Bull. Natl. Mus. Nat. Sci., Ser. C, 47, pp. 41–51, December 27, 2021

DOI: 10.50826/bnmnsgeopaleo.47.0_41

Tabulate corals from the Middle and Upper Permian formations in the Julfa area, Northwest Iran

Shuji Niko[1]* and Mahdi Badpa[2]

[1]Department of Environmental Studies, Faculty of Integrated Arts and Sciences, Hiroshima University, Higashihiroshima, Hiroshima 739-8521, Japan

[2]Department of Geology, Payame Noor University of Qom, Qom, Iran

*Author for correspondence: niko@hiroshima-u.ac.jp

Abstract To provide basic information on the End-Permian Extinction of tabulate corals, we examined their taxonomic characters and stratigraphic distributions using the material from the Permian-Triassic boundary section at Kuh-e-Ali Bashi of the Julfa area, Northwest Iran. The results are as follows: pyrgiid auloporid *Cladochonus* sp. indet. from the Roadian? to Wordian (lower middle? to middle middle Permian) Gnishik and the Capitanian (upper middle Permian) Khachik formations; favositid *Sutherlandia khachikensis* sp. nov. and micheliniid *Protomichelinia favositoides* from the Khachik Formation; micheliniid *Julfamichelinia allata* from the Wuchiapingian (lower upper Permian) Julfa Formation; and micheliniid "*Michelinia*" *vesiculosa* from the Changhsingian (upper upper Permian) Ali Bashi Formation. *Julfamichelinia* is a new genus proposed herein. In this stratigraphic section, auloporid and favositid corals disappeared near the Capitanian/Wuchiapingian transition. The latest appearance of the only surviving micheliniid is approximately 4 m below the Permian-Triassic boundary.

Key words: End-Permian Extinction, *Julfamichelinia* n. gen., Kuh-e-Ali Bashi, Iran, Tabulata

Introduction

Since trailblazing works by Abich (1878), Frech and Arthaber (1900), and Stoyanow (1910), paleontological investigations in Transcaucasia (Armenia, Azerbaijan) and Northwest Iran on both banks of the Araxes River have been providing crucial knowledges about the End-Permian Extinction. This study focused on tabulate coral fossils in the Julfa area, Northwest Iran, and described their stratigraphic distributions with detailed taxonomic considerations. Its purpose is to provide the basic information for future discussions concerning the extinction process of the Tabulata.

Repositories: Except for a specimen (NMNS PA20010; *Julfamichelinia allata*), that is housed in the National Museum of Nature and Science, Tokyo, all examined specimens are housed in the paleontological collections at Ferdowsi University of Mashhad, Mashhad, Iran.

Geologic setting and material

Geology of the Julfa area was revealed by Stepanov *et al.* (1969) and Teichert *et al.* (1973). According to their results, the Permian-Triassic strata in the area consist of the Gnishik Formation (bedded limestone), the Khachik Formation (bedded limestone with abundant occurrence of chart nodules), the Julfa Formation (limestone and shale), the Ali Bashi Formation (shale with thin intercalations of limestone and *Paratirolites* limestone in its uppermost part), and the Elikah Formation (limestone, shale, and massive to thick bedded dolostone in its uppermost part) in ascending order. Considering previous age determinations based on ammonoids (Stepanov *et al.*, 1969; Teichert *et al.*, 1973; Ghaderi, *et al.*, 2014b; Korn *et al.*, 2015), bivalves (Stepanov *et al.*, 1969), brachiopods (Stepanov *et al.*, 1969; Ghaderi, *et al.*, 2014a), conodonts (Sweet and Mei, 1999; Partoazar, 2002; Kozur, 2004, 2005, 2007; Henderson *et al.*, 2008; Shen and Mei, 2010; Ghaderi, *et al.*, 2014b), foraminifers (Stepanov *et al.*, 1969; Altiner *et al.*, 1980; Ghaderi, *et al.*, 2014a), nautiloids (Teichert and Kummel, 1973) and rugose corals (Iljina, 1965; Flügel, 1971; Ezaki, 1991), the most probable ages for each formation are as follows: Gnishik = Roadian? to Wordian (lower middle? to middle middle Permian); Khachik = Capitanian (upper middle Permian); Julfa = Wuchiapingian

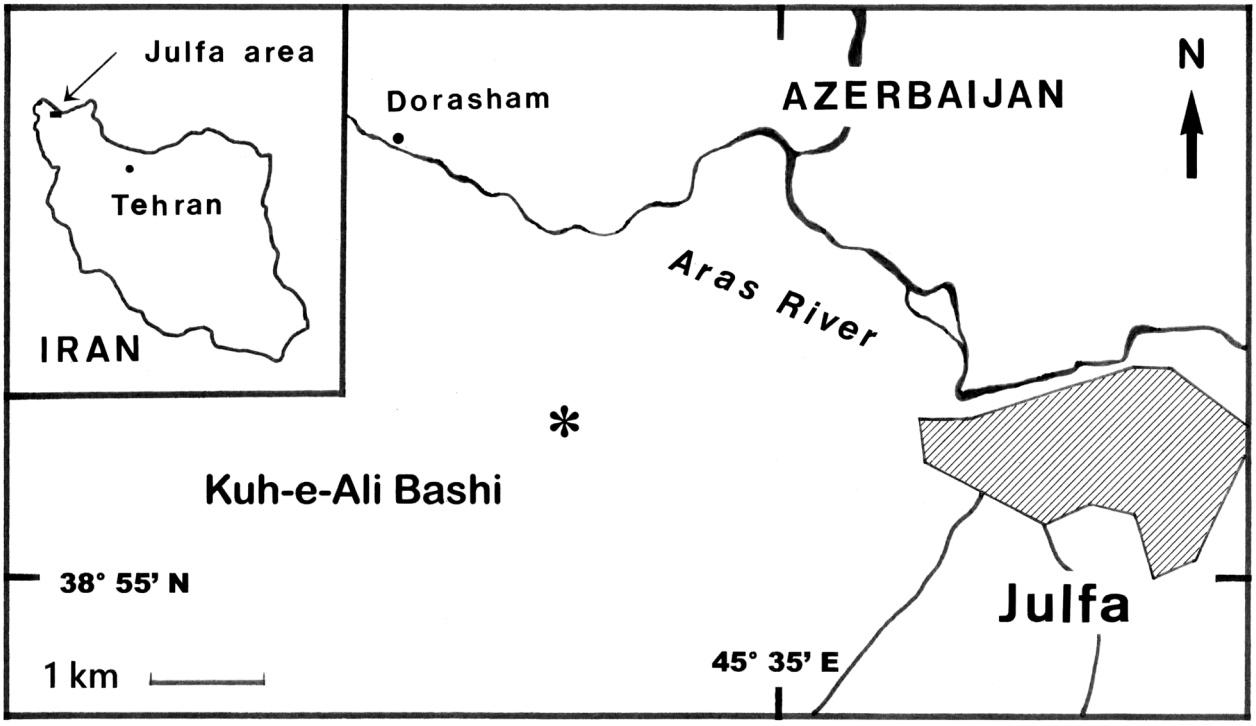

Fig. 1. Index map showing fossil locality (asterisk) in the Julfa area, Northwest Iran.

(lower upper Permian); Ali Bashi = Changhsingian (upper upper Permian); Elikah = Induan (lower Lower Triassic). Paleogeographically, the Julfa area was situated in a low latitude area during the middle Permian to Early Triassic time (e.g., Muttoni *et al.*, 2009).

The material described herein was obtained from the Khachik and Julfa formations at an outcrop (38.9°N, 45.5°E) along a tributary of the main valley of Kuh-e-Ali Bashi (the Ali Bashi Mountains; Fig. 1), in which Teichert *et al.* (1973) examined four parallel stratigraphic sections. There are many previous records of fossil corals from the area; however, most of them are not described and/or illustrated. Only Teichert *et al.* (1973), Ezaki (1991) and Ghaderi, *et al.* (2019) make reference to morphological information concerning tabulate corals (see below). In addition to the actual specimens, the authors considered these reliable records with taxonomic reexaminations.

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 khachikensis sp. nov.

(Figs. 2-A–F)

Material examined: Holotype, J168, from which two thin sections were prepared.

Occurrence and age: The holotype was collected from the Capitanian (upper middle Permian) Khachik Formation.

Diagnosis: Small species of *Sutherlandia* with subspherical corallum, having maximum diameter of 11 mm; distal corallites subcylindrical, approximately 1.2 mm in diameter; intercorallite walls commonly thickened, attaining 0.35 mm; mural pores (tunnels) well-developed; squamulae 0.2–0.3 mm in length; tabulae common, but restrict in proximal corallites.

Description: A single small corallum is available for study; it is cerioid, encircling crinoid stem to form subspherical growth shape; maximum diameter of corallum is 11 mm. Except for the most proximal corallites that adhere to crinoid stem and have semicircular transverse sections, usual corallites are radially arranged and prismatic to rounded subprismatic; transverse sections of prismatic portions have 3–6 sides; corallite diameters ranges from 0.3 mm to

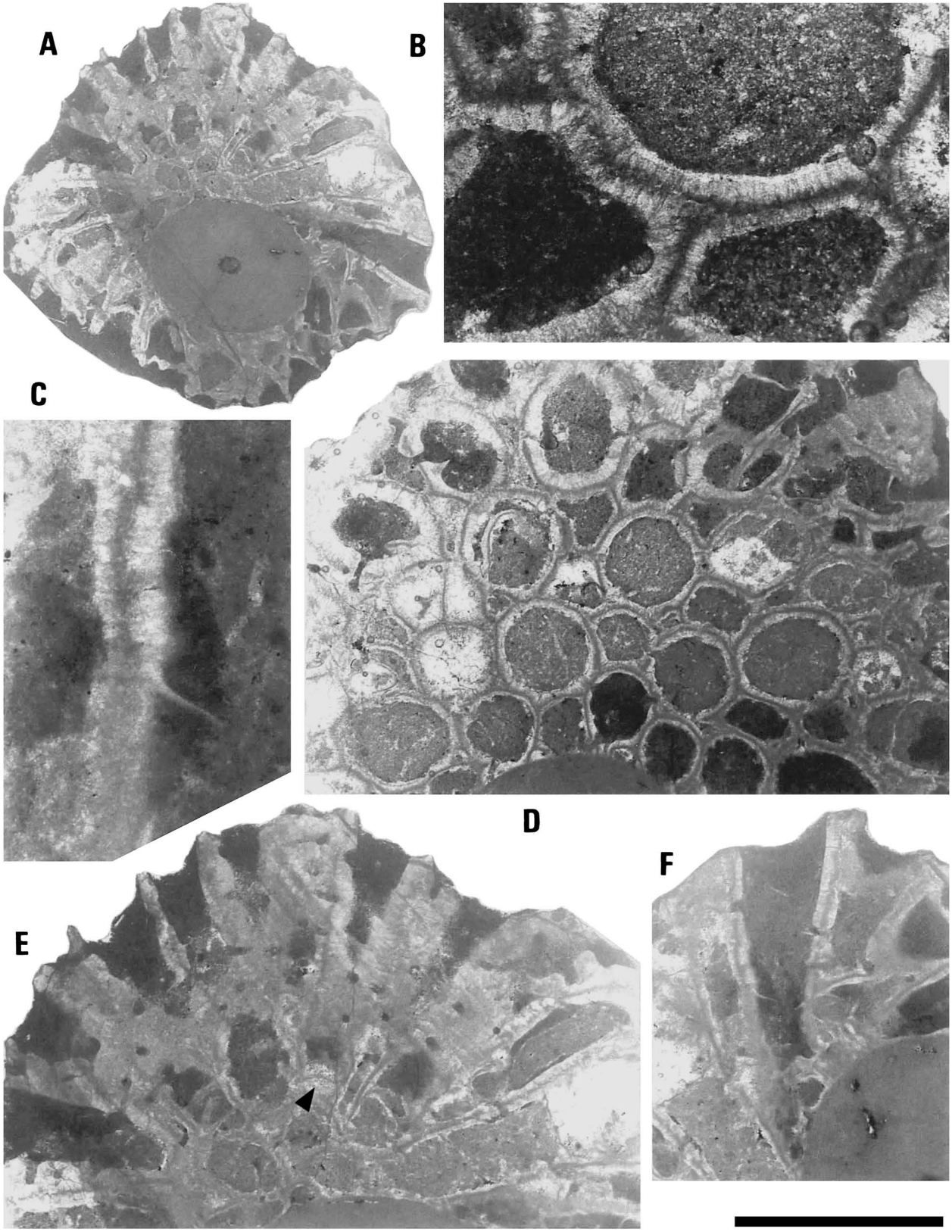

Fig. 2. *Sutherlandia khachikensis* sp. nov., holotype, J168, thin sections. **A**, longitudinal section of corallum. **B**, partial enlargement to show intercorallite wall structure, transverse section. **C**, partial enlargement to show intercorallite wall structure and details of squamula, longitudinal section. **D**, transverse to oblique sections of corallites. **E**, longitudinal sections of corallites, arrow indicates complete tabula. **F**, longitudinal sections of corallites. Scale bar: A = 7 mm; B, C = 0.7 mm; D–F = 2.5 mm.

1.4 mm with approximately 1.2 mm mean (n = 15) in distal subcylindrical portion; lumina (tabularia) rounded polygonal to circular in transverse section; calices perpendicularly oriented to corallum surface and very deep; increase of new corallite frequently with intermural (?) type. Intercorallite walls variable in thinness; thickened walls attaining 0.35 mm are most common, but thin walled portions with 0.10 mm in thickness are partly recognized; wall structure consists of median dark line and stereoplasm; microstructure of stereoplasm is rect-radiate fibers; mural pores (to mural tunnels in portion of thickened walls) well-developed on corallite faces as mid-wall pores forming a single row and corallite angles as angle pores in rare cases; profiles of pores (tunnels) are roughly circular with diameters of 0.08–0.13 mm; squamulae sporadic, 0.2–0.3 mm in length; approximate ratios of squamula length per lumen diameter are up to 0.4; no distinct septal spine observable; tabulae complete, common in proximal portion of corallites and absent in distal one; profiles of tabulae are weakly up arched.

Etymology: The specific name derbies from the type stratum, named the Khachik Formation.

Discussion: Corallum morphology of this specimen is also suggestive of *Pseudofavosites* Gerth (1921; type species, *P. stylifer* Gerth, 1921) in the generic placement, but its possession of complete tabulae clearly corresponds to that of *Sutherlandia*.

Among the known five Permian species of the genus, *Sutherlandia khachikensis* sp. nov. is most similar to *S. jilinensis* (Tchi, 1980, p. 160, 161, pl. 86, figs. 5a, b) from the lower Permian in North China. However, the Chinese species has thinner intercorallite walls (up to 0.20 mm) and fewer tabulae than those of the new species. *Sutherlandia jamalensis* Niko, Badpa, Ghaderi and Ataei (2018, p. 21–23, figs. 3-1–8), that was the only known species of *Sutherlandia* in Iran, is clearly distinguishable from *S. khachikensis* by the presence of well-developed septal spines in its distal corallites.

Family Micheliniidae Waagen and Wentzel, 1886

Subfamily Micheliniinae Waagen and Wentzel, 1886

Genus ***Julfamichelinia*** gen. nov.

Type species: *Michelinopora allata* Tchudinova *in* Ruzhentsev and Sarycheva, 1965.

Diagnosis: Genus of Micheliniinae characterized by small cerioidal coralla with strong holotheca and fibrous intercorallite wall structure; both mid-wall and angle pores developed; septal spine probably absent; incomplete tabulae most common.

Discussion: Although the type species of *Julfamichelinia* gen. nov. was assigned previously to *Michelinopora* Yabe and Hayasaka (1915; type species, *Michelinia* (*Michelinopora*) *multitabulata* Yabe and Hayasaka, 1915) by Tchudinova (*in* Ruzhentsev and Sarycheva, 1965) or *Protomichelinia* Yabe and Hayasaka (1915; type species, *Michelinia* (*Protomichelinia*) *microstoma* Yabe and Hayasaka, 1915) by Ezaki (1991), it lacks synapomorphies found with *Michelinopora* including very large coralla, more than 1 m in diameter and closely spaced complete tabulae, and lacks numerous septal spines, that are the most distinct generic diagnosis of *Protomichelinia*. In addition, there are no reports of presence of holotheca from *Michelinopora* and *Protomichelinia*.

Its possession of holotheca and dominance of incomplete tabulae make *Julfamichelinia* superficially resemble *Michelinia* Koninck (1841; type species, *Calamopora tenuiseptata* Phillips, 1836), but their structure of intercorallite walls shows great differences. *Julfamichelinia* has fibrous wall structure, whereas lamellar structure of *Michelinia* can be observed in thin sections of the lectotype of *M. tenuiseptata* figured by Hill (1981).

Lafuste and Plusquellec (1985) described a michelinid having angle pores and fibrous wall structure based on a fragmentary specimen from the upper Permian of East Afghanistan and suggested it represents a new genus. This specimen may belong *Julfamichelinia*.

Julfamichelinia allata

(Tchudinova *in* Ruzhentsev and Sarycheva, 1965)

(Figs. 3-A–H)

Michelinopora allata Tchudinova *in* Ruzhentsev and Sarycheva, 1965, p. 154, pl. 10, figs. 2a, b.

Michelinia sp., Flügel, 1968, p. 300, pl. 25, figs. 1, 2.

Protomichelinia allata (Tchudinova); Ezaki, 1991, p. 128, 130, pl. 26, figs. 2a, b, 3, 4a, b; Ghaderi *et al.*, 2019, pl. 3, figs. 3a–c [4?].

Material examined: G36, G83, G86, G142, G145, G171a, G171b, G189, G300–302, NMNS PA20010.

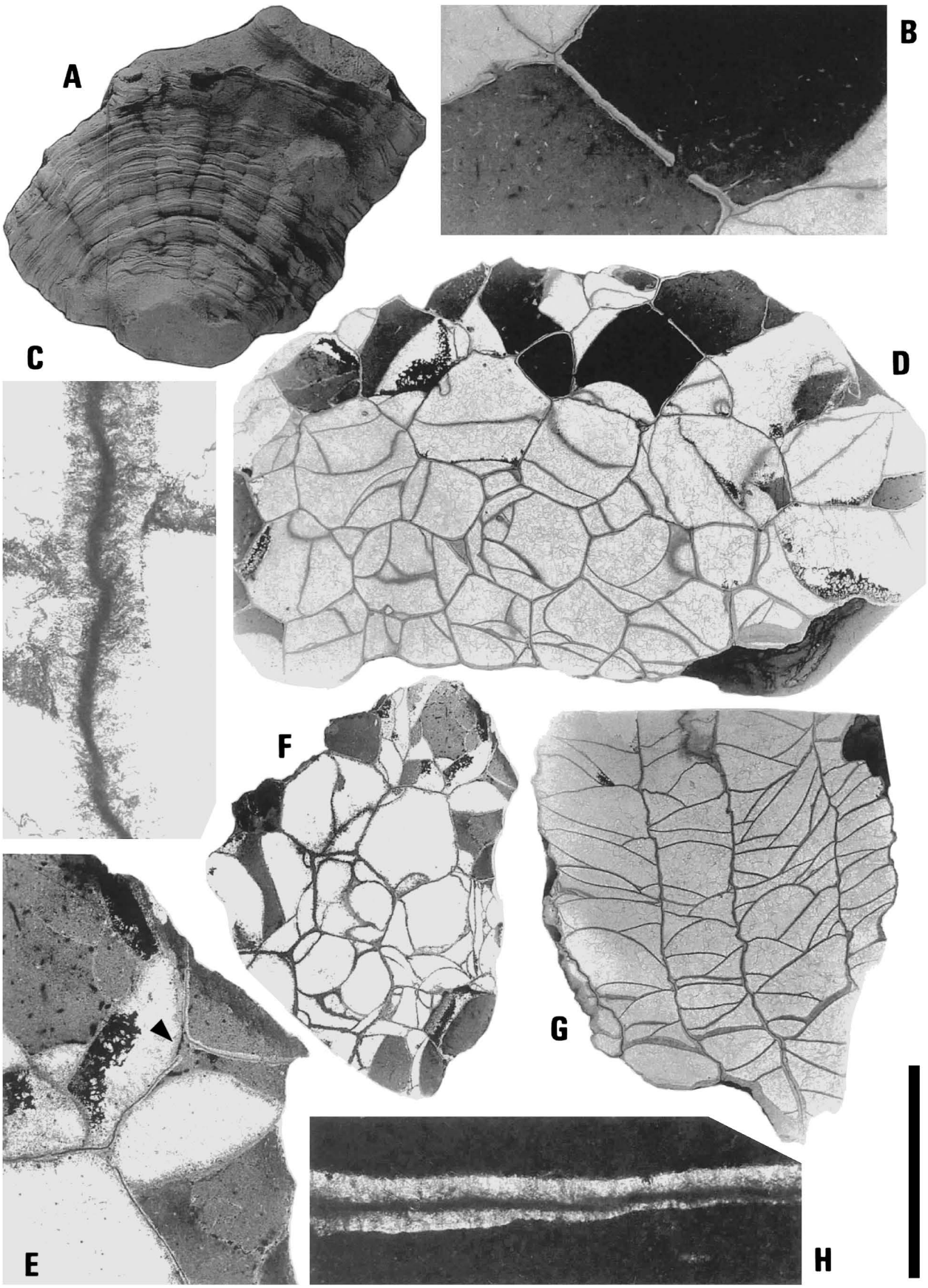

Fig. 3. *Julfamichelinia allata* (Tchudinova *in* Ruzhentsev and Sarycheva, 1965). **A–D**, **G**, **H**, NMNS PA20010. A, side view of corallum. B, partial enlargement to show details of mid-wall pore, transverse thin section. C, partial enlargement to show intercorallite wall structure, longitudinal thin section. D, transverse thin section of corallum. G, longitudinal thin section of corallum. H, partial enlargement to show intercorallite wall structure, transverse thin section. **E**, **F**, G86, thin section. E, partial enlargement to show details of angle pore (arrow), transverse section. F, transverse section of corallum. Scale bar: A = 24 mm; B, E = 4 mm; C, H = 0.7 mm; D, F, G = 12 mm.

Occurrence and age: All specimens examined herein were collected from the Wuchiapingian (lower upper Permian) Julfa Formation.

Description: Coralla cerioid, variable in growth shape, exhibiting subcylindrical, bulbous, to fan-shaped, small for the subfamily and surrounded by strong holotheca; the largest coralla (NMNS PA20010) has 49 mm in maximum diameter and 41 mm in maximum height; growth ridges developed on holotheca. Corallites prismatic to subprismatic; except for peripheral corallites that indicate fan-shaped, subtrapezoidal to sub-polygonal transverse sections; most corallites have polygonal sections with 3–9 sides; diameters of corallites are 1.9–7.6 mm. Intercorallite walls thin to moderate, 0.08–0.23 mm, indicate sinuations in longitudinal section, and differentiated into median dark line and stereoplasm; microstructure of stereoplasm is rect-radiate fibers; mural pores relatively rare, occur on corallite faces as mid-wall pores and at corners as angle pores; diameters of mural pores are relatively large, 0.3–0.4 mm; no distinct septal spine observable; tabulae well-developed; incomplete tabulae with dissepimental and uparched profiles are most common, but complete ones not rare; there are 3–10 tabulae in corallite length 5 mm; some tabulae thickened, attaining 0.5 mm.

Discussion: The syntypes of this species ware collected from the Wuchiapingian Dzhulfa Formation of Dorasham, Azerbaijan and Ogbin, Armenia (Tchudinova *in* Ruzhentsev and Sarycheva, 1965). Its occurrences from the Julfa Formation are previously recorded by Ezaki (1991) and Ghaderi *et al.* (2019).

Michelinia sp. from the Wuchiapingian Nesen Formation in the Alborz Mountains, North Iran (Flügel, 1968), closely resembles *Julfamichelinia allata* in its external morphologies and corallite diameters. There is a high possibility that they are conspecific.

Teichert *et al.* (1973, p. 393, 394, pl. 1, figs. 8–10) discovered a single micheliniid corallum from the Ali Bashi Formation of the Julfa area and assigned it to *Michelinia vesiculosa* Tchudinova (*in* Ruzhentsev and Sarycheva, 1965, p. 152, pl. 8, figs, 2a, b), whose type locality is the Gnishik Formation in Vedi, Armenia. Because its wall structure is not documented, the generic placement of this species is uncertain at present. "*Michelinia*" *vesiculosa* is distinguished from *Julfamichelinia allata* by having vesicular tabulae.

Genus ***Protomichelinia*** Yabe and Hayasaka, 1915

Type species: *Michelinia* (*Protomichelinia*) *microstoma* Yabe and Hayasaka, 1915.

Protomichelinia favositoides (Girty, 1907)

(Figs. 4-A–F)

Michelinia favositoides Girty, 1907, p. 38, 39; 1913, p. 312, 313, pl. 29, figs. 1, 2; Hudson, 1958, p. 188, 189, pl. 32, figs. 5, 6.

Protomichelinia favositoides (Girty); Flügel, 1964, p. 428, pl. 34, figs. 1, 2; Ezaki, 1991, p. 124, 126, pl. 25, figs. 1, 2a, b.

Protomichelinia microstoma (Yabe and Hayasaka); Ghaderi *et al.*, 2019, pl. 3, figs. 1, 2.

Material examined: J59, J73.

Occurrence and age: Locality of all examined specimens examined herein is same as *Sutherlandia khachikensis* sp. nov. (this report).

Description: Coralla cerioid, nodular in growth form; diameter of the largest corallum (J73) attains 33 mm; holotheca probably absent. Corallites prismatic with 3–8 sides in transverse section; corallite diameters 1.1–2.4 mm; calices shallow. Intercorallite walls variable in thickness, thin to thickened, ranging from 0.12 to 0.33 mm; structurally walls differentiated into median dark line and stereoplasm, the latter of which indicates rect-radiate fibers in microstructure; mural pores uncommon, occur on corallite faces; diameters of mural pores are small, 0.1 mm; septal spines numerous, low-conical to rod-like with 0.06–0.19 mm in height; tabulae well-developed; complete tabulae most common; there are 3–5 tabulae in corallite length 2 mm; some tabulae slightly thickened.

Discussion: The type locality of this species is the middle Permian Wushan Limestone near Chongqing, South China. Subsequently, it is recorded from the Zinnar Formation, northern Iraq (Hudson, 1958), the Ruteh Limestone in the Alborz Mountains, North Iran (Flügel, 1964), the Surmaq Formation in the Abadeh area, Central Iran (Ezaki, 1991).

Yabe and Hayasaka (1915) and Hudson (1958) suggested that *Protomichelinia favositoides* is con-

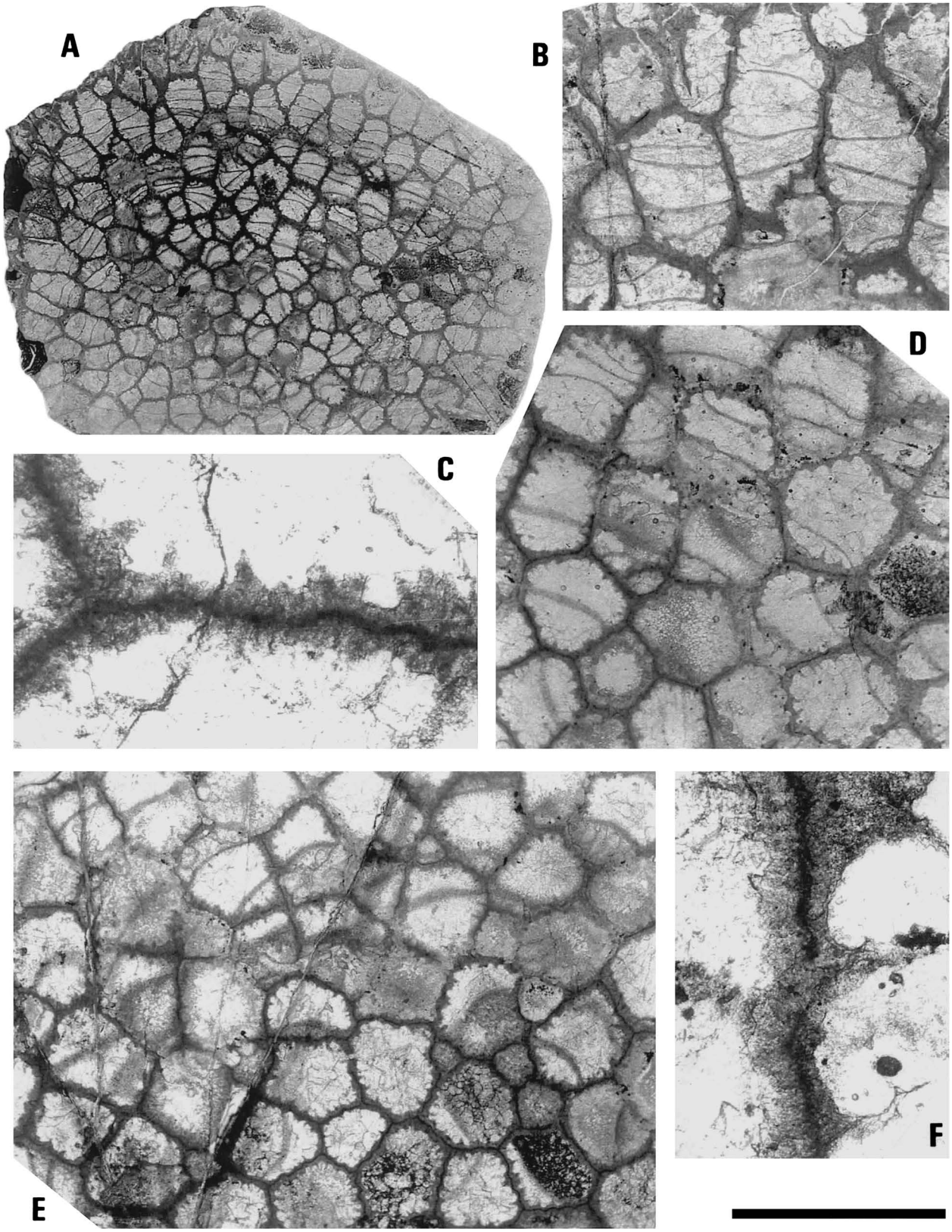

Fig. 4. *Protomichelinia favositoides* (Girty, 1907), thin sections. **A**, **B**, **D**, J73. A, transverse section of corallum. B, partial enlargement to show oblique sections of corallites. D, partial enlargement to show transverse sections of corallites. **C**, **E**, **F**, J59. C, partial enlargement to show intercorallite wall structure, transverse section. E, partial enlargement to show transverse sections of corallites. F, partial enlargement to show intercorallite wall structure and details of septal spines, longitudinal section. Scale bar: A = 12 mm; B, D, E = 4 mm; C, F = 0.7 mm.

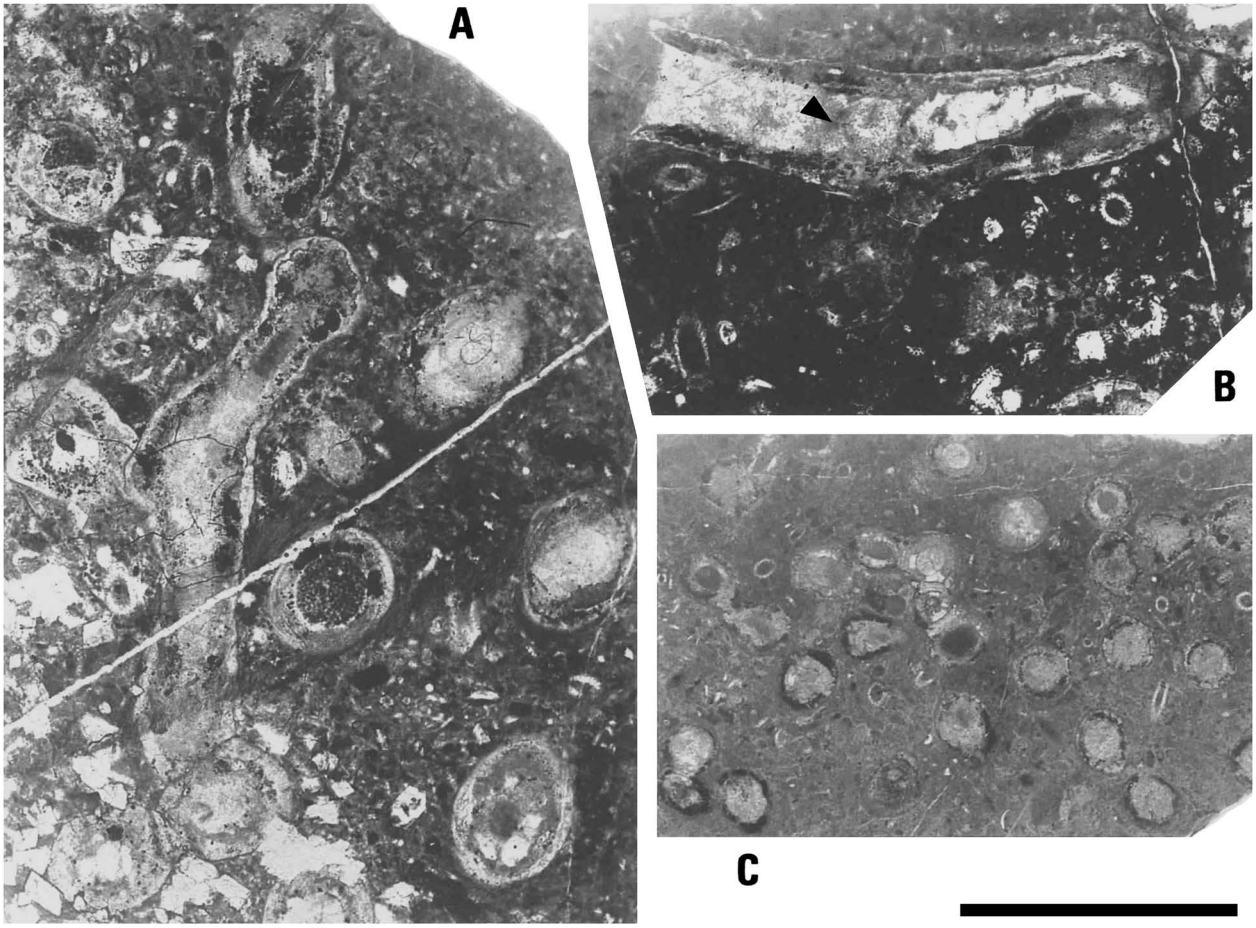

Fig. 5. *Cladochonus* sp. indet., J200, thin sections. **A**, longitudinal to transverse sections of corallites. **B**, longitudinal to transverse sections of corallites, arrow indicates complete tabula. **C**, transverse sections of corallites. Scale bar: A, B = 3.5 mm; C = 7 mm.

specific with *P. microstoma*. We disagree with their point of view, because weaker development of mural pores in *P. favositoides* than those of *P. microstoma* serve to specific differentiate. Previously, the examined specimens herein were mistakenly identified by Ghaderi *et al.* (2019) as *P. microstoma*.

Order Auloporida Sokolov, 1947
Superfamily Auloporoidea Milne-Edwards and Haime, 1851
Family Pyrgiidae Fromentel, 1861
Genus ***Cladochonus*** McCoy, 1847
Type species: *Cladochonus tenuicollis* McCoy, 1847.

Cladochonus sp. indet.
(Figs. 5-A–C)

Sinopora asiatica (Mansuy, 1913); Ezaki, 1991, p. 132, 134 [part], pl. 27, fig. 2 [not figs. 3a, b]; Ghaderi *et al.*, 2019, pl. 3, figs. 5, 6.

Material examined: J200.

Occurrence and age: Same as *Sutherlandia khachikensis* sp. nov. (this report).

Description: A single corallum is available for study; it is mat-like in growth form having maximum observable diameter of 30 mm. Corallites cylindrical, at least 8.0 mm in length and 1.4–1.9 mm in diameter; each corallite consists of prostrate proximal and upwardly directed distal portions; distal corallites frequently anastomose between adjoining ones; calices very deep with faintly inflated rim; daughter corallite of new offset arises near boundary of proximal and distal portions of proceeding corallite. Corallite walls thick to very thick, attaining 0.44 mm; septal spin like projections developed; tabulae rare, complete.

Discussion: The present specimen was illustrated by Ghaderi *et al.* (2019) as *Sinopora asiatica*, but the holotype of this species, *Romingeria asiatica* Mansuy (1913, p. 111, 112, pl. 11, fig. 13), possesses the umbelliferous daughter corallites and new corallites of the type species of the genus *Sinopora*

(*Monilopora dendroidea* Yoh *in* Yoh and Huang, 1932) are lateral and indicate bifurcate form with proceeding corallite. Ruther, the above-mentioned corallite morphologies correspond to those of the pyrgiid genus *Cladochonus*. Ezaki (1991) assigned an auloporid, recovered from the upper part of the Gnishik Formation, to *S. asiatica*. We believe it is also conspecific with the present *Cladochonus* sp. indet. judging from their morphological similarities.

Conclusion

The following stratigraphic distributions of tabulate corals in the Julfa area, Northwest Iran, were identified: pyrgiid auloporid *Cladochonus* sp. indet. ranging from the Roadian? to Wordian (lower middle? to middle middle Permian) Gnishik to the Capitanian (upper middle Permian) Khachik formations; favositid *Sutherlandia khachikensis* sp. nov. and micheliniid *Protomichelinia favositoides* from the Khachik Formation; micheliniid *Julfamichelinia allata* from the Wuchiapingian (lower upper Permian) Julfa Formation; and micheliniid "*Michelinia*" *vesiculosa* from the Changhsingian (upper middle Permian) Ali Bashi Formation.

The results indicate at least two phases during the extinction process of tabulate corals. The first phase occurred near the Capitanian/Wuchiapingian transition, where favositid and auloporid corals disappeared. Because the combination of favositids, micheliniids and auloporids is also typically recognized in other tabulate coral faunas in a low latitude areas of early Permian age, e.g., the mid-Panthalassan reef limestones (see Niko, 2001, 2017; Niko *et al.*, 2012; Senzai and Niko, 2005), this disappearance phase covering the multiple families probably represents the beginning of the extinction of the Tabulata. The latest appearance of the only surviving micheliniid in the area is "1 m above base of *Paratirolites* limestone" (Teichert *et al.*, 1973). This horizon situates approximately 4 m below the Permian-Triassic boundary defined by Kozur (2007) using an index conodont *Hindeodus parvus*.

Acknowledgements

We are grateful to Drs. A. Ghaderi and A. R. Ashouri for their assistances in the field. We also wish to thank Dr. M. Fujikawa for his helpful discussions and review.

References

Abich, H. (1878) Geologische Forschungen in den Kaukasischen Ländern. Theil I, Eine Bergkalkfauna aus der Araxesenge bei Djoulfa in Armenien. 126 pp., 11 pls. Adolf Holzhausen, Wien.

Altiner, D., Baud, A., Guex, J. and Stampfli, G. (1980) La limite Permian-Trias dans quelques localités du Moyen-Orient: Recherches stratigraphiques et micropaléontologiques. *Rivista Italiana di Paleontologia e di Stratigrafia*, **85**: 683–714.

Cocke, J. M. and Bowsher, A. L. (1968) New tabulate genus *Sutherlandia* (Coelenterata, Anthozoa) from Pennsylvanian of Oklahoma and Kansas. *The University of Kansas Paleontological Contributions*, **33**: 1–8.

Dana, J. D. (1846) Structure and classification of zoophytes: U. S. exploring expedition during the years 1838, 1839, 1840, 1841, 1842 under the command of Charles Wilkes, U. S. N. Volume 7, 740 pp., 61 pls. Lea and Blanchard, Philadelphia.

Ezaki, Y. (1991) Permian corals from Abadeh and Julfa, Iran, West Tethys. *Journal of the Faculty of Science*, *Hokkaido University*, *Series 4*, **23**: 53–146.

Flügel, H. W. (1964) The geology of the upper Djadjerud and Lar valleys (N-Iran). *Rivista Italiana di Paleontologia e di Stratigrafia*, **70**: 403–444, pls. 28–34.

Flügel, H. W. (1968) Korallen aus der oberen Nesen-Formation (Dzhulfa-Stufe, Perm) des zentralen Elburz (Iran). *Abhandlungen*, *Neues Jahrbuch für Geologie und Paläontologie*, **130**: 275–304, pl. 25.

Flügel, H. W. (1971) Upper Permian corals from Julfa. *Report*, *Geological Survey of Iran*, **19**: 109–139.

Frech, F. and Arthaber, G. von (1900) Über das Paläozoicum in Hocharmenien und Persien. Mit einen Anhang über die Kreide von Sirah in Persien. *Beiträge zur Paläontologie und Geologie Österreich-Ungarns und des Orients*, **12**: 161–308, pls. 15–22.

Fromentel, E. de (1861) *Introduction à l'Étude des Polypiers Fossiles*, 357 pp. F. Savy, Paris.

Gerth, H. (1921) Die Anthozoën der Dyas von Timor. *Paläontologie von Timor*, **9**: 65–147, pls. 145–150.

Ghaderi, A., Badpa, M. and Ashouri, A. R. (2019) Permian corals of Ali-Bashi Mountains, Julfa, Northwest of Iran. *Scientific Quarterly Journal*, *Geosciences*, **29**: 97–109. (In Persian with English abstract)

Ghaderi, A., Garbelli, C., Angiolini, L., Ashouri, A. R., Korn, D., Rettori, R. and Mahmoudi Gharaie, M. H. (2014a) Faunal change near the end-Permian extinction: The brachiopods of the Ali Bashi Mountains, NW Iran. *Rivista Italiana di Paleontologia e Stratigrafia*, **120**: 27–59.

Ghaderi, A., Leda, L., Schobben, M., Korn, D. and Ashouri, A. R. (2014b) High-resolution stratigraphy of the Changhsingian (late Permian) successions of NW Iran and the Transcaucasus based on lithological features, conodonts and ammonoids. *Fossil Record*, **17**: 41–57.

Girty, G. H. (1907) Descriptions of new species of Upper Paleozoic fossils from China. *Proceedings of the United States National Museum*, **33**: 37–48.

Girty, G. H. (1913) A report on Upper Paleozoic fossils collected in China in 1903-04. In: Willis, B. *et al.*, (Eds.), Research in China: Volume 3. pp. 297–334, pls. 27–29, Carnegie Institution, Washington.

Henderson, C. M., Mei, S., Shen, S. and Wardlow, B. R. (2008) Resolution of the reported upper Permian conodont occurrences from northwestern Iran. *Permophiles*, **51**: 2–9.

Hill, D. (1981) Part F, Coelenterata. Supplement 1, Rugosa and Tabulata. In: Moore R. C. *et al.*, (Eds.), Treatise on Invertebrate Paleontology. pp. F1–F762, Geological Society of America and University of Kansas, Boulder, Colorado and Lawrence, Kansas.

Hudson, R. G. S. (1958) Permian corals from northern Iraq. *Paleontology*, **1**: 174–192, pls. 32–35.

Iljina [Ilina], T. G. (1965) Tetraradiate corals of the late Permian and Early Triassic of Transcaucasia. *Akademiia Nauk SSSR*, *Trudy Paleontologicheskogo Instituta*, **107**: 1–105, pls. 1–20. (In Rissian)

Koninck, L. G. de (1841–1844) Description des animaux fossiles qui se trouvent dans le terrain carboniferère de Belgique. 650 pp., pls. A–H, H. Dessain, Liège.

Korn, D., Ghaderi, A., Leda, L., Schobben, M. and Ashouri, A. R. (2015) The ammonoids from the late Permian *Paratirolites* Limestone of Julfa (East Azerbaijan, Iran). *Journal of Systematic Paleontology*, **14**: 841–890.

Kozur, H. W. (2004) Pelagic uppermost Permian and the Permian-Triassic boundary conodonts of Iran. Part I: Taxonomy. *Hallesches Jahrbuch für Geowissenschaften*, *Reihe B*, **18**: 39–68.

Kozur, H. W. (2005) Pelagic uppermost Permian and the Permian-Triassic boundary conodonts of Iran. Part II: Investigated sections and evaluation of the conodont faunas. *Hallesches Jahrbuch für Geowissenschaften*, *Reihe B*, **19**: 49–86.

Kozur, H. W. (2007) Biostratigraphy and event stratigraphy in Iran around the Permian-Triassic boundary (PTB): Implications for the causes of the PTB biotic crisis. *Global and Planetary Change*, **55**: 155–176.

Lafuste, J. and Plusquellec, Y. (1985) Structure et microstructure de quelques Micheliniidae et Michelinimorphes (Tabulata paléozoïques). *Bulletin du Museum National d'Histire Naturelle*, *Série 4*, **7**: 13–63.

Lecompte, M. (1952) Madréporaires paléozoïques. In: Piveteau, J., (Ed.), Traité de Paléontologie. pp. 419–538, Masson et Cie, Paris.

Mansuy, H. (1913) Faunes des calcaires à *Productus* de l'Indochine, première série. *Mémoires du Service Géologique de l'Indochine*, **2**: 1–137, pls. 1–13.

M'Coy, F. (1847) On the fossil botany and zoology of the rocks associated with the coal of Australia. *The Annals and Magazine of Natural History*, **20**: 145–157, 226–236, 298–321, pls. 9–17.

Milne-Edwards, H. and Haime, J. (1850) A monograph of the British fossil corals. First part. Introduction; corals from the Tertiary and Cretaceous formations. 71 pp., 11 pls. Monographs of the Palaeontographical Society, London.

Milne-Edwards, H. and Haime, J. (1851) Monographie des polypiers fossiles des terrains paléozoïques, précédée d'un tableau général de la classification des polypes. *Archives du Muséum d'Histoire. Naturelle*, *Paris*, **5**: 1–502, pls. 1–20.

Muttoni, G., Mattei, M., Balini, M., Zanchi, A., Gaetani, M. and Berra, F. (2009) The drift history of Iran from the Ordovician to the Triassic. *Geological Society of London*, *Special Publication*, **312**: 7–29.

Niko, S. (2001) Auloporid tabulate corals from the lower Permian Ryozensan Limestone, Shiga Prefecture. *Bulletin of the National Science Museum*, *Series C*, **27**: 15–23.

Niko, S. (2017) Early Permian tabulate corals from the Funafuseyama Limestone, Gifu Prefecture, Japan. *Bulletin of the National Museum of Nature and Science*, *Series C*, **43**: 19–25.

Niko, S., Badpa, M., Ghaderi, A. and Ataei, M. R. (2018) Early Permian tabulate corals from the Jamal Formation, East-Central Iran. *Bulletin of the National Museum of Nature and Science*, *Series C*, **44**: 19–29.

Niko, S., Haikawa, T. and Fujikawa, M. (2012) Permian tabulate corals from the Akiyoshi Limestone Group, Yamaguchi Prefecture. *Bulletin of the Akiyoshi-dai Museum of Natural History*, **47**: 5–10, pls. 2–4.

Partoazar, H. (2002) Permian-Triassic boundary conodonts from Julfa-Abadeh Belt along Northeast and Central Iran. *Permophiles*, **41**: 34–40.

Phillips, J. (1836) Illustrations of the geology of Yorkshire. Part II. The Mountain Limestone district. 253 pp., 25 pls. John Murray, London.

Ruzhentsev, V. E. and Sarycheva, T. G. (1965) Development and change of marine organisms at the Paleozoic and Mesozoic boundary. *Akademiia Nauk SSSR*, *Trudy Paleontologicheskogo Instituta*, **108**: 1–431. (In Russian)

Senzai, Y. and Niko, S. (2005) An early Permian tabulate coral *Sutherlandia* from the Tamba Belt in the Oji area, Kameoka City, Kyoto Prefecture, Central Japan. *Chigakukenkyu*, **54**: 3–7. (In Japanese with English abstract)

Shen, S. and Mei, S. (2010) Lopingian (late Permian) high-resolution conodont biostratigraphy in Iran with comparison to South China zonation. *Geological Journal*, **45**: 135–161.

Sokolov, B. S. (1947) New syringoporids from the Taymyr. *Byullrtin Moskovskogo Obschchestva Ispytatelei Prirody*, *Otdel Geologischeskii*, **22**: 19–28. (In Russian)

Stepanov, D. L., Golshani, F. and Stöcklin, J. (1969) Upper Permian and Permian-Triassic boundary in North Iran. *Report*, *Geological Survey of Iran*, **12**: 1–72, pls. 1–15.

Stoyanow, A. A. (1910) On the character of the boundary of Palaeozoic and Mesozoic near Djulfa. *Verhandlungen der Russisch-Kaiserlichen Mineralogischen Gesellschaft zu St. Petersburg*, **47**: 61–135, pls. 6–9.

Sweet, W. C. and Mei, S. (1999) The Permian Lopingian and basal Triassic sequence in Northwest Iran. *Permophiles*, **33**: 14–18.

Tchi [Chi], Y. (1980) Tabulata. In: Shenyang Institute of Geology and Mineral Resources (Ed.), Paleontological atlas of Northeast China. (1), Paleozoic volume, pp. 153–

188, 646–649, pls. 67–87, Geological Publishing House, Beijing. (In Chinese)

Teichert, C. and Kummel, B. (1973) Nautiloid cephalopods from the Julfa beds, upper Permian, Northwest Iran. *Bulletin of the Museum of Comparative Zoology at Harvard College*, **144**: 409–434.

Teichert, C., Kummel, B. and Sweet, W. (1973) Permian-Triassic strata, Kuh-e-Ali Bashi, northwestern Iran. *Bulletin of the Museum of Comparative Zoology at Harvard College*, **145**: 359–472.

Waagen, W. H. and Wentzel, J. (1886) Salt Range fossils: Volume 1, *Productus* limestone fossils; 6, Coelenterata. *Palaeontologica Indica*, **13**: 835–924, pls. 97–116.

Wedekind, R. (1937) Einführung in die Grundlagen der Historischen Geologie. II.Band. Mikrobiostratigraphie, Die Korallen- und Foraminiferenzeit. 136 pp., 16 pls. Ferdinand Enke, Stuttgart.

Yabe, H. and Hayasaka, I. (1915) Palaeozoic corals from Japan, Korea and China. I. *Michelinia* and *Favosites*. *The Journal of the Geological Society of Tokyo*, **22**: 55–70.

Yoh, S. S. and Huang, T. K. (1932) The coral fauna of the Chihsia Limestone of the lower Yangtze Valley. *Palaeontologica Sinica*, *Series B*, **8**: 1–71, pls.1–10.