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Early Permian Tabulate Corals from the Jamal Formation, East-Central Iran

Shuji Niko[1], Mahdi Badpa[2], Abbas Ghaderi[3] and Mohammad Reza Ataei[3]

[1] Department of Environmental Studies, Faculty of Integrated Arts and Sciences, Hiroshima University, 1–7–1 Kagamiyama, Higashihiroshima 739–8521, Japan
[2] Department of Geology, Payame Noor University of Qom, Qom, Iran
[3] Department of Geology, Faculty of Science, Ferdowsi University of Mashhad, Mashhad, Iran

Abstract Seven species of tabulate corals, *Sutherlandia jamalensis* sp. nov., *Pseudofavosites exiguus* Flügel, 1972, *P. fusiforme* (Flügel, 1972), *Michelinia* sp. indet., *Gertholites*? *diversaporus* (Flügel, 1972), *G.* sp. indet., and *Thamnoptychia directa* (Flügel, 1972), are described from the Bagh-e Vang Member (late early Permian) of the Jamal Formation at the Tabas area, East-Central Iran. The discoveries of *Sutherlandia* and *Thamnoptychia* mark the first records of these genera in Iran. This assemblage inhabited on the southern shelves of the Paleotethys along northern margin of Gondwana.
Key words: late early Permian, Jamal Formation, Iran, Gondwana, Tabulata

Introduction

Permian tabulate corals are poorly known from Iran. Since the initial study by Flügel (1964), who described *Michelinia*? cf. *glomerata* M'Coy, 1849, *Protomichelinia abnormis* (Huang, 1932), *P. favositoides* (Girty, 1908), *P. laosensis* (Mansuy, 1914) and *Cystomichelinia biknia* Flügel, 1964 from the Ruteh Limestone, only 13 species of the subclass have been recorded by Flügel (1968, Nesen Formation; 1972, Jamal Formation; 1995, Jamal Formation; 1997, "Mittere schiefrige Fazies der *Yabeina*-Zone Perm, Zagros Mountains"), Ezaki (1991, Surmaq, Adadeh, Hambast and Gnishik formations), Ataei *et al.* (2018, Jamal Formation), and Ghaderi *et al.* (in press, Khachik, Julfa and Ali-Bashi formations).

This contribution deals with new material collected from the Jamal Formation in two localities at the Tabas area of East-Central Iran. They are Shesh-Angosht (coordinates of N33°59′15″ and E56°46′50″) on the western flank of the Shesh-Angosht Mountain and Bagh-e Vang (coordinates of N33°58′27″ and E56°47′33″) on the southwestern flank of the Bagh-e Vang Mountain (Figs. 1, 2). The purposes are to revise the systematics of the known tabulate coral species by previous workers (Flügel, 1972, 1995; Ataei *et al.*, 2018) and add undescribed taxa for the fauna.

Repositories: Except for a specimen S72 that is kept in the National Museum of Nature and Science, Tokyo, Japan, all specimens are housed in the paleontological collections at Ferdowsi University of Mashhad, Mashhad, Iran.

Geologic setting

The Jamal Formation was introduced by Stöcklin *et al.* (1965) for the Permian rocks consisting mainly of limestone and dolomite in the Shotori and Shirgesht mountain ranges of the Tabas Block. Its thickness ranges from 293 to 473 m (Stöcklin *et al.*, 1965; Ruttner *et al.*, 1968; Leven and Vaziri Mohaddam, 2004). The succession rests unconformably upon eroded surface of sandstone belonging to the Carboniferous Sardar Formation and is conformably overlain by the Lower Triassic Sorkh Shale Formation (Partoazar *et al.*, 2014). The stratigraphic interval in which all examined tabulate corals occur represents the lowest ca. 60 m part (= Bagh-e Vang Member in Partoazar, 1995), where carbonate facies are sandy to marly and contain interlayers of sandstone, shale, and olistolith.

The lowest member was dated by various taxa. These results are as follows: Bolorian (= Kungurian; fusulinids; Leven and Vaziri Mohaddam, 2004), Yakhtashian (= Artinskian) to Bolorian (fusulinids; Arefifad, 2006), Artinskian to Kungu-

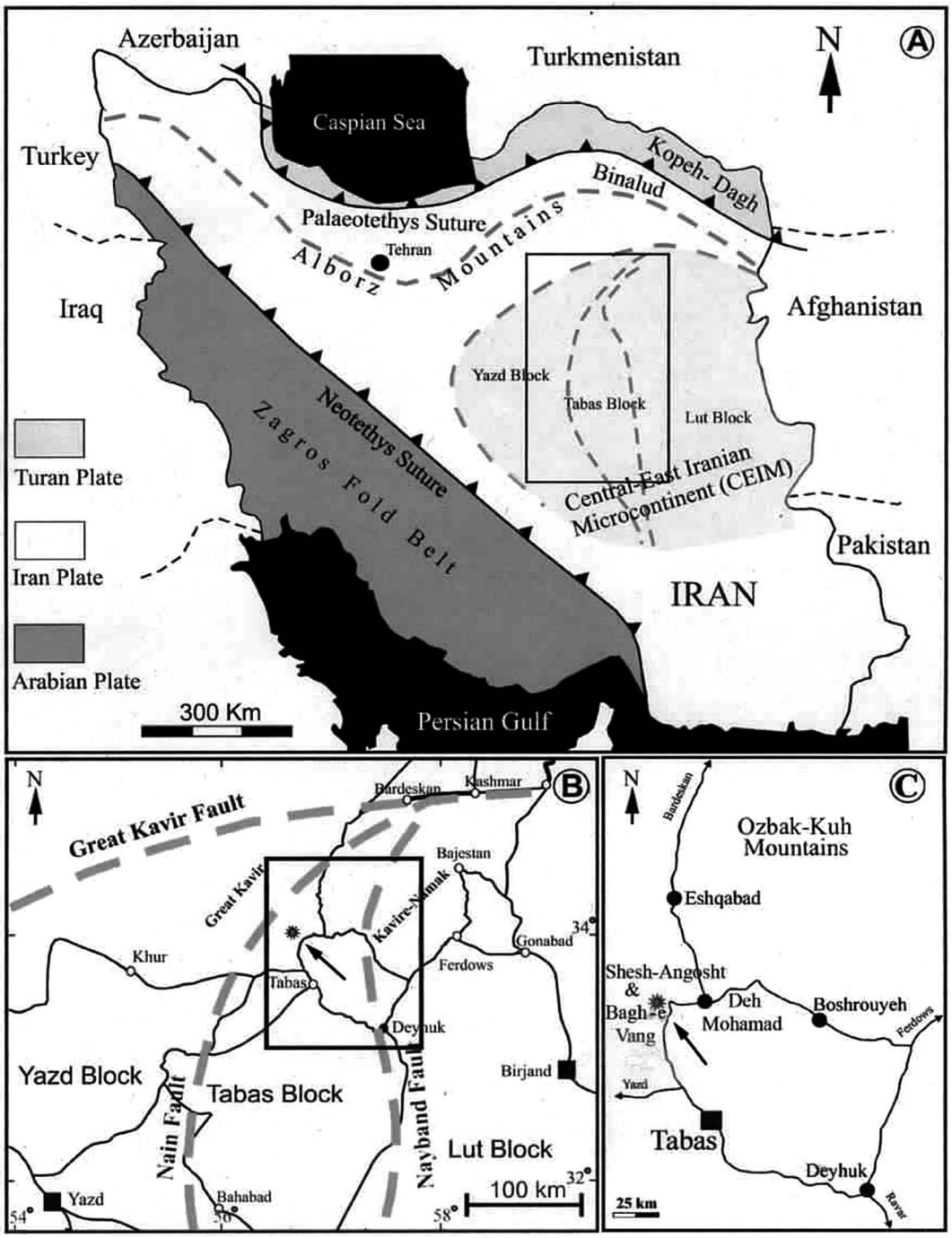

Fig. 1. Maps showing geologic setting and geographic position of tabulate coral localities (modified from Badpa *et al.*, 2016). **A**, tectonic map of Iran. **B**, close-up of rectangular area in Fig. 1A, note fossil localities (asterisk) belonging to the Tabas Block. **C**, close-up of rectangular area in Fig. 1B, showing detailed position of fossil localities (asterisk) in the Tabas area, East-Central Iran.

rian (bryozoans; Ernst *et al.*, 2006), Bolorian to early Kubergandinian (= early Roadian; fusulinids; Leven and Gorgij, 2011), and Sakmarian to Kungurian (conodonts; Voulo, 2014). Taking these information into consideration, the age of tabulate corals examined herein is best constrained as late early Permian. The Tabas Block forms the Central-East Iranian Microcontinent with the Yazd and Lut blocks, whose paleogeographic position is interpreted to have been part of northern margin of Gondwana during early Permian time (e.g. Berberian and King, 1981; Scotese and Langford, 1995; Ruban *et al.*, 2007). It is concluded that, therefore, habitat of the Jamal tabulate coral assemblage was on the southern shelves of the Paleotethys.

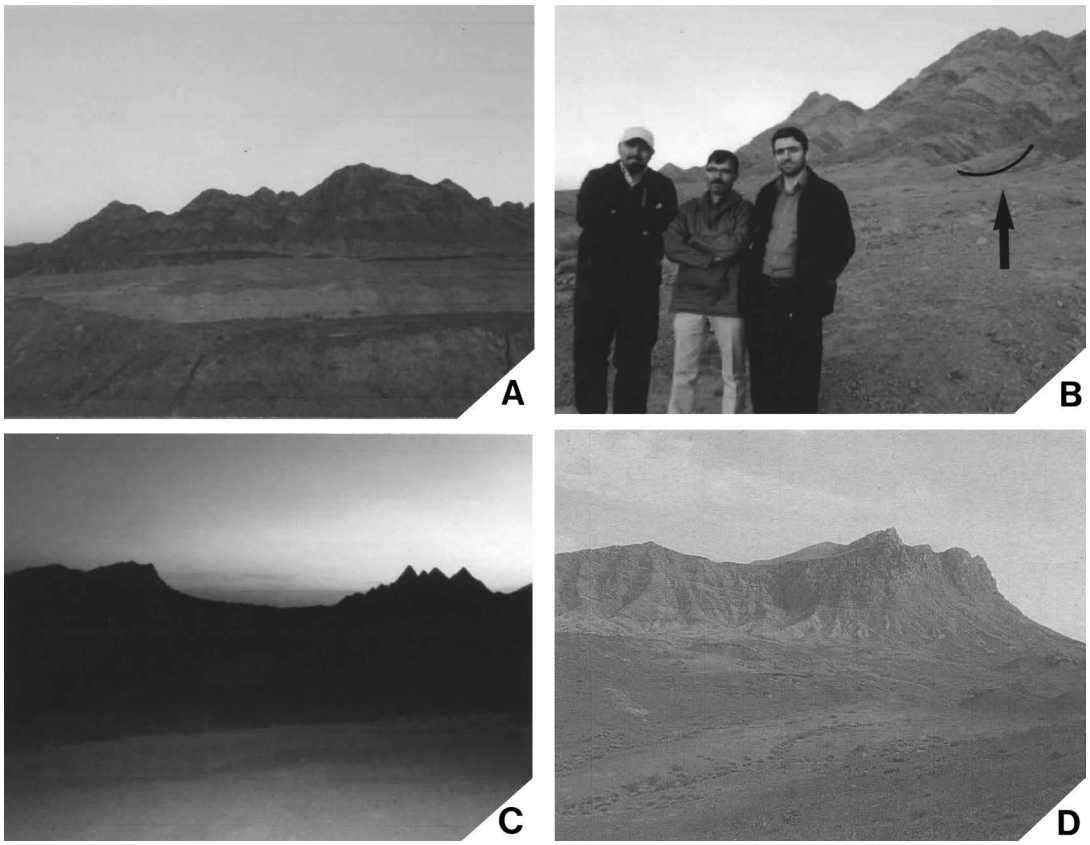

Fig. 2. Exposures of the Permian Jamal Formation and landscape of the Shirgesht Mountain Range in the Tabas area, East-Central Iran. **A**, the Shesh-Angosht Mountain. Flank of front is Shesh-Angosht locality. **B**, close-up of Shesh-Angosht locality, showing the Bagh-e Vang Member (arrow). The persons are the third author (A. G), the forth author (M. R. A.) and the second author (M. B.), from left to right. **C**, silhouette of the Bagh-e Vang Mountain (left) and the Shesh-Angosht Mountain (right). Distance between these mountains is about 1 km. **D**, the Bagh-e Vang Mountain. Bagh-e Vang locality is on other side of the mountain.

Systematic Paleontology

Subclass Tabulata Milne-Edwards and Haime, 1850

Order Favositida Wedekind, 1937

Suborder Favositina Wedekind, 1937

Superfamily Favositoidea Dana, 1846

Family Favositidae Dana, 1846

Subfamily Emmonsiinae Lecompte, 1952

Genus ***Sutherlandia*** Cocke and Bowsher, 1968

Type species: *Sutherlandia irregularis* Cocke and Bowsher, 1968.

Sutherlandia jamalensis sp. nov.

(Figs. 3-1–8)

Pseudofavosites sp., Flügel, 1972, p. 93, 94, pl. 6, fig. 3; 1995, p. 39.

Material examined: Holotype, specimen S43, from which two thin sections were made. Paratype, specimen S76.

Locality: Shesh-Angosht.

Diagnosis: Species of *Sutherlandia* with corallum diameter of 12–14 mm and prismatic to subcylindrical corallites; diameters of distal corallites approximately 1.7 mm; intercorallite walls thickened, 0.10–0.61 mm; squamulae relatively short for genus; conical to hemi-spherical septal spins developed at distal corallites; tabulae relatively rare, complete.

Description: Coralla cerioid, subspherical in growth form and consist of radially arranged corallites; diameters of coralla are small for the subfamily, but moderate for the genus, indicating 12–14 mm. Corallites prismatic to subcylindrical; transverse sections of proximal portions of corallites are 3–5 sided polygonal, then they shift to rounded polygonal to nearly circular in distal portions; diameters of corallites range from 0.4 to 2.2 mm with approximately 1.7 mm mean (n = 7) at distal corallites; lumina (tabularia) rounded polygonal to circu-

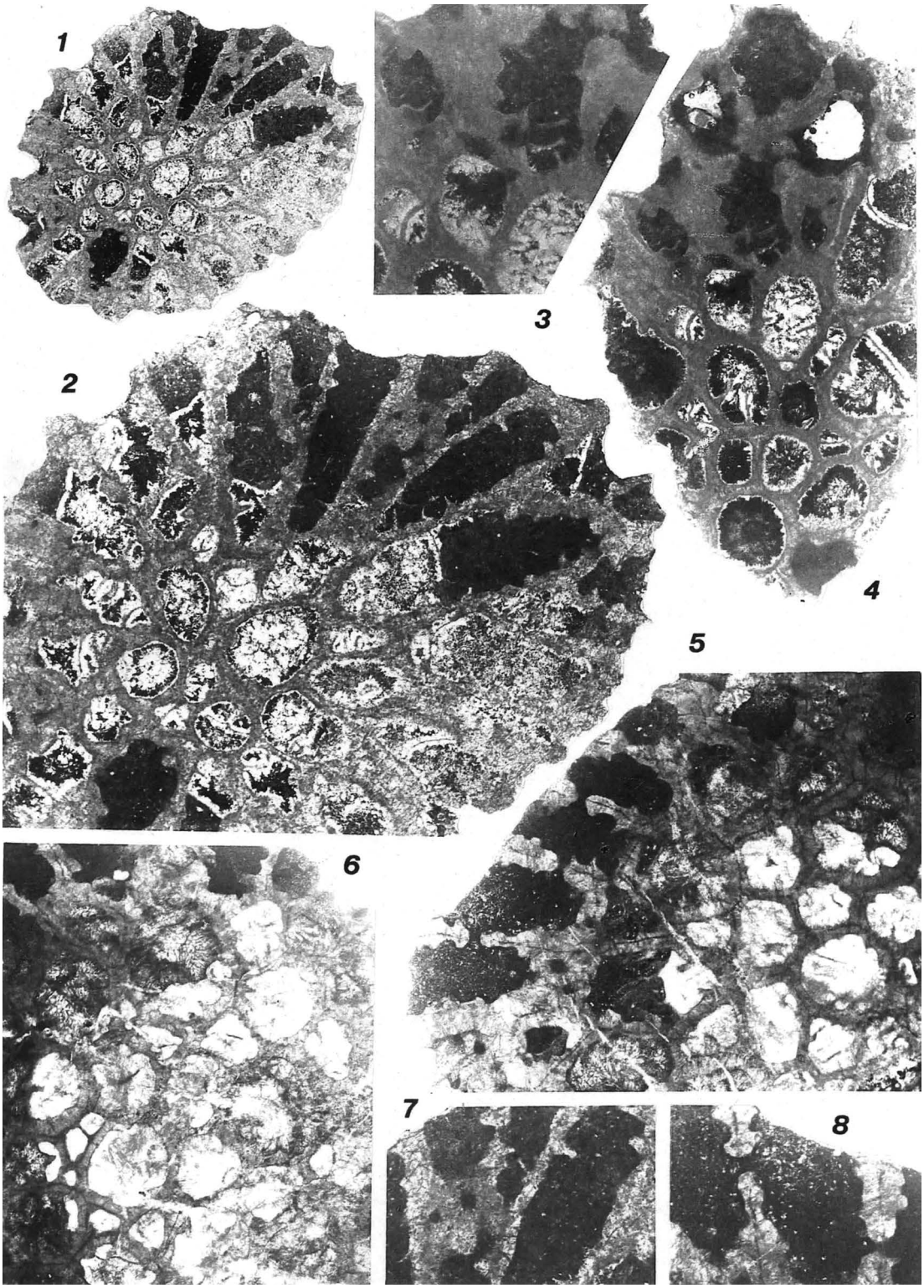

Fig. 3. *Sutherlandia jamalensis* sp. nov., thin sections. **1–4**, **7**, holotype, specimen S43. **1**, transverse section (slightly off its center) of corallum, ×5. **2**, partial enlargement of Fig. 3-1, showing transverse to longitudinal sections of corallites, ×10. **3**, partial enlargement of Fig. 3-4, showing squamulae, septal spines and tabula, ×14. **4**, oblique section (off its center) of corallum, note complete tabulae, ×10. **7**, partial enlargement of Fig. 3-1, showing mural pores, squamulae and septal spines, ×14. **5**, **6**, **8**, paratype, specimen S76. **5**, **6**, transverse to oblique sections of corallites, ×10. **8**, partial enlargement of Fig. 3-5, showing mural pores and septal spines, ×14.

lar in transverse section; calices deep to very deep and perpendicularly oriented to corallum surface; no calical modification recognized; increase of new corallite is intermural(?). Intercorallite walls thickened, 0.10–0.61 mm, differentiated into median dark line and stereoplasm, the latter of which has rect-

radiate fibers in microstructure; mural pores occur on corallite faces, forming two rows, and circular to subcircular in profile; diameters of pores are 0.06–0.31 mm; squamulae commonly occur in proximal corallites and sporadic in distal ones, relatively short for the genus, 0.25–0.48 mm; approximate ratios of squamula length per lumen diameter are up to 0.6; thickness of squamula is thin to moderately thickened, attaining 0.13 mm; considerable squamulae replaced by conical to hemi-spherical septal spins at distal corallites; spine length 0.08–0.23 mm; tabulae relatively rare, complete, slightly concave to nearly transverse.

Etymology: The specific name is derived from the type stratum, named the Jamal Formation.

Discussion: Although Flügel (1972) placed this species in *Pseudofavosites*, we herein transfer it to *Sutherlandia* on the basis of the possessions of thickened intercorallite walls and complete tabulae. The present two specimens represent the first record of the genus from Iran.

Permian occurrences of *Sutherlandia* are very rare. As far as we know, only four species are previously documented from North China (Tchi, 1980; Lin, 1983; Ding *et al.*, 1984) and Japan (Senzai and Niko, 2005). Among them, the new species most resembles *S. finitimus minor* (Ding *in* Ding *et al.*, 1984, p. 85, pl. 16, figs. 1a, a′, b, b′, c, c′, 2a–d, d′; Lin *et al.*, 1988, p. 419), which is reported from the middle Permian of Inner Mongolia. However, the presence of conical to hemi-spherical septal spins distinguishes it from the Chinese species.

Family Pseudofavositidae Sokolov, 1950

Genus ***Pseudofavosites*** Gerth, 1921

Type species: *Pseudofavosites stylifer* Gerth, 1921.

Pseudofavosites exiguus Flügel, 1972

(Figs. 4-1–3)

Pseudofavosites extraspinosus exiguus Flügel, 1972, p. 93, pl. 6, fig. 2; 1995, p. 39; Ataei *et al.*, 2018, figs. 4a, b.

Material examined: Specimen S35.

Locality: Shesh-Angosht.

Description: An incomplete corallum is available for study; it is cerioid and consists of radially arranged corallites; growth form of corallum is probably sub-spherical with approximately 18 mm in maximum diameter. Corallites prismatic to subprismatic, whose diameters range from 0.5 to 1.8 mm; transverse sections of each corallite are quadrate in proximal portion, then become rounded polygonal in distal one; calices very deep. Intercorallite walls 0.04–0.21 mm in thickness; mural pores occur at corallite angles and faces; profiles of pores are longitudinally elliptical having diameters of 0.20×0.25, 0.22×0.29 mm in typical ones; squamulae well developed though all growth stages of corallites and long, attaining 0.67 mm; tabula absent.

Discussion: In the original description by Flügel (1972), this species was established as a new subspecies of *Pseudofavosites extraspinosus* Sokolov (1955, p. 157, pl. 7, figs. 7, 8, text-figs. 30a, b), of which the types are known from the lower Permian of the Urals. However, *P. extraspinosus* lacks squamulae in proximal portion of corallites and has larger corallite diameters (1.5–2.5 mm) than those of the Iranian species. We think that these morphologic differences beyond intraspecific variations.

The distinctive characters between *Pseudofavosites exiguus* and an associated species in the Jamal Formation, *P. fusiforme*, are given in the discussion of the latter species.

Pseudofavosites fusiforme (Flügel, 1972)

(Figs. 4-4–6)

Favosites fusiforme Flügel, 1972, p. 92, pl. 6, fig. 1; 1995, p. 39.

Pseudofavosites extraspinosus exiguus Flügel; Ataei *et al.*, 2018, figs. 5a, b.

Material examined: Specimens S42, B163.

Localities: Shesh-Angosht (S42) and Bagh-e Vang (B183).

Description: Coralla cerioid formed by radially arranged corallites, sub-spherical in growth form and encircling crinoid stems; diameters of coralla are large for the genus, attaining to at least 32 mm. Corallites prismatic and measure 0.3–2.6 mm in diameter; except for the most proximal adhesive portions where transverse sections of corallite are triangular to quadrate, then they become rounded polygonal in distal one; calices very deep. Intercorallite walls 0.07–0.25 mm in thickness; mural pores occur at corallite angles and faces; profiles of pores

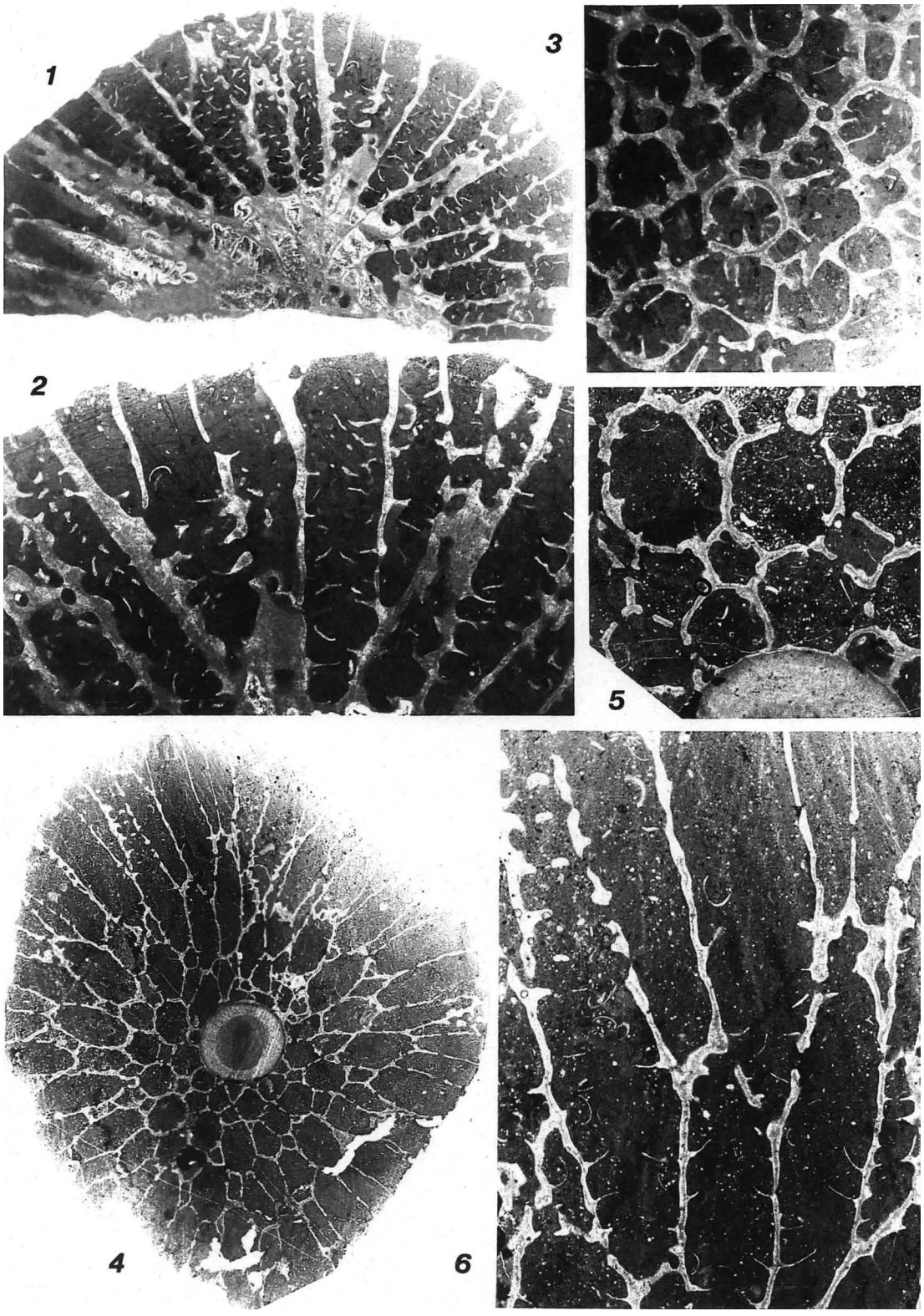

Fig. 4. **1–3**, *Pseudofavosites exiguus* Flügel, 1972, specimen S35, thin sections. **1**, transverse section of corallum, ×5. **2**, partial enlargement of Fig. 4-1, showing longitudinal sections of corallites, × 10. **3**, transverse sections of corallites, ×10. **4–6**, *Pseudofavosites fusiforme* (Flügel, 1972), specimen S42, thin sections. **4**, transverse section of corallum, ×3. **5**, partial enlargement of Fig. 4-4, showing transverse sections of corallites, ×10. **6**, partial enlargement of Fig. 4-4, showing longitudinal sections of corallites, × 10.

are longitudinally elliptical to circular having diameters of 0.20 × 0.27, 0.13 mm in typical ones; squamulae common in proximal and almost absent in distal portions of corallites; lengths of squamulae are long, attaining 0.88 mm; thickness of squamulae is mostly very thin; tabula absent.

Discussion: This species, originally introduced by Flügel (1972) as *Favosites fusiforme*, is herein transferred to *Pseudofavosites* on the basis of the preserved characters of newly collected specimens from the identical stratum with the holotype. Among them, the corallum encircling crinoid stem and the possession of squamulae warrant the generic assignment.

Pseudofavosites fusiforme differs from *P. exiguus* by having larger corallite diameters and fewer squamulae.

Family Micheliniidae Waagen and Wentzel, 1886

Subfamily Micheliniinae
Waagen and Wentzel, 1886

Genus ***Michelinia*** de Koninck, 1841

Type species: *Calamopora tenuiseptata* Phillips, 1836.

Michelinia sp. indet.
(Figs. 5-1, 2)

Material examined: Specimen S9.

Locality: Shesh-Angosht.

Description: A fragmentary corallum is available for study; it is cerioid and 13 mm in maximum diameter. Corallites prismatic with transverse sections of 4–8 sided polygonal; diameters of corallites are 1.6–4.3 mm. Intercorallite walls weakly thickened for the genus, 0.19–0.46 mm; mural pores circular in profile and occur on corallite faces and at angles; diameters of pores are 0.10–0.31 mm; septal spines well developed, low conical; tabulae numerous, in which incomplete tabulae are predominant, but complete ones not rare.

Discussion: This specimen is tentatively assigned to *Michelinia* rather than *Protomichelinia* because

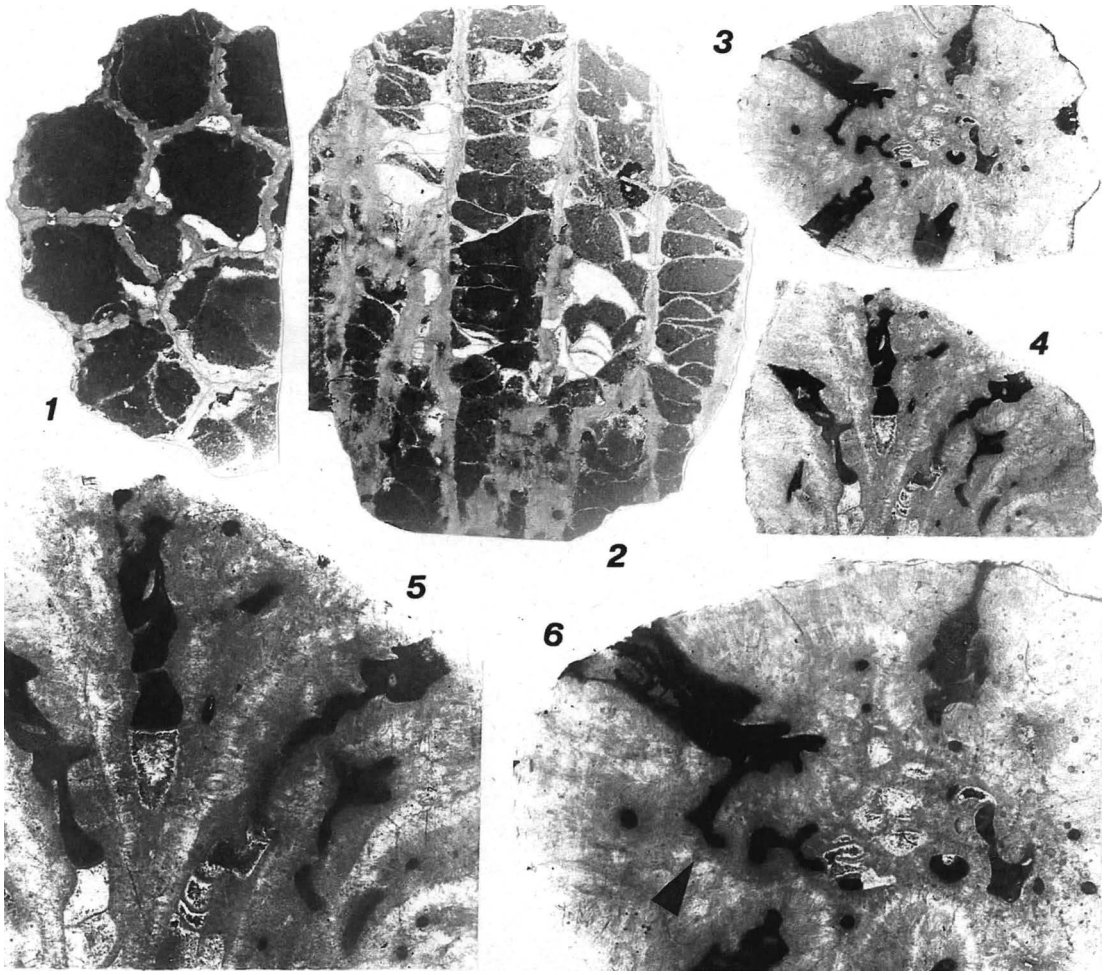

Fig. 5. **1**, **2**, *Michelinia* sp. indet., specimen S9, thin sections. **1**, transverse sections of corallites, ×5. **2**, longitudinal sections of corallites, ×5. **3–6**, *Gertholites* sp. indet., specimen S58, thin sections. **3**, transverse section of branch, ×5. **4**, longitudinal section of branch, ×5. **5**, partial enlargement of Fig. 5-4, showing longitudinal sections of corallites, ×10. **6**, partial enlargement of Fig. 5-3, showing transverse to longitudinal sections of corallites, arrow indicates vermiform tunnels, ×10.

of being well-developed incomplete tabulae. However, it is too fragmentary to be identified confidently.

Superfamily Pachyporoidea Gerth, 1921

Family Pachyporidae Gerth, 1921

Genus *Gertholites* Sokolov, 1955

Type species: *Pachypora curvata* Waagen and Wentzel, 1886.

Gertholites*? *diversaporus (Flügel, 1972)

(Figs. 6-1–4)

Trachypora archilaeus[sic] *diversapora* Flügel, 1972, p. 94, 95, pl. 6, figs. 4, 5; 1995, p. 39.
Gertholites diversaporus (Flügel); Tourneur, 1988, p. 305.

Material examined: Specimen S66.

Locality: Shesh-Angosht.

Description: A fragment of cylindrical branch is available for study; it is cerioid and 9 mm in diameter. Corallites prismatic to subprismatic with transverse sections of indistinct 4–7 sided to rounded polygonal; diameters of corallites are 0.2–2.7 mm; each corallite consists of directly longitudinal proximal portion and outwardly curved distal one; proximal and distal portions respectively form axial and peripheral zones; calices deep, open upward with 55°–70° for branch surface. Intercorallite walls relatively thin in axial zone, 0.11–0.36 mm; then, their thickness abruptly increases attaining approximately 1.2 mm to form stereozone at peripheral zone; apparent mural pore is not observable in axial zone; mural tunnels in peripheral zone are circular profiles and 0.08–0.15 mm in diameter; septal spines rare, restrict in in calical pit, high conical, and 0.13–0.36 mm in length; septal ridges also developed in calical pit; tabulae sporadic, complete.

Discussion: This species was established by Flügel (1972) as a new subspecies of *Trachypora achilleos* Heritsch (1937, p. 206–209, figs. 1–10), whose the type series is known from the Upper Carboniferous of Chios, Greek. Subsequently, it was removed from the abolished genus (see Lecompte, 1939) and placed in *Gertholites* by Tourneur (1988). Among the known pachyporid genera, *Gertholites* seems the most apposite for the generic assignment. However, neither the holotype nor the present newly collected specimen indicate anastomosed mural tunnels that is the most diagnostic character of *Gertholites*. The possession of septal ridges in this Iranian species also beyond the diagnosis of the genus.

Gertholites sp. indet.

(Figs. 5-3–6)

Material examined: Specimen S58.

Locality: Shesh-Angosht.

Description: A fragment of cylindrical branch is available for study; it is cerioid and 10 mm in diameter. Corallites subprismatic with rounded polygonal transverse sections; each corallites gradually divergent; approximate diameters of corallites are 0.5–2.5 mm; calices mostly deep, open oblique upward. Intercorallite walls uniformly thickened in axial zone of branch, 0.15–0.44 mm; then, their thickness abruptly increases attaining approximately 1.8 mm to form peripheral stereozone; mural tunnels vermiform and anastomosed with circular profiles; diameters of tunnels are 0.12–0.27 mm; septal spines common, high conical with more or less curved tips, and 0.19–0.48 mm in length; tabulae rare, complete.

Discussion: This specimen is placed in *Gertholites* on the basis of the possessions of thickened intercorallite walls, vermiform and anastomosed mural tunnels, and high conical septal spines. It probably represents new species, but identification is uncertain because of insufficient material.

Genus ***Thamnoptychia*** Hall, 1876

Type species: *Madrepora limbata* Eaton, 1832.

Thamnoptychia directa (Flügel, 1972)

(Figs. 6-5–9)

Trachypora directus Flügel, 1972, p. 95, pl. 6, figs. 6, 7; 1995, p. 39.

Material examined: Specimens S72, S82, B165.

Localities: Shesh-Angosht (S72, S82) and Bagh-e Vang (B165).

Description: Coralla ramose consisting of cylindrical and cerioid branches; branching probably bifurcate; diameters of branches are 6–12 mm. Corallites prismatic to subprismatic with indistinct 4–9

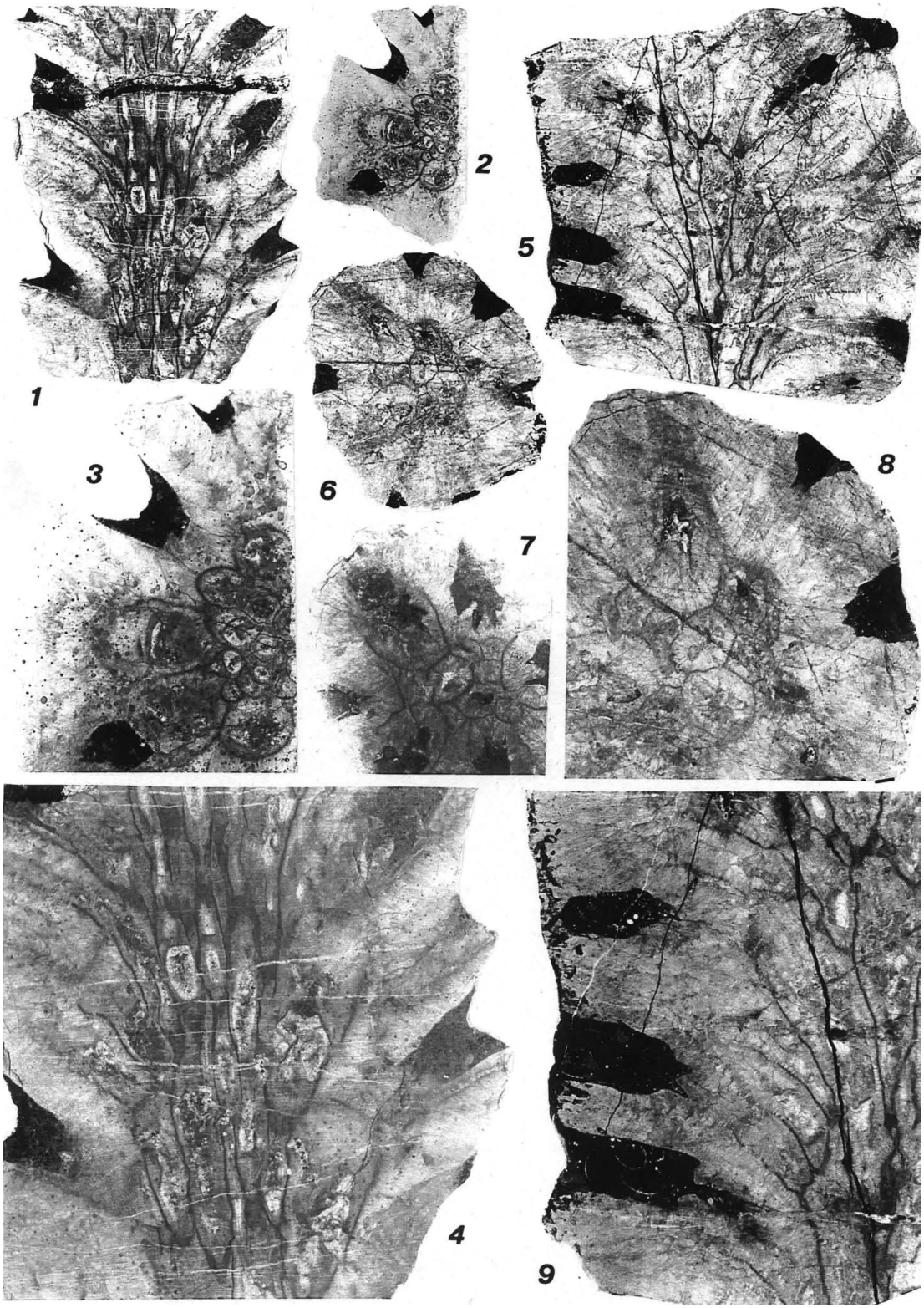

Fig. 6. **1–4**, *Gertholites*? *diversaporus* (Flügel, 1972), specimen S66, thin sections. **1**, longitudinal section of branch, ×5. **2**, transverse section of branch, ×5. **3**, partial enlargement of Fig. 6-2, showing transverse to oblique sections of corallites, ×10. **4**, partial enlargement of Fig. 6-1, longitudinal sections of corallites, ×10. **5–9**, *Thamnoptychia directa* (Flügel, 1972), thin sections. **5**, **6**, **8**, **9**, specimen B165. **5**, longitudinal sections of branches, ×5. **6**, transverse section of branch, ×5. **8**, partial enlargement of Fig. 6-6, showing transverse to oblique sections of corallites, ×10. **9**, partial enlargement of Fig. 6-5, showing longitudinal sections of corallites, ×10. **7**, specimen S72, oblique to transverse sections of corallites, note well-developed septal ridges, ×10.

sides, whose diameters 0.3–3.8 mm; each corallite consists of directly longitudinal proximal portion and outwardly curved distal one; proximal and distal portions of corallites respectively form axial and peripheral zones; calices open at nearly right angle to branch surface. Intercorallite walls uniformly thickened in axial zone, 0.17–0.75 mm; then, their thickness increases attaining approximately 1.5 mm to form wide stereozone; lumina (tabularia) almost closed by thickened walls; mural pores circular in profile and occur at corallite angles and faces, then they shift tunnels in peripheral zone; diameters of pores (tunnels) are 0.08–0.17 mm; septal spines well developed, conical, 0.13–0.23 mm in length; septal ridges also developed in calical pit; tabulae rare, complete.

Discussion: Because *Trachypora* is an obsolete genus name (Lecompte, 1939), we transfer this Iranian species described by Flügel (1972) to *Thamnoptychia* on the basis of its perpendicularly directed calices to the branch surface, wide stereozone, almost closed lumina (tabularia), and rare tabulae. *Thamnoptychia directa* described herein represents the first record of the genus from Iran.

Acknowledgements

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