# Zitteliana

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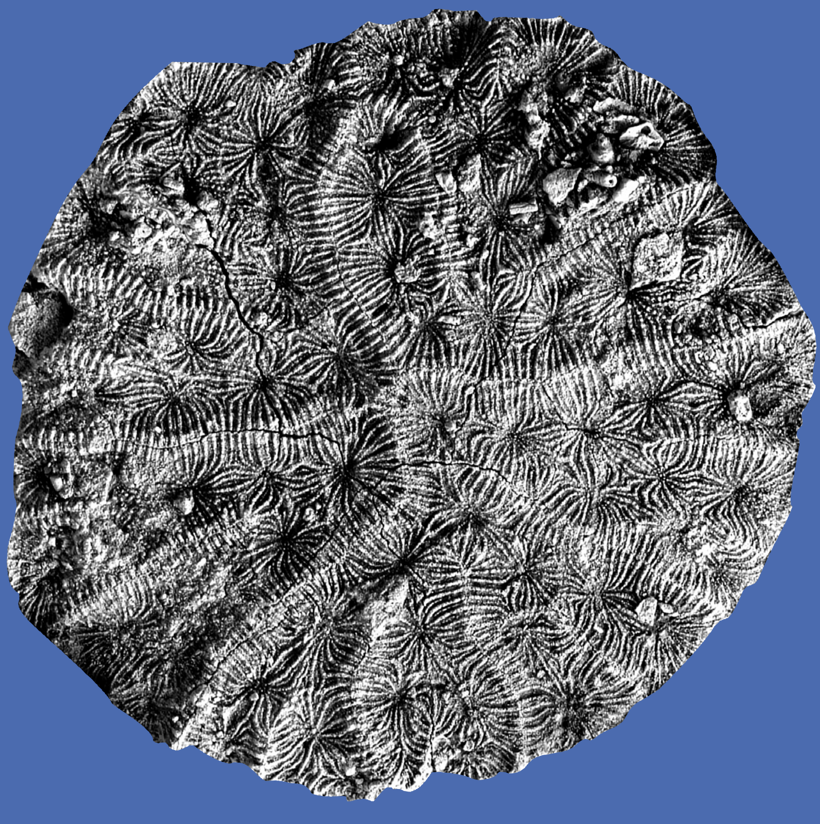
für Paläontologie und Geologie

**46**



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**Cover Illustration**: Coral *Collignonastraea meandra* (d´Orbigny, 1850) from the Toarcian (Lower Jurassic) of the Kuh-e-Shisui area (Iran); PIW2004III 40. For details see Pandey & Fürsich: Jurassic corals from the Shemshak Formation of the Alborz Mountains, Iran, pp. 41-74 in this issue.

**Umschlagbild**: Koralle *Collignonastraea meandra* (d´Orbigny, 1850) aus dem Toarcium (Unterjura) der Gegend um Kuh-e-Shisui (Iran); PIW2004III 40. Für weitere Infomationen siehe Pandey & Fürsich: Jurassic corals from the Shemshak Formation of the Alborz Mountains, Iran, S. 41–74 in diesem Heft.

| Zitteliana | A46 | 41-74 | 3 Textfigs, 7 Pls, 20 Tabs | München, 31.12.2006 | ISSN 1612-412X |
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# Jurassic corals from the Shemshak Formation of the Alborz Mountains, Iran

By
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## Abstract

Nineteen taxa of scleractinian corals are described and figured from the Toarcian-Lower Bajocian part of the Shemshak Formation of the Alborz Mountains. Dominant taxa are *Isastrea, Microsolena, Trigerastraea, Periseris*, and *Collignonastraea*. Most of these corals occur near the top of the formation (Lower Bajocian), close to the top of a large-scale shallowing cycle. Scattered specimens are found in transgressive lags of small-scale parasequences in the Toarcian part of the succession. Corals are very rare in the Shemshak Formation with the exception of Rian, NE of Semnan, where strongly reduced sedimentation rates facilitated the establishment of coral meadows and a patch reef in a mixed carbonate-siliciclastic setting on the crest of a tilted fault block.

**Key words:** Scleractinia, Jurassic, taxonomy, Shemshak Formation, Alborz Mountains

## Kurzfassung

Neunzehn Taxa der Scleractinia werden aus der Shemshak-Formation des Elburz-Gebirges beschrieben und abgebildet. Sie stammen aus dem Zeitraum Toarcium-unteres Bajocium und werden von den Gattungen *Isastrea, Microsolena, Trigerastraea, Periseris*, und *Collignonastraea* dominiert. Die meisten Korallen finden sich dicht unter dem Top der Formation, im obersten Abschnitt eines großen Verflachungszyklus. Vereinzelt treten Korallen auch in transgressiven Ästen von Parasequenzen des Toarcium auf. Korallen sind sehr seltene Elemente der Benthosfauna der Shemshak-Formation, außer in Rian, nordöstlich Semnan, wo sich aufgrund stark reduzierter Nettosedimentation am Top einer rotierten Scholle Korallenrasen und Fleckenriffe auf einem gemischt karbonatisch-siliziklastischen Substrat etablieren konnten.

**Schlüsselwörter:** Scleractinia, Jura, Taxonomie, Shemshak-Formation, Elburz-Gebirge

## 1. Introduction

Taxonomic work on Jurassic corals from Iran is scanty. Flügel (1966) was the first to describe the coral fauna of a small Middle Jurassic patch reef from the eastern margin of the Tabas Block. He identified 18 taxa based on limited material that was made available to him by Stöcklin. Based on extensive field collections Pandey & Fürsich (2003) described and figured 92 taxa of scleractinian corals from east-central Iran, spanning the Toarcian to Kimmeridgian time interval. The corals occur scattered or form small patch reefs, partly in association with microbial crusts, in siliciclastic settings but are surprisingly rare on the extensive carbonate platform (Esfandiar Limestone Formation) that extended along the eastern margin of the Tabas Block. Corals have not been recorded from the Shemshak Formation of the Alborz Range to date because they represent a very rare element of the benthic fauna. During field work in the eastern and central Alborz Mountains in the years 2002–2006, more than 100 coral specimens have been collected; they form the basis of the present study. By describing and figuring this coral fauna we contribute to the knowledge of the biota of the Shemshak Formation and close a gap in our understanding of the distribution pattern of corals along the northern margin of the Tethys during the Jurassic.

## 2. Geological framework

The Shemshak Formation (Upper Triassic–Lower Bajocian) of the Alborz Mountains represents a massive pile of siliciclastic sediments, which may reach up to 4000 m in thickness. The formation is widespread not only along the Alborz Range, but also across other parts of the Iran Plate (Textfig. 1; Seyed-Emami et al. 2001). Originally it was interpreted as the fill of a foreland basin that existed south of the rising Cimmerian mountain range (e.g., Stöcklin 1974; Alavi 1996), produced by collision of the Iran Plate with the Turan Plate (part of Eurasia) during the early Late Triassic (the so-called Early Cimmerian Orogeny). New investigations produced a more

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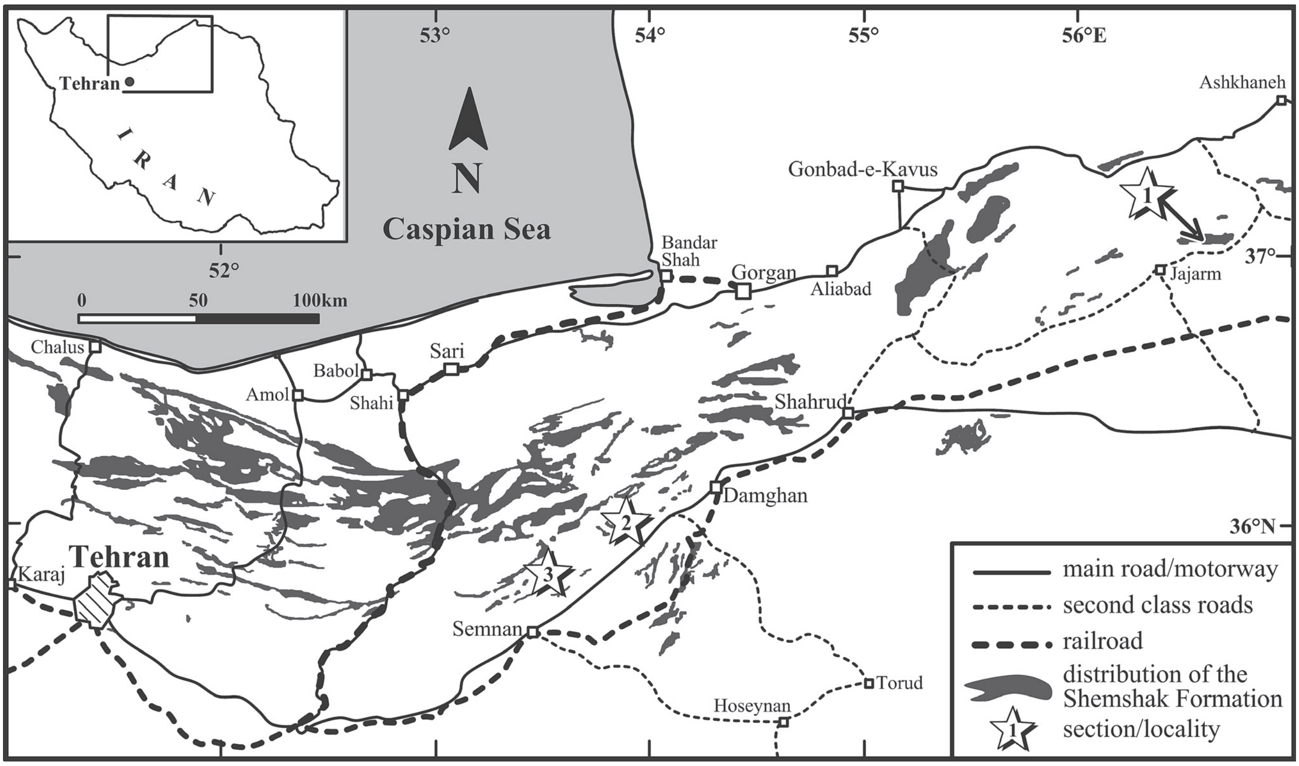
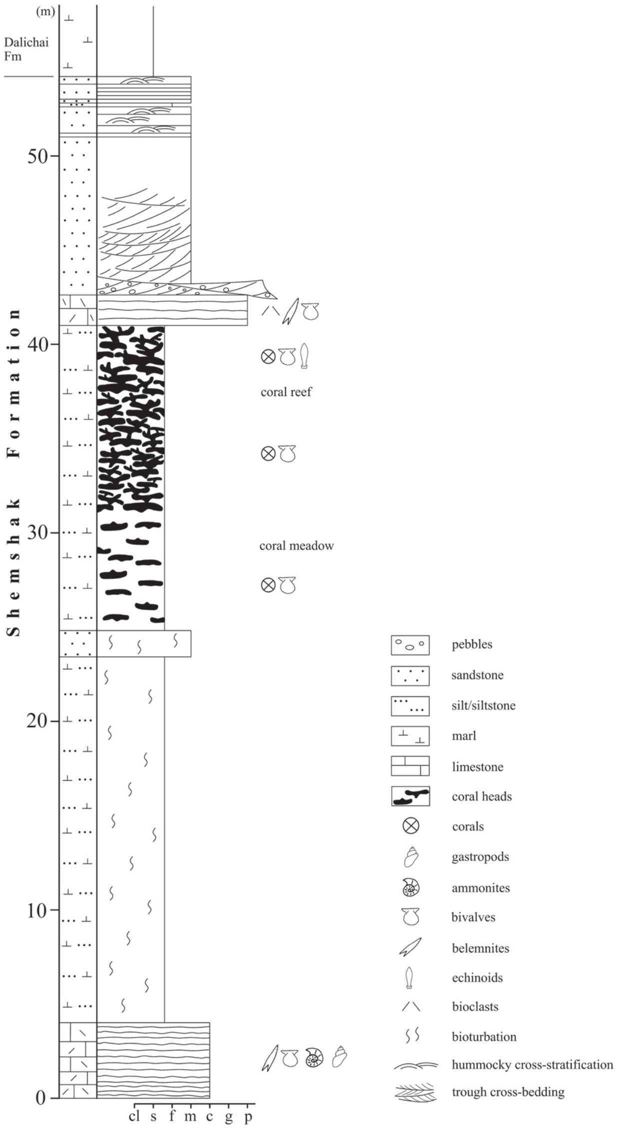



**Textfigure 1:** Distribution of the Shemshak Formation in the Alborz Mountains with position of coral localities. 1: Golbini; 2: Rian; 3: Sharif-Abad.

complex scenario for the evolution of the basin in which the sediments of the Shemshak Formation were deposited (Fürsich et al. 2005, 2006). It appears that, in the northern part of the present-day Alborz Range, a remnant of the Palaeotethys persisted during the Late Triassic. This remnant basin was deeper in the north where low-energy carbonates and fine-grained argillaceous silts containing ammonites and the posidoniid bivalve *Halobia* accumulated and shallower to the south where marginal marine, fluvial and lacustrine conditions prevailed. Towards the end of the Triassic, the basin became gradually infilled. Around the Triassic-Jurassic boundary, final collision between the two plates resulted in increased uplift in the area of the southern part of the present-day Caspian Sea. This is indicated by a thick package of conglomerates (up to 1000 m thick) occurring in the northern part of the Alborz Mountains which, towards the south, grades into medium- and coarse-grained sandstones of fluvial origin. Still further south these sediments interfinger with shallow marine environments. This is the typical foreland-basin stage of the Shemshak Formation. The onset of extensional tectonic movements in the Toarcian, in combination with a global sea-level rise at that time, caused widespread marine transgression and led to deposition of fine-grained, partly organic-rich siliciclastic sediments, up to several 100 m thick, during the Aalenian, which can be interpreted as the fill of a young rift basin. The so-called Mid-Cimmerian tectonic movements around the Early-Late Bajocian boundary caused a shallowing of the basin with a return to marginal marine and fluvial conditions, before renewed deepening in connection with accelerated opening of the South Caspian Basin in the north set in. During the Late Bajocian, a carbonate system developed within the basin that persisted until the end of the Jurassic and, locally, into the Cretaceous. It consisted of basinal and slope sediments (Dalichai Formation), interspersed with carbonate platforms (Lar Formation) and deeper, somewhat condensed glauconitic limestones (Shal Formation), the latter present only in the western part of the Alborz Range.

The non-marine parts of the Shemshak Formation contain a rich flora (e.g., Fakhr 1977), whereas marine invertebrates in the marine part are generally scarce and often poorly preserved. It is solely in the Toarcian-Aalenian part of the succession that ammonites and bivalves are moderately common, associated with rare brachiopods, serpulids, and gastropods. Corals are extremely rare and largely confined to the Lower Bajocian top part of the formation where they occur as scattered individuals (e.g., at Golbini); a few individuals also occur within transgressive lags of small T-R cycles (parasequences) at Sharif-Abad (Textfig. 1). The only exception to this is a small coral patch reef that occurs at the top of the formation at Rian (N 35° 46´ 03´´, E 53° 39´ 03´´; see Textfig. 1).

At Rian, the top of the Shemshak Formation is, in contrast to most other localities, developed in a mixed carbonate-siliciclastic facies (Textfig. 2). Exposed are rubbly, bioclastic packstones containing the bivalves *Entolium*, *Ctenostreon*, *Homomya*, the gastropod *Pseudomelania,* and ammonites indicative of the Fallaciosum Zone (Upper Toarcian). These fossiliferous limestones are followed by bioturbated silty marls. Coral growth set in after deposition of a fine-grained sandstone. The change to silty marls must have gone hand in hand with a reduction in the rate of sedimentation that facilitated coral growth. The corals, above all colonial forms with a diameter of up to 30 cm, occur isolated whereby platy




**Textfigure 2:** Section through the top part of the Shemshak Formation at Rian with position of the coral meadow and patch reef. Cl: clay; s: silt; f: fine-sand; m: medium-sand; c: coarse-sand; g: gravel; p: pebbles; m: mudstone; w: wackestone; f: floatstone; p: packstone; g: grainstone; r: rudstone.

growth forms dominate. Apparently, they formed meadows on a comparatively soft sea floor. Up-section, coral density increases and after 6 m coral heads form a dense fabric, the background sediment becoming restricted to small pockets between the coral heads. This patch reef is dominated by three growth forms; dendroid to phaceloid (e.g., *Thecosmilia*), umbrella-shaped to globose (e.g. *Isastrea, Trigerastraea*), and platy (e.g., *Isastrea, Periseris, Collignonastraea, Microsolena*). Solitary forms are rare (*Montlivaltia*). Among the colonial taxa, *Isastrea, Microsolena, Periseris*, and *Collignonastraea* dominate. Altogether 16 taxa have been recorded from the patch reef, but the true species diversity is probably higher, because time for collecting the fauna was limited. For this reason, no quantitative collecting was conducted and only few ecological observations were made in the field.

Associated reef-dwelling organisms include the oyster *Actinostreon*, the pectinid *Chlamys,* and cidaroid echinoids, the latter represented by spines and some isolated plates. Most corals (78%; n = 51) are encrusted, but never occur in high density. Framework encrusters include serpulids (found on 42 % of the specimens), oysters (40%), thecideidinid brachiopods (36%), crustose bryozoans (10%), and sclerosponges (8%). Only 26% of the corals are bored; bivalve borings (*Gastrochaenolites*) are rare (6%), cylindrical borings (*Trypanites*) probably manufactured by polychaetes are more common (20%).

The reef grew in comparatively quiet water, judging from the low degree of skeletal debris and the fine-grained background sediment. The reef is overlain by rubbly biorudstones with abundant oyster and coral debris. Reef growth may have been abruptly terminated by the onset of high-energy conditions.

As can be seen from Textfig. 2, the rudstone is followed by a thin, trough cross-bedded conglomerate with quartz, lydite, limestone and sandstone pebbles, and oyster debris, which up-section grades into large-scale trough cross-bedded fine-grained sandstone. This in turn is overlain by hummocky cross-stratified sandstones. The marls of the Dalichai Formation follow with a sharp change in facies.

The conglomerate layer is interpreted as the expression of the Mid Cimmerian tectonic movements. Such conglomerates have been found nearly everywhere along the Alborz Mountains at this stratigraphic level. In other sections of the Shemshak Formation, the first ammonites above the conglomerate layer invariably belong to the Upper Bajocian, whereas those below the unconformity belong to the Lower Bajocian. Assuming that this picture also holds true of the Rian section, part of the Upper Toarcian, the Aalenian and the Lower Bajocian are represented by merely 40 m of sediment. This is in marked contrast to most other areas of the Alborz Range where thicknesses up to 800–900 m have been recorded for the same stratigraphic interval (e.g., Fürsich et al. 2005). The strongly reduced thickness at Rian could be explained by large-scale erosion at the Mid Cimmerian unconformity. While this may be true to some extent, the fact that the uppermost Shemshak Formation is represented by carbonate sediments and a prolific coral fauna points to strongly reduced siliciclastic influx. This would fit the position of the Rian area on top of a tilted fault block which was bypassed by much of the sediment delivered to the Shemshak Basin.

## 3. Material

106 specimens were available for study. Most of them come from the patch reef at Rian. Other material was obtained from the topmost Shemshak Formation (Lower Bajocian) at Golbini (N 37° 05´ 13´´, E 56° 44´ 41´´) and from the Toarcian part of the formation at Sharif-Abad (N 35° 42´ 42´´, E 53° 26´ 17´´) (Textfig. 1, Tab. 1). Three specimens of *Collignonastraea meandra* from the Toarcian of the Kuh-e-Shisui area, northern Lut Block, east-central Iran, have been included in the present study to better demonstrate the morphological character of the taxon.

The material has been deposited in the collections of the Institut für Paläontologie of Würzburg University (prefix PIW).

**Table 1:** List of corals from the Shemshak Formation of the eastern and central Alborz Mountains described and figured in the present paper. S.-A.: Sharif-Abad. For localities see Textfig. 1. Note that most taxa come from the coral meadow and patch reef at Rian.

| Taxon | Rian | Golbini | S.-A. |
|---|---|---|---|
| *Stephanastrea simonneliana* D´ORBIGNY | | | • |
| *Montlivaltia cornutiformis* GREGORY | • | | |
| *Montlivaltia caryophyllata* LAMOUROUX | • | | |
| *Thecosmilia trichotoma* (GOLDFUSS) | • | | |
| *Thecosmilia dichotoma* (KOBY) | • | | |
| *Thecosmilia langi* KOBY | • | | |
| *Thecosmilia magna* ÉTALLON | • | | |
| *Coenotheca zolleriana* QUENSTEDT | • | | |
| *Isatrea bernardiana* (D´ORBIGNY) | • | • | |
| *Isastrea propinqua* ÉTALLON | • | | |
| *Trigerastraea*? *ampakabensis* ALLOITEAU | | • | |
| *Thamnasteria mettensis* MILNE-EDWARDS & HAIME | • | | |
| *Thamnasteria iranensis* PANDEY & FÜRSICH | • | | |
| *Periseris elegantula* (D´ORBIGNY) | • | | |
| *Collignonastraea meandra* (D´ORBIGNY) | • | | • |
| *Ovalastrea* sp A | • | | |
| *Microsolena verdati* KOBY | • | | |
| *Microsolena ornata* KOBY | | • | |
| *Kobya crassolamellosa* GREGORY | • | | |

Abbreviations of measurements:

- c-c minimum distance between centers of corallites
- c'c' distance between centers of corallites within a series
- cf calicular fossa
- d diameter of corallites
- D diameter of corallum
- Dc density of costae per 2 mm (when not mentioned otherwise)
- Ds density of septa at the periphery (or where septa are almost parallel) per 2 mm (when not mentioned otherwise)
- Dt.c depth of calice
- Dt number of trabeculae at the distal margin of septa per 2 mm (when not mentioned otherwise); density of septa in parentheses refer to common range
- H height of corallum
- Lc length of collines: in case of a single measurement the value indicates maximum length
- Msp. morphospecies
- Ns number of septa; number of septa in parentheses refer to common range
- Shape shape of corallum
- Wc width of calicular series
- Wp width of peritheca

**Plate 1**

Fig. 1: *Montlivaltia cornutiformis* GREGORY, 1900 msp. from Rian. Scale bar 5 mm; PIW2006III 75. a: Side view showing curved corallum and very small traces of epitheca. Note slight distortion in the pattern of costae; b: calicular view.

Fig. 2: *Montlivaltia caryophyllata* LAMOUROUX, 1821 msp. from Rian. Side view showing curved corallum. Note epitheca with concentric folds. Scale bar 5 mm; PIW2006III 18.

Figs 3–4: *Thecosmilia trichotoma* (GOLDFUSS, 1826) msp. from Rian. Scale bar 10 mm. 3: Side view showing epitheca with concentric folds. Note trichotomous budding at 10 mm from the broken base and the three corallites growing in one plane; PIW2006III 68. 4. Specimen PIW2006III 21; a: side view showing epitheca with concentric folds. Note budding at 17 mm from the base and the three corallites growing in one plane, b: calicular view. Note rejuvenation in the central corallite.

Fig. 5: *Thecosmilia dichotoma* (KOBY, 1884) msp. from Rian. Side view showing epitheca with concentric folds. Note dichotomous budding. Scale bar 10 mm; PIW2006III 69.

Figs 6–8: *Thecosmilia langi* KOBY, 1884 msp. from Rian. Scale bar 10 mm. 6: Side view showing alternating thin and thick costae; PIW2006III 72. 7: Upper view showing at least five corallites; PIW2006III 77. 8: Upper view showing stage just about to bud; PIW2006III 71.

Fig. 9: *Stephanastrea simonneliana* D´ORBIGNY, 1850 from Sharif-Abad. Specimen PIW2006III 79. a: Small segment of the upper surface. Scale bar 10 mm, b: close-up view of upper surface showing a few calices. Note rings of pali in the center of calices. Scale bar 2.5 mm.

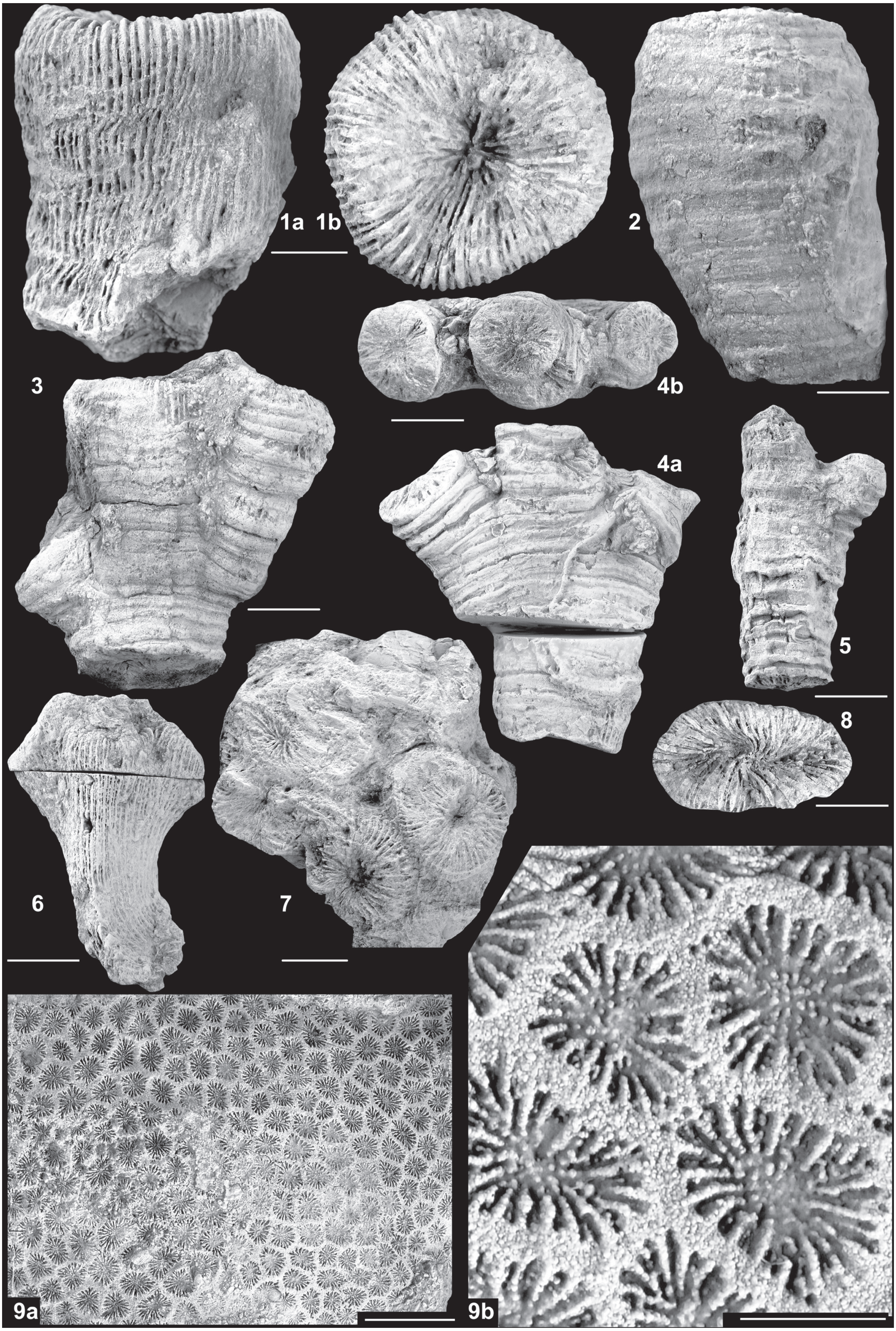

1a
1b
2
3
4b
4a
5
8
6
7
9a
9b

**Table 2:** Dimensions (in mm) of *Stephanastrea simonneliana* D'ORBIGNY

| Specimen | d | c-c | Ns | Ds/2 mm | Dt | Remarks |
|---|---|---|---|---|---|---|
| PIW2006III 79 | 2.2–4.0 | 2.0–4.3 | 29–35 | 9–10 | 5/0.5 mm | discoidal, cerioid with plocoid aspects |
| *Stephanastrea simonneliana* D'ORBIGNY of LATHUILIÈRE (2000a: 53, figs3.1–3.13) | | 1.2–3.8 | 18–48 | 6–11 | 8–14/mm | lamellar, thamnasterioid to subcerioid |
| (?) *Stephanastrea ramulifera* ÉTALLON of MORSCH (1996: 676, pl. 83, fig. 1a–e) | 1.5–2.5 | 1.5–2.5 | 16–24 | 4–6 | – | ramose, cerioid with plocoid aspects |
| *Stephanastrea ramulifera* ÉTALLON (1864: 402, pl. 57, fig. 2) | 1.5 | | three complete cycles | – | – | ramose, cerioid (=*Actinastrea ramulifera* according to ROSENDAHL 1985: 32) |
| *Stephanastrea montuosa* BEAUVAIS (1966: 990, pl. 1, fig. 1) | 0.8–2.2 | 1–2 | 22–32 | – | – | globulose, cerioid (= junior synonym of *simonneliana*) |
| *Stephanastrea montuosa* BEAUVAIS (1966: 990, pl. 1, fig. 2) | 1–2 | 1–2 | 22–27 | – | – | globulose, cerioid (= junior synonym of *simonneliana*) |
| *Stephanastrea jurassica* (RONIEWICZ 1976: 35, pl. 1, figs 1–5a,b, textfig. 1) | 1.5–2 | 1.5–2 | 24–35 | – | – | cerioid with plocoid or sub-thamnasterioid aspects |

## 4. Taxonomy

Class Anthozoa EHRENBERG, 1834
Subclass Zoantharia DE BLAINVILLE, 1830
Order Scleractinia BOURNE, 1900
Suborder Archaeocoeniina ALLOITEAU, 1952
(nom. corr. ex Archeocaeniida ALLOITEAU, 1952)
Family Actinastraeidae ALLOITEAU, 1952

Genus *Stephanastrea* ÉTALLON, 1864
Type species *Stephanastrea ramulifera* ÉTALLON, 1864

*Stephanastrea simonneliana* D´ORBIGNY, 1850
Pl. 1, Fig. 9a,b

1850 *Synastrea simonneliana* sp. nov. – D´ORBIGNY: 293.
1850 *Stephanocoenia bernardiana* sp. nov. – D´ORBIGNY: 292 [according to LATHUILIÈRE 2000a].
1966 *Stephanastrea montuosa* sp. nov. – BEAUVAIS: 990, pl. 1, figs 1–2.
2000a *Stephanastrea simonneliana* D'ORBIGNY – LATHUILIÈRE: 53, figs 3.1–13 [cum syn.].

Material: Three specimens from the Shemshak Formation at Sharif-Abad (PIW2006III 79-81).
Dimensions: see Table 2.

Description: Corallum colonial, discoidal, cerioid to subplocoid. Upper surface moderately arched, lower surface covered with very fine costae. Corallites distinct, small, moderately deep, hexagonal, pentagonal, tetragonal to subcircular, bordered by thick septo-parathecal wall. Number of corallites increasing by intracalicular budding. Occasionally, when a pentagonal and a subcircular corallite lie next to each other the corners are filled up with costae and dissepiments giving the appearance of a plocoid growth structure. Septa compact to subcompact, alternatively thick, long and thin, small, anastomosing with pronounced denticles along the distal margin. Trabeculae at the inner edge of the septa standing out separately, the innermost ones forming pali. Dissepiments common near the periphery of corallites. Columella parietal, papillose to spongy.

Remarks: The small, polygonal corallites with septo-parathecal wall and the position of trabeculae at the inner edge of the septa forming, albeit very poorly preserved, pali arranged in two rings around the parietal papillose columella, refer the present specimens to *Stephanastrea* ÉTALLON. The only puzzling character is the intercalicular budding in species of the genus as mentioned by a few earlier workers (WELLS 1956: F370; RONIEWICZ 1976: 36; LATHUILIÈRE 2000a: 55). However, BEAUVAIS (1966: 990) and MORSCH (1996: 676) have mentioned both inter- and intracalicular budding for the genus *Stephanastrea*.

Another comparable genus is *Allocoenia* ÉTALLON (1859), which possesses only one cycle of pali (BEAUVAIS 1964: 109, tab. 9). RONIEWICZ (1976: 36, pl. 1, fig. 6a,b) mentioned pali at the inner edge of the second cycle of septa. WELLS (1956: F437) placed *Allocoenia* in his list of unrecognizable genera. We believe that in such forms it is very difficult to determine whether pali are arranged in one or two rings. The dimensions of the present specimens are quite within the range of variation of *Stephanastrea simonneliana* D'ORBIGNY described and illustrated by LATHUILIÈRE (2000a), except that *S. simonneliana* is thamnasterioid to subcerioid. In contrast, the growth structure of the present specimens is cerioid with some traces of being plocoid. Changes in the colonial structures have been observed in many cases (e.g., LATHUILIÈRE 1989: 887; VERON 1995: 16; PANDEY et al. 2002: 350; PANDEY & FÜRSICH 2003: 122), and have obviously been caused by environmental stress. *Stephanastrea montuosa* BEAUVAIS (1966) also exhibits a cerioid growth structure and has been considered a junior synonym of *S. simonneliana* D´ORBIGNY by LATHUILIÈRE (2000a).

Suborder Faviina VAUGHAN & WELLS, 1943
(nom. corr. ex Faviida VAUGHAN & WELLS, 1943; after WELLS 1956)
Family Montlivaltiidae DIETRICH, 1926, emend. ALLOITEAU, 1952

Remarks: The present specimens display forms transitional from *Montlivaltia* to *Thecosmilia* as earlier recorded by LATHUILIÈRE (1996a, 1996b). Therefore, the following montlivaltiid genera are regarded as morphological units and not as phyletic genera.

Morphogenus *Montlivaltia* LAMOUROUX, 1821
Type species *Montlivaltia caryophyllata* LAMOUROUX, 1821

*Montlivaltia cornutiformis* GREGORY, 1900 msp.
Pl. 1, Fig. 1a,b

1900 *Montlivaltia cornutiformis* sp. nov. – GREGORY: 85, pl. 4, figs 5–8, pl. 5, figs 1–3, pl. 9, fig. 11.
2003 *Montlivaltia cornutiformis* GREGORY – PANDEY & FÜR SICH: 35, pl. 8, figs 1–3 [cum syn.].

Material: Two specimens from the top of the Shemshak Formation at Rian (PIW2006III 19, 75).
Dimensions: see Table 3.
Description: Corallum solitary, curved, short, tapering towards broken attachment area. Calice moderately deep, subcircular in outline. Septa compact, thin or thick, lateral surfaces ornamented with very small granules. Distal margin of septa asymmetrically curved with the maximum projection at the periphery. Dissepiments abundant. Columellar cavity small, elongated. Wall parathecal. Epitheca thin.
Remarks: One of the specimens (PIW2006III 75) was found in association with *Thecosmilia*. In morphological characters it looks like a broken branch of *Thecosmilia* but since it does not show any sign of further budding it cannot be associated with *Thecosmilia*. The other specimen (PIW2006III 19) exhibits concentric folds on the epitheca.
The transverse section near base is circular to subcircular. The distal margins of the septa are mostly truncated. The shape of the corallum, the asymmetric curvature of the distal margin of the septa with maximum projection at the periphery, and the elongated outline of the columellar cavity closely match specimens from the upper Baghamshah Formation of east-central Iran, assigned to *Montlivaltia cornutiformis* (GREGORY) by PANDEY & FÜRSICH (2003).

*Montlivaltia caryophyllata* LAMOUROUX, 1821 msp.
Pl. 1, Fig. 2

1821 *Montlivaltia caryophyllata* sp. nov. – LAMOUROUX: 78, pl. 79, figs 8–10.
2003 *Montlivaltia caryophyllata* LAMOUROUX – PANDEY & FÜRSICH: 32, pl. 7, figs 1–8, pl. 9, fig. 5 [cum syn.].

Material: One specimen from the top of the Shemshak Formation at Rian (PIW2006III 18).
Dimensions: see Table 4.
Remarks: The morphological characters and the dimensions of the specimen closely fit *Montlivaltia caryophyllata* LAMOUROUX described from Bathonian to Lower Callovian rocks of east-central Iran (PANDEY & FÜRSICH 2003). The inner edges of septa extend beyond the axial part and produce the appearance of a columella. The septal density is slightly higher in the present specimen than in the material from east-central Iran. Both features can be attributed to rejuvenation of the corallum after attaining a height of about 14 mm.

Morphogenus *Thecosmilia* MILNE-EDWARDS & HAIME, 1848
Type species *Lithodendron trichotomum* GOLDFUSS, 1826

Remarks: According to BARON-SZABO (2002: 44), the type specimen kept in the Goldfuss collection in Bonn is missing. Therefore she created as neotype another specimen from the

**Table 3:** Dimensions (in mm) of *Montlivaltia cornutiformis* GREGORY

| Specimen | H | D | Ns | Ds | Dt.c | cf |
|---|---|---|---|---|---|---|
| PIW2006III 75 | 22.8 | 18 | 87 | 4/2 (Dc: 5/2) | 3 | 1 |
| | mid height | 20 | – | – | – | – |
| | base (broken) | 14 | – | – | – | – |
| PIW2006III 19 | 43 | 21.2 | >69 | 4/2 (Dt: 5/2) | 1 | – |

**Table 4:** Dimensions (in mm) of *Montlivaltia caryophyllata* LAMOUROUX

| Specimen | D | H | Ns | Ds/2 | Cf | shape |
|---|---|---|---|---|---|---|
| PIW2006III 18 | 13 | 26.5 | 51 | 5–6 | Nil | Curved |
| | 17.5 | 14 | – | – | – | – |
| | 10 | base broken | – | – | – | – |

Goldfuss collection (no. 32), which closely resembles the type specimen (BARON-SZABO 2002: pl. 27, figs 1–4).

*Thecosmilia trichotoma* (GOLDFUSS, 1826) msp.
Pl 1, Figs 3, 4a,b, Textfig. 3

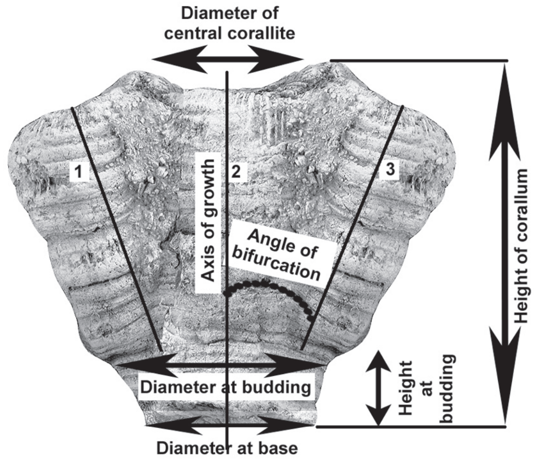
1826 *Lithodendron trichotomum* sp. nov. – GOLDFUSS: 45, pl. 13, fig. 6.
1884 *Thecosmilia trichotoma* MÜNSTER – KOBY: 168, pl. 45, figs 1–2.
1875 *Thecosmilia trichotoma* (GOLDFUSS) – BECKER & MILASCHEWITSCH: 152, pl. 38, figs 1–5.
1954 *Thecosmilia trichotoma* (GOLDFUSS) – GEYER: 180 [cum syn.].
non 1960 *Thecosmilia trichotoma* (GOLDFUSS) – RONIEWICZ: 454, pls 1–2, pl. 3, figs 1–2 [according to ELIÁŠOVÁ 1976].
1976 *Thecosmilia trichotoma* (GOLDFUSS) – ELIÁŠOVÁ 1976: 169, pl. 4, fig. 2.
1968 *Thecosmilia trichotoma* (GOLDFUSS) – LAMBELET: 125, figs 60–66.
1985 *Thecosmilia trichotoma* (GOLDFUSS) – ROSENDAHL: 47.
1991 *Thecosmilia trichotoma* (GOLDFUSS) – LAUXMANN: 146 [cum syn.].
1993 *Thecosmilia trichotoma* (GOLDFUSS) – BERTLING: 90, pl. 2, figs 3–4 [cum syn.].
1994a *Thecosmilia trichotoma* (GOLDFUSS) – ELIÁŠOVÁ: 67, pl. 2, figs 1–4.
1997 *Thecosmilia trichotoma* (GOLDFUSS) – TURNŠEK: 206, figs a–c [cum syn.].
2002 *Thecosmilia trichotoma* (GOLDFUSS) – BARON-SZABO: 43, pl. 27, figs 1–4.

Material: Two specimens from the top of the Shemshak Formation at Rian (PIW2006III 21, 68).

Dimensions: see Table 5.

Description: Corallum colonial, short, total height ranging from 46–48.3 mm, branching simultaneously into three corallites after a growth of 10 to 17 mm. Corallites mostly in one plane. Branches forming an angle of up to 20° with the axis. Corallites circular to oval in outline. Calices shallow to almost flat. Septa compact, lamellar, of *Montlivaltia*-type, arranged in at least five to six incomplete cycles, mostly alternating thin and thick, those of first two cycles almost equal in thickness, nearly reaching the center leaving a narrow columellar cavity, occasionally anastomosing at the inner edge. Third to fifth cycle increasingly shorter, but not much different in thickness. Distal margin of primary septa arching. Carinae with fan-shaped pattern (density at the distal margin 4 per 2 mm). Dissepiments common. Budding intracalicular. Holotheca thick, with concentric folds, where weathered showing costae.

Remarks: Rejuvenation can be seen in one of the specimens (PIW2006III 21). All four specimens show the characteristic features of *Thecosmilia* such as intracalicular budding, dendroid to phaceloid colonial forms, *Montlivaltia*-like septa and common endothecal vesicular dissepiments. Table 5, giving the dimensions of various species of *Thecosmilia* described by earlier workers, documents a wide range of variation. Most of this variation is ecophenotypic. Based on descriptions by earlier workers, the most common features of *Thecosmilia* can be rewritten as follows:




**Textfigure 3:** *Thecosmilia trichotoma* (GOLDFUSS) msp. of Pl. 1, Fig. 3 showing various dimensions. Note the simultaneous growth of the three corallites.

1. Corallum: colonial, dendroid to phaceloid.
2. Height of the colony: small to great in the same species depending upon duration of environmental setting favourable for coral growth (LATHUILIÈRE 1996a).
3. Distomodaeal or tristomodaeal budding. The pattern of branching and angle of bifurcation should not be considered as a specific character, because it is most likely also influenced by environmental parameters. There is not much difference in the height of budding in the different species of *Thecosmilia* (Tab. 5).
4. Presence of thin or thick epitheca is a function of environmental conditions including the presence of microbiota interacting with the outer coral skeleton (RONIEWICZ & STOLARSKI 1999: 160).
5. The diameter of the corallites is to some extent genetically determined, but also influenced by the water-energy/grain size (WIJSMAN-BEST 1972: 17; VERON 2000: 101; PANDEY & FÜRSICH 2001: 494). Otherwise, in the same colony, the diameter of all corallites of similar age would have been similar.

**Table 5:** Dimensions (in mm) of *Thecosmilia trichotoma* (GOLDFUSS) (see also Textfig. 3)

| Specimen | H and characteristic morphological features | d | Ns | Ds |
|---|---|---|---|---|
| PIW2006III 21 | 46<br>17 at budding<br>14 before budding<br>base | 9.8–14.4<br>27.2<br>21<br>16.6 | 44–65<br>–<br>77<br>– | 5–6/2<br>–<br>3–4/2<br>– |
| PIW2006III 68 | 48.3<br>>10 at budding<br>broken base | 13.6–24<br>25<br>21 | Ca 70<br>–<br>– | 4/2<br>–<br>– |
| *Thecosmilia trichotoma* GOLDFUSS of BECKER & MILASCHEWITSCH (1875: 152, pl. 38, figs 1–5) | corallites more or less at same height, not in one plane | 13/11<br>18/13<br>18/15<br>23/17<br>20/17<br>22/20 | 53<br>66<br>84<br>87<br>91<br>91 | –<br>–<br>–<br>–<br>–<br>– |
| *Thecosmilia trichotoma* MILNE-EDWARDS & HAIME of ÉTALLON (1864: 386, pl. 55, fig. 2) | 100, a few corallites, epitheca thick | 15–28 | 30–45 | – |
| *Thecosmilia trichotoma* MÜNSTER of KOBY (1884: 168, 454, pl. 45, figs 1–2) | 40–50, corallites more or less at same height, rapidly bifurcating, not in one plane | 15–18 | 80–90 | 18–20/10 |
| *Thecosmilia trichotoma* (GOLDFUSS) of RONIEWICZ (1960: pls 1–2, pl. 3, figs 1–2) | ?300 | 18–28 | 70–127 | 8–9/5 |
| *Thecosmilia trichotoma* (GOLDFUSS) of ELIÁŠOVÁ (1976: 169, pl. 4, fig. 2) | – | 10–19 | 78–92 | 5–6/2 |
| *Thecosmilia trichotoma* (GOLDFUSS) of ROSENDAHL (1985: 47) | – | 10–20 | 70–90 | 8–9/5 |
| *Thecosmilia trichotoma* (GOLDFUSS) of LAUXMANN (1991: 146) | – | 10–23 | 50–106 | – |
| *Thecosmilia trichotoma* (GOLDFUSS) of BERTLING (1993: 90) | diameter of the colony 100–300 | – | 100 | 7–9/5 |
| *Thecosmilia trichotoma* (GOLDFUSS) of ELIÁŠOVÁ (1994a: 67, pl. 2, figs 1–4) | – | 11–22 | 50–100 | 6–8/5 |
| *Thecosmilia? dichotoma* (KOBY 1884: 175, pl. 46, figs 4–8) | 300–500 | 5–15 | – | 8/5 |
| *Thecosmilia dichotoma* KOBY 1864 of GEYER (1954: 182, pl. 14, fig. 15) | colony phaceloid, long, epitheca thick | 8–15 | 45–65 | costae 8/5 |
| *Thecosmilia dichotoma* KOBY of LAUXMANN (1991: pl. 6, fig. 10) | thin corallites | 7.5–13/9–16 | 45–63 (5 cycles) | – |
| *Thecosmilia dichotoma* KOBY (ROSENDAHL 1985: 47, pl. 1, fig. 7) | – | 6–12 | 40–60 | 10/5 |

Tab. 5 cont.

| | | | | |
|---|---|---|---|---|
| *Thecosmilia irregularis* ÉTALLON (THURMANN & ÉTALLON 1864: 384, pl. 54, fig. 9) | corallites are in different planes and at different height with higher angle of branching; height at budding: 20–30 mm | 6–18 | 5 full cycles | – |
| *Thecosmilia irregularis* ÉTALLON of GEYER (1954: 181, pl. 54, figs 13–14) | corallites are at different height | 8–15 | 4 full cycles | 8–9/5 |
| *Thecosmilia irregularis* ÉTALLON of LAUXMANN (1991: 148, pl. 6, fig. 9) | colony short, 45º divergence | 6–9/7.5/13 | 44–58 | |
| *Thecosmilia magna* ÉTALLON (1864: 385, pl. 54, fig. 11) | 150; rapidly budding at a height of 30–40 mm | 12 | 5 cycles, 80 | costae: 32 |
| *Thecosmilia magna* THURMANN of KOBY (1884: 166, pl. 44, figs 1–3) | 100–200, several branches, budding at 30 mm | 12–18 | – | costae: 18/10 |
| *Thecosmilia magna* THURMANN 1864 of GEYER (1954: 181) | colony phaceloid, long | 12–20 | 4 full cycles | 7–8/5 |
| *Thecosmilia pauciseptata* ERRENST (1990: 188, pl. 9, fig. 1) | septa thin and comparatively few | 9–12 (c-c: 13–22) | 18–24 | – |
| *Thecosmilia longimana* QUENSTEDT of ERRENST (1990: 188, pl. 9, fig. 2) | phaceloid, abundant dissepiments, branches not in one plane | 11–16 (c-c: 14–20) | 52–ca. 80 | – |
| *Thecosmilia langi* KOBY 1884 (161, pl. 49, figs 1–9) | 50–70, more than three branches, budding intracalicular, not in one plane, irregular, colony thamnasterioid to dendroid | 10–30 | – | costae: 13–14/ 10 |
| *Thecosmilia langi* KOBY of RONIEWICZ (1976: 63, pl. 11, fig. 2a,b) | – | 3.5/2.5 | 116–140 | 4/5 |
| *Thecosmilia langi* KOBY of ERRENST (1990: 189, pl. 9, fig. 3) | colony irregular, thamnasterioid to dendroid, intracalicular budding, not in one plane | 20–27 (c-c: 20–26) | ca.70 | – |
| *Thecosmilia langi* KOBY of PANDEY & FÜRSICH (2003: 48, pl. 14, fig. 1) | – | 9–10 (c-c:10) | 58–73 | 5–6/2 |
| *Thecosmilia bruntrutana* ÉTALLON (1864: 383, pl. 54, fig. 7) | angle of bifurcation 60º, not in one plane, height at budding 25–35 mm, columella: spongy | at budding 15–25 at the base 10 | 60–70 | – |
| *Thecosmilia crassa* D´ORBIGNY of ÉTALLON (1864: 383, pl. 54, fig. 8) | 100–120, few branches, angle of bifurcation more than 20º, columella: spongy | 12–18 | 90 costae | – |
| *Thecosmilia laxata* ÉTALLON (1864: 384, pl. 54, fig. 10) | 150, few branches, not in one plane, height at budding 30–60 mm, columella: spongy | 10–15 | 80 | – |
| *Thecosmilia sublevis* ÉTALLON (1864: 385, pl. 54, fig. 1) | 5–600, not in one plane, height at budding 100 mm | 5–25 | 5 cycles | – |

Tab. 5 cont.

| | | | | |
|---|---|---|---|---|
| *Thecosmilia costata* FROMENTEL of KOBY (1884: 169, pl. 45, figs 3–4, pl. 55, figs 9–17, pl. 59, figs 4–7) | 200–300, a few corallites | 10–30 | – | 16/10 |
| *Thecosmilia jaccardi* KOBY (1884: 171, pl. 45, figs 5, 7–8, 10–11) | 100, a few corallites | 20 | – | 14/10 |
| *Thecosmilia jaccardi* KOBY, 1884 of BEAUVAIS (1966: 1001) | lectotype | 12.5 | – | Dc 2–3/2 |
| | Fig. 7 of KOBY Dt 5/2mm | 9–16 | | Dc 2–3/2 |
| | Fig. 8 of KOBY | 20–28 | | Dc 2–3/2 |
| | Fig. 10 of KOBY | 13–20 | | Dc 3/2 |
| | Fig. 11 of KOBY | 10–15 | | Dc 3/2 |
| *Thecosmilia* mg *zolleriana* morphe *jaccardi* (QUENSTEDT) of LATHUILIÈRE (2000a: 68, figs 10.5, 7, 8) | 500, phaceloid, branches form angles of 90–130º | 14–16 | 70 | 7–8/5 |
| | | 11–17 | 67 | 7–8/5 |
| | | 15–20 | 79 | 7/5 |
| | | 20–22 | 74 | 5–7/5 |
| | | 18 | ? | 7–8/5 |
| | | 8.9–18.5 | 36–76 | 6–7/5 |
| *Thecosmilia*? *plicata* (KOBY 1884: 174, pl. 46, figs 1–2) | 150–200, corallites subcylindrical, epitheca thick | 10–15 | – | 18/10 |

The original illustration of *Lithodendron trichotomum* given in GOLDFUSS (1826: 45, pl. 13, fig. 6) shows that the corallum, which primarily branched into two, exhibits three cases of simultaneous budding in both branches. This clearly suggests that the corallum was dichotomous at an early stage of astogeny and became trichotomous at a later stage. With respect to the height at which budding takes place and the number of corallites which bud simultaneously, the diameter of corallites and number of septa are quite close to *Thecosmilia trichotoma* described by KOBY (1884), even though in KOBY´s material the angle of branching is slightly higher. *Thecosmilia trichotoma* as figured by BECKER & MILASCHEWITSCH (1975) shows a larger number of corallites. *Thecosmilia trichotoma* described by RONIEWICZ (1960) shows a cluster of colonies, each individual budding into up to three corallites. KOBY (1884: 167) and GEYER (1954: 181) did not include *Thecosmilia trichotoma* MILNE-EDWARDS & HAIME of ÉTALLON (1864: 386, pl. 55, fig. 2) in their list of synonymies, perhaps because it simultaneously buds into four.

*Thecosmilia dichotoma* KOBY and *T. jaccardi* KOBY exhibit a low number of septa and a lower septal density in comparison to *T. trichotoma* (Tab. 5). *Thecosmilia magna* ÉTALLON buds rapidly and therefore possesses several branches. *Thecosmilia irregularis* ÉTALLON buds irregularly. *Thecosmilia langi* KOBY is also similar to *T. irregularis* with respect to budding but has a smaller angle of branching. *Thecosmilia longimana* QUENSTEDT (ERRENST 1990) and *Thecosmilia langi* KOBY exhibit similar septa and dissepiments. LAUXMANN (1991: 146) and BERTLING (1993: 90) considered *T. longimana* QUENSTEDT (1881: 697, pl. 170, fig. 17) as a junior synonym of *T. trichotoma*. Considering all the specimens of *T. langi* illustrated by KOBY, it is unlikely that *T. langi* represents a separate species. However, until the type material has been restudied *T. langi* is regarded as a separate species (see below). *Thecosmilia bruntrutana* ÉTALLON, *Thecosmilia laxata* ÉTALLON, and *Thecosmilia crassa* D'ORBIGNY show an angle of branching greater than 20º. *T. laxata* also shows a wider range in the height of budding (30–60 mm). *Thecosmilia sublevis* ÉTALLON buds at 100 mm height, much higher than most of the species mentioned above. *Thecosmilia costata* FROMENTEL shows well-developed uniform costae. A thin holotheca is present in one of the specimens (KOBY 1884: pl. 55, fig. 9). *Thecosmilia*? *plicata* KOBY is phaceloid, long and possesses a greater number of corallites.

*Thecosmilia dichotoma* (KOBY, 1884) msp.
Pl. 1, Fig. 5

non 1826 *Lithodendron dichotomum* sp. nov. – GOLDFUSS: 44, pl. 13, fig. 3 (= *Cladophyllia*, according to GEYER 1954: 182).
1884 *Thecosmilia dichotoma* sp. nov. – KOBY: 175, pl. 46, figs 4–8.
1897 *Thecosmilia koniakensis* sp. nov. – OGILVIE: 201, pl. 14, fig. 1.
1954 *Thecosmilia? dichotoma* KOBY – GEYER: 182, pl. 14, fig. 15 [cum syn.].
1966 *Thecosmilia dichotoma* KOBY – RONIEWICZ: 212, pl. 12, fig. 3.
1972 *Thecosmilia dichotoma* KOBY – TURNŠEK: 175, pl. 13, figs 3–4.
1974 *Thecosmilia dichotoma* KOBY – MORYCOWA: 466, pl. 5, fig. 1.
1976 *Thecosmilia dichotoma* KOBY – ELIÁŠOVÁ: 169, pl. 1, fig. 2.
1985 *Thecosmilia dichotoma* KOBY – ROSENDAHL: 47, pl. 1, fig. 7.
1989 *Thecosmilia dichotoma* KOBY – BEAUVAIS: 269, pl. 66, fig. 2.
1991 *Thecosmilia dichotoma* KOBY – LAUXMANN: 149, pl. 6, fig. 10.
1991 *Thecosmilia dichotoma* KOBY – LEBANIDZE: 21, pl. 7, fig. 2.
1997 *Thecosmilia dichotoma* KOBY – TURNŠEK: 204, figs a–d [cum syn.]

**Table 6:** Dimensions (in mm) of *Thecosmilia dichotoma* (Koby)

| Specimen | H | d | Ns | Ds/2 mm |
|---|---|---|---|---|
| PIW2006III 69 | 40.5 | 6.4–9.0 | 31–56 | 8 |
| | 23 at 2nd budding | 16.7 | – | – |
| | 15 at 1st budding | 15.6 | – | – |
| | base | 12.4 | 50 | 4 |

Material: One specimen from the top of Shemshak Formation at Rian (PIW2006III 69).

Dimensions: see Table 6.

Remarks: The morphological features of this specimen are similar to those described above as *Thecosmilia trichotoma* except for the budding. In the present specimen the budding is dichotomous, whereas in *T. trichotoma* it is trichotomous. The diameter of the corallites is also lower (Lauxmann 1991: 149), although the ranges overlap. *Thecosmilia dichotoma* figured by Koby (1884: 175, pl. 46, figs 4–8) are bigger colonies than the juvenile one described here.

Apparently, the figures of *Thecosmilia plicata* Koby (1884: 174, pl. 46, figs 1–2) look similar. According to Koby, the corallites are long and subcylindrical and the species differs from others by smaller, irregular branches. However, there appears to be no difference to *Thecosmilia dichotoma*. Bendukidze (1982: 50) considered *T. plicata* Koby as a junior synonym of *T. dichotoma*. *T. dichotoma* Koby from the Aptian of central Greece illustrated by Baron-Szabo (2002: 43, pl. 28, figs 1–3) shows at least three polyp centers. Therefore, it cannot be included in this species.

*Thecosmilia langi* Koby, 1884 msp.
Pl. 1, Figs 6–8

1884 *Thecosmilia langi* sp. nov. – Koby: 161, pl. 49, figs 1–9.
1976 *Thecosmilia langi* Koby – Roniewicz: 63, pl. 11, fig. 2a,b.
1990 *Thecosmilia langi* Koby – Errenst: 189, pl. 9, fig. 3.
2003 *Thecosmilia langi* Koby – Pandey & Fürsich: 48, pl. 14, fig. 1.

Material: 5 specimens from the top of the Shemshak Formation at Rian (PIW2006III 70–72, 74, 77).

Dimensions: see Table 7.

Description: Colonies phaceloid to dendroid, height ranging from 18–44.5 mm, colony in plan view circular to oval. Corallites more or less oval to subcircular. Budding intracalicular, into two to four corallites, irregularly to more or less simultaneously, angle of bifurcation up to 20° from the axis. Calice shallow to almost flat. Septa compact, lamellar, of the *Montlivaltia*-type, alternating between thin and thick, those of the first two cycles of equal thickness, occasionally anastomosing and twisted, reaching the center leaving a small columellar area. Septa of higher cycles increasingly shorter and thinner. Lateral surfaces of septa covered with granules and spinules. Dissepiments common. Budding intracalicular. Holotheca thick, with concentric folds, showing costae where weathered.

Remarks: The interior of all specimens is recrystallized. The twisted nature of the septa can be related to the budding. The various shapes of the colonies as figured by Koby (1884), the thamnasterioid to dendroid relationship of the corallites, and the septal density all fall within the range of variation of *Thecosmilia langi* Koby.

There is some overlap with the morphological characters of *Thecosmilia trichotoma* Goldfuss, 1826, such as the diameter of the corallites, number of septa, and density of septa. However, the number of simultaneous buds is higher than three in *T. langi*. The septal density in *Thecosmilia jaccardi* Koby, 1884 is lower (2–3 per 2 mm). Septal density in the present

**Table 7:** Dimensions (in mm) of *Thecosmilia langi* Koby

| Specimen | H | d | Ns | Ds/2mm |
|---|---|---|---|---|
| PIW2006III 70 | 43.7 | 14–20 | 48 | 4 |
| | 19 at budding | 22.5 | | |
| | base | 14 | | |
| PIW2006III 71 | 38.3 at 2nd budding | 27.8/14.6 | 80 | 4 |
| | 17 at 1st budding | 12 | – | |
| | base | 11 | 46 | |
| PIW2006III 72 | 44.5 | 10–11.7 | – | 4 (costae 4–6) |
| | 28 at budding | 22.2 | 88 | |
| | base | 15 | | |
| PIW2006III 74 | 19.4 | 17.5 | >60 | 4 |
| PIW2006III 77 | 30 (c-c: 18–10) | 20/17, 19/17, 14, 10/17.5 | >56 | 3–4 (dt: 4/2) |

**Table 8:** Dimensions (in mm) of *Thecosmilia magna* ÉTALLON

| Specimen | H | D | c-c | Ns | Ds |
|---|---|---|---|---|---|
| PIW2006III 76 | 41 | 35.6/30, 20 | 21 | >78 | 3/2 |
| PIW2006III 78 | 17.5 | ~36 | ~15 | ~98 | 3–4/2 (dt: 6/2) |

specimens is either lower or higher than in other species of *Thecosmilia*. Apparently, the alternating thick and thin costae of *Thecosmilia gresslyi* KOBY (1884: 167, pl. 44, fig. 4) are similar to those in specimen PIW2006III 72, but their density (2 per 2 mm) differs.

*Thecosmilia magna* ÉTALLON, 1864 msp.
Pl. 2, Fig. 1a,b

1864 *Thecosmilia magna* sp. nov. – ÉTALLON: 385, pl. 54, fig. 11.
1884 *Thecosmilia magna* THURMANN – KOBY: 166, pl. 44, figs 1–3.
1954 *Thecosmilia magna* THURMANN – GEYER: 181 [cum syn.].

Material: Two specimens from the top of the Shemshak Formation at Rian (PIW2006III 76, 78).
Dimensions: see Table 8.
Description: Corallum short, rapidly budding. Colony phaceloid with parathecal wall between adjacent corallites. Corallites distinct, almost flat near the periphery but depressed in the central area. Septa compact, *Montlivaltia*-like, occasionally anastomosing.
Remarks: Occasional thamnasterioid costae on the upper surface produce the appearance of *Complexastrea*. The colony resembles *Montlivaltia dilatata* MICHELIN (KOBY: 120, pl. 39, fig. 4a,b, pl. 40, fig. 8), which also shows intracalicular budding, but has a lower septal density (10–12 per 10 mm). The calicular fossa in the Iranian specimens is small (in contrast to 4–5 mm in *M. dilatata*). Moreover, for *M. dilatata* no parathecal and epithecal walls between adjacent corallites have been mentioned. The general morphological characters of the specimens, including septal densities, match those of *Thecosmilia magna* ÉTALLON illustrated by KOBY (1884: 166, pl. 44, figs 1–3). *Thecosmilia magna* THURMANN of GEYER (1954: 181) has a much greater height. *Thecosmilia gresslyi* KOBY (1884: 167, pl. 44, fig. 4, pl. 45, fig. 12) is another comparable species but its density of septa is lower (2 per 2 mm).

Morphogenus *Coenotheca* QUENSTEDT, 1881
Type species *Coenotheca pyramidalis* QUENSTEDT, 1881

*Coenotheca zolleriana* QUENSTEDT, 1881 msp.
Pl. 2, Fig. 2a,b

1881 *Coenotheca zolleriana* sp. nov. – QUENSTEDT: 608, pl. 165, figs 38, 41–43.
1881 *Coenotheca zolleriana lobata* subsp. nov. – QUENSTEDT: 609, pl. 165, fig. 38.
1881 *Coenotheca zolleriana montifer* subsp. nov. – QUENSTEDT: 611, pl. 165, fig. 41.
1881 *Coenotheca zolleriana astreiformis* subsp. nov. – QUENSTEDT: 612, pl. 165, fig. 43.
1996a *Coenotheca* mg *zolleriana* QUENSTEDT – LATHUILIÈRE: 582, 598, pl. 72, figs 6–14, pl. 76, figs 4–7.
2003 *Coenotheca zolleriana* QUENSTEDT – PANDEY & FÜRSICH: 46, pl. 11, figs 2–6.

Material: One specimen from the top of the Shemshak Formation at Rian (PIW2006III 73).
Dimensions: see Table 9.
Description: Corallum thamnasterioid, subpatellate, calicular surface concave. Lower part pedunculate with weakly developed fronds, attachment area circular in outline and moderately large. Calice centers small, distinct. Budding intracalicular. Costo-septa compact, confluent, composed of trabeculae, *Montlivaltia*-like, thin and thick septa alternating, those of first two cycles reaching the center leaving a small columellar area. Lateral surfaces of septa ornamented with tiny granules. Epitheca on lower surface with very faint concentric rugae.
Remarks: The specimen closely fits *Coenotheca zolleriana* QUENSTEDT described from the basal part of the Parvadeh Formation of east-central Iran (PANDEY & FÜRSICH 2003) with respect to the thamnasterioid colony, *Montlivaltia*-like septa, and weakly developed fronds. The holotheca in the present specimen is well preserved.

Family Isastreidae ALLOITEAU, 1952
Genus *Isastrea* MILNE-EDWARDS & HAIME, 1851
Type species *Astrea helianthoides* GOLDFUSS, 1826

Remarks: All specimens described here show the diagnostic features of *Isastrea* such as a cerioid colony, intracalicular budding, septo-parathecal wall, *Montlivaltia*-like compact septa (GILL & LAFUSTE 1971), and common vesicular dissepiments. The outer part of the septa of adjacent corallites commonly alternate and a dissepiment joins them in such a way that it appears that this part of the septum bifurcates. This feature has been described and illustrated by RONIEWICZ

**Table 9:** Dimensions (in mm) of *Coenotheca zolleriana* QUENSTEDT

| Specimen | H | D | c-c | Ns | Ds/2 mm |
|---|---|---|---|---|---|
| PIW2006III 73 | 18 | 20.5 | 5–6 | 96 | 4–6 |

(1982: figs 6–8) and LATHUILIÈRE (1988: pl. 1, fig. 1, pl. 6, figs 1–6, 2000a: figs 6.6, 6.8).

Identification at the species level is mostly based on dimensions. Which dimensions should be considered as important is a matter of debate. Most of them are related either to ontogenic stages, depend on the mode of preservation, or reflect environmental conditions. For example, the thickness of septa may increase due to deposition of lamellar layers and, simultaneously, the granules and spinules of the lateral septal surfaces may be hidden by such lamellar layers or may be obliterated during diagenetic recrystallization. The total appearance of the calicular surface depends upon the taphonomic fate of the coral, the type of sediment infilling the corallum, and the diagenetic history of the skeleton.

The specimens of *Isastrea* described here come from a patch reef at the top of the Shemshak Formation (Lower Bajocian) at Rian. A patch reef with a comparable species diversity of reef-building corals has been described by LATHUILIÈRE (2000a) from the Lower Bajocian (Propinquans and Humphriesianum zones) of eastern France. *I. bernardiana* D'ORBIGNY and *I. tenuistriata* (MACCOY) are the two species of Isastrea described from this reef facies (LATHUILIÈRE 1988: 287, 2000a: 61). In addition the only other valid species occurring in the Bajocian are *I. richardsoni* MILNE-EDWARDS & HAIME (1851: 138; PRINZ 1991: 185) AND *I. limitata* (LAMOUROUX) (PANDEY & FÜRSICH 1993: 17). All other species, described by KOBY (1885: 277–286) and BEAUVAIS (1966: 1004–1007) have been merged with *I. bernardiana* D'ORBIGNY by LATHUILIÈRE (1988: 287). *I. bernardiana* differs from *I. tenuistriata* by having fewer septa (LATHUILIÈRE 1988: 275, fig. 4), but LATHUILIÈRE (2000a: 63) found it difficult to distinguish between the two species. *I. richardsoni* shows a characteristic thickening of primary septa towards the center of calices (PRINZ 1990: 173). *I. limitata*, in general, has a smaller corallite diameter (3–5.9 mm) (MILNE-EDWARDS & HAIME 1851: 114; PANDEY & FÜRSICH 1993: 17).

The numbers of septa in the present specimens vary widely and fill the gap between the two species (*I. bernardiana* and *I. tenuistriata*) described from France. The density of trabeculae, which ERRENST (1990: 193–195) considered one of the bases of differentiating between species, does not differ much. All measured specimens were arranged in order of increasing trabecular density (first preference) and according to increasing septal density (second preference). These features, together with the range of numbers of septa in corallites, thickness of septa, septal ornamentation, and appearance (whether individual trabeculae are distinct; which may be related to the inter-trabecular distance or reflect the preservation quality), were taken into account. Based on these criteria the material from the Shemshak Formation falls into three groups comparable to Isastrea thurmanni (ÉTALLON), Isastrea helianthoides (GOLDFUSS), and Isastrea bernensis ÉTALLON, respectively. However, in view of their wide variation in dimensions and comparable morphological characters these species are here assigned to *I. bernardiana*.

Rejuvenation is a common feature of these corals, the interiors of which are nearly always recrystallized so that internal structures are not seen.

### *Isastrea bernardiana* (D´ORBIGNY, 1850)
### Pl. 2, Figs 3–5; Pl. 3, Figs 1–4

1850 *Prionastrea bernardiana* sp. nov. – D´ORBIGNY: 293.
1988 *Isastrea bernardiana* (D´ORBIGNY) – LATHUILIÈRE: 287, pls 1–4, pl. 5, figs 1–3, pl. 6, figs 1–3 [cum syn.].
1989 *Isastrea bernardiana* (D´ORBIGNY) – LATHUILIÈRE: 887, pls 1–2 [cum syn.].
1994 *Isastrea bernardiana* (D´ORBIGNY) – PANDEY & FÜRSICH: 78, fig. 2.
1996a *Isastrea bernardiana* (D´ORBIGNY) – LATHUILIÈRE: pl. 73, figs 11–12.
2000a *Isastrea bernardiana* (D´ORBIGNY) – LATHUILIÈRE: 61, figs 6.5–6.8 [cum syn.].
2003 *Isastrea bernardiana* (D´ORBIGNY) – PANDEY & FÜRSICH: 53, pl. 12, figs 1–2.

Material: 25 specimens from the top of the Shemshak Formation at Rian (PIW2006III 1–4, 16, 26, 28–29, 30, 32–34, 36–37, 46), the topmost part of the Shemshak Formation at Golbini (PIW2004III 1–5, 8–9, 12–13), and the Kashafrud Formation at Qal'eh Sangi (PIW2006III 67).

Dimensions: see Table 10.

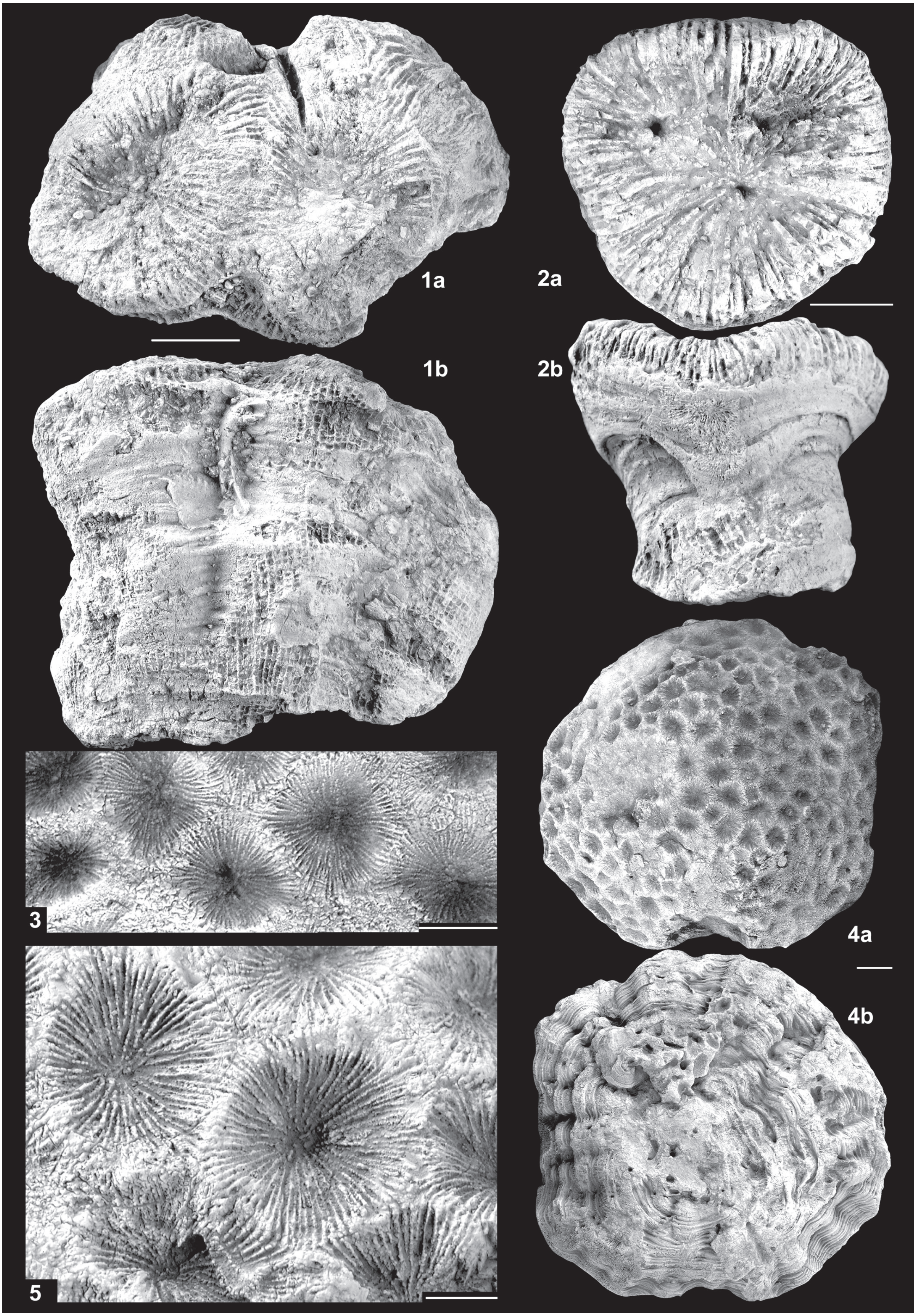
Description: Corallum cerioid, small to moderately large, massive, globose, umbrella-shaped, cup-shaped, discoidal, flat to crustose with upper surface convex, flat to concave. Corallites hexagonal, pentagonal to subrounded in transverse section. Calices distinct, moderately deep to deep, mono-, di- to tricentric showing intracalicular budding. Septa compact, thin, moderately thick to thick, of *Montlivaltia*-type, mostly non-anastomosing, occasionally anastomosing near the inner edge, arranged in more than four or five cycles, those of the first two or three cycles nearly reaching the center, the remaining ones increasingly shorter and occasionally thinner. Septa of fifth cycle incomplete. Lateral margin covered with granules and spinules. Distal margin with sharp, symmetrical or asymmetrical, acutely to obtusely angular denticles corresponding to

**Plate 2:**

Fig. 1: *Thecosmilia magna* ÉTALLON, 1864 msp. from Rian. Scale bar 10 mm; PIW2006III 76. a: Upper view of thamnasteriod colonial structure, b: side view showing traces of holotheca.

Fig. 2: *Coenotheca zolleriana* QUENSTEDT, 1881 msp. from Rian. Scale bar 5 mm; PIW2006III 73. a: Upper view showing three corallite centers and the thamnasteriod colonial structure, b: side view with well preserved holotheca. Note the distinct edge zone.

Figs 3–5: *Isastrea bernardiana* (D´ORBIGNY, 1850) from Rian. 3: Close up view of part of the upper surface showing dense and mostly non-anastomosing septa. Scale bar 5 mm; PIW2006III 2. 4: Specimen PIW2006III 32. Scale bar 10 mm. a: Upper surface view, b: lower surface view showing holotheca with concentric rugae. 5: Close-up view of part of the upper surface of specimen PIW2006III 36 showing distinct denticles along the distal margin and mostly non-anastomosing septa. Note the poorly defined columellar fossa and confluent septa of adjacent corallites. Scale bar 2.5 mm.


1a
2a
1b
2b
3
4a
4b
5

trabeculae, which form carinae on the lateral surfaces of septa. Trabeculae at the inner edge of septa occasionally widely spaced and in some cases look like a papillose to spongy columella. Septa of adjacent corallites confluent to non-confluent and in a few cases alternating with the septo-parathecal wall. Endothecal vesicular and cellular dissepiments common. Columellar fossa not always well demarcated, occasionally with trabeculae. Lower surface covered with holotheca, concentric folds and rugae, and coarse radial folds corresponding to corallites. Attachment area small to moderately large.

Remarks: The trabecular density of *I. thurmanni* Étallon is not known except for the material investigated by Errenst (1990: 195, pl. 11, fig. 4a,b) and Beauvais (1964: 168). In these specimens it ranges from 6 to 8 per 2 mm. The upper range is similar to the lower range in the present specimens. The mean of the distance between centers of trabeculae for *Isastrea bernardiana* ranges from 0.12 mm to 0.66 mm (Lathuilière 1988: 287). This means that the distance is not constant, but changes according to their position in relation to the inner or outer edge of septa. The number of septa and septal ornamentation of the first specimen group compares well with the illustrations and descriptions of *I. thurmanni* Étallon (1864: 390, pl. 55, fig. 9) made by earlier workers. The present specimens are also close to *Isastrea crassa* (Goldfuss) (Errenst 1990: 194, pl. 11, fig. 3a,b) with respect to the number of septa and their ornamentation. The density of septa and trabeculae in *thurmanni* and in *crassa* vary to a great extent (see Errenst 1990: 194–195 and Beauvais 1964: 168–169). Both species have been recorded from the Oxfordian by Koby (1885).

The columellar fossa in the second group of specimens is well demarcated in some of the specimens. In specimen PIW2006III 29 occasionally a few trabeculae seem to have occupied the columellar fossa. In specimens PIW2006III 37

**Table 10:** Dimensions (in mm) of *Isastrea bernardiana* d'Orbigny

a) Specimens comparable to *I. thurmanni* (Étallon, 1864)

| Specimen | D | H | d | Ns | c-c | Ds/2 | Dt/2 | Dt.c | shape/upper surface |
|---|---|---|---|---|---|---|---|---|---|
| PIW2006III 32 | 114.4 | 50 | 8–10 | 66–75 | 4.5–10 | 7–8 | 8 | 2–4 | globose/convex |
| PIW2006III 67 | >86.6 | 47.5 | 5–8.4 | 50 | 5.5–7 | 6 | 10 | 1.6–2.8 | flat/flat |
| PIW2006III 34 | >116.3 | 46.6 | 6.5–9 | 53 | 4.5–7 | 6 | 10 | 1.4–2.2 | fragment/convex |
| PIW2006III 30 | >51.5 | >31.5 | 4.5–6.6 | 50–53 | 4–6.8 | 6–7 | 10 | 2.4 | fragment/convex |
| PIW2006III 36 | >90 | >59 | 8–9.5 | 64–83 | 4.5–7.5 | 7–8 | 10 | 1.2–2.5 | fragment/convex |
| PIW2006III 1 | >93 | 36 | 6.3–7.5 | 39–~70 | 6.5–9 | 8–10 | 10 | 2.5–3 | fragment/convex |
| PIW2006III 33 | >73 | 39 | 5.8–9.2 | 42–64 | 4.5–6.7 | 5–7 | 12 | 1.3–2.5 | fragment/convex |
| PIW2006III 4 | 51 | 21.5 | 5.5–7.5 | 52–62 | 7–8 | 7 | 12 | 1–1.5 | umbrella-shaped/flat |
| PIW2006III 2 | >54 | >24 | 7–9 | 72–81 | 6.5–8.5 | 7–10 | 12 | 2–3 | fragment/flat |
| PIW2006III 28 | >77 | 40 | 6.5–7.2 | 69 | 6.5–7.8 | 9 | 12 | 2 | cup-shaped/flat |
| *I. thurmanni* Étallon (1864: 390, pl. 55, fig. 9) | | | 15–20 | 72–100 | – | – | – | – | – |
| *I. thurmanni* Étallon of Koby (1885: 272, pl. 79, fig. 1, pl. 84, fig. 4) | | | – | 70–120 | – | 4–5 | – | – | – |
| *I. thurmanni* Étallon of Beauvais (1964: 168) | | | 11–20 | 60–90 | 8–17 | – | 8 | – | – |
| *I. thurmanni* Étallon of Errenst (1990: 195, pl. 11, fig. 4a,b) | | | 9–25 | 70 | 11–19 | – | 6–7 | – | – |
| *I. crassa* (Goldfuss) of Koby (1985: 273, pl. 30, fig. 2) | | | – | 55–70 | – | 3 | – | – | – |
| *I. crassa* (Goldfuss) of Beauvais (1964: 169) | | | 9–18 | 70–80 | 9.5–18 | 4–5 | 5–7 | – | – |
| *I. crassa* (Goldfuss) of Errenst (1990: 194, pl. 11, fig. 3a,b) | | | 10–14 | 60–92 | 7–13 | – | 8–9 | – | – |

Tab. 10 cont.

b) Specimens comparable to *I. helianthoides* (Goldfuss) of Pandey & Fürsich (2003: 54, pl. 14, figs 4–5)

| Specimen | D | H | d | Ns | cc | Ds/2 | Dt/2 | Dt.c | shape/upper surface |
|---|---|---|---|---|---|---|---|---|---|
| PIW2004III 1 | >90 | >40 | 7–10 | 50–56 | 6–8 | 5 | 8 | 3 | cup-shaped/convex |
| PIW2006III 16 | >72 | 37.3 | 7.8 | 39–44 | 4.8–6.5 | 5 | 8 | 1.5–2.2 | fragment/concave |
| PIW2006III 26 | >86 | 22.5 | 8–8.5 | 49 | 4.5–7 | 6 | 9 | 1.2–1.8 | flat/concave |
| PIW2006III 29 | >78 | 35 | 6.5–7 | 52–55 | 5–9 | 6–7 | 9 | 1–2 | flat/flat |
| PIW2004III 12 | 62 | <26 | 9–10 | 40 | 7–8.5 | 5 | 8–10 | 1.5–1.7 | cup-shaped/flat |
| PIW2006III 3 | ca 80 | ca 32 | 7.3–9 | 29–40 | 5.5–8 | 3–6 | 10 | 1–1.2 | discoidal/uneven |
| PIW2006III 37 | >115 | 38 | 6.3–7.2 | 48–54 | 2.5–5.5 | 6 | 10 | 0–1 | flat/concave to flat |
| PIW2004III 8 | 112.5 | 45 | 5.2–8 | 41–45 | 4–5.8 | 5 | ca 10 | 1.3–2.4 | cup-shaped/convex |
| *I.* cf. *helianthoides* of Roniewicz (1976: 66, pl. 13, fig. 4) | | | 5–6 | 35–44 | 4–6 | – | 10 | – | – |
| *I. helianthoides* of Errenst (1990:193, pl. 11, fig. 2) | | | 6–10 | 44–54 | 6.5–10 | – | 9–10 | – | – |

c) Specimens comparable to *I. bernensis* Étallon

| Specimen | D | H | d | Ns | cc | Ds/2 | Dt/2 | Dt.c | shape/upper surface |
|---|---|---|---|---|---|---|---|---|---|
| PIW2004III 5 | 25 | 13.8 | 8–12 | >44 | 6.5–10 | 4–7 | 8 | 1.5–2 | cup-shaped/convex |
| PIW2004III 3 | 63 | 33.5 | 6–7.5 | 40 | 6–8.5 | 5 | 8 | 2–3 | cup-shaped/flat |
| PIW2004III 4 | ~ 90 | >30 | 6–8 | >34 | 6–8.4 | 5 | – | 2–2.5 | cup-shaped/flat |
| PIW2004III 2 | >75 | >33.5 | 7–8 | 42–43 | 5–8 | 4 | 9 | 2–2.5 | cup-shaped/flat-concave |
| PIW2004III 13 | ~ 75 | ~75 | 6–9 | 24–34 | 5–8 | 5 | 9–10 | 2–2.5 | discoidal/convex |
| PIW2006III 46 | 84 | 35 | 10–14.2 | 50–70 | 11–14 | 5 | – | 4.6–6.8 | discoidal/concave |
| *I. bernensis* Étallon (1864: 392, pl. 55, fig. 12) | | | 5–6 | 36 | | – | – | – | – |
| *I. bernensis* of Koby (1885: 275, pl. 82, figs 1–4) | | | 3–9 | 36–55 | – | 4 | – | – | – |
| *I. bernensis* of Beauvais (1964: 166, pl. 17, fig. 1) | | | 5–10 | 25–45 | 3–9 | 4–5 | 6–9 | – | – |
| *I. bernensis* of Roniewicz (1976: 67, pl. 13, figs 2–3) | | | 7–11 | 50–68 | 7–9 | 4–5 | 13–15 | – | – |
| *I. bernensis* of Rosendahl (1985: 48, pl. 5, fig. 7) | | | 6–10 | 50–70 | 6–8 | 4–5 | – | – | – |
| *I. bernensis* of Errenst (1990: 193, pl. 11, fig. 1a–c) | | | 5–10 | 44–58 | 5–10 | – | 12 | – | – |

and PIW2004III 9 rejuvenation has well progressed. This specimen group differs from the first group in having thicker and fewer septa in each corallite and a well-demarcated columellar fossa. The columellar fossa in specimen PIW2006III 29 is transitional between the two groups. A part of specimen PIW2006III 26 exhibits a plocoid growth structure, possibly due to some environmental stress. Specimen PIW2006III 3 has some affinity with *Isastrea browni* (Duncan) (1872: 16, pl. 2, figs 1–5; Negus & Beauvais 1975: 190, pl. 2, fig. 1) because of its lower number of septa and septal density, but the general septal morphology is the same. The dimensions, septal ornamentation, and columellar fossa of *Isastrea bernardiana* (d'Orbigny) described from the Hojedk Formation and the basal Parvadeh Formation (Bajocian) of east-central Iran (Pandey & Fürsich 2003) match well with this group.

In plan view, the distal margin of septa in the third specimen group, comparable to *I. bernensis,* occasionally looks like a closely beaded structure. These specimens agree well with those of the second group comparable to *Isastrea helianthoides* (GOLDFUSS) with respect to the dimensions, except that the trabeculae are more distinct and the columellar area is not that well demarcated. The number of septa and septal density in the second and third groups vary, but those of the third group are close to the lower end of this range. The trabecular density, too, falls within the range of variation of *I. bernensis* described by earlier workers (ÉTALLON 1864; BEAUVAIS 1964; RONIEWICZ 1976; ROSENDAHL 1985; ERRENST 1990). Specimen PIW2006III 46 is comparatively poorly preserved but matches the illustration given by ERRENST (1990).

This species is the only coral so far recovered from the Upper Bajocian-Bathonian Kashafrud Formation of the Koppeh Dagh. It has been here included for comparison.

*Isastrea propinqua* ÉTALLON, 1864
Pl. 4, Figs 1, 4

1864 *Isastrea propinqua* sp. nov. – ÉTALLON in THURMANN & ÉTALLON: 392, pl. 55, fig. 13.
1885 *Isastrea propinqua* THURMANN – KOBY: 285, pl. 81, figs 3–4.
1900 *Isastrea propinqua* THURMANN & ÉTALLON 1864 var. *kachensis* var. nov. – GREGORY: 126, pl. 16, figs 5–6.
1993 *Isastrea propinqua* ÉTALLON – PANDEY & FÜRSICH: 18, pl. 5, figs 2–3, 7, textfig. 12.
2003 *Isastrea propinqua* ÉTALLON – PANDEY & FÜRSICH: 54, pl. 13, fig. 1.

Material: Nine specimens from the top of the Shemshak Formation at Rian (PIW2006III 20, 35, 38–39, 43, 47–48, 53, 65).

Dimensions: see Table 11.

Description: Corallum cerioid, discoidal, flat, massive. Upper surface convex to uneven. Lower surface with holotheca and concentric folds and rugae. Corallites polygonal in outline. Calices almost flat to shallow. Septa *Montlivaltia*-like, non-anastomosing, thin and occasionally becoming hair-like towards the axis, arranged in five cycles. Septa of first cycle and a few of the second cycle nearly reaching the center, the remaining ones increasingly shorter. Denticles at the distal margin conspicuous. In plan view, occasionally only the beaded distal margin of septa is visible. Calicular center in some cases eccentric. Wall parathecal.

Remarks: Rarely, patches on the upper surface of the colonies resemble a thamnasterioid colonial structure. In specimen PIW2006III 43, the holotheca has been eroded and faint radial fronds corresponding to corallites are visible. The diameter of a few corallites of specimen PIW2006III 47 ranges from 3.2–5.2 mm, which is unusually small for the species, but matches values recorded from the Kachchh Basin of western India (PANDEY & FÜRSICH 1993: 18).

Family "Andemantastraeidae ALLOITEAU, 1951"

Remark: For the assignment of the genus *Trigerastraea* to the family Andemantastraeidae see PANDEY & FÜRSICH (2003: 58).

Genus *Trigerastraea* ALLOITEAU, 1952
Type species *Isastrea trigeri* DE FROMENTEL, 1867

Remarks: It has always been difficult to separate *Isastrea* from *Trigerastraea*. Both genera exhibit a similar colonial structure. In *Isastrea* the septa are compact, whereas in *Trigerastraea* they are subcompact. In *Isastrea* the wall is septoparathecal (see above), whereas in *Trigerastrea* it is synapticulothecal (ALLOITEAU 1952: 77; BEAUVAIS 1965: 874). In most specimens the septa are not well preserved and it is difficult to distinguish between the two. In the present specimens the calices occasionally have a colline-like appearance, continuing to adjoining calices. In well-preserved specimens one can easily see the subcompact nature of septa.

*Trigerastraea*? *ampakabensis* ALLOITEAU, 1958
Pl. 4, Figs 2–3, 5–8

?1958 *Trigerastraea ampakabensis* sp. nov. – ALLOITEAU: 77, pl. 12, fig. 3, pl. 14, fig. 6, pl. 16, fig. 6, pl. 31, fig. 1.

Material: Five specimens from the uppermost part of the Shemshak Formation near Golbini (PIW2004III 10, 11, 14, 18, 24), and 4 specimens from the top of the formation at Rian (PIW2006III 5, 23, 31, 66).

Dimensions: see Table 12.

Description: Corallum low, umbrella- to cup-shaped, discoidal, massive, cerioid to meandroid. Upper surface convex. Lower surface covered with costae, attachment area small. Calices polygonal to subrounded and mono-, di-, tri- to polycentric. Collines tectiform, long (maximum observed length: 57.5 mm) to short, running more or less parallel to the slope of the upper convex surface. Budding intracalicular, with two simultaneous buddings on opposite sides of the parent corallite. Septa subcompact, anastomosing, arranged in at least five cycles. With pores along the distal and inner edges of septa. Septa of adjacent corallites along the wall alternating. Lateral surfaces of septa covered with carinae corresponding

**Plate 3**

Figs 1–4: *Isastrea bernardiana* (D'ORBIGNY, 1850) from Rian. 1: Specimen PIW2004III 1. a: Close-up view of part of upper surface. Note the distinct calicular fossa. Scale bar 10 mm, b: part of longitudinal thin-section showing parathecal wall between two corallites and dissepiments. Scale bar 2 mm. 2: Specimen PIW2004III 5. Scale bar 10 mm. a: Upper surface view, b: lower surface view showing holotheca with concentric folds only on the proximal part. 3: Specimen PIW2004III 2. Scale bar 10 mm. a: Upper surface view showing encrustation by serpulids, b: close up view of the same surface showing the mostly distinct nature of the columellar fossa. 4: Specimen PIW2006III 29, close-up view of part of upper surface. Note at least five cycles of septa, the non-confluent or alternate organization of septa of adjacent corallites (*Isastrea-like* wall structure), and the distinct calicular fossa. Scale bar 5 mm.

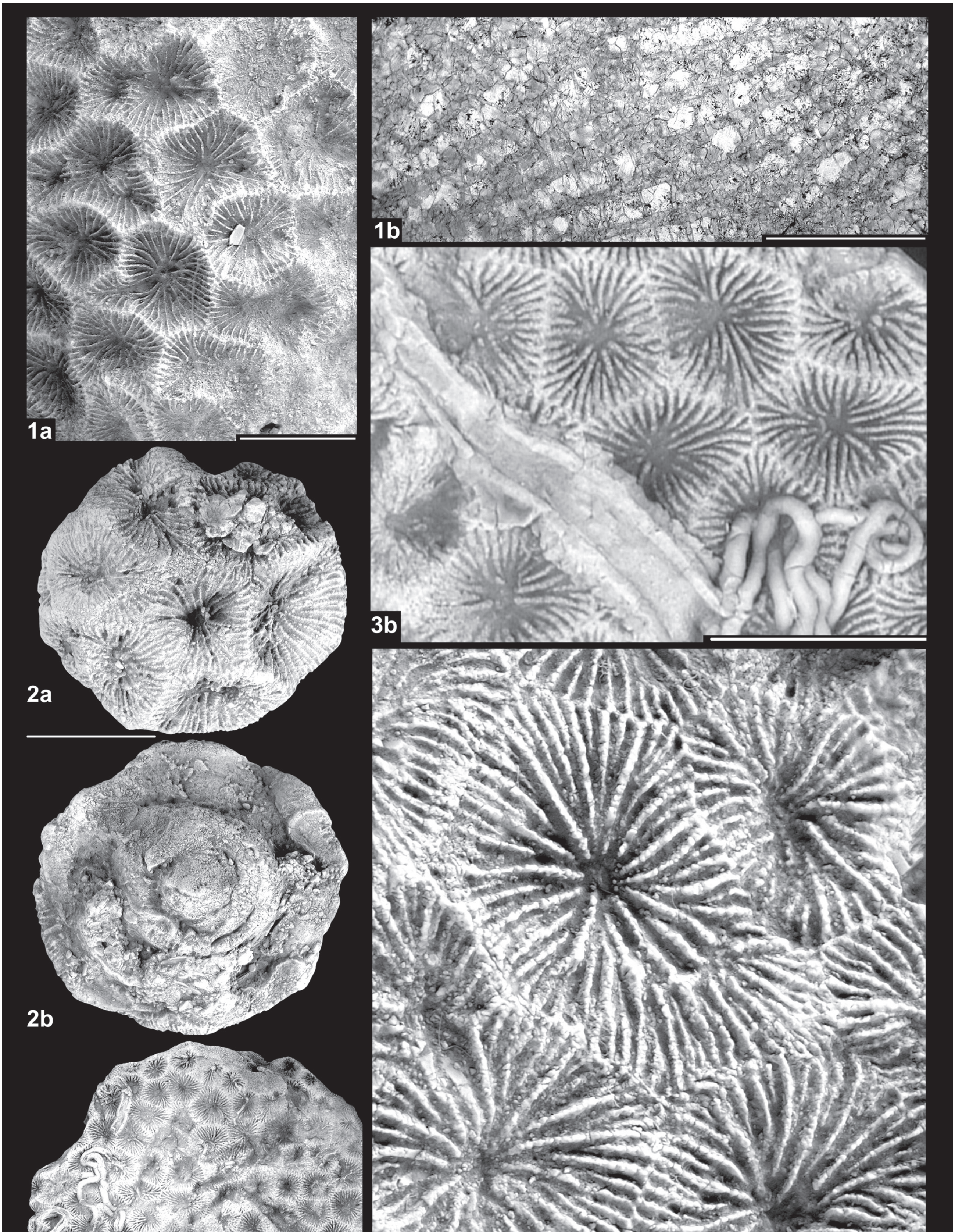

1a
1b
2a
2b
3a
3b
4

**Table 11:** Dimensions (in mm) of *Isastrea propinqua* Étallon

| Specimen | D | H | d | Ns | cc | Ds/2 | Dt/2 | Dt.c | shape/upper surface |
|---|---|---|---|---|---|---|---|---|---|
| PIW2006III 35 | 82 | 26 | 6–9 | 36–47 | 5–7 | 4–5 | 12 | 1–2 | discoidal/convex |
| PIW2006III 38 | >83 | >24.5 | 7 | 29 | 6.8–8.2 | 4 | 9 | 0–1 | flat/uneven |
| PIW2006III 39 | >125 | 23 | 8–8.5 | 38–42 | 6.5–8 | 4–5 | 9 | 0–1 | crustose/concave |
| PIW2006III 43 | d80 | 23 | 7.3 | 32 | 5.5–6.3 | 5 | 8–9 | 0–1 | cup-shaped/concave |
| PIW2006III 47 | >130 | 57 | 3.2<br>3.8<br>4.6<br>5.2<br>7 | 22<br>21<br>28<br>35<br>40 | 4–5 | 6<br>5<br>–<br>5<br>6 | 10 | – | fragment/uneven |
| PIW2006III 48 | – | – | 6.5–8.6 | 32 | 5.5–7 | 4–5 | 12 | 0 | fragment/flat |
| PIW2006III 53 | – | >24.5 | 5–6.2 | 41–49 | 2.5–6.5 | 6 | 10–12 | 1.8 | fragment/flat |
| PIW2006III 65 | – | – | 3.8–7.8 | 22–36 | 4–5–6.6 | 5 | 11 | | fragment/flat |

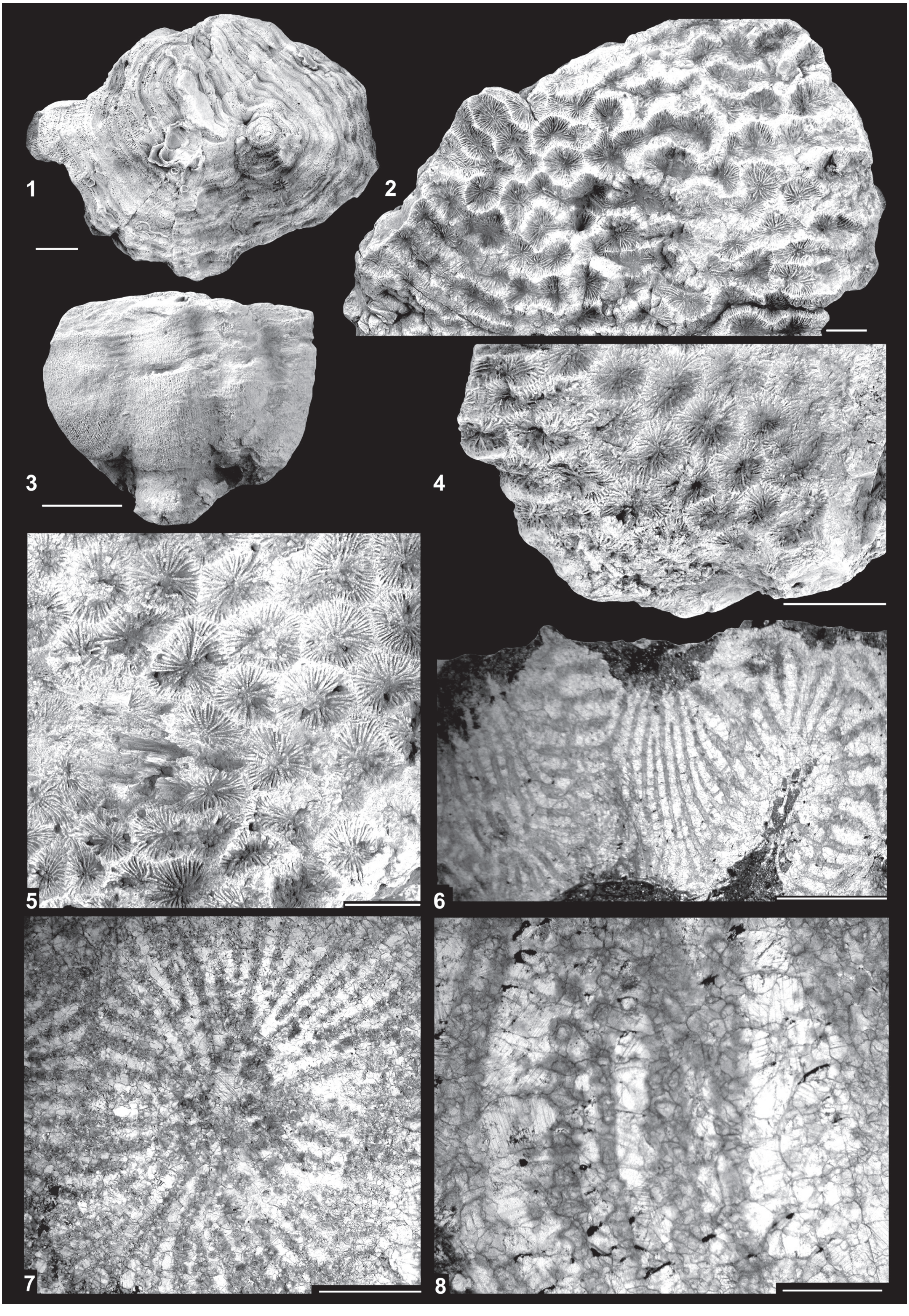
**Table 12:** Dimensions (in mm) of *Trigerastraea*? *ampakabensis* Alloiteau

| Specimen | D | H | d | Ns | cc | Ds/2 | Dt/2 | Dt.c | shape/upper surface |
|---|---|---|---|---|---|---|---|---|---|
| PIW2004III 10 | 96 | 30 | 12–13 | 48 | 7–1.3 | 6 | 8 | 1–2.5 | umbrella-shaped/convex |
| PIW2006III 23 | >93 | 53 | 8–12 | 60 | 8–10 | 5 | 10 | 2.2–3 | cup-shaped/concave |
| PIW2006III 5 | 31 | 30 | 9.5 | 46 | 8–10 | 8 | 8 | 1 | wedge-shaped/flat |
| PIW2004III 18 | 105 | 40 | 4–8.0 | 43 | 4–8 | 5 | 11 | 1.2–1.5 | cup-shaped/convex |
| PIW2004III 24 | 52 | 25 | 5–9 | >32 | 6–7 | 5 | – | 1.5 | umbrella-shaped/convex |
| PIW2006III 86 | 80 | 37 | 3–5.6 | 35–50 | 3.5–5 | 5–7 | 8 | 0.8–1.5 | globose/convex |
| PIW2004III 11 | 48.5 | 14 | 9–10 | 47 | 4.5–7 | 5 | 11 | 0.8–1.2 | discoidal/convex |
| PIW2006III 31 | 137.6 | 53.8 | 6.4–9.5 | 40 | 8 | 4–5 | 6–7 | 2.5–3.5 | low cup-shaped/flat |
| *T. ampakabensis* (holotype) | 120 | 77 | – | 38 | 4.5–10 | 6 | – | – | low |

**Plate 4**

Figs 1, 4: *Isastrea propinqua* Étallon, 1864 from Rian. 1: Lower surface view showing holotheca with concentric folds and rugae. Scale bar 10 mm; PIW2006III 35. 4: Part of upper surface of specimen PIW2006III 53. Note the tendency to form valleys along the periphery of the corallum. Scale bar 1 mm.

Figs 2–3, 5–8: *Trigerastraea*? *ampakabensis* Alloiteau, 1958 from Golbini. 2: Upper surface view of a broken colony. Note the meandroid colonial structure and series of corallites. Scale bar 10 mm; PIW2006III 31. 3: Side view showing fronds corresponding to corallites. Note fine costae and traces of holotheca with fine concentric folds. Scale bar 10 mm; PIW2006III 5. 5: Part of upper surface showing mono- to dicentric corallites. Scale bar 10 mm; PIW2006III 23. 6: Part of longitudinal thin-section showing septoparathecal wall and dissepiments. Scale bar 4 mm; PIW2004III 14. 7: Close-up view of a transverse thin-section showing subcompact nature of septa. Note septoparathecal wall. Scale bar 2 mm; PIW2004III 18. 8: Close-up view of a longitudinal thin-section showing subcompact nature of septa. Scale bar 1 mm; PIW2004III 11.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to trabeculae and granules. Distal margin with conspicuous denticles. Endothecal vesicular dissepiments very common. Wall predominantly septo-parathecal. Columella parietal, papillose to spongy. Lower surface of corallum covered with holotheca and concentric rugae.

Remarks: In specimen PIW2006III 23 the pores along the inner edges of the septa could not be seen very clearly, but the septa exhibit a conspicuously denticulated distal margin. Simultaneous budding on opposing sides of the parent corallite is seen (Milne-Edwards & Haime 1851: 116). In one of the corallites vesicular dissepiments, about 1.5 mm below the distal margin, can be easily confused with ledge-like (or long balcony-like) structures. In specimens PIW2006III 5 and 31 well-developed fronds corresponding to corallites can be seen on the lower surface.

The septal density in the present specimens differs from *Trigerastraea serialis* (Milne-Edwards & Haime) described from the basal Esfandiar Limestone and Korond formations (Lower Callovian and Lower Kimmeridgian, respectively) of east central Iran (Pandey & Fürsich 2003: 58). *Trigerastraea ampakabensis* Alloiteau, 1958 from the Bathonian of Madagascar is the closest comparable species with respect to dimensions. The predominance of a septo-parathecal wall prevents the assignment of these specimens to *Trigerastrea*, as the genus possesses a synapticulothecal wall (Alloiteau 1958: 77; Beauvais 1965: 874). Several thin-sections through the present specimens show this septo-parathecal wall like in *Isastrea* very clearly, but the presence of synapticulae along the periphery cannot be ruled out (Pl. 4, Fig. 6). As none of the figures given by earlier workers clearly shows a synapticulothecal wall (see Alloiteau 1958: 79, fig. 13), the species is referred to *Trigerastrea* with doubt, until the type material has been re-investigated.

Family Thamnasteriidae Vaughan & Wells, 1943, emend. Alloiteau, 1952

Genus *Thamnasteria* Lesauvage, 1823

Type species *Thamnasteria lamourouxi* Lesauvage, 1823

### *Thamnasteria mettensis* Milne-Edwards & Haime, 1851
Pl. 5, Figs 1–2

1851 *Thamnasteria mettensis* sp. nov. – Milne-Edwards & Haime: 141, pl. 30, fig. 3.
2000b *Thamnasteria mettensis* Milne-Edwards & Haime – Lathuilière: 161, figs 13.4, 13.6, 13.9, 18, 19 [cum syn.].
2003 *Thamnasteria mettensis* Milne-Edwards & Haime – Pandey & Fürsich: 75, pl. 20, fig. 3, pl. 21, figs 1, 4–6.

Material: Three specimens from the top of the Shemshak Formation at Rian (PIW2006III 7, 15, 24).

Dimensions: see Table 13.

Description: see Pandey & Fürsich (2003).

Remarks: The specimen is a small fragment of a moderately large corallum. The morphological characters of *Thamnasteria mettensis* described and illustrated by Lathuilière (2000b) closely match those of the present specimens.

The size of the corallites, organization of septa, presence of a small but conspicuous columella also fit *Thamnasteria gracilis* (Münster, 1826) illustrated in Goldfuss (1826: 112, pl. 38, fig. 13; see also Koby 1887: 371, pl. 102, fig. 1a; Pandey & Fürsich 2003: 74, pl. 20, fig. 5). *T. gracilis* has been recorded from the Oxfordian and Kimmeridgian, whereas *T. mettensis* is a Bajocian species. If the phyletic continuity between the Bajocian *T. mettensis* and other numerous upper Jurassic species

**Table 13:** Dimensions (in mm) of *Thamnasteria mettensis* Milne-Edwards & haime

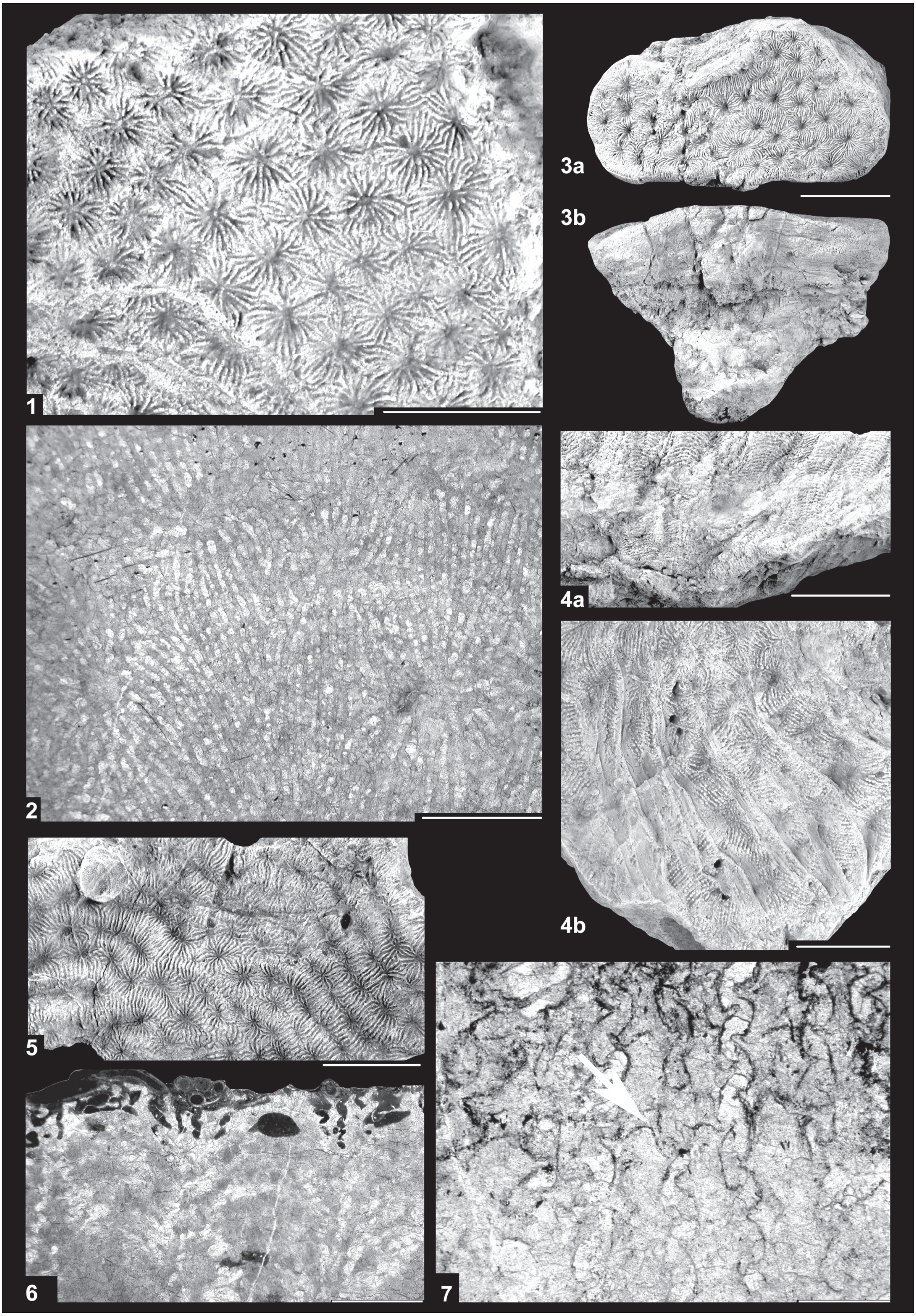
| Specimen | d | c-c | Ns | Ds |
|---|---|---|---|---|
| PIW2006III 7 | 3–3.3 | 2–3.5 (on the surface | 35–36 | 5/1 |
| | – | 1.3–2.5 (in transverse section) | – | – |
| PIW2006III 15 | 1.1–1.8 | 1.7–1.9 | 22–30 | 6–7/1 |
| PIW2006III 24 | 2–2.5 | 1.8 | 28–34 | 11–12/2 |

**Plate 5**

Figs 1–2: *Thamnasteria mettensis* Milne-Edwards & Haime, 1851 from Rian. 1: Part of upper surface showing thamnasteriod colonial structure. Scale bar 5 mm; PIW2006III 15. 2: Longitudinal thin-section showing circumoral budding. Note the parallel arrangement of septa. Scale bar 2 mm; PIW2006III 24.

Fig. 3: *Thamnasteria iranensis* Pandey & Fürsich, 2003 from Rian. Scale bar 10 mm; PIW2006III 45. a: Upper surface view showing corallites with distinct calicular fossa, b: side view showing holotheca and traces of concentric rugae.

Figs 4–7: *Periseris elegantula* (d´Orbigny, 1850) from Rian. 4: Specimen PIW2006III 64. Scale bar 10 mm. a: Part of longitudinally broken surface showing continuous menianae on lateral surfaces of septa, b: part of upper surface showing traces of holotheca, which is covered due to encrustation or rejuvenation of colony. 5: Part of upper surface showing calicular series. Note circumoral budding. Scale bar 10 mm; PIW2006III 42. 6: Longitudinal thin-section showing pennular structures and vesicular dissepiments. Scale bar 2 mm; PIW2006III 17. 7: Longitudinal thin-section showing pennular structures, vesicular dissepiments, synapticulae, and growth halts (arrowed). Scale bar 0.5 mm; PIW2006III 49.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3a
3b
4a
4b
5
6
7

**Table 14:** Dimensions (in mm) of *Thamnasteria iranensis* PANDEY & FÜRSICH

| Specimen | D | H | d | c-c | Ns | Ds/2 | Dt |
|---|---|---|---|---|---|---|---|
| PIW2006III 45 | 33.8 | 24 | 2.5–3.5 | 2.4–3.2 | 30 | 9–10 | 8/1 |
| *T. iranensis* (PANDEY & FÜRSICH 2003: 78) | 23–40 | 10–17 | – | 2.8–4.5 | 28–51 | 7–9 | 11–12/2 |

of *Thamnasteria* is ascertained, *Thamnasteria mettensis* should be considered as a junior synonym of *T. gracilis*.

*Thamnasteria iranensis* PANDEY & FÜRSICH, 2003
Pl. 5, Fig. 3a,b

2003 *Thamnasteria iranensis* sp. nov. – PANDEY & FÜRSICH: 78, pl. 22, figs 1–2, 4–5.

Material: One specimen from the top of the Shemshak Formation at Rian (PIW2006III 45).

Dimensions: see Table 14.

Description: Corallum small, thamnasterioid, subturbinate. Upper surface slightly concave, elongated in plan view. Subconical lower surface covered with holotheca. Colony formed by intracalicular marginal budding. Calices superficial but distinct. Calicular fossae moderately large, distinct, deep, irregularly arranged. Costosepta thin, subcompact, densely packed, isotropic, non-anastomosing. Trabeculae dense, subcircular, subquadrangular, subrectangular to subelongated in cross-section. Distal part of septa occasionally compact, in some cases individual trabeculae stand out as denticles, distal margin towards center mostly moniliform. Synapticulae and dissepiments present. Columella papillose. Holotheca thin.

Remarks: The specimen is moderately well preserved and closely matches *Thamnasteria iranensis* described from a ?Lower Bajocian patch reef within the Badamu Formation north of Kalshaneh, east-central Iran (PANDEY & FÜRSICH 2003). The trabecular density is higher in the present specimen than in earlier described ones. In most corallites no columella is seen within the columellar fossa.

Suborder Fungiina DUNCAN, 1884
(nom corr. ex Fungiida DUNCAN, 1884)
Family Latomeandridae ALLOITEAU, 1952

Genus *Periseris* FERRY, 1870
Type species *Agaricia elegantula* D´ORBIGNY, 1850

Remarks: LATHUILIÈRE (1990) studied the septa of the genus in detail using a numerical population approach. The authors also investigated material of the genus from the Middle Bathonian of the Kachchh Basin (PANDEY & FÜRSICH 1993: 37), Callovian of northwestern Jordan (PANDEY et al. 2000: 10), and the Toarcian-Lower Callovian of east-central Iran (PANDEY & FÜRSICH 2003: 94). Based on these investigations the diagnostic features of *Periseris* are emended as follows: colonies thamnasterioid, occasionally meandroid. Columella styliform, variable in appearance. Septa anastomosing, subcompact, rarely perforated, consisting of pennular trabeculae and continuous menianae, which turn upward at the margin. When viewed laterally these continuous menianae appear like horizontal carinae arranged parallel to the distal margin (LATHUILIÈRE 1990: pl. 3, fig. 1). Synapticulae and vesicular dissepiments are present but lacking in wall structure.

ALLOITEAU (1958: 165) described the new genus *Dimorphomeandra* (type species: *Dimorphomeandra besairiei* ALLOITEAU, 1958), a form closely comparable to *Periseris*. The new genus was assigned to the family Andemantastraeidae ALLOITEAU, 1952. The status of the family was found doubtful (LATHUILIÈRE 1988: 272, 287; PANDEY & FÜRSICH 2003: 71). Based on observations made by ALLOITEAU and on personal observations on the type specimens (MO 5048–MO 5053 in the Muséum national d'Histoire, Paris) and on specimens from the ?Bajocian to Bathonian of east-central Iran (PANDEY & FÜRSICH 2003: 71) the emended diagnostic characters of the genus are as follows: Colonies meandroid, formed initially by circumoral budding, but during later growth stages budding may be merely intracalicular. Calice centers distinct, arranged mostly in concentric series, occasionally in vallies, separated by tholiform collines. Vallies profound to less profound. Diameter of the central corallite not larger than that of other corallites. Radial elements mostly parallel, anastomosing, subcompact, running transverse to collines. Distal margin of septa with subequal, sharp denticles, which diminish towards the inner part of the septa. Lateral surfaces of septa covered with spinules, synapticulae and horizontal carinae. Columella parietal, spongy.

External morphological features and septal microarchitecture of both genera are similar. The only difference between the two genera is the presence of pennular trabeculae in *Periseris*, which in the type specimens of *Dimorphomeandra* seem to be lacking. Considering the state of preservation of the type specimens of *Dimorphomeandra*, it will be hardly possible to notice the presence of pennulae. In such cases the pennular structures can only be seen in thin-sections, which are, however, not available. While describing a new species of *Dimorphomeandra, D. iranensis*, from east-central Iran, the present authors did not pay sufficient attention to the presence of pennulae in the Iranian specimens, which otherwise are very similar to the type material of *Dimorphomeandra*. The study of additional material from Iran suggests that the carinae on the septal surfaces, which are parallel to the distal margin, are actually meniana. If this is also true of the type material of *Dimorphomeandra* described by ALLOITEAU then there is no difference between the two genera.

At the time ALLOITEAU (1958) founded the new genus detailed information on the septal micro-architecture of most allied genera was not available. Later on, this was provided by RONIEWICZ (1966, 1982), GILL (1967), LATHUILIÈRE (1990), MORYCOWA & RONIEWICZ (1995), PANDEY & LATHUIILIÈRE

(1997), and others. *Dimorphomeandra concentrica* RONIEWICZ, as described by the author, exhibits transversely arranged, small but conspicuous granules on the septal surfaces. RONIEWICZ (1976: 102, pl. 31, figs 1–4) provisionally assigned the taxon to the family Latomeandridae. ELIÁŠOVÁ (1994b: 6) recorded semi-lunar pennulae in Dimorphomeandra from the Cretaceous of the Bohemian Basin and included the genus in the family Latomeandridae. In the light of this, the type material of *Dimorphomeandra* must be carefully re-examined. Pending the investigation of thin-sections of the type material, the status quo of the two genera is retained. However, the Iranian specimens, which exhibit pennular septa and earlier on were assigned to *Dimorphomeandra*, have to be re-assigned to *Periseris*.

*Periseris elegantula* (D´ORBIGNY, 1850)
Pl. 5, Figs 4–7

1850 *Agaricia elegantula* sp. nov. – D´ORBIGNY: 293.
1990 *Periseris elegantula* (D´ORBIGNY 1850) – LATHUILIÈRE: 38, pl. 1, figs 1–2, pl. 2, figs 1–4, pl. 3, figs 1–6, pl. 4, figs 1–7, pl. 5, figs 1–6 [cum syn.].
1993 *Periseris elegantula* (D´ORBIGNY 1850) – PANDEY & FÜRSICH: 37, pl. 11, fig. 2, textfig. 22.
1993 *Periseris* cf. *renevieri* (KOBY) – PANDEY & FÜRSICH: 37, pl. 6, fig. 14, textfig. 23.
2000b *Periseris elegantula* (D´ORBIGNY) – LATHUILIÈRE: 157, figs 13.1–13.2.
2003 *Dimorphomeandra iraniensis* sp. nov. – PANDEY & FÜRSICH: 71: pl. 19, figs 1–3, 5.
2003 *Periseris elegantula* (D´ORBIGNY) – PANDEY & FÜRSICH: 94: pl. 28, figs 1–6.

Material: Nine specimens from the top of the Shemshak Formation at Rian (PIW2006III 14, 17, 41–42, 49–50, 52, 60, 64).

Dimensions: see Table 15.

Description: Specimens flat to foliaceous or encrusting, meandroid to thamnasterioid with circumoral colony formation. Calice centers distinct. Corallites arranged in concentric to irregular series. When arranged concentrically, diameter of the central calice hardly larger than that of other corallites in the concentric rings. In meandroid forms corallite series separated by tholiform collines. Collines low to high. Septa moderately thick, anastomosing, subcompact, rarely perforated, arranged parallel to each other and transverse to collines, confluent with adjacent corallites and consisting of pennular trabeculae. Pennulae turning upward at the margin, edge with very fine denticles. Menianae continuous and, when viewed laterally, appearing like horizontal carinae parallel to the arched distal margin (density 4 per mm). Pores along the distal margin irregular. Distal margin of septa denticulated, denticles subequal. Vesicular dissepiments very common. Synapticulae present, columella variable, small in cross-section, papillose to spongy

**Table 15:** Dimensions (in mm) of *Periseris elegantula* (D´ORBIGNY)

| Specimen | d | c-c | Ns | Ds/2 | Dt/2 |
|---|---|---|---|---|---|
| PIW2006III 14 | 3–3.2 | 1.5–2 | 21 | 6 | 6 |
| PIW2006III 17 | 3.8 | 3 | 25 | 6 | 8 |
| PIW2006III 41 | 1.8–2.5 | 0.5–2.5 | 22 | 5–6 | 8 |
| PIW2006III 42 | 2.5 | 2.3–2.7 | 25 | 5 | 7 |
| PIW2006III 49 | 2–4 | 1.5–3.5 | 15–19 | 5–6 | 8 |
| PIW2006III 50 | 2–3.2 | 1.5–4.2 | 21–27 | 4–5 | 7 |
| PIW2006III 52 | 2.2 | 2.2 | 19 | 6 | 8–10 |
| PIW2006III 60 | 2.4 | 1.2–3.9 | 22 | 7 | 10 |
| PIW2006III 64 | 3–4 | 2.5–6 | 18–33 | 5 | 6–7 |
| *Dimorphomeandra besairiei* (ALLOITEAU 1958: 166–170) | 4–10 | 2–8.5 | 32–80 | 4–8 (5–7) | – |
| *Dimorphomeandra confusa* (REUSS) of ELIÁŠOVÁ (1994b: 6) | | 3.0–3.5 | 24 | 8 | – |
| *Dimorphomeandra concentrica* (RONIEWICZ 1976: 102) | 2–3 | 2–8 | 20–32 | 7–8 | – |
| *Periseris renevieri* (KOBY 1887: 379) | | 2–3 | 18–24 | 7 | – |
| *Periseris* cf. *renevieri* of PANDEY et al. (2000: 11) | 4.0 | 2.0–3.5 | 24–30 | 7–9 | – |
| *Periseris* cf. *renevieri* of PANDEY & FÜRSICH (1993: 37) | 4 –6.2 | | 25–30 | 5 | – |
| *Periseris elegantula* of PANDEY & FÜRSICH (1993: 37) | | 2–3 | 25–27 | 9 | – |
| *Periseris elegantula* (D´ORBIGNY) of LATHUILIÈRE (1990: 38, 2000b: 157) | | 1.2–7.6 | 9–33 (16–24) | 3–7 (4–6) | – |
| *Periseris elegantula* (D´ORBIGNY) of PANDEY & FÜRSICH (2003: 71, 94) | 2.2–7 | 1.2–6 | 18–32 | 4–8 (5–7) | – |

and occasionally barely visible. Rarely a thin, wavy inner part of a septum occupies the axial area. Wall between calicular series along collines parathecal. Holotheca with concentric folds or rugae.

Remarks: With respect of external morphological features and septal microarchitecture, the present specimens are very similar to *Periseris elegantula* and to *Dimorphomeandra iraniensis* PANDEY & FÜRSICH, 2003 from Middle Jurassic strata of east-central Iran. Due to recrystallization, the denticles at the distal margin are, for the most part, not well preserved and the septa look compact. The trabeculae seem to be denser in the lower part (5 per 1 mm) than in the upper part of the colony (4 per 1 mm).

Considering the wide range of variation in the dimensions of *Periseris elegantula* from the Bajocian of the Paris Basin (LATHUILIÈRE 1990) and the overlapping dimensions with other species of *Periseris* and *Dimorphomeandra* it is very difficult to distinguish different species. In order to decide whether *Periseris renevieri* can be included in *Periseris elegantula* the type material must be examined.

Genus *Ovalastrea* D´ORBIGNY, 1849
Type species *Astrea caryophylloides* GOLDFUSS, 1827

*Ovalastrea* sp. A
Pl. 6, Fig. 1

Material: One specimen from the top of the Shemshak Formation at Rian (PIW2006III 6).

Dimensions: see Table 16.

Description: Corallum flat, plocoid. Corallite monostomodaeal, more or less oval in outline. Septa subcompact, consisting of pennular trabeculae, confluent with those of adjacent corallites, rarely alternating, moderately thin, non-anastomosing, arranged in at least five cycles. Of these, the first three cycles are nearly complete. Septa of first two cycles nearly reaching the center, leaving a columellar area of about 0.5 mm in diameter. Septa of third cycle slightly shorter than those of the two primary cycles. Septa of fourth cycle extending for only half of the corallite radius. Septa of the fifth cycle confined to the periphery of the corallites. Distal margin of costosepta asymmetrically arched. Denticles along distal margin conspicuous, acutely to obtusely angular, their size decreasing from the corallite periphery towards the center. Septal surfaces covered with spinules and mi-pennulae-like structures. Dissepiments common, synapticulae present, wall parathecal.

Remarks: The specimen is moderately well preserved. It appears to be a fragment of a large colony. The conspicuous denticles occasionally produce a feature reminiscent of a beaded distal margin. Due to recrystallization it is sometimes difficult to distinguish between dissepiments and synapticulae. There is no trace of a columella.

The characteristic morphological features match those of *Ovalastrea* D´ORBIGNY. The corallites in the Iranian specimen are not raised above the general upper surface of the corallum in contrast to most species of *Ovalastrea*. The specimen differs from the two species of the genus described earlier from Callovian to Oxfordian rocks of east-central Iran (*Ovalastrea plicata* (KOBY) and *Ovalastrea* sp. A; PANDEY & FÜRSICH 2003: 96, 98) on the basis of a thinner peritheca and the absence of a columella. All other known species differ either because of their lower septal and trabecular density or thicker peritheca (KOBY 1884: 206, 210; KOBY 1904: 95–96; BEAUVAIS 1964: 259–260; ROSENDAHL 1985: 59; ELIÁŠOVÁ 1994b: 5). *O. bihinense* (GREGORY, 1925: 23, pl. 4, fig. 1) resembles the present specimen in also possessing non-anastomosing septa.

Genus *Collignonastraea* ALLOITEAU, 1958
Type species *Comoseris jumarense* var. *radiata* GREGORY, 1900

Remarks: PANDEY & FÜRSICH (2003: 84) presented an overview of the genus and documented the plasticity of the external morphological features in response to micro-environmental

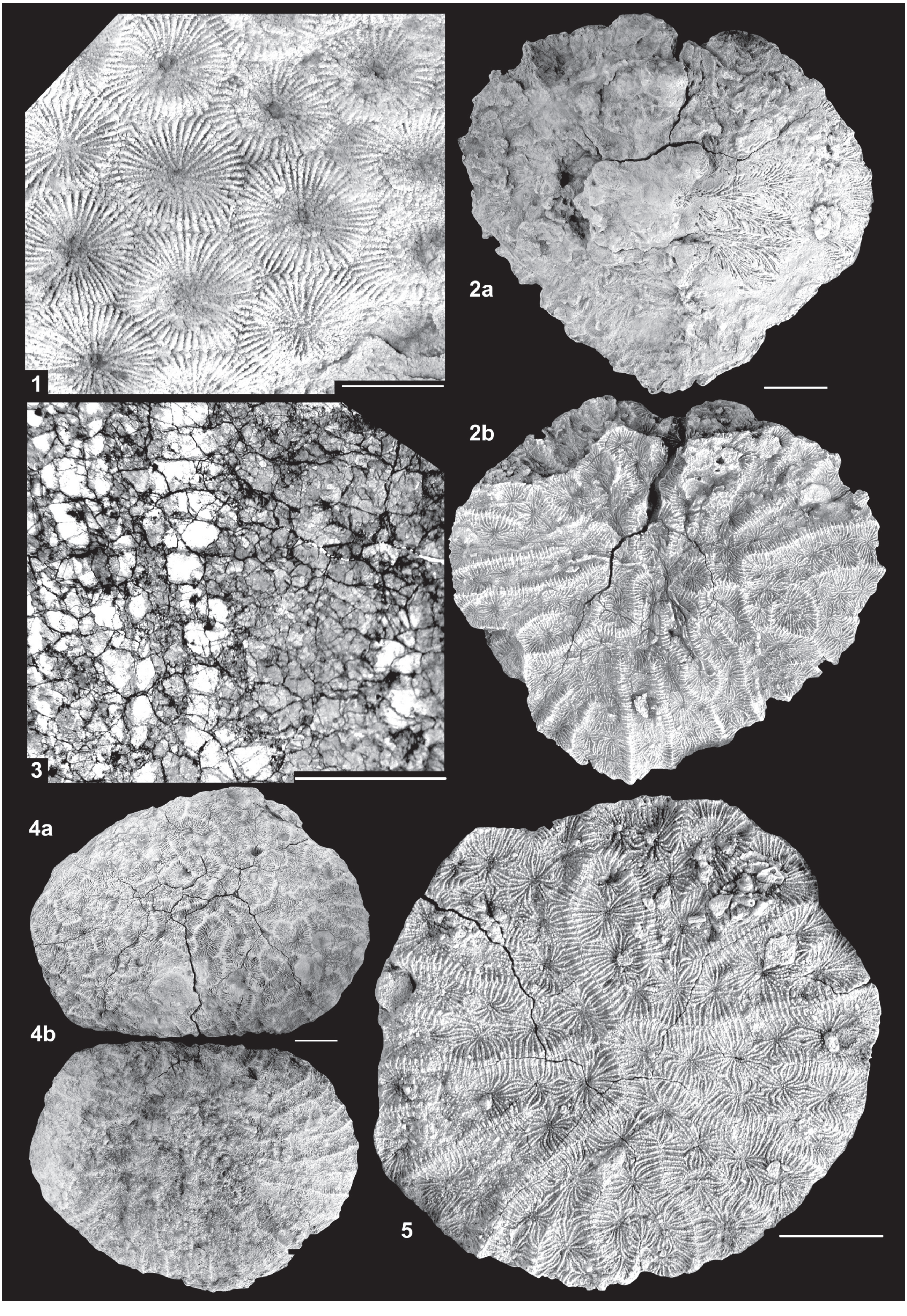
**Table 16:** Dimensions (in mm) of *Ovalastrea* sp. A

| Specimen | d | c-c | Ns | ds | dt | Wp |
|---|---|---|---|---|---|---|
| PIW2006III 6 | 5.5 | 4.6–6 | 47 | 4–5/1 | 8/1 | 0–6 |

**Plate 6**

Fig. 1: *Ovalastrea* sp. A from Rian. Part of upper surface showing plocoid colonial structure and monostomodaeal calices. Scale bar 5 mm; PIW2006III 6.

Figs 2–5: *Collignonastraea meandra* (D´ORBIGNY, 1850). 2: Specimen PIW2004III 41 from the Toarcian of the Kuh-e-Shisui area. Scale bar 10 mm. a: Lower surface showing costae just below the eroded part of holotheca, b: upper surface showing radial collines towards the periphery. 3: Specimen PIW2004III 43 from the Toarcian of the Kuh-e-Shisui area. Longitudinal thin-section showing septa at right angle to the lateral surface and the vesicular dissepiments. Note the lack of pennular structures. Scale bar 2 mm. 4: Specimen PIW2006III 84 from Sharif-Abad. Scale bar 10 mm. a: Upper surface showing meandroid series of calices between collines, b: lower surface showing radial arrangements of calicular series. 5: Specimen PIW2004III 40 from the Toarcian of the Kuh-e-Shisui area. Upper surface showing radial arrangement of calicular series as in *Collignonastraea jumarense* (GREGORY). Note septa of valley. Scale bar 10 mm.


1
2a
2b
3
4a
4b
5

factors. The assignment of the genus *Collignonastraea* to the family Latomeandridae ALLOITEAU, 1952 has to be reviewed once again in light of facts that emerged from the observation on specimens described here. The original diagnostic characters of the family Latomeandridae (ALLOITEAU 1952: 672) have been modified (MORYCOWA & RONIEWICZ 1995: 378), and in the emended characters the corals of this family possess pennular structures. However, this diagnostic feature is absent in the genus *Collignonastraea* (e.g., GREGORY 1900: 160; ALLOITEAU 1958: 98; BEAUVAIS 1966; CARATINI & BEAUVAIS 1969: 31; BEAUVAIS 1972: 80; NEGUS & BEAUVAIS 1975: 193; PANDEY & FÜRSICH 1993: 40; 2003: 84; PANDEY et al. 2000: 14; see also present material).

As mentioned earlier, *Microphyllia* D´ORBIGNY (1849) is one of the most comparable genera to this genus (LATHUILIÈRE 2000b: 161; PANDEY & FÜRSICH 2003: 84). BEAUVAIS (1964: 248, pl. 34, fig. 6) described the neotype of the genus *Microphyllia*, *Meandrina soemmeringii*, from material collected by GOLDFUSS from Nattheim, southern Germany. From the description of the septal ornamentation the presence of pennular structures cannot be ruled out.

Based on a survey of the literature *Microphyllia* D´ORBIGNY is characterized by often narrow vallies, corallites with linear budding, vallies splitting dichotomously into two with no or rare septa of the valley, and with septa having pores and pennular trabeculae. It can be easily differentiated from *Collignonastraea* ALLOITEAU, which is characterized by often wide vallies, corallites showing linear or circumoral budding and vallies occasionally splitting into two, always with septa of the valley and with septa having pores but trabeculae without pennular structures. As mentioned above, none of the species of *Collignonastraea* show pennular structures, whereas only some of the species described under *Microphyllia* do not show pennular structure.

The interior of some of our specimens is recrystallized and could not be studied. Clearly, some species of the two genera need to be reconsidered as far as their generic assignment is concerned.

*Collignonastraea meandra* (D´ORBIGNY, 1850)
Pl. 6, Figs 2–5

1850 *Oulophyllia meandra* sp. nov. – D´ORBIGNY: 293, pl. 1.
1851 *Latomeandra meandra* D´ORBIGNY – MILNE-EDWARDS & HAIME: 86.
1857 *Latimeandra meandra* D´ORBIGNY – MILNE-EDWARDS: 548. pl. 2.
1885 *Latimeandra salinensis* sp. nov. – KOBY: 250, pl. 74, figs 2–3, 5.
1900 *Comoseris jumarense radiata* sp. et var. nov. – GREGORY: 157, pl. 19, figs 1–8.
1900 *Comoseris jumarense irregularis* sp. et var. nov. – GREGORY: 158, pl. 19, figs 9–15, pl. 20, fig. 1.
1900 *Comoseris plana* sp. nov. – GREGORY: 160, pl. 20, figs 6–8, non fig. 9.
1966 *Collignonastraea meandra* D´ORBIGNY – BEAUVAIS: 1021, pl. 10, fig. 5.
1966 *Collignonastraea salinensis* KOBY – BEAUVAIS: 1020, pl. 13, fig. 5, pl. 14, figs 1–2.
1978 *Collignonastraea plana* (GREGORY) – BEAUVAIS: 67, pl. 6, fig. 3.
1978 *Collignonastraea jumarense* (GREGORY) – BEAUVAIS: 65, pl. 6, fig. 4.
1978 *Collignonastraea grossouvrei* BEAUVAIS – BEAUVAIS: 66, pl. 6, fig. 2.
1993 *Collignonastraea jumarensis* (GREGORY) – PANDEY & FÜRSICH: 39, pl. 10, figs 5–6, 8–13, 15–16.
2000 *Collignonastraea jumarensis* (GREGORY) – PANDEY et al.: 14, pl. 4, fig. 4.
2000b *Microphyllia meandra* (D´ORBIGNY) – LATHUILIÈRE: 160, fig. 13.5.
2003 *Collignonastraea meandra* D´ORBIGNY – PANDEY & FÜRSICH: 84, pl. 25, figs 3–5.

Material: Three specimens from the Shemshak Formation at Sharif-Abad (PIW 2006III 82–84), 1 specimen from the top of the Shemshak Formation at Rian (PIW2006III 25), and 4 specimens from the Toarcian of Kuh-e-Shisui (PIW 2006III 40–43).

Dimensions: see Table 17.

Description: Corallum discoidal, colonial, meandroid. Calicular series predominantly radial, particularly along the periphery. Budding intracalicular. Upper surface slightly convex, or flat to concave, subcircular in plan view. Lower surface conical with small attachment area, covered with holotheca with concentric rugae and folds. Calices distinct, mono- to bicentric with polygonal outline towards the center and arranged mostly in single series in valleys between collines towards the periphery. In a few cases, the corallite series show circumoral budding and divide the single series into two before forming a colline between the two daughter corallites. Collines prominent, tectiform. Valleys commonly splitting into two near the periphery. Calices bordered by septo-synapticulotheca along the collines. Septa alternately thin and thick, commonly

**Table 17:** Dimensions (in mm) of *Collignonastraea meandra* (D´ORBIGNY)

| Specimen | D | H | Lc | Wc | c-c | Ns | Ds/2 | Dt/1 |
|---|---|---|---|---|---|---|---|---|
| PIW2006III 25 | >150 | >60 | 42.5 | 5–6.5 | 2.5–6.5 | >35 | 5–6 | – |
| PIW2006III 82 | 87.6 | 20 | 37 | 5.8–7.6 | 4.5–5 | 34–41 | 4–7 | 4–5 |
| PIW2006III 84 | >78.7 | >29 | >38 | 3.8–5.5 | 3.6–7.5 | 31–41 | 4–8 | – |
| *C. jumarensis* (GREGORY) of PANDEY & FÜRSICH (1993) | 12.8–44 | 5–19.5 | 20.0 | 2.4 – 6.8 | 2.2 – 6 | 25 – 63 | 5–8 | – |
| *C. jumarensis* (GREGORY) of PANDEY et al. (2000) | 50.0/46.0 | 11 | 17 | 3 | 3 | ca 50 | 7 | – |

anastomosing, confluent within the valley with septa of the valley; confluent, subconfluent to non-confluent across the collines. Septa of first and second cycles reaching the center, those of the third and fourth cycles increasingly shorter and thinner. Denticles along distal margins of septa conspicuous, ranging from obtuse to acute-subangular. Maximum denticle density (8 per 1 mm) in the middle, and minimum (4 per 1 mm) near the outer and inner parts of septa, due to the trabecular fan system. Septal surfaces covered with granules and spinules. Synapticulae and dissepiments common, along the periphery vesicular dissepiments steeply inclined. Columella small in cross-section, parietal, papillose to spongy.

Remarks: Some of the features described above are based on specimens from the Kuh-e-Shisui area, northern Lut Block, which are better preserved than the material from the Shemshak Formation. The strata are Toarcian in age (Seyed-Emami et al. 2004) and thus time-equivalent to parts of the Shemshak Formation of the Alborz Mountains.

In thin-sections, the septa do not show any pennular structure. At places the spinules on the septal surfaces look like inconspicuous pennulae. Pores in the septa are not visible, but this may be due to recrystallization, because the density of trabeculae at the inner margin of the septa suggests that pores might have been present. In some cases, perhaps due to recrystallization, the columella is not clearly demarcated. It seems that the parietal columella is formed by the innermost trabeculae of one or a few of the septa. Vesicular dissepiments are quite common. In most specimens, the holotheca is eroded.

The various dimensions of the present specimens, as well as those of specimens described earlier on from the Callovian of Jordan (Pandey et al. 2000) and from the Badamu Formation (Toarcian) of east-central Iran (Pandey & Fürsich 2003) fall within the range of variation of the specimens from the Middle Bathonian of the Kachchh Basin described as *Collignonastraea jumarensis* (Gregory) by Pandey & Fürsich (1993). As other morphological characters are also similar, *C. jumarensis* is considered as a junior synonym of *C. meandra*.

Specimen PIW2006III 25, a fragment of a large specimen (>150 mm in diameter), has a weathered upper surface. The abundance of dissepiments is reminiscent of *Isastrea*. The nature of septa (? subcompact) and of the wall (? parathecal or synapticulothecal) is not clear, but the long series of corallites, traces of collines, the papillose columella, and the dimensions favour its assignment to *C. meandra*. Another specimen (PIW2006III 84) is strongly abraded. This specimen reveals transitional characters from a regular radial arrangement of corallites as in *C. jumarensis* to an irregular meandroid arrangement as in *Collignonastraea meandra*.

Suborder Microsolenina Morycowa & Roniewicz, 1995
Family Microsolenidae Koby, 1890

Genus *Microsolena* Lamouroux, 1821
Type species *Microsolena porosa* Lamouroux, 1821

*Microsolena verdati* Koby, 1889
Pl. 7, Figs 1–2

1889 *Microsolena verdati* sp. nov. – Koby: 489, pl. 123, figs 10–11.
2003 *Microsolena verdati* Koby – Pandey & Fürsich: 106, pl. 30, figs 1, 5–6, pl. 31, figs 1–5 [cum syn.].

Material: Thirteen specimens from the top of the Shemshak Formation at Rian (PIW2006III 8–13, 22, 40, 44, 51, 54, 58, 61).

Dimensions: see Table 18.

Description: see Pandey & Fürsich (2003).

Remarks: The specimens are well preserved, at least externally. With respect to morphological characters and dimensions they fall within the range of variation of *Microsolena verdati* Koby, 1889 (Pandey & Fürsich 2003: 106). The trabecular density may reach 6 per 2 mm or even more, when measured near the inner edge of the distal margin.

*Microsolena ornata* Koby, 1887
Pl. 7, Figs 3, 5

1887 *Microsolena ornata* sp. nov. – Koby: 399, pl. 107, figs 1–2.
2003 *Microsolena ornata* Koby – Pandey & Fürsich: 107, pl. 32, fig. 5, pl. 34, figs 1–5.

Material: Five specimens from the uppermost Shemshak Formation near Golbini (PIW2004III 19–20, 26–28).

Dimensions: see Table 19.

Remarks: All specimens are poorly preserved and the interior is mostly recrystallized. However, the thamnasterioid colony, corallite centers, septal morphology, denticulated menianae, subcircular to rectangular outline of pennulae in plan view, etc. as well as the dimensions match those of *Microsolena ornata* Koby (Pandey & Fürsich 2003: 107). In thin-sections it was possible to measure the pennular width (0.36 mm), the tra-

**Table 18:** Dimensions (in mm) of *Microsolena verdati* Koby

| Specimen | D | H | d | c-c | c'-c' | Ns | Ds/2 | Dt/2 |
|---|---|---|---|---|---|---|---|---|
| PIW2006III 40 | 93 | 51 | 4–7.5 | 5–7.2 | 3–5.8 | 29–34 | 5–6 | 5–6 |
| PIW2006III 44 | 4.8.5 | 23.5 | 6.3–7 | 5–7 | 4–5.5 | 26–28 | 5 | 5 |
| PIW2006III 51 | 49.2 | 19.4 | 5–7.5 | 7.8 | 4–5.2 | 28–35 | 5 | 5 |
| PIW2006III 58 | 80 | 32 | 5.5–6 | 5.7 | 5 | 34 | 5 | 4–5 |
| PIW2006III 61 | 80 | 32.2 | 6 | 7–8.5 | 4–4.5 | 32 | 5 | 5 |
| PIW2006III 8 | 55.5 | 25.6 | 5.5–3 | 5.3–6.8 | 3.5–5 | 25–34 | 4–5 | 4–6 |

**Table 19:** Dimensions (in mm) of *Microsolena ornata* KOBY

| Specimen | D | H | c-c | c'-c' | Ns | Ds/2 | Dt/2 |
|---|---|---|---|---|---|---|---|
| PIW2004III 27 | 67.5 | 41 | 5 | 3.5–4 | 37 | 7–8 | 6 |
| PIW2003III 28 | 77 | 52.5 | 3.5–6 | 3.5–6 | 30 | 6–7 | 5–7 |
| PIW2003III 19 | 120 | 72 | – | – | – | 6 | 6–7 |
| PIW2003III 20 | 91 | 50 | 3–4.5 | 3.8–6.5 | 33 | 7 | 6 |
| PIW2003III 26 | 85 | 40 | 7.8–10 | 5–6 | – | 6 | 5–6 |

becular width in the middle between two pennulae (0.15 mm), and the length of trabeculae between two successive pennulae (0.5 mm). The specimens differ from *Microsolena verdati* KOBY on the basis of a higher septal and trabecular density.

Genus *Kobya* GREGORY, 1900
Type species *Kobya crassolamellosa* GREGORY, 1900

Remarks: Specimens of the microsolenid *Kobya* from the Bathonian of Kachchh (PANDEY & FÜRSICH 1993; PANDEY et al. 1999) possess a low septal and trabecular density (5–6 per 2 mm in both cases) compared to other microsolenids. In specimens of *Kobya crassolamellosa* GREGORY (1900) and *Microsolena verdati* KOBY (1889) from Iran the septal and trabecular densities are quite similar (for emended diagnosis of *Kobya* see PANDEY & FÜRSICH 2003: 108).

*Kobya crassolamellosa* GREGORY, 1900
Pl. 7, Fig. 4

1900 *Kobya crassolamellosa* sp. nov.– GREGORY: 170, pl. 21, figs 15–17, pl. 22, figs 2, 5–8, pl. 23, fig. 1, pl. 2A, fig. 7.

2003 *Kobya crassolamellosa* GREGORY – PANDEY & FÜRSICH: 110, pl. 33, fig. 5 [cum syn.].

Material: 6 specimens from the top of the Shemshak Formation at Rian (PIW2006III 55–57, 59, 62–63).

Dimensions: see Table 20.

Remarks: The specimens correspond closely to material of the species described from the top of the Baghamshah Formation of the Kamar-e-Mehdi area, Iran (PANDEY & FÜRSICH 2003). Externally one can easily separate *Microsolena verdati* KOBY (described above) from *Kobya crassolamellosa* GREGORY on the basis of features of the distal septal margin. In *M. verdati* it is more or less beaded, occasionally pennular structures are distinct, and the columella is parietal but weak, whereas in *K. crassolamellosa* the septa appear subcompact along the distal margin, the pennular structures are very rarely distinct, and the columella is conspicuous, papillose to spongy. This is because of thicker trabeculae in *Kobya crassolamellosa*. In specimen PIW2006III 59, the characters of the distal septal margin appear to be transitional between the two taxa in question. In such a case a more detailed study of thin-sections of several samples of both taxa from various sedimentary basins is required to understand the variability of the species.

**Table 20:** Dimensions (in mm) of *Kobya crassolamellosa* GREGORY

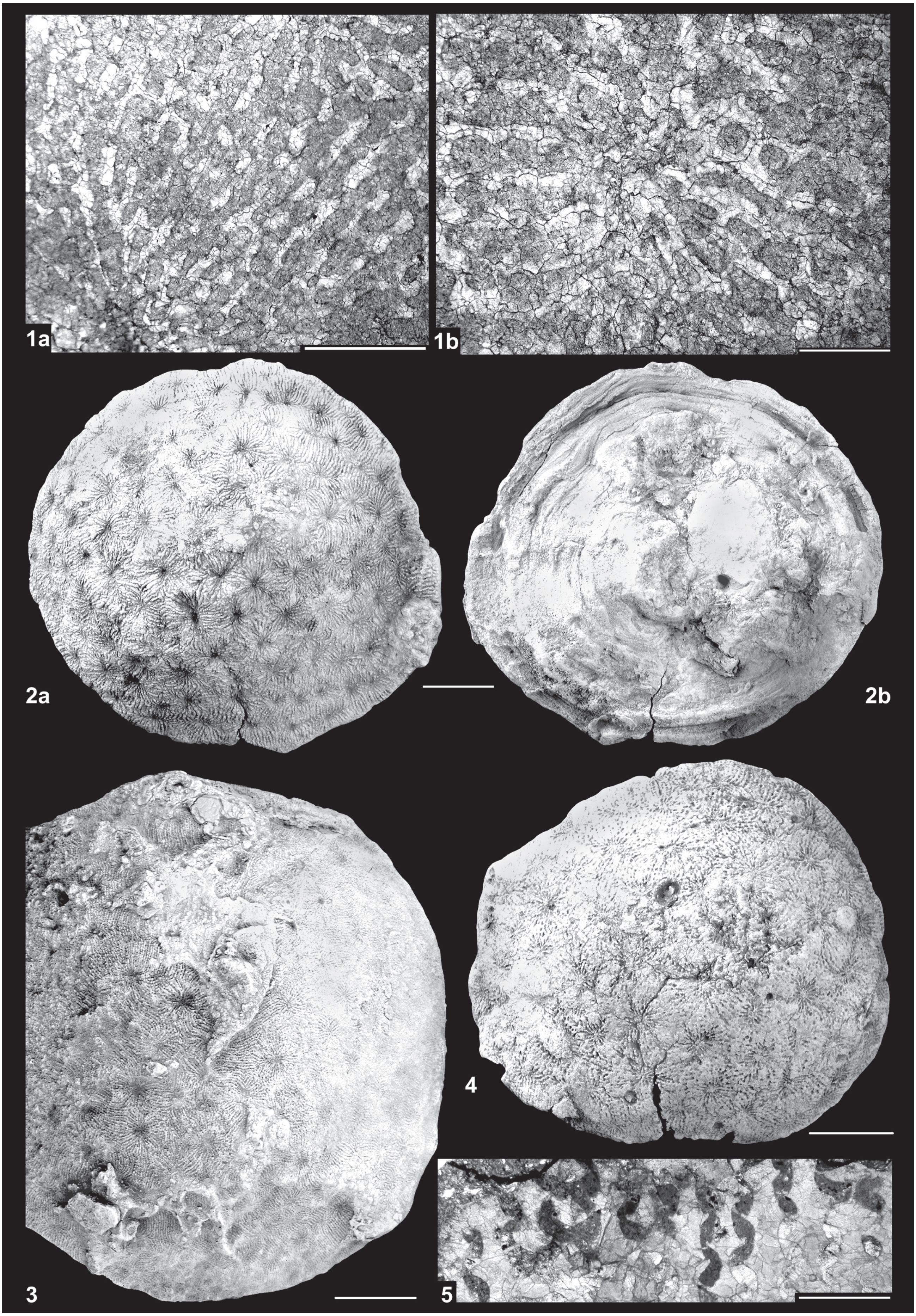
| Specimen | D | H | d | c-c | c'-c' | Ns | Ds/2 | Dt/2 |
|---|---|---|---|---|---|---|---|---|
| PIW2003III 55 | 65.4 | 22 | 5 | 7 | 5–7 | ~24 | 4–5 | 4–5 |
| PIW2003III 56 | 62.0 | 18.5 | 5 | 6.5–7.8 | 3.6–4.5 | ~30 | 5 | 5 |
| PIW2003III 57 | 29.3 | 10.3 | 3.5–4 | 4–5 | 4.8 | 34 | 5–6 | 5–6 |
| PIW2003III 59 | 59.4 | 26.4 | 5 | 6.4–7 | 4.3–6 | ~25 | 4 | 4 |

**Plate 7**

Figs 1–2: *Microsolena verdati* KOBY, 1889 from Rian. 1: Specimen PIW2006III 22. a: Transverse section showing septal organization. Scale bar 2 mm, b: transverse section showing pores in septa. Scale bar 1 mm. 2: Specimen PIW2006III 8. Scale bar 10 mm. a: Upper surface showing circumoral budding, b: lower surface showing holotheca with concentric rugae.

Figs 3, 5: *Microsolena ornata* KOBY, 1887 from Golbini. 3: Upper surface showing poorly distinct corallite centers. Scale bar 10 mm; PIW2004III 27. 5: Longitudinal thin-section showing well preserved pennular structures and synapticulae. Scale bar 1 mm; PIW2004III 26.

Fig. 4: *Kobya crassolamellosa* GREGORY, 1900 from Rian. Upper surface view showing circumoral budding. Scale bar 10 mm; PIW2006III 56.


1a
1b
2a
2b
3
4
5

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