Kühn), *D. paronai* (Kühn), *D. persicus* (Cox), *D. euphratica* Karacabey-Öztemür and *D. orontica* Karacabey-Öztemür are synonymous with *D. morgani* (Douvillé), excepting only *D. striatus* (Douvillé), *D. quadrizonalis* Özer and *D. vanensis* Özer. The Iraqi specimens show close similarities with *D. morgani* determined from SE Anatolia (Karacabey-Öztemür, 1979; Özer, 1986, 2010 a), Zagros region (Khazaei et al., 2010; Asgari Pirbaluti et al., 2012), and also the UAB-Oman region (Morris and Skelton, 1995; Steuber and Schlüter, 2012).

Family : Radiolitidae d'Orbigny, 1847

Genus : *Praeradiolites* Douvillé, 1902

Type species : *Sphaerulites ponsiana* d'Archiac 1835

Praeradiolites subtoucasi Toucas, 1907

(plate II, figures A-F; plate III, figures A-H)

1907 *Praeradiolites subtoucasi* Toucas, page 31, plate 3, figures 8, 9.

1954 *Praeradiolites subtoucasi* Toucas, Astre, pages 61, 76-77, 83, plate 6, figures 1, 2.

1965 *Praeradiolites subtoucasi* Toucas, Pamouktchiev, page 37, plate 4, figure 1, text-figure 6.

1976 *Praeradiolites subtoucasi* Toucas, Lupu, page 126, plate 17, figures 4,5a-b, plate 39, figure 6.

1977 *Praeradiolites subtoucasi* Toucas, Pons, page 69, plate 50, figures 1a-d.

1992 *Praeradiolites subtoucasi* Toucas, Vicens, page 201, plate 75, figures 1-15, plate 76, figures 3-4, plate 79, figures 1-5.

1995 *Praeradiolites* cf. *subtoucasi* Toucas, Morris and Skelton, page 292, plate 6, figures 3, 4.

1999 *Praeradiolites subtoucasi* Toucas, Fenerci, pages 90-94, text-figures 3.28, 3.29, plate VII, figures 1-7.

2001 *Praeradiolites* cf. *subtoucasi* Toucas, Götz, page 69, plate 7, figures 17.

2006 *Praeradiolites subtoucasi* Toucas, Pons and Vicens, pages 15,16, figure 13 F, figure 14 G.

2008 *Praeradiolites subtoucasi* Toucas, Pons and Vicens, pages 219-234, figure 1 F (copy of 2006 *Praeradiolites subtoucasi* Toucas, Pons and Vicens, page 15, figure 13 F), figure 14 G (copy of 2006 *Praeradiolites subtoucasi* Toucas, Pons and Vicens, page 16, figure 14 G).

Material: Seven specimens with both valves (Nos. Sh1, Sh2, Sh3, Sh 4, Sh5, Sh7 and Sh8) and two RV (Nos. Sh13 and Sh14) from Sherawezha section.

Description: The RV is generally cylindro-conical and robust, however a single specimen is very long and acute and another one is conical in shape (Plate II, Figures A, B, D; Plate III, Figures A, B, E). The length of the valve varies from 80mm to 170 mm and its surface is ornamented with horizontal growth lines. The growth lamellae are continuously observed around the ventral part of the valve, while they show undulations in the radial band area (Plate II, Figures A, B, D; Plate III, Figure A).The valve is characterized by three very pronounced longitudinal costae and both the Ab and Pb are represented by two deep longitudinal grooves (Plate II, Figures A, D; Plate III, Figures A, E). The radial bands show approximately the same width. The Ib is represented by longitudinal costae and has a width ranges from 7 mm to 10 mm. The ventral and posterior bands are represented by longitudinal costae (Plate II, Figures C, E, F; Plate III, Figures A, E, F, H).

The transverse section of the RV is of rounded triangular form and its diameter ranges from 45x60 mm to 55x110 mm (Plate II, Figures C, E, F; Plate III, Figures D, F, H). However, some specimens show round transverse sections (Plate III, Figure G). The op is generally thicker (16 mm) on the dorso-ventral side than in the posterior part (10 mm), and it consists essentially of closely packed rectangular cells. But, some polygonal or pentagonal cells are also observed around the pb. The growth lamellae are continuously stacked in the dorso-ventral side of the valve (Plate II, Figures E, F; Plate III, Figures G, H). However, compact structure is also observed in the outermost margin of the growth lamellae. The inner margin of the op shows slight indentations next to the radial bands (Plate II, Figures C, E, F; Plate III, Figures D, G, F, H). The L is long (15 mm), has a thin stem (0.5 mm), and is rounded at its extremity. But, it is broken-off in some specimens (Plate II, Figures E, F; Plate III, Figures G, H). The cardinal apparatus is well developed and preserved; the at is bigger than the pt (Plate II, Figures E, F; Plate III, Figure G).

The LV is very flat or slightly convex and consists of growth lamellae (Plate II, Figures A, B, D; Plate III, Figures A, B, C, E). The ol is 10 mm thick in the transverse section of the valve. The myophore apophyses, teeth and L are partially preserved.

Discussion: The specimens show some similarity to *Praeradiolites aristidis* (Munier-Chalmas), however the radial bands of our specimens are deeper and better-developed than those of the latter species. Anyway, it is regarded as synonymous with *Praeradiolites subtoucasi* Toucas by Vicens (1992). Because of the sub-triangular transverse section of the RV, approach *Praeradiolites toucasi* (d'Orbigny), but they have less developed radial bands. The radial bands of our specimens may also be compared with those of *Praeradiolites boucheroni* (Bayle), but their L is long while that of latter species is small and triangular.

Genus : *Sauvagesia* Choffat, 1886

Type species : *Sphaerulites sharpei* Bayle, 1857

Sauvagesia somalica Tavani, 1949

(plate IV, figures A-C)

1949 *Sauvagesia somalica* Tavani, page 17, plate 1, figure 4, plate 4, figure 4.

1949 *Sauvagesia attenuata* Tavani, page 17, plate 1, figures 8, 9, plate 2, figure 2, plate 4, figure 11.

1971 *Sauvagesia somalica* Tavani, Vogel, pages 62, 72.

1992 *Sauvagesia somalica* Tavani, Pons et al., page 237, text-figures 20 a-b.

2012 *Sauvagesia* cf. *somalica* Tavani, Asgari Pirbaluti et al., page 60, plate 4, figure 2.

Material: A single specimen with both valves (No. Sh12) from Sherawezha section.

Description: The RV is cylindro-conical. The apex having broken off, the present length of the valve is about 65 mm (Plate IV, Figure A). The surface of the valve is ornamented with densely longitudinal costae and grooves. The radial bands are very well preserved, the Pb and Ab are slightly concave limited by 5 mm thick longitudinal costae and Pb is wider than Ab (Plate IV, Figure A). The transverse section across the RV very close to commissure, is semicircular with diameters of 50x60 mm (Plate IV, Figure C). The op is thick (15 mm) and composed of very small polygonal cells with prismatic pattern. But, some compact structure (Pons and Vicens, 2008) can be observed in the radial bands area and towards the outer part of op. The L is present, 2 mm long and truncated at its extremitiy.

The LV is conical, approximately 10 mm height, and presents radial costae. The transverse section of the valve shows thin lamellar, compact ol with some sections ressembling the orifices and also a few fusiform structures in the il flanking the myophores (Plate IV, Figure B).

Discussion: The presence of the L, the structure of the op, the ornamentation of the RV and the shape of the radial bands indicate that this specimen has the characteristic of the genus *Sauvagesia* Choffat. The radial bands of the specimen present very similar structure with those of the *Sauvagesia somalica* determined by Tavani (1949). The specimen shows also the same characters of *Sauvagesia attenuata* Tavani, however this species is synonymous with *Sauvagesia somalica* as proposed by Pons et al., (1992). The structure of the op and the radial bands show very close resemblance with Fig. 20 b of Pons et al. (1992).

A few orifices like sections across radial canals situated within the ol, and fusiform structures like pallial canals in the il of the LV, they may be compared with those of *Kurtinia* illustrated by Karacabey-Öztemür (1980). These features suggest the possibility of a relationship of studied specimen with *Kurtinia*. However, the determination here based on a single specimen, so it needs another well-preserved LVs for proving this similarity.

Genus : *Lapeirousia* Bayle, 1878

Type species : *Sphaerulites jouanneti* Des Moulins, 1826

Lapeirousia jouanneti (Des Moulins, 1826) Bayle, 1878

(plate IV, figures D-F)

1826 *Sphaerulites* Des Moulins, page 99, plate 3, figures 1, 2.

1850 *Radiolites Jouanneti* d'Orbigny, Orbigny, page 223, plate 564.

1878 *Lapeirousia Jouanneti* (Des Moulins), Bayle, plates CX, CXI.

1886 *Lapeirousia jouanneti* (Des Moulins), Douvillé, page 403, text-figure 19.

1900 *Lapeirousia Jouanneti* (Des Moulins), Parona, page 17, plate 2, figure 6.

1908 *Sphaerulites Jouanneti* Des Moulins, Toucas, page 58, plate 10, figures 4-5.

1910 *Lapeirousia jouanneti* (Des Moulins), Douvillé, page 26, plate 6, figures 2, 3; text-figures 25, 26.

1929 *Lapeirousia jouanneti* (Des Moulins), Klinghardt, page 98, plate 13, figures 4, 5; plate 14, figure 2.

1969 *Lapeirousia jouanneti* (Moulins), Pamouktchiev, page 75, plate 1, figures 1, 2, plate 2, figures 1, 2, text-figures C, D.

1992*a* *Lapeirousia jouanneti* (Des Moulins), Özer , page 139, plate 1, figure 10.

1993 *Lapeirousia jouanneti* (Des Moulins), Plenićar, page 57, plate 11, figures 1, 2.

1995 *Lapeirousia jouanneti* (Des Moulins), Morris and Skelton, page 302, figures 7 a, b.

Material: Five right valve sections from the field photographs of Khewata section and four right valves (Nos. Su2, Su3, Su11 and Su 12) selected from many specimens of Sura Qalat section.

Description: The RV is conical, flat-based, probably 55 mm high and its transverse section is ovaloid, approximately 60x70 mm (Plate IV, Figures D, F). The Pp and Ap are lensoid in section and demarcated within op by a layer 1 mm thick (Plate IV, Figure E).

Discussion: The structure of the op and the presence of the pseudopillars show that these specimens are belong to *Lapeirousia* Bayle. The pseudopillars present the typical characteristics of the species.

Family : Hippuritidae Gray, 1848

Genus : *Hippurites* Lamarck, 1801

Type species : *Hippurites bioculatus* Lamarck, 1801

Hippurites cornucopiae Defrance, 1821

(plate IV, figure G)

1821 *Hippurites cornucopiae* Defrance, page 195, plate 58, figures 1 a, b.

1897 *Hippurites cornucopiae* Defrance, Douvillé, page 223, plate 22, figures 11, 12, text-figure 72.

1900 *Hippurites comucopiae* Defrance, Parona, page 10, plate 1, figure 1.

1910 *Hippurites (Hippuritella) cornucopiae* Defrance, Douvillé, page 79, plate 7, figures 3-5.

1933 *Hippurites cornucopiae* Defrance, Kühn, page 159, plate 1, figure 3.

1949 *Hippurites (Hippuritella) cornucopiae* Defrance, Tavani, page 13, plate 4, figures 7, 9.

1949 *Hippurites (Hippuritella) somalicus*, Tavani, page 14, plate 4, figure 6.

1961 *Hippurites (Hippuritella) cornucopiae* Defrance, Devidé-Nedela and Polsak, pages 364, 373, plate 3, figure 4, text-figure 4.

1972 *Hippurites (Hippuritella) comucopiae* Defrance, Sladić-Trifunović, plate 11, figures 2, 3.

1983 *Hippurites cornucopiae* Defrance, Camoin, page 223, plate 7, figure 1.

1983 *Hippurites cornucopiae* Defrance, Özer, page 17, plate 3, figures 6, 7.

1988 *Hippurites cornucopiae* Defrance, Accordi et al., page 140, text-figure 5, plate 1, figure 12.

1992*b* *Hippurites cornucopiae* Defrance, Özer, page 77, plate 1, figures 1, 2.

1992 *Hippurites cornucopiae* Defrance, Pons et al., page 284, plate 3, figures 1-3, text-figures 3/1a-c, 2a-b.

1994 *Hippurites cornucopiae* Defrance, Pons and Sirna, page 274, plate 1, figures 1-2, plate 2, figures 1-6, plate 3, figures 1-7.

1995 *Hippurites cornucopiae* Defrance, Morris and Skelton, page 292, plate 5, figures 4-7.

1999 *Hippurites cornucopiae* Defrance, Steuber, page 124, text-figures 46a-c, e-f.

2010 *Hippurites cornucopiae* Defrance, Khazei et al., page 706, text-figures 2, tb. 1, 2, plate 1, figures 3-5, plate 2, figures 2, 3.

2012 *Hippurites cornucopiae* Defrance, Steuber and Schlüter, pages 49, 50, 52, figure 10 A.

2012 *Hippurites cornucopiae* Defrance, Asgari Pirbaluti et al., plate 4, figures 5-7.

Material: Numerous specimens of the RV (see Figure 5) and a specimen (No. Su1) showing a cluster of orientated individuals from Sura Qalat section. A few specimens of the RV (Nos. Kh4 and Kh5) from Khewata section.

Description: The RV is cylindro-conical in shape, the length is 120 mm and the surface of the valve is generally smooth with two pillars that are represented by longitudinal grooves. The transverse section is generally circular and the diameter varies from 10 mm to 20 mm. The L is reduced. The pp is open at the base, however the ap is pinched at the base and it is better developed than the posterior one, and recurved towards the posterior part of the valve in some sections (Plate IV, Figure G). Different growth stages show a variation in pinching of the ap, but the posterior one is always open at the base. The cardinal apparatus is partly preserved. The ol is approximately 1 to 2 mm and it shows radial ribbings.

The LV is generally absent or partly preserved.

Discussion: The pillars of the specimens are characteristic for the species and also show clear similarities with those of Somalia, the UAE-Oman region, Iran and SE Anatolia (Tavani, 1949; Pons et al., 1992; Özer, 1992 b; Morris and Skelton, 1995; Khazaei et al., 2010; Steuber and Schlüter, 2012).

4. Age Of The Rudist Fauna

The species of the rudist fauna from NE Iraq vary in abundance according to measured stratigraphic sections (Figure 6). The Arabian Plate endemic genus *Dictyoptychus* is abundantly found in the Khewata section, where *Lapeirousia jouannetti* is represented also in abundance, however the specimens of *Hippurites cornucopiae* are very rare. The latter species and *Lapeirousia jouanneti* are very abundant in the Sura Qalat section, where the specimens of *Praeradiolites subtoucasi* are abundant, but those of *Dictyoptychus* are very rare. The Sherawazha section is characterized by the high abundance of *Praeradiolites subtoucasi. Hippurites cornucopiae* and *Dictyoptychus*, but *Lapeirousia jouanneti* and *Sauvagesia somalica* are very rare in this section.

Hippurites cornucopiae seem to be a unique species within the rudist fauna showing a wide distribution and indicating a Maastrichtian age; whereas the other determined species were found in the late Campanian-Maastrichtian or Maastrichtian formations of the central and eastern Mediterranean Tethys and Arabian Plate (Steuber, 2002).

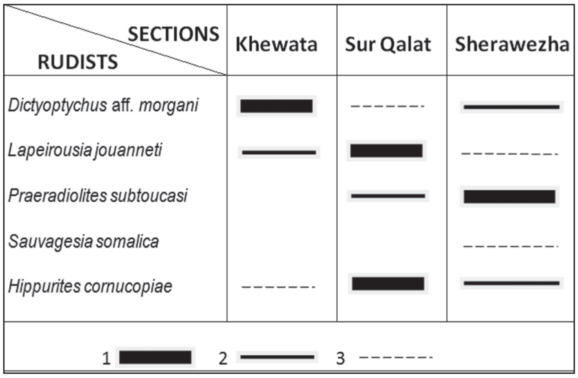

Figure 6- The abundance distribution of the rudists according to the measured- stratigraphic sections. 1-very abundant, 2-abundant, 3-rare.

Rudist biozones have recently been proposed for the central-eastern Mediterranean Tethys and Arabian plate based on Sr-isotope data and numerical ages of the rudist shells by Steuber and Schlüter (2012). Because of the presence of Arabian endemic rudists in the NE Iraq fauna, the Arabian plate biozones of these authors are considered in this study. Three rudist biozones for mid-Campanian-Maastrichtian interval have been suggested by Steuber and Schlüter (2012):

1-*Torreites*/*Vaccinites* aff. *vesiculosus* interval biozone: Middle Campanian. The base of this biozone is determined by the first occurrence of *Torreites* Palmer and *Vaccinites* aff. *vesiculosus* (Woodward) in the Simsima Formation (Oman) (Grubić, 1979; Skelton and Wright, 1987; Morris and Skelton, 1995; Simonpietri et al., 1998; Schumann, 1995, 2010) and the top with the lowest occurrence of *Dictyoptychus* in the Terbüzek Formation (Alidamı-Adıyaman) (Schlüter, 2008; Özer et al., 2008; Steuber et al., 2009).

2- *Dictyoptychus* interval biozone: uppermost Campanian-Lower Maastrichtian. The Sr-isotope analysis and numerical ages of rudist shells (Schlüter, 2008; Özer et al., 2008; Steuber et al., 2009) from the shallow marine rudist-bearing limestone lenses in the Terbüzek Formation cropping out around Alidamı village-Adıyaman (Yalçın, 1976; Karacabey-Öztemür, 1979; Meriç et al., 1985; Özer, 1986, 1992*c*, 2002, 2010*a*; Özcan, 2007; Özer et al., 2009) and the first occurrence of *Dictyoptychus* characterize the base of the biozone. The first occurrence of *Hippurites cornucopiae* in the locality of Oman, Buraimi, Jebel As Saifr determine the top of the biozone (Morris and Skelton, 1995). This biozone contains also two rudist genera endemic to the Arabian plate, *Vautrinia* (Vautrin) and *Paracaprinula* Piveteau, while *Hippuritella lapeirousei* Goldfuss and *Pseudosabinia* Morris and Skelton have been found in the Kahta, Besni-Adıyaman, Gölbaşı-KahramanMaraş, Yayladağı-Antakya, Çermik-Diyarbakır and Körkandil-Siirt in SE Anatolia (Erentöz, 1949; Karacabey-Öztemür, 1979; Karacabey-Öztemür and Selçuk, 1981; Özer, 1986, 1991, 2002, 2010*a, b*; Steuber et al., 2009).

3- *Hippurites cornucopiae* interval biozone: mid-Upper Maastrichtian. The base of this biozone is determined by the first occurrence of *Hippurites cornucopiae* in the locality of Oman, Buraimi, Jebel As Saifr. *Hippurites cornucopiae* was found in the SE Anatolia, Zagros-Iran, Oman Mountains (the border of the UAE and Oman), Somalia and Yemen (Steuber, 2002). The top of the biozone can not defined, but some little hippuritids were found a few metres below of the K/T boundary in the Oman Sur Qualhat locality, apparently belonging to *Hippurites cornucopiae* (Schlüter et al., 2008). *Dictyoptychus* Douvillé, *Vaccinites* aff. *oppeli* Douvillé and *Pseudosabinia* Morris and Skelton accompanied this zone.

The numerical ages data play an important role for the determinations of the biozones as explained above, obtained from the rudist shells of SE Anatolia, located in the northernmost part of the Arabian Plate. The presence of *Hippurites cornucopiae* indicates a Maastrichtian age for the NE Iraq rudist fauna. The rudist fauna determined here, is assigned to the *Hippurites cornucopiae* interval biozone of Steuber and Schlüter (2012) and so of mid- to Late Maastrichtian age. The paleontologic reports on the benthic foraminifers of the Aqra Formation (Al-Kubaysi, 2008; Sadiq, 2009; Zebari, 2010), including the presence of *Racemiguembelina fructicosa* (Egger) indicate an earliestLate Maastrichtian age. Moreover, many planktonic foraminifers, which were recently determined from the Tanjero Formation (Sharbazheri, 2008; personal report of K.H. Karim, 2013) of the NE Iraq, support this age.

5. Palaeobiogeography

The Zagros fold-thrust belt was formed from the convergence between the Arabian and Eurasian plates, and because of the closing of the Mediterranean Tethys during the Late Cretaceous, ophiolitic material cropsout widely in northeastern Iraq (Buday, 1980; Buday and Jassim,1987; Jassim and Goff, 2006; Karim, 2004; Karim and Surdashy, 2006; Karim et al., 2007). The Campanian-Maastrichtian rudist-bearing formations (or platforms) of northeastern Iraq are developed over these rocks (Buday, 1980; Karim, 2004, 2005; Al-Barzinjy, 2005; Sadiq, 2008) and located on the northern border of the Arabian platform (Figure 7), about 20º or 21º N paleolatitude (Dercourt et al., 1986). Due to insufficient data about the shallow marine carbonate platforms, northeastern Iraq was included in the thin continental crust in the previous palaeogeographic reconstructions (Dercourt et al., 1986; Camoin et al., 1993). The recently obtained stratigraphic data (Karim, 2004, 2005; Al-Barzinjy, 2005; Sadiq, 2008) and also new data presented in this study allowed us, by contrast, to add the presence of carbonate platforms around northeastern Iraq to the palaeogeographic map of Dercourt et al. (1986) (Figure 7). This has important implications for the palaeobigeography of the northern side of Arabian plate as indicated below.

Although the rudist fauna of NE Iraq has a low diversity, it contains both some species that show a wide distribution in the Mediterranean Tethys and Afro-Arabian region, and *Dictyoptychus,* which is endemic to the Arabian plate (Özer, 1986, 2010*a*; Morris and Skelton, 1995; Steuber and Schlüter, 2012), as well as *Sauvagesia somalica*, which shows a geographic distribution likewise limited to the same plate according to present knowledges (Tavani, 1949; Pons et al., 1992; Steuber, 2002; Asgari Pirbaluti et al., 2012). Indeed, the Arabian Plate rudist fauna consists of, beside *Dictyoptychus,* endemic genera such as *Vautrinia* (Vautrin)*, Paracaprinula* Piveteau*, Eodictyoptychus* Skelton and El-Asa'ad and *Semailia* Morris and Skelton and species like *Hippurites syriaca* Vautrin and *Pironaea syriaca* (Vautrin)*,* which have not so far been observed in the Mediterranean Tethys (Özer, 1991, 1992*c, d*, 2002, 2010*a*; Özer et al., 2008, 2009; Skelton and El-Asa'ad, 1992; Morris and Skelton, 1995; Schlüter, 2008; Steuber et al., 2009; Steuber and Schlüter, 2012). The main reason for the absence of such Arabian Plate endemic rudists, other than *Dictyoptychus,* from the NE Iraq rudist fauna may be that they are limited to the latest Campanian-Early Maastrichtian age formations as indicated by Steuber and Schlüter (2012).

The biogeographic and stratigraphic distributions of the rudists of NE Iraq are as follows:

Dictyoptychus is abundantly represented in the Late Campanian-Maastrichtian formations of the Afro-Arabian region such as in SE Turkey (Karacabey-Öztemür, 1979; Karacabey-Öztemür and Selçuk, 1981; Özer, 1986, 1991, 1992*c, d*, 2005, 2010*a*; Özer et al., 2008, 2009), Iran (Douvillé, 1904, 1910; Kühn, 1933; Cox 1933, 1934; Khazaei et al.,

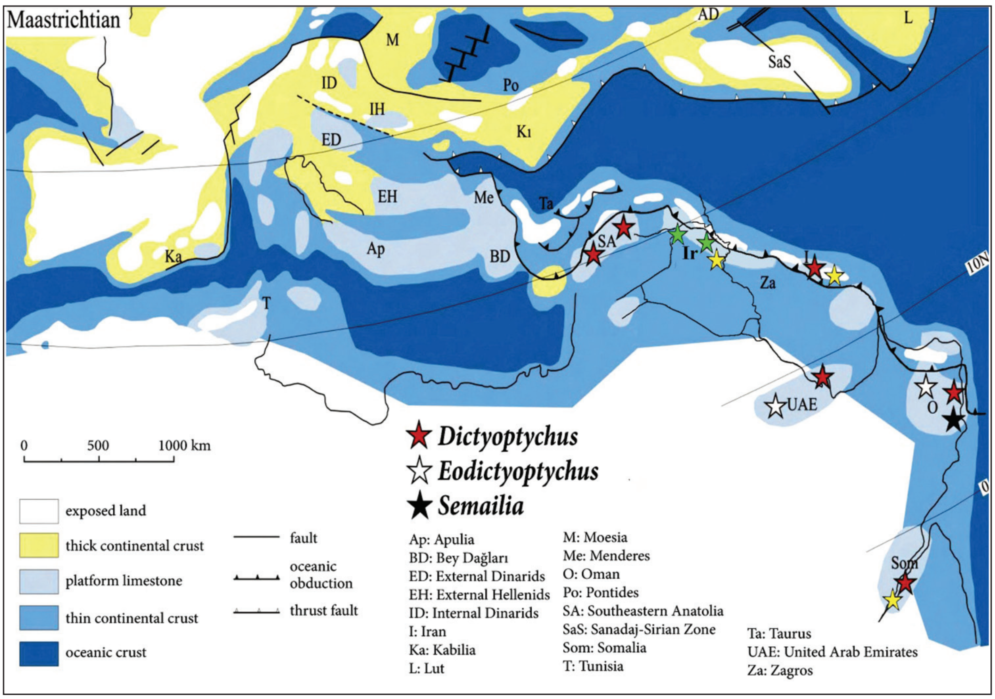

Figure 7- Maastrichtian palaeogeographical reconstruction of the Mediterranean area (simplified and partly modified after Dercourt et. al., 1986) showing the distribution of endemic rudists *Dictyoptychus* (green asterisks for localities in Iraq) and Sauvagesia somalica (yellow asterisks) and also *Eodictyoptychus* and *Semailia* in the Afro-Arabian plate (after Özer, 2010*a*). Ir indicates NE Iraq.

2010; Asgari Pirbaluti et al., 2012), Saudi Arabia, the UAE, Oman (Kühn, 1929; Morris and Skelton, 1995; Skelton and Smith, 2000; Steuber and Schlüter, 2012) and Somalia (Tavani, 1949; Pons et al., 1992).

Sauvagesia somalica seems to be also endemic to the Arabian platform. It was first determined from the Maastrichtian of Somalia (Tavani, 1949; Pons et al., 1992), and reported from the Maastrichtian of Iran and Afghanistan (Vogel, 1971). It was recently also determined from the Maastrichtian of the Central Zagros region of Iran (Asgari Pirbaluti et al., 2012).

Other determined rudists show a very wide geographic distribution in the Mediterranean Tethys as follows:

Hippurites cornucopiae is abundantly represented in the Maastrichtian of the central and eastern Mediterranean Tethys (Steuber, 2002) and also SE Turkey, Iran, Oman, the UAE, Somalia and Yemen of the Arabian Plate (Özer 1992 b, Özer et al., 2009; Pons and Sirna, 1994; Morris and Skelton, 1995; Khazaei et al., 2010; Steuber and Schlüter, 2012; Asgari Pirbaluti et al., 2012).

Praeradiolites subtoucasi is mainly represented in the Campanian-Maastrichtian of the Mediterranean Tethys from Spain to Turkey (Steuber, 2002), but has also been recorded from the mid-Maastrichtian of Oman (Morris and Skelton, 1995).

Lapeirousia jouanneti shows very a similar distribution to that of *Praeradiolites subtoucasi.* It is mainly recorded from the Campanian-Maastrichtian of the Mediterranean Tethys (Steuber, 2002), but is also found in the Maastrichtian of Iran (Douvillé, 1904). Some *Lapeirousia* specimens showing resemblance to this species were also demonstrated from the Maastrichtian of the UAE-Oman border region (Morris and Skelton, 1995) and Zagros region in Iran (Khazaei et al., 2010; Asgari Pirbaluti et al., 2012).

These data show that all of the determined rudists of NE Iraq have a distribution in the Maastrichtian formations of the Arabian Plate.

Although the Maastrichtian rudist-bearing formations are well known from the SE Anatolia-Turkey and SW Iran along the Zagros fold-thrust belt (Özer, 1986, 1992*c, d*, 2002, 2010*a, b*; Özer et al., 2008, 2009; Steuber et al, 2009; Khazaei et al, 2010), the palaeobiogeographic relationships of these regions were attributed to faunal resemblances (Özer, 1992*c, d*; Özer et al., 2008) because of our insufficient knowledge about NE Iraq. So, the palaeobiogeographic approaches have been limited in the northern border of the Arabian Plate. But, the discovery of the rudist-bearing formations in this study fills an important palaeobiogeographic gap between SE Turkey and Iran and allows us to identify the presence of a path-way for larval distribution during the Maastrichtian along the Zagros fold-thrust belt from SE Turkey across NE Iraq towards SW Iran (Figure 7). The relationship of this path-way with other rudist localities such as Oman, the UAE and Somalia of the Arabian Plate is not yet known, but a connection in the Maastrichtian is implied by the presence also *Dictyoptychus* and *Hippurites cornucopiae* in these localities. According to the increase our knowledge in the following years the migration routes in the Arabian Plate will be better interpreted.

6. Conclusions

The Aqra Formation cropping out around Sulaimaniya city-NE Iraq consists mainly of detrital limestones. Three stratigraphic sections at Khewata, Sura Qalat and Sherawezha are characterised by abundant rudist associations. The rudist fauna consists of *Dictyoptychus* aff. *morgani*, *Praeradiolites subtoucasi*, *Sauvagesia somalica, Lapeirousia jouanneti* and *Hippurites cornucopiae*, which are determined from the NE Iraq for the first time.

The age of the rudist fauna is considered to be mid- to Late Maastrichtian based on the *Hippurites cornucopiae* interval zone proposed by Steuber and Schlüter (2012) for the Arabian Plate.

Dictyoptychus and *Sauvagesia somalica* are characteristic endemic rudists for the Arabian Plate. Other rudists are seen mainly in the central-eastern Mediterranean Tethys, but also in the Arabian Plate. The determination of rudists from NE Iraq both augments the palaeobiogeographic and taxonomic database and indicates a palaeobiogeographic relationship between SE Turkey, NE Iraq and SW Iran during the Maastrichtian involving larval dispersion along the Zagros fold-thrust belt.

Acknowledgements

Authors would like to thank Peter W. Skelton for his valuable constructive comments and English corrections that helped to improve the quality of the manuscript. Thanks also to Feride Özyol (DEÜ-İzmir) for the organisation of the rudist photos in the plates.

Received: 01.03.2013
Accepted: 23.07.2013
Published: December 2013

References

Accordi, G., Carbone, F., Sirna, G., Catalano, G., Reali, S. 1988. Sedimentary events and rudist assemblages of Maiella Mt. (central Italy): Paleobiogeographic implications. *Geologica romana* 26, 135-147.

Archiac, A. de. 1835. Mémoire sur la formation crétacée du Sud-Ouest de la France. *Mémoires de la Société géologique de France* 2, 157-192.

Al-Barzinjy, S. T. M. 2005. Stratigraphy and basin analysis of Red Bed Series from northeastern Iraq-Kurdistan Region. Ph.D. thesis, University of Sulaimani (unpublished)

Al-Kubaysi, K. N. 2008. Biostratigraphy of Aqra, Tanjero and Shiranishs Formation in Chwarta Area, Sulaimanyah Governorate, NE-Iraq. *Iraqi Bulletin of Geology and Mining* 4, 1-23.

Asgari Pirbulati, B., Khazaei, A., Jafarian, M. A., Khosrow-Tehrani, K., Afghah, M., Abiyat, A. 2012. Biostratigraphy of the Tarbur Formation in Tang-e-Zendan section, Sabzeh kuh (Southwest Borujen) based on Foraminifera and Rudists. *Journal of Sciences Esfahan University–Research stratigraphy and sedimentology* 45, 49-64.

Astre, G. 1954. Radiolitidés nord-pyrénéens. *Mémoires de la Société géologique de France*, N.S., 71, 140 p.

Bayle, E. 1878. Fossiles principaux des terrains. *Mémoire pour servir à l'Explication de la Carte géologique de la France* vol. 4b.

Bellen, R. C. Van, Dunnington, H. V., Wetzel, R., Morton, D. 1959. Lexique Stratigraphique International. Asie, Iraq 3c, 10a, 333 p.

Buday, T. 1980. Regional Geology of Iraq: Vol. I, Stratigraphy: Kassab, I. I., Jassim, S. Z. (Ed.). *Publication of Establishment of Geological Survey of Iraq, Baghdad* 445p.

Buday, T., Jassim, S. Z. 1987. The Regional Geology of Iraq: Tectonic Magmatism, and Metamorphism. Kassab, I.I., Abbas, M.J. (Ed.). *Geosurv, Baghdad* 2, 445 p.

Camoin, G. 1983. Plates-formes carbonatées et récifs à rudistes du Crétacé de Sicile. *Travaux du Laboratoire de Géologie historique et de Paléontologie* 13, 244 p.

Camoin, G., Bellion, Y., Dercourt, J., Guiraud, R., Lucas, J., Poisson, A., Ricou, L. E., Vrielynck, B. 1993. Atlas Tethys Palaeoenvironmental Maps, Explanatory Notes. Dercourt, J., Ricou, L. E., Vrielynck, B. (Ed.). *Gauthier-Villars* Paris, 179-196.

Cox, L. R. 1933. The evolutionary history of the rudists. *Proceedings of the Geologists' Association* 44, 379-388.

Cox, L. R. 1934. On the structure of the Persian rudist genus *Trechmanella* (formerly *Polyptychus*), with the description of a new species. *Proceedings of the Malacological Society of London* 21, 42-66.

Defrance, J. L. M. 1821. Hippurites. Defrance, J. L. M. (Ed.). *Dictionnaire des sciences naturelles* 21, 195-197.

Dercourt, J., Zonenshain, L. P., Ricou, L. E., Kazmin, V. G., Le Pichon, X., Knipper, A. L., Grandjacquet, C., Sbortshikov, I.M., Geyssant, J., Lepvrier, C., Pechersky, D.H., Boulin, J., Sibuet, J.-C., Savostin, L.A., Sorokhtin, O., Westphal, M., Bazhenov, M.L., Lauer, J.P., Biju-Duval, B., 1986. Geological evolution of the Tethys belt from the Atlantic to the Pamirs since the Liassic. *Tectonophysics* 123, 241-315.

Des Moulins C. 1826. Essai sur les sphérulites qui existent dans les collections de MM. F. Jouannet, membre de l'Académie royale des Sciences, belle Lettres et Arts de Bordeaux, et Charles Des Moulins. *Bulletin d'Histoire naturelle de la Société Linnéenne de Bordeaux* 5, 1, 148-303.

Devidé-Nedela, D., Polsak, A. 1961. Sur la présence du Maestrichtien dans la région de Bespelj au nord de Jajce (Bosnie). *Geoloski Vjesnik* 14, 355-374.

D'Orbigny, A. de.1847. Paléontologie française, Terrains crétacés. II-III, Lamellibranchia. 1-807.

Douvillé, H. 1886. Essai sur la morphologie des rudistes. *Bulletin de la Société géologique de France* 3, 14, 389-404.

Douvillé, H. 1897. Etudes sur les rudistes. Distribution régionale des Hippurites. *Mémoires de la Société géologique de France, Paléontologie* 6, 6, 187-230.

Douvillé, H. 1902. Classification des Radiolites. *Bulletin de la Société géologique de France* 4, 2, 461-477.

Douvillé, H. 1904. Mollusques fossiles. Morgan, J. de : Mission scientifique en Perse, volume 3, Etudes géologiques, partie 4, Paléontologie, 191–380.

Douvillé, H. 1905. Observations. Morgan, J. de : Notes sur la géologie de la Perse et sur les travaux paléontologiques de H. Douvillé sur cette region. *Bulletin de la Société géologique deFrance* 5, 170–189

Douvillé, H. 1910. Etudes sur les rudistes. Rudistes de Sicile, d'Algérie, d'Egypte, du Liban et de la Perse. *Mémoires de la Société géologique de France* 41, 83 p.

Dubertret, L. 1966. Liban, Syrie et bordure des pays voisins. Première partie. Tableau stratigraphique, avec carte géologique au millionième. *Notes et Mémoires sur le Moyen-Orient* 8, 251-385.

Erentöz, L. 1949. Note sur la repartition stratigraphique des quelques *Hippurites* provenant du Sud-Est de la Turquie. *Bulletin of the Geological Society of Turkey* 2, 1, 14-28.

Fenerci, M. 1999. Cretaceous rudist fauna of Kocaeli Peninsula and Western Pontides, Ph D. Thesis, Dokuz Eylül Üniversitesi, 232 p. İzmir-Turkey.

Götz, S. 2001. Rudisten-Assoziationen der keltiberischen Oberkreide SE-Spaniens: Paläontologie, Palökologie und Sediment-Organismus-Wechselwirkungen. *Bayerische Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche* Klasse, *Abhandlungen* N. F. 171, 1-112.

Grubić, A. 1979. *Torreites milovanovici* sp. nov. from Oman, *T. coxi* sp. nov. and *T. chubbi* sp. nov. from Jamaica, a new description of the genus *Torreites* Palmer, and a reference to the significance of its palaeogeographic distribution. *Vesnik Geologija, A37. Zavod za geoloska i geofizicka Istrazivanja* 81–95.

Jassim, S.Z., Goff, J. C. 2006. Geology of Iraq. *Dolin, Prague and Moravian Museun, Berno,* 341p.

Karacabey-Öztemür, N. 1979. Two new species of the genus *Dictyoptychus* in Turkey. *Bulletin of the Mineral Research and Exploration Institute of Turkey* 92, 35-39.

Karacabey-Öztemür, N. 1980. Two new genera of Radiolitidae (*Balabania* n. gen. *Kurtinia* n. gen.) from Turkey. *Geological Bulletin of Turkey* 23, 79-86.

Karacabey-Öztemür, N., Selçuk, H. 1981. A new genus and two new species of rudists from Hatay, Turkey. *Bulletin of the Mineral Research and Exploration Institute of Turkey* 95/96, 97-105.

Karim, K. H. 2004. Basin analysis of Tanjero Formation in Sulaimaniya area, NE-Iraq, Ph.D. thesis, University of Sulaimani (unpublished) 131p.

Karim, K.H. 2005. Some sedimentary and structural evidence of possible graben in Chuarta-Mawat area, Sulaimaniya area, NE-Iraq. *Iraqi Journal of Earth Science* 5, 9-18.

Karim, K.H., Surdashy, A.M. 2006. Sequence Stratigraphy of Upper Cretaceous Tanjero Formation in Sulaimaniya area, NE-Iraq, Kurdistan Academician Journal, 4, 10-28.

Karim, K. H., Surdashy, A. M., Al-Barzinjy, S. T. 2007. Concurrent and lateral deposition of flysch and molasse in the foreland basin of Upper Cretaceous and Paleocene from NE-Iraq, Kurdistan Region. *2nd International Conference on Geo-Resources in the Middle East and North Africa (GERMENA II), Cairo University* 757-769.

Khazaei, A.R., Skelton, P.W., Yazdi, M. 2010. Maastrichtian rudist fauna from Tarbur Formation, (Zagros region, SW Iran), Preliminary observations. Özer, S., Sarı, B., Skelton, P. W. (Ed.). Jurassic-Cretaceous Rudists and Carbonate Platforms, Part (A), 8th International Rudist Congress. *Turkish Journal of Earth Sciences* 19, 703–719.

Klinghardt, F. 1929. Die stammesgeschichtliche Bedeutung, innere Organisation und Lebensweise von *Eoradiolites liratus* Conrad sp. *Palaeontographica* 72, 95-101.

Kühn, O. 1929. Beiträge zur Palaeontologie und Stratigraphie von Oman (Ost-Arabien). *Annalen des Naturhistorischen Museums in Wien* 43, 13-33.

Kühn, O. 1933. Rudistae from eastern Persia. *Records of the Geological Survey of India* 46, 151-179.

Linnaeus, C. 1758. Systema Naturae. 10th ed. , *Holmiae (Salvius)* 1, 824 p.

Lupu, D. 1976. Contributions à l'étude des rudistes sénoniens des Monts Apuseni. *Institut de Géologie et Géophysique, Mémoires* 24, 83-151.

Ma,ala, K. A. 2008. Geological map of the Sulaimaniyah Quadrangle, sheet N1-38-3, scale 1:20000. Published by Establishment of Geological Survey of Iraq, Badgdad.

Meriç, E., Oktay, F. Y., Özer, S. 1985. Besni Formasyonu'nun Alidamı (Kahta-Adıyaman) kuzeybatısındaki stratigrafik gelişimi ile ilgili yeni gözlemler. *Jeoloji Mühendisliği* 25, 51-54.

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), Geology Series* 51, 277-305.

Newell, N. D. 1965. Classification of the Bivalvia. *American Museum Novitates* 2206, 125.

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. *Cretaceous Research* 28, 621—641.

Özer, S. 1983. Les formations à rudistes du Sénonien supérieur d'Anatolie centrale (Turquie). *Travaux du Laboratoire de Stratigraphie et de Paleoécologie* N.S. 1, 32 p.

Özer, S. 1986. Faune de Rudistes maestrichtienne de I'environ de Kahta-Adıyaman (Anatolie sud-est). *Bulletin of the Mineral Research and Exploration Institute of Turkey* 107, 101-105.

Özer, S. 1991. Yayladağı (Hatay) Mestrihtiyen rudist faunası ve biyocoğrafyası. Yetiş, C. (Ed.). Ahmet Acar Jeoloji Sempozyumu, Çukurova Üniversitesi, Bildiriler 145-152.

Özer, S. 1992*a*. Deux nouvelles espèces du genre *Miseia* (rudistes) en Turquie. Remarques systématiques et phylogénétiques. *Palaeontographica* A, 220, 131-140.

Özer, S. 1992*b*. Presence of rudist-bearing limestone blocks derived from the Arabian platform in Gevaş (Van) ophiolite. *Bulletin of the Mineral Research and Exploration* 114, 75-82.

Özer, S. 1992*c*. Rudist carbonate ramp in southeastern Anatolia, Turkey. Simo, J. A. T., Scott, R. W., Masse, J.-P. (Ed.). Atlas of Cretaceous Carbonate Platforms. *American Association of Petroleum Geologist Bulletin* Memoir 56, 163-171.

Özer, S. 1992*d*. Stratigraphic setting and biogeographic characteristics of rudists in SE Anatolia. *Turkish Association Petroleum Geoloical Bulletin, Special issue for M.Ozan Sungurlu* 4, 47-58.

Özer, S. 2002. Distributions stratigraphiques et géographiques des rudistes du Crétacé superieur en Turquie. Sladic-Trifunović, M., Grubić, A. (Ed.). Proceedings-First International Conference on rudists (Beograd, 1988). *USGY, Memorial publication* 173-187.

Özer, S. 2005. Two new species of canaliculate rudists (Dictyoptychidae) from southeastern Turkey. *Geobios* 38, 2, 235-245.

Özer, S. 2010*a*. *Dictyoptychus* Douvillé: taxonomy, revision, phylogeny and biogeography. Özer, S., Sarı, B., Skelton, P. W. (Ed.). Jurassic-Cretaceous Rudists and Carbonate Platforms, Part (A), 8th International Rudist Congress. *Turkish Journal of Earth Sciences* 19, 5, 583-612.

Özer, S. 2010*b*. Campanian-Maastrichtian *Pseudosabinia* from Turkey: Descriptions and taxonomic problems. Özer, S., Sarı, B., Skelton, P. W. (Ed.). Jurassic-Cretaceous Rudists and Carbonate Platforms, Part (A), 8th International Rudist Congress. *Turkish Journal of Earth Sciences* 19, 5, 643-669.

Özer, S., Sarı, B., Önal, M. 2008. Campanian-Maastrichtian rudist-bearing mixed silisiclastic-carbonate transgressive-regressive system tracts of the eastern and southeastern Anatolia: faunal correlation, depositional facies and palaeobiogeographic significance. Eighth International Congress on Rudists June 23-25 2008 İzmir-Turkey, Pre-meeting Field Trip (1) Excursion Guide, *Dokuz Eylul University* 1-28.

Özer, S., Meriç, E., Görmüş, M., Kanbur, S. 2009. Biogeographic Distributions of Rudists and Benthic Foraminifera: An Approach to Campanian-Maastrichtian Palaeobiogeography of Turkey. *Geobios* 42, 623-638.

Pamouktchiev, A. 1965. Faune rudiste du Maëstrichtien de l'arrondissement du Breznik (II). *Annuaire de l'Université de Sofia, Faculté de Géologie et Géographie, Livre 1, Géologie* 58, 25-46.

Pamouktchiev, A. 1969. Représentants maëstrichtiens du genre *Lapeirouseia*, Bulgarie de l'Ouest. *Izvestija na geologicheskija Institut, Serija Paleontologija* 18, 71-81.

Parona, C. F. 1900. Sopra alcune rudiste senoniane dell'Appennino meridionale. *Memorie dell'Accademia delle Scienze di Torino, Classe di Scienze fisiche, matematiche e naturali* 50, 1-23.

Plenićar, M. 1993. *Radiolites* from the Cretaceous beds of Stranice near Slovenske Konjice (Slovenia). *Slovenska Akademija Znanosti in Umetnosti, Razred za naravoslovne Vede, Razprave* 34, 45-103.

Pons, J.M. 1977. Estudio estratigráfico y paleontológico de los yacimientos de rudistidos del Cretácico sup. del Prepirineo de la Prov. de Lerida. *Universidad Autónoma de Barcelona, Publicaciones de Geología* 3, 105 p.

Pons, J.M., Sirna, G. 1994. Revision of *Hippurites cornucopiae* Defrance and proposal of a neotype. Matteucci, R. et al. (Ed.), Studies on ecology and paleoecology of benthic communities, *Bollettino della Società paleontologica italiana* Spec. Vol. 2, 269-278.

Pons, J. M., Vicens, E. 2006. Field Guide to Pyrenean Rudist Bivalves, International Congress on Bivalvia July 22-26. 2006, Barcelona, Organism Diversity and Evolution 6. *Electronic Supplement 16* part 3, 1-18.

Pons, J. M., Vicens, E. 2008. The structure of the outer shell layer in radiolitid rudists, a morphoconstructional approach. *Lethaia* 41, 219-234.

Pons, J.M., Schroeder, J.H., Höfling, R., Moussavian, E. 1992. Upper Cretaceous rudist assemblages in northern Somalia. *Geologica Romana* 28, 219–241.

Sadiq, D. M. 2009. Facies analysis of Aqra Formation in Chwarta-Mawat Area from Kurdistan Region, NE−Iraq. MSc thesis, College of Science, University of Sulaimani, 98 p. (unpublished).

Sharbazheri, K. M. I. 2008. Biostratigraphy and paleoecology of Cretaceous/Tertiary boundary in the Sulaimani region, Kurdistan, NE-Iraq. Phd thesis, College of Science, University of Sulaimani, 122 p. (unpublished).

Schlüter, M. 2008. Late Cretaceous (Campanian-Maastrichtian) rudist-bearing carbonate platforms of the Mediterranean Tethys and the Arabian plate. Phd Thesis, Fakultät für Geowissenschaften der Ruhr-Universität Bochum, 99 p.

Schlüter, M., Steuber, T., Parente, M., Mutterlose, J. 2008. Evolution of Maastrichtian-Paleocene tropical shallow-water carbonate platform (Qualhat, NE Oman). *Facies* 54, 513-527.

Schumann, D. 1995. Upper Cretaceous rudists and stromatoporoid associations of central Oman (Arabian Peninsula). *Facies* 32, 189-202.

Schumann, D. 2010. The morphology and function of the upper valve of *Vaccinites vesiculosus* (Woodward). Özer, S., Sarı, B., Skelton, P. W. (Ed.). Jurassic-Cretaceous Rudists and Carbonate Platforms, Part (B), 8th International Rudist Congress. *Turkish Journal of Earth Sciences* 19, 6, 791–798.

Simonpietri, G., Philip, J., Platel, J.-P., 1998. Etude statistique des espèces du genre *Vaccinites* (Hippuritacea, Hippuritidae) du Campanien du Sultanat d'Oman. Masse, J.-P., Skelton, P.W. (Ed.).

Quatrième Congrès International sur les Rudistes. *Geobios* Mémoire spécial, 22, 313–329.

Skelton, P. W. 2013. Rudist classification for the revised Bivalvia volumes of the 'Treatise on Invertebrate Paleontology'. *Carribean Journal of Earth Science* 45, 9-33.

Skelton P.W., Wright, V.P. 1987. A Caribbean rudist bivalve in Oman: island hopping across the Pacific in the Late Cretaceous. *Palaeontology* 30, 505–529.

Skelton, P.W., El-Asa'ad, G. M. A. 1992. A new canaliculate rudist bivalve from the Aruma Formation of central Saudi Arabia. *Geologica romana* 28, 105-117.

Skelton, P.W., Smith. A. B. 2000. A preliminary phylogeny of rudist bivalves: sifting clades from grades. Harper, E.M., Taylor, J.D., Crame, J.A. (Ed.). The evolutionary biology of the Bivalvia. *Geological Society, London* Special Publications, 177, 97-127.

Sladić-Trifunović, M. 1972. Senonian limestones with orbitoides and rudists from Kozluk (Northeastern Serbia). *Geoloski Anali balkanskoga Poluostrva* 37, 2, 111-150.

Steuber, T. 1999. Cretaceous rudists of Boeotia, central Greece. *Special Papers in Palaeontology* 61, 229 p.

Steuber, T. 2002. A palaeontological database of Rudist Bivalves (Mollusca: Hippuritoidea,Gray1848). http://www.ruhr-uni-bochum.de/sediment/rudinet/intro.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. *Cretaceous Research* 30, 41-48.

Steuber, T., Schlüter, M. 2012. Strontium-isotope stratigraphy of Upper Cretaceous rudist bivalves: biozones, evolutionary patterns and sea-level change calibrated to numerical ages. *Earth-Science Reviews* 114, 42-60.

Tavani, G. 1949. Rudiste ed altri Molluschi cretacei della lligiurtinia (Africa orientale). *Palaeontographia Italica* 66, 1–40.

Toucas, A. 1907. Etudes sur la classification et l'évolution des radiolitidés: *Agria* & *Praeradiolites*. *Mémoires de la Société géologique de France, Paléontologie* 36, 14, 1-46.

Toucas, A. 1908. Etudes sur la classification et l'évolution des radiolitidés: *Sphaerulites* & *Radiolites*. *Mémoires de la Société géologique de France, Paléontologie* 36, 16, 47-78.

Vicens, E. 1992. Estudio de la fauna de rudistas (Hippuritidae y Radiolitidae) de los materiales cretácicos del Pirineo oriental: implicaciones bioestratigráficas. Universidad Autónoma de Barcelona, Publicaciones de Geología, Phd Thesis, 255 p.

Vogel, K. 1971. On the Upper Cretaceous in east Iran and in west and north Afghanistan. *Geological Survey of Iran* Report, 20, 56-79.

Yalçın, N. 1976. Geology of the Narince-Gerger area (Adıyaman province) and its petroleum possibilities. *Revue de la Faculté des Sciences de l'Université d'İstanbul* B 41, 57-82.

Zebari, B.G.A. 2010. Sedimentology of Aqra Formation (Upper Cretaceous) in selected sections in the Kurdistan region-Iraqi. MSc thesis, Salahaddin University (unpublished). 135p.

PLATES

PLATE - I

Dictyoptychus aff. *morgani* (Douvillé).

A**-C.** Khewata section, No. Kh 2.

A**-** Both valves, ventral side. Note robuste conical, very smooth surface of the RV and very depressed LV.

B- Top view of the partly preserved LV.

C- Enlargement of the LV showing thin longitudinal radial canals (arrow) observed beneath the eroded parts of the ol.

D- Upper view of LV. Note thin ol and longitudinal radial canals (arrow) in the eroded parts. Sherawezha section, No. Sh 6.

E, F. Khewata section, No. Kh 3.

E- Both valves, anterior side. Note the dense and fine growth lamellae (arrow) in the RV. The LV is very depressed.

F- Transverse section of the RV passing too close the commissure showing the basal attachement of the myocardinal arc within the LV. Some badly preserved canals of the il can be observed.

G- Transverse section of the RV passing 10 mm below of the commissure. Sherawezha section, No. Sh 9.

H- Transverse section of the RV passing 10 mm below of the commissure. The il contains some badly preserved canals. Sherawezha section, No. Sh 10.

I- Bivalve specimen, field photograph, in life position. Note thick ol. Khewata section, No. Kh 1.

Scale indicates 10 mm.

PLATE - I

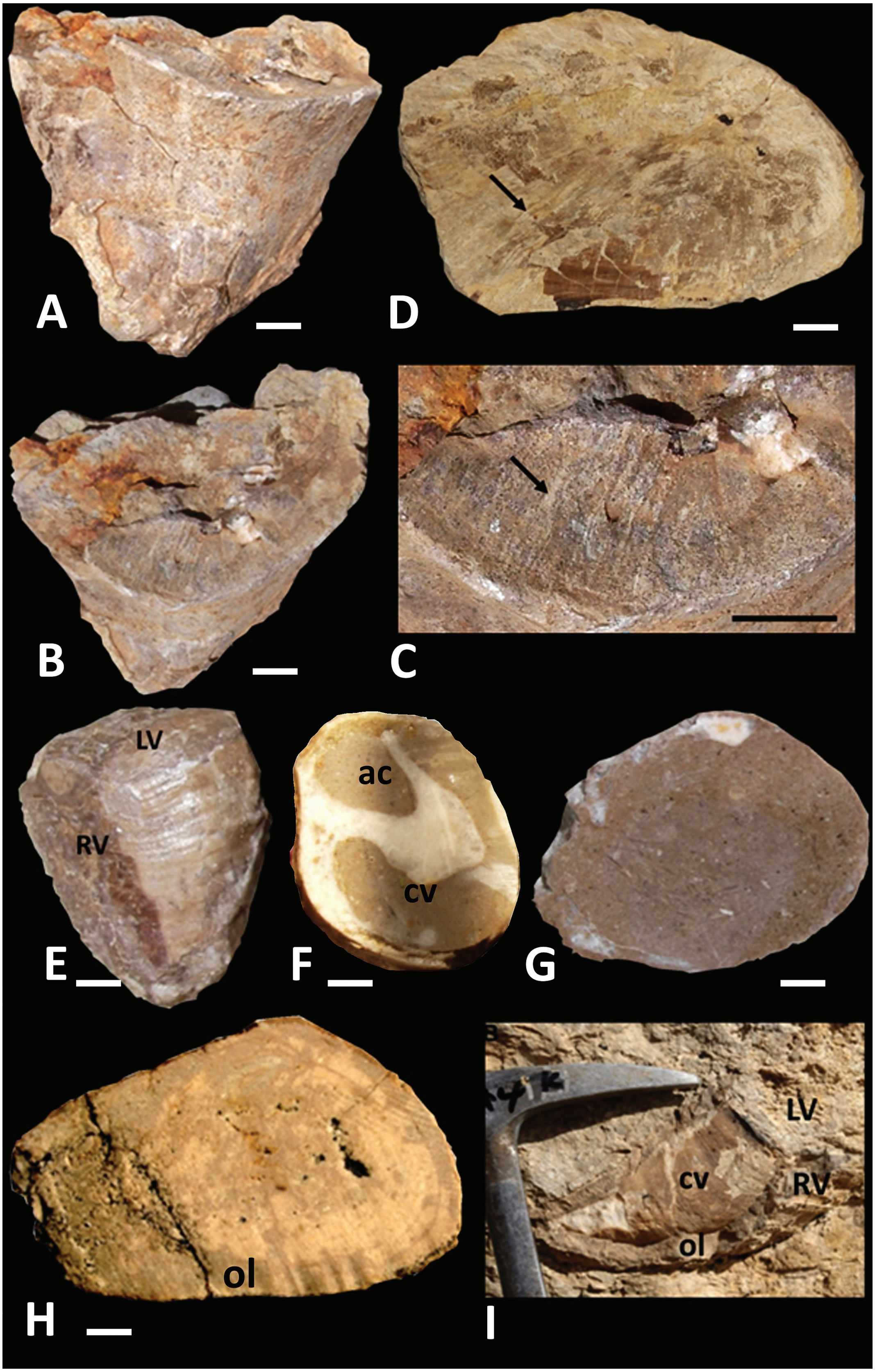

PLATE - II

Praeradiolites subtoucasi Toucas.

A-C. Sherawezha section, No. Sh 3.

A- Both valves showing two radial bands (Ab, Pb) delimited by three very pronounced longitudinal costae. Note very robust RV and flattened LV.

B- Ventral part. Note horizontal growth lamellae.

C- Transverse section of the RV passing 20 mm below of the commissure. L is present, but broken off. Note very thick op and radial bands (Ab, Pb).

D-F. Sherawezha section, No. Sh 2.

D- Both valves showing three very pronounced longitudinal costae and two radial bands (Ab, Pb). Horizontal growth lamellae are well-preserved. Note flat LV consisting of horizontal growth lamellae showing resemblance to those of RV.

E, F- Transverse sections of the RV passing 15 mm below of the commissure. Note the long L and well-preserved cardinal apparatus.

Scale indicates 10 mm.

PLATE - II

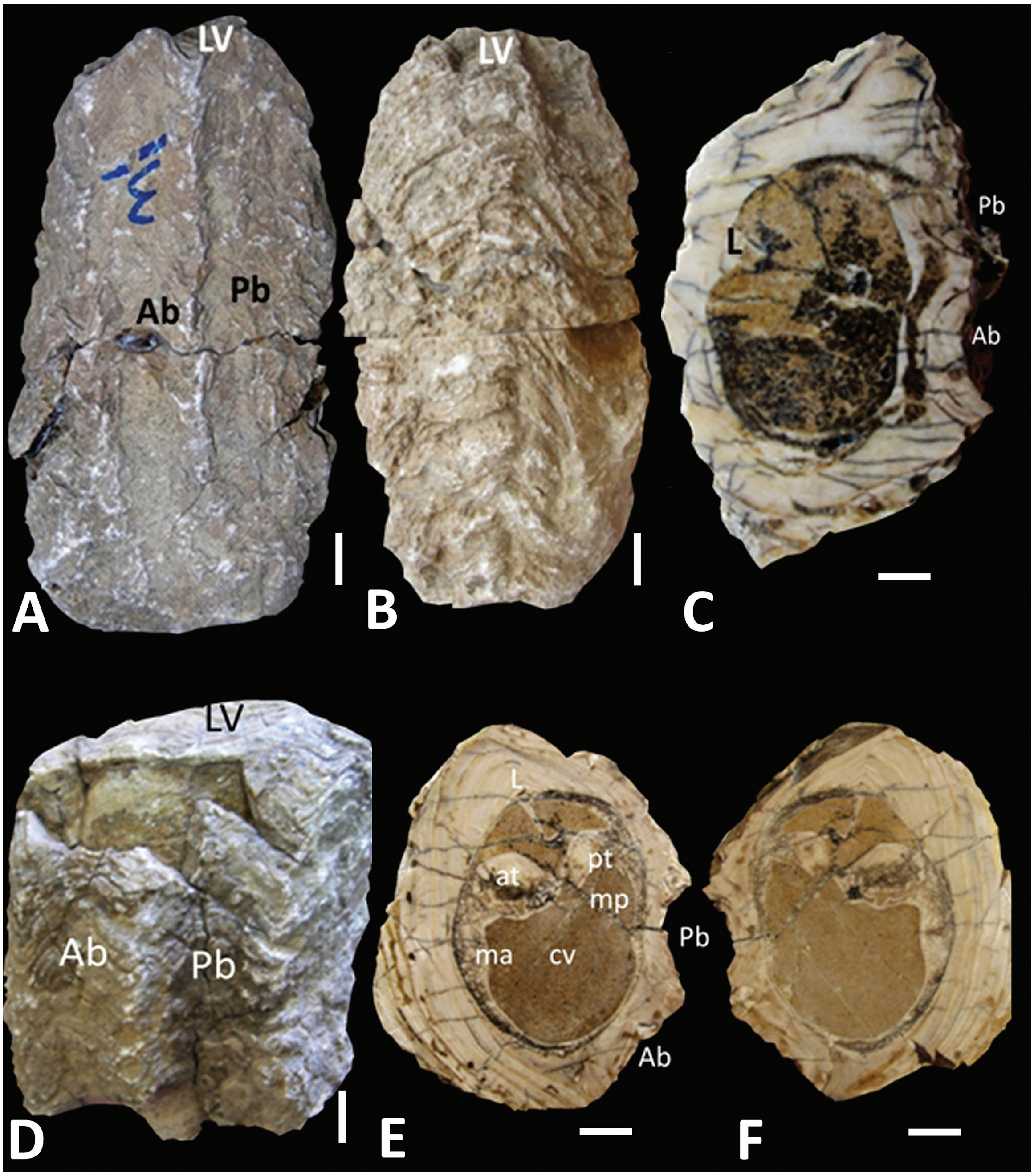

PLATE - III

Praeradiolites subtoucasi Toucas.

A-D. Sherawezha section, No. Sh 4.

A- Both valves showing two radial bands. Compare the radial bands and longitudinal costae with those of plate II, figures A and D.

B- Both valves, ventral side. Note the strong development of the growth lamellae in both valves.

C- LV, top view, growth lamellae are very well-preserved.

D- Transverse section of the RV passing 15 mm below of the commissure. The L is broken off.

E, F. Sherawezha section, No.Sh 5.

E- Both valves showing two radial bands. Note the greater length and lesser width of the RV compared with other specimens of the species.

F- Transverse section of the RV passing 10 mm below of the commissure. The L is partly preserved. Three longitudinal costae and radial bands can be well-observed.

G- Transverse section of the RV passing 10 mm below of the commissure. The L and cardinal apparatus are well-observed. Note the circular section of the valve compared with the other specimens of the species. Sherawezha section, No. Sh 7.

H. Transverse section of the RV passing 10 mm below of the commissure, juvenil form. Sherawezha section, No. Sh 8.

Scale indicates 10 mm.

PLATE - III

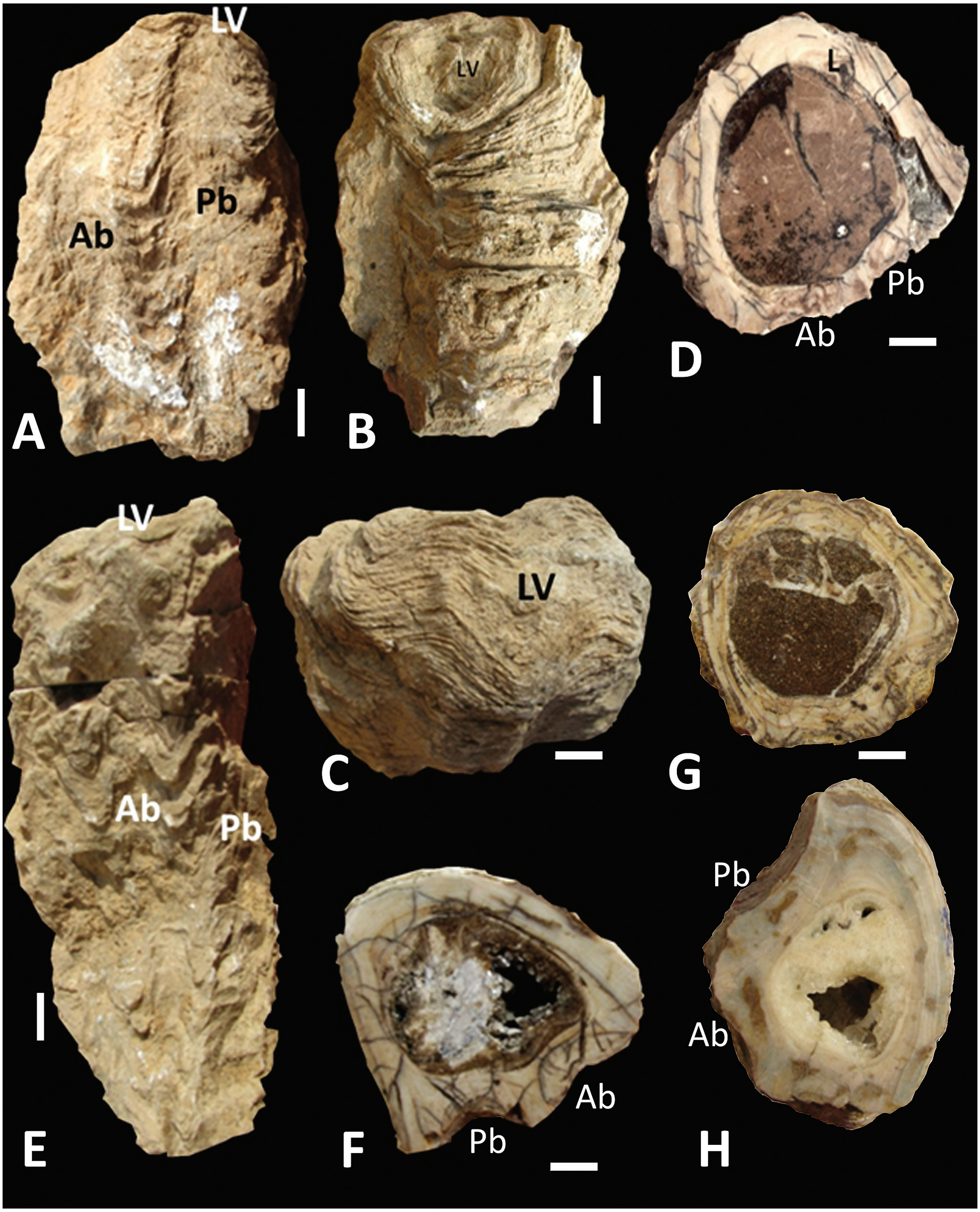

PLATE - IV

Sauvagesia somalica Tavani.

A-C. Sherawezha section, No. Sh 12.

A- Both valves showing two slightly concave radial bands limited by longitudinal costae.

B- LV, top view. Note a few orifices like sections across radial canals situated within the ol, and fusiform structures like pallial canals in the il flanking the myophores.

C- Transverse section of the RV passing 10 mm below of the commissure. Note thick op composed of very small polygonal cells in prismatic pattern.

Lapeirousia jouanneti (Des Moulins)

D-F. Sura Qalat section, No. Su 12.

D- Upper view of the RV showing the pseudopillars (Ap, Pp).

E- Enlargement of the pseudopillars showing spout-like shape. Note their demarcation by a compact layer (arrows) within the op.

F- Field photograph showing the typical outer shell layer and pseudopillars of the species. Khewata section.

G- *Hippurites cornucopiae* Defrance, from biostrome of Sura Qalat section, No. Su 1. Transeverse sections of RVs. The pillars can be clearly observed.

Scale indicates 10 mm.

PLATE - IV