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THE CODIACEAN GENERA *ANCHICODIUM* JOHNSON, 1946 AND *IRANICODIUM* NOV. GEN. FROM THE PERMIAN JAMAL FORMATION OF SHOTORI MOUNTAINS, NORTHEAST IRAN

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Key words: Algae, Codiaceans, *Anchicodium*, *Iranicodium*, Permian, Jamal Formation, Shotori Mountains, Iran.

Abstract. Definition of the codiacean genus *Anchicodium* Johnson (Algae, Chlorophyta) is revised. *Anchicodium* is morphologically straight, curved, undulating or even irregular tapes and not cylindrical as defined by previous authors. *Anchicodium* is restricted to the Carboniferous-Permian time interval and known with 14 species, described by different authors. The majority of species were initially established by inadequte description and illustrations. Critical discussions and reviews of the individual species are carried out. *Anchicodium iranicum* nov. sp. and *Anchicodium maximum* nov. sp. are described from the Permian Jamal Formation exposed in two localities in the Shotori Mountains, northeast Iran.

Iranicodium, a new genus of codiacean family with type species *I. asymmetricum* nov. sp. is similar to *Anchicodium*, but differs from it by having different skeletal elements on opposite sides of the thallus tape.

Riassunto. Viene rivista in questo articolo la definizione del genere di Codiacee *Anchicodium* Johnson (Algae, Chlorophyta). Morfologicamente *Anchicodium* è costituito da nastri diritti, curvi, ondulati o addirittura irregolari e non cilindrici come indicato da precedenti autori. *Anchicodium* è limitato all'intervallo di tempo Carbonifero-Permiano e se ne sono state descritte 14 specie. La maggioranza di queste è stata fondata su descrizioni e illustrazioni inadeguate, per cui sono qui discusse criticamente e riviste le singole specie. *Anchicodium iranicum* nov. sp. e *Anchicodium maximum* nov. sp. sono descritte provenienti dalla Formazione Jamal di età permiana, esposta in due località nelle Shotori Mountains, nel nordest dell' Iran.

Iranicodium, un nuovo genere di codiacee, con specie tipo *I. asymmetricum* nov. sp. è simile ad *Anchicodium*, ma ne differisce per avere elementi scheletrici diversi sui lati opposti del nastro del tallo.

Introduction

Calcareous algae are one of the most abundant fossil groups in Late Paleozoic shallow-water carbonates. Among the calcareous green algae, both groups of dasycladaceans and codiaceans are locally rock building representatives. Codiaceans, including the so-called "phylloid" algae, occur very abundantly in Carboniferous and Permian shallow water carbonates (Wray 1977: 84). The term "phylloid" was introduced by Pray & Wray (1963) for such Paleozoic calcareous algae without or with poorly defined internal features for generic identification. Most abundant representatives of these algae are *Eugonophyllum* Konishi & Wray (1961), *Ivanovia* Khvorova (1946), *Calcifolium* Maslov (1956), *Anchicodium* Johnson (1946), and *Neoanchicodium* Endo (1954). Due to re-crystallization, preservation of the phylloid algae is poor, particularly the internal or medullar zone. The cortical zone shows some structures in well-preserved specimens, which were shown schematically by Wray (1977: fig. 84). Such structures are not recognizable, however, in most cases in phylloid algae and also in most recovered specimens from the Jamal Formation.

Thin-sections, containing the illustrated specimens of *Anchicodium* and *Iranicodium* are deposited in Geozentrum Nordbayern, Department of Paleontology, University Erlangen-Nürnberg (material: "Senowbari-Daryan: Permian Iran, Bagh-e Vang").

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Geographic position and geological overview of localities

Permian deposits of central Iran, the so-called Jamal Formation (Stöcklin et al. 1965), crop out in several localities of the Shotori Mountains (Leven & Taheri 2003). *Anchicodium* was found in two sections of the Permian Jamal Formation, located about 65 km and 45 km north of the town of Tabas (Fig. 1). These localities are described briefly below:

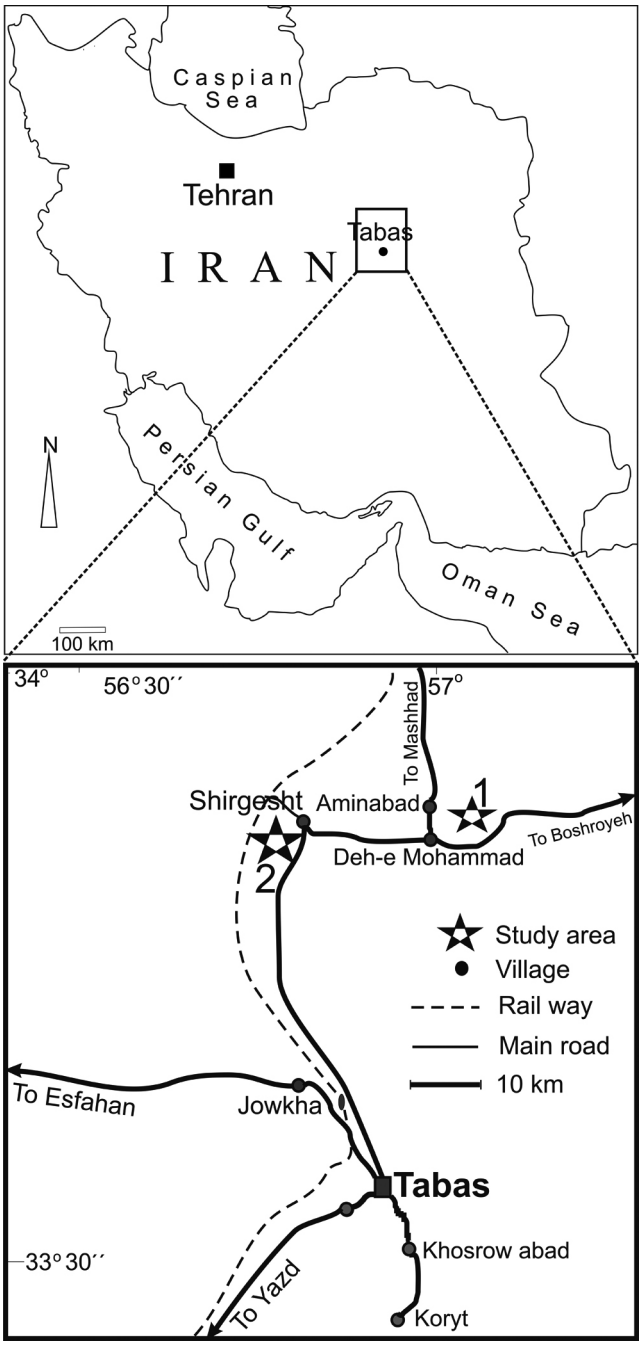

Fig. 1 - Geographic position of investigated sections of Permian Jamal Formation in Shotori Mountains, northeast Iran. 1) section near the town of Deh-e Mohammed, 2) Kuh-e Bagh-e Vang section.

1. *Bagh-e Vang locality (locality 2 in Fig. 1).* The section of the Kuh-e Bagh-e Vang (Bagh-e Vang Mount) is located 45 km north of the town of Tabas, near the town of Shirgesht (geological map 1:100.000 of Shirgesht completed by Ruttner et al. 1968). A section of the Permian Jamal Formation crops out on the western and southern flank of the Kuh-e Bagh-e Vang (N: 33° 58′ 60″, E: 56° 47′ 66″, Fig. 2). Permian sediments in this section overlain the Carboniferous Sardar Formation, which includes siltstones, shales and sandstones. The Permian deposits are overlain by the Lower Triassic Sorkh Shale Formation.

The Permian section of the Jamal Formation in the Bagh-e Vang locality reaches a thickness of 293 m (Ruttner et al. 1968) to 300 m in western flank (Leven & Vaziri Mohaddam 2004), but we (one of the authors: KR) measured it on the southern flank of this mount as about 320 m. Generally the Jamal Formation in this locality is composed of sandy limestone with some olistoliths (Fig. 3), dark shale, and medium- to thin-bedded marly limestone. Partoazar (1995) introduced the name Bagh-e Vang member for the 60 m of the lower part (Asselian-Sakmarian in age) of the Jamal Formation of this section. The middle part of the section is characterized by medium-bedded limestone intercalated with chert layers. The summit of the section is covered by massive carbonates (Fig. 2), which lead to the Lower Triassic Sorkh-e Shale Formation. Based on fusulinids, Leven & Vaziri Mohaddam (2004) recognized 10 litho-units within the Jamal Formation in Bagh-e Vang. The sponges of this locality were studied by Senowbari-Daryan et al. (2005, 2006) and the bryozoans by Ernst et al. (2006).

2. Deh-e Mohammed locality (locality 1 in Fig. 1). This locality lies about 65 km north of the town of Tabas, about 5 km northeast of the small village of Deh-e Mohammed, about 1 km from the road of Tabas – Boshruye, in an area called Agheldun (Fig. 1, N: 33° 59‘ 46.6“, E: 57° 01‘ 46“). The Permian deposits are 290 m thick and overlie the Carboniferous Sardar Formation, which is about 26 m thick in this locality. The 247 meters of the lower and middle part of the Permian deposits were sampled. The topmost 43 meters of the upper part of the formation are dolomitic and were not sampled. Ernst et al. (2009) described the bryozoan fauna of this locality.

Systematic Paleontology

Stem **Chlorophycophyta**? Papenfuss, 1946

Class **Chlorophyceae**? Kützing, 1843

Family Anchicodiaceae Shuysky, 1987

Remarks. The systematic position of phylloid algae in higher category as Clorophycophyta, Rhodophy-

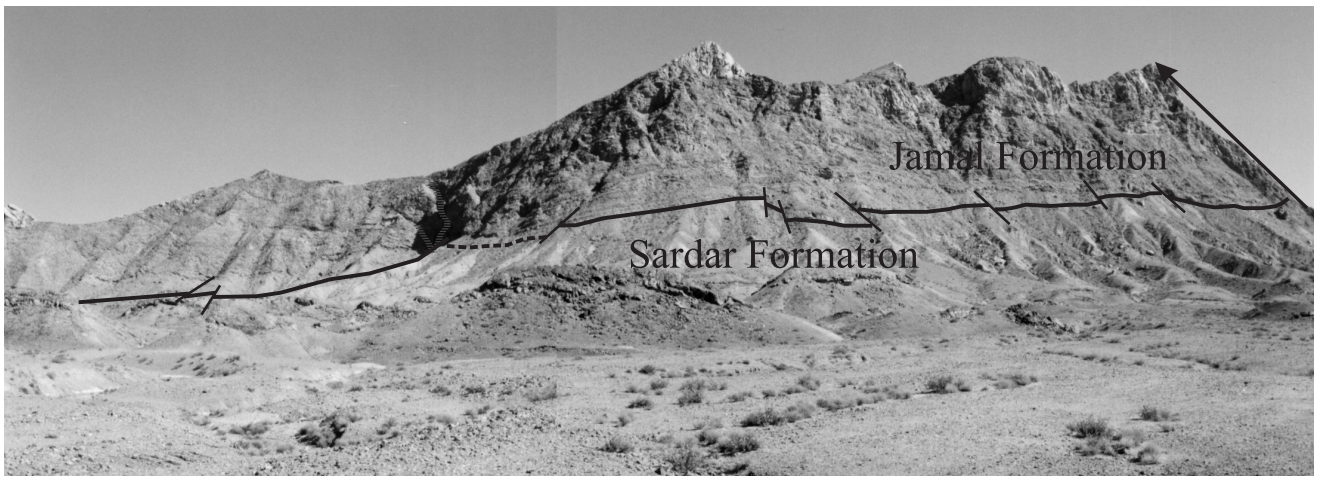

Fig. 2 - View of the Kuh-e Bagh-e Vang from the west side showing the boundary between the Carboniferous and Permian deposits. The white-appearing conical part of the top is dolomitic and most probably reefal limestone. The arrow at the right side of the photograph indicates the sampled section.

cophyta is disputed (Flügel 1977; Riding & Guo 1991; Mamet & Villa 2004). *Anchicodium* e. g. is listed as possibly "Ancestral Squamaraceae" by Flügel (1977).

Generally the medullar zone of phylloid algae of the Jamal Formation is strongly re-crystallized and any structures are not recognizable. Re-crystallization of the cortical zone has commonly destroyed the structure of the whole thallus. According to Vachard et al. (1989, fig. 4) specimens of phylloid algae are in reality *Archaeolithophyllum*, which are strongly re-crystallized. These authors interpreted the structure of the cortical zone, including the conceptacles in *Eugnophyllum,* as borings of endolithic organisms filled by microgranular cement. The well-preserved structures of cortical and medullar zones of specimens of *Anchicodium*, described in this paper, do not confirm the interpretation of Vachard et al. (1989), at least not for material from the Shotori Mountains described below. Based on re-crystallisation pattern of the thallus *Anchicodium* is compared as chlorophytes with *Halimeda* by Torres & Baars (1992). Investigation of phylloid algae with blue-light epifluorescence microscope was carried out by Dawson (1992). In fact the internal structure is clearly recognizable by epifluorescence light as shown by Dawson. Similar or identical alga, identified as *Archaeolithophyllum missouriense* by Dawson (1992) is described as *Kasimophyllum demuesensis* by Mamet & Villa (2004).

Genus *Anchicodium* Johnson, 1946

Type species: *Anchicodium funile* Johnson, 1946

Remarks. The definition of the genus or species differentiation and characteristics of Paleozoic codia-

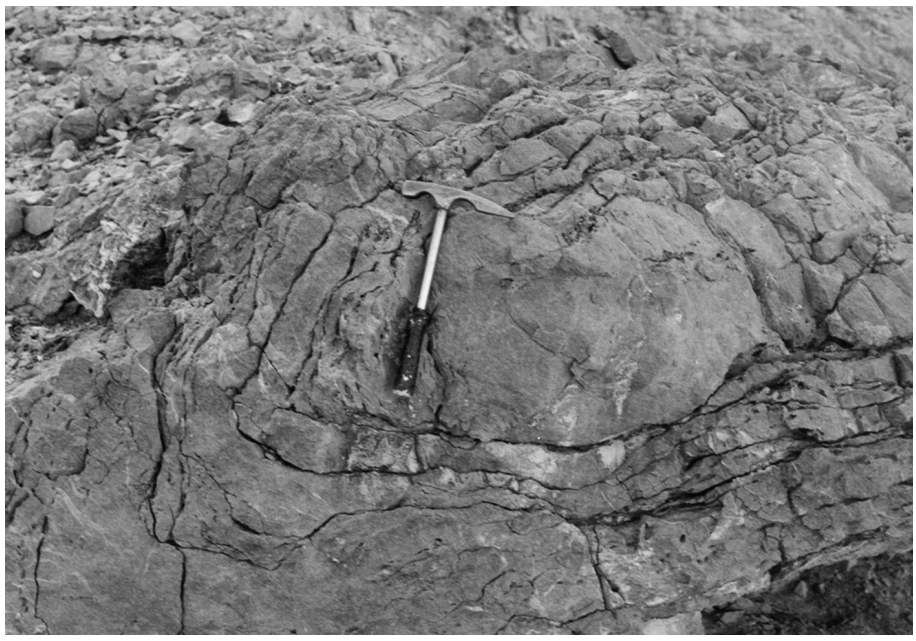

Fig. 3 - Small olistolithe with slumping structure within the Jamal Formation in Kuh-e Bagh-e Vang.

cean algae, such e. g. *Anchicodium* or *Eugonophyllum* are not plausible and exactly defined in the literature. Plate or tape-like thallus of *Anchicodium*, e. g. is defined originally as "cylindrical" by Johnson (1964). Specimens from the Jamal Formation show the platy or tape-like nature of *Anchicodium*. In *Iranicodium* nov. gen. the skeletal elements (threads and the wall between them) of the thallus are different on opposite sides of the tape.

The internal structure of almost all species of *Anchicodium* described by previous authors is re-crystallized or poorly preserved and details of the thallus are not recognizable (e. g. see Johnson 1946; Endo 1951, 1953, 1954, 1961a; Endo & Horiguchi 1957; Homann 1972; Kulik 1978). Most of earlier documented species were described and illustrated, based on only one broken or re-crystallized specimen showing only partially features of the thallus. As shown here in Pl. 1, fig. B-C, the thallus of *Anchicodium* is an undulating plate or tape-like and its length is very variable. Most specimens seem to be broken and are parts of a large specimen. Therefore, the thallus length can not be a characteristic feature for species determination. Relatively well-preserved specimens of the genus *Anchicodium*, which show the internal structure of the thallus, were described and illustrated as *A. japonicum* by Flügel & Flügel-Kahler (1980: p. 116, pl. 1, figs. 2-3). A more detailed description of different species, described by previous authors, is necessary.

Original diagnosis of *Anchicodium*. "Colonies assigned to this genus commence as a crustose mass from which straight or nearly straight cylindrical thalli develop. Thalli may branch or develop rounded protuberances. Some are irregularly constricted, but others are very regular. Each thallus is composed of a sponge-like mass of rounded threads or branches. Center tends to become poorly organized or pithlike, but, toward outer margins of thalli, branches tend to become parallel. In some species, branches end in tufts or fine branches that usually are perpendicular to outer surface of thallus. Outer part of thallus calcified, but amount of calcification varies. It may affect only a narrow outer zone or extend inward through entire thallus. Calcified areas usually preserve microstructure, whereas uncalcified portions are filled with clear calcite. No sporangia observed" (Johnson 1946: 1098).

According to Konishi & Wray (1961) the "straight or nearly straight cylindrical thallus" (Johnson 1946: 1098) of *Anchicodium* is similar to *Eugonophyllum* and *Ivanovia* as being phylloid or blade-shaped.

Torres & Baars (1992) investigated some thin sections of original material of Johnson and concluded that the original descriptions of *Anchicodium* (and therefore the cylindrical shape of the thallus) were valid.

Torres & Baars (1992: fig. 1) illustrated several specimens of *Anchicodium funile* Johnson with "circular cross sections". They write at page 677: "A phylloid alga cannot provide a circular cross section with radiating calcite utricular molds comparable to those shown". In fact all "circular sections" of Torres & Baars are connected as a part with the platy thallus of *Anchicodium*. We interpret the "circular sections" in fig. 1 of Torres & Baars, indicated by arrows as protuberances, as originated from the platy or tape-like thallus. Also the divergently orientation of the skeletal elements in "circular sections" illustrated in figs.1/2-5 by Torres & Baars (1992) support this interpretation. Such protuberances or swellings are common in specimens of *Anchicodium* and also in our material from the Permian of Bagh-e Vang (Pl. 1, fig. B; Pl. 2, fig. D). Both specimens in Pl. 1, fig. B show that the protuberances are originated from one and the same side of the thallus. As shown in Pl. 1, fig. G the swelling or protuberance is open at the upper part. Cross sections of such protuberances appear circular. Similar characteristic of *Anchicodium* was observed also by Wu (1991: 123), who defined the genus of *Anchicodium* as "bladed with one surface flat and the other having tubercles".

We agree with following diagnosis for *Anchicodium* given by Mamet (1991: 375): "Crustose, wavey, phylloid plates (tape- or ribbon-like). Spongy mass of highly branching threads, terminated in triangular-shaped "utricles"".

Additional species. *A. ankarensis* Bilgütay, 1960 (Lower Permian), *A. densum* Endo, 1961a (Permian), *A. expresum* Wu, 1991 (Middle Permian), *A. flexuosum* Endo, 1961b (Middle Permian), *A. fukujiense* Endo & Horiguchi, 1957 (Permian), *A. funile* Johnson, 1946 (Upper Carboniferous-Permian), *A. gracile* Johnson, 1946 (Upper Carboniferous), *A. japonicum* Endo, 1953 (Lower Permian), *A. magnum,* Endo 1951 (Carboniferous-Permian), *A. nodosum* Johnson, 1946 (Upper Carboniferous), *A. permianum,* Johnson 1946 (Lower Permian), *A. plumosum,* Johnson 1946 (Upper Carboniferous), *A. sindbadi* Elliott, 1970 (Permian), *A. undulatum* Johnson, 1946 (Upper Carboniferous).

Remarks. Johnson (1946: 1098) defined *Anchicodium* ".. as a crustose mass from which straight or nearly straight cylindrical thalli develop". Illustrations of several species described by Johnson and all other species, described by later authors and also all our specimens from the Permian Jamal Formation do not show the cylindrical thalli of *Anchicodium*. We will define *Anchicodium* as straight, curved or even irregular undulating tape- or ribbon-like.

Johnson (1946: 1098) noted that the "species of *Anchicodium* are differentiated on the basis of diameter

of branches, diameter of thallus and shape of the external appearance of thallus". It should be noted that not the "diameter", but the thickness of the plates should be considered as the criterion for species determinations. Because of different shapes of the thallus the "external appearance" (straight, curved, undulating etc.) is not useful for the identifications of the species.

In addition to the type species – *Anchicodium funile* – described by Johnson (1946) five additional species of genus with short description, poor documentation and without their comparison and differences were described by the same author. Following remarks are made about all the known species of the genus *Anchicodium* or the species are shortly described.

Anchicodium ankarensis Bilgütay, 1960

* 1960 *Anchicodium ankarensis* n. sp. - Bilgütay, p. 58-60, pl. III, figs. 4-7.

Remarks. The type material of *Anchicodium ankarensis*, illustrated by Bilgütay (1960: pl. III, figs. 4-7) lacks a designation of the holotype. Apparently different fossil skeletons are united to this species. The identity of specimens illustrated in figs. 5-6 with 4 or 7 is uncertain. Bilgütay's specimens 5-6 exhibit cavities of a diameter of 0.072-0.144 mm that were interpreted as possibly reproductive organs by him. Such cavities are not known in *Anchicodium*. The data of these cavities are not taken in consideration here in Table 1.

Occurrence. The species is known only from the Lower Permian of Caracadere area near Ankara, Turkey.

Anchicodium densum Endo, 1961a

1961a *Anchicodium densum* new species- Endo, p. 133-134, pl. 5, fig. 8.

Remarks. This species was described and named for only one poorly preserved specimen. It appears to be a weathered and broken specimen, but according to Endo (1961a: 134) "the generic and specific features are unique and very clear". We could not follow the clearness of the generic and species features. The biometrical data of the thallus are presented in Tab. 1. Because of the original poor description and illustration of the species, we propose to limit the species name *densum* to only that specimen, illustrated by Endo (1961a: pl. 5, fig. 8).

Occurrence. Permian of Akiyoshi Limestone Group, Japan.

Anchicodium expressum Wu, 1991

1991a *Anchicodium expressum* sp. nov. - Wu, p. 123, pl. 20, fig. 7, pl. 21., fig. 2.

1991b *Anchicodium expressum* sp. nov. - Wu, p. 765, pl. 2, fig. 7, pl. 3 fig. 2.

Remarks. The two poorly preserved specimens of *A. expressum*, illustrated by Wu (1991a and 1991b) do not allow the recognition of any details about this "species".

Occurrence. Middle Permian of Maokou Formation, Longin, Guangxi, China.

Anchicodium flexuosum Endo, 1961b

1961b *Anchicodium flexuosum* new species - Endo, p. 108, pl. 19, fig. 5.

Tab. 1 - Biometrical data of all known species of the genus *Anchicodium*, based on original descriptions. LT: length of the thallus, TT: thickness of the thallus, PP: diameter of the threads or primary pores in medullar zone (axial region), SP: diameter of the secondary threads or pores in the cortical zone. All measurements are in mm. *) Type species of the genus. **) The data are from Johnson (1946: 1100). Apparently there is an error, because the "ordinary branches" are cited as larger than the "diameter" (= thickness of the alga). Most probably these data should be 0.3-0.35 mm. The data in parenthesis for *A. magnum* are from Homann (1972). There is no designation of holotype for species indicated with +.

Species	LT	TT	PP	SP	Author
A. ankarensis +	3.60	0.816-1.128	0.22-0.33	-	Bilgütay 1960
A. densum	2.282	0.405	0.054	0.041	Endo 1961b
A. expressum	-	0.67-1.00	0.025	0.01	Wu 1991
A. flexuosum +	12	0.54	0.071-0.090	?	Endo 1961b
A. fukujiense +	?	0.27-1.188	?	0.05	Endo & Horiguchi 1957
*A. funile**	30	0.03-0.035**	0.14-0.17	0.007	Johnson 1946
A. gracile	several cm	0.385-0.50	?	0.0045-0.0066	Johnson 1946
A. iranicum n. sp.	34	0.3-0.9	0.2-0.4	0.01-0.03	this paper
A. japonicum	-	0.521-0.573	0.0625	0.0261	Endo 1953
A. magnum +	1500	0.4689-2.1882 (0.220-3.630)	0.0521-0.0782	0.02	Endo 1953
A. maximum n. sp.	8	2.2-3	0.3	0.1 mm	this paper
A. nodosum	?	0.22-0.55	0.016-0.04	?	Johnson 1946
A. permianum	?	0.275-0.32	?	0.007-0.009	Johnson 1946
A. plumosum	?	0.66-1.76	0.0154-0.0198	?	Johnson 1946
A. sindbadi	7.5	0.68	0.020-0.04	?	Elliott 1970
A. undulatum	?	0.286-0.33	0.0154	?	Johnson 1946

Remarks. Like other species of the genus, this species was also poorly described and illustrated by Endo (1961b). Endo's illustrations show two specimens (most probably the same species) of *Anchicodium*. Endo, however, did not indicate the holotype of *A. flexuosum*. For biometrical data of *A. flexuosum* see Table 1.

Occurrence. *A. flexuosum* is known only from the type locality, Odaniyama Formation, Lower Middle Permian of Japan.

Anchicodium fukujiense Endo & Horiguchi, 1957

1957 *Anchicodium fukujiense* new species - Endo & Horiguchi, p. 175, pl. XV, figs. 1-2.

? 1986 *Anchicodium* cf. *A. fukuiense* Endo - Tien (in Fontaine), pl. 10, fig. 7.

Remarks. Several specimens of *A. fukujiense* are illustrated in pl. 15, figs. 1-2 by Endo & Horiguchi (1957) without designating the holotype. All specimens are internally strongly re-crystallized and thallus structures are not recognizable. Endo & Horigochi (1957: 175) noted, that "the center of thallus is poorly organized and may have been composed of a sponge-like mass of very fine thread-like filaments". In our opinion the illustrated specimens by Endo & Horiguchi do not allow the identification of these specimens to species level. We propose to limit the species name *fukujiense* to the original material and no more use this name in future. Specimens, described as "*Teutloporella*? *hidensis* new species" and illustrated in pl. 15, fig. 4-5 by Endo & Horiguchi (1957) are listed among the dasycladales algae by Granier & Grgasovic (2000: 155) and seem to be a specimen of *Anchicodium*.

Occurrence. Known from the Permian of the Ichinotai Group, west of Fukuji village, Japan and probably from the Permian of Kampuchea (Tien 1986).

Anchicodium funile Johnson, 1946

1946 *Anchicodium funile* n. sp. - Johnson, p. 1100, pl. 2, fig. 8, pl. 3, fig. 4, pl. 7, fig. 1.

1992 *Anchicodium funile* Johnson. - Torres & Baars, p. 677, fig. 1/1-6.

Remarks. According to Johnson (1946) this species reaches lengths of 30 mm. He gives the "diameter" (= thickness) of the thallus as 0.03-0.035 mm. There seems to be errors in these data. Most probably "diameter" should be 0.30-0.35 mm. Johnson gives the diameter of ordinary pores as 0.14-0.17 mm, and those of peripheral pores as 0.007 mm.

The validity of the original description of this species by Johnson is confirmed by Torres & Baars (1992), based on examination of lecto- and neotypes of Johnsons's original material.

Occurrence. This species is known from several Pennsylvanian and Permian localities (Wakarusa Limestone, Lyon County; Auburn shale Shawnce County; Burlingame Limestone, Labette County, Kansas), described by Johnson (1946). *A. funile* Johnson is described by Torres & Baars (1992), based on thin sections of lecto- and neotypes of Johnson's original material.

Anchicodium gracile Johnson, 1946

1946 *Anchicodium gracile* n. sp. - Johnson, p. 1098, pl. 3, fig. 1-2.

Remarks. Johnson (1946: 1099) noted that the thallus length of *A. gracile* may be several centimeters. This is not evidence from his illustrated specimens, which seem to be broken. According to him the diameter (= thickness) of the thallus ranges from 0.385-0.50 mm, and diameters of the branches 0.0045-0.0066 mm.

Occurrence. This species is described only by Johnson (1946) and is known from the Capitan Creed Member of the Stanton Limestone (upper Middle Pennsylvanian), Franklin County, Kansas. A possible occurrence was also reported by the same author from the Oread Limestone (lower Upper Pennsylvanian), Osage County, Kansas.

Anchicodium japonicum Endo, 1953

1953 *Anchicodium japonicum* n. sp. - Endo, p. 123-124, pl. 11, fig. 5, pl. 12, figs. 5-7.

1961a *Anchicodium japonicum* Endo - Endo, p. 133, pl. 2, fig. 7.

1980 *Anchicodium japonicum* Endo - Flügel & Flügel-Kahler, p. 116, pl. 1, figs. 2-3.

Remarks. Flügel & Flügel-Kahler (1980) described this species from the Trogkofel beds of the Carnic Alps, Austria, noting (correctly) the tape-like morphology of the thallus. Biometrical data of the thallus given by Flügel & Flügel-Kahler (p. 117) are moderately larger than the data given in the original description by Endo (1953).

Occurrence. Lower Permian in Japan (Kitakami-Mountais, Japan: Endo, 1953; W-Honshu: Endo, 1961a) and Trogkofel beds in Carnic Alps, Austria (Flügel & Flügel-Kahler, 1980)

Anchicodium magnum Endo, 1951

1951 *Anchicodium magnum*, new species - Endo, p. 125-126, pl. 11, figs. 3-5.

1952 *Anchicodium magnum* Endo - Endo, p. 247, pl. 23, figs. 6-7.

1954 *Anchicodium magnum* Endo - Endo, p. 218, pl. 19, fig. 4.

1957 *Anchicodium magnum* Endo - Endo, p. 292-293, pl. 41, fig. 4, pl. 42, fig. 2.

1957 *Anchicodium magnum* Endo - Endo & Horiguchi, p. 175-176, pl. 15, fig. 3.

1961a *Anchicodium magnum* Endo - Endo, p. 134, pl. 6, figs. 4-6.

1961 *Eugonophyllum magnum* (Endo) - Konishi & Wray, p. 663, pl. 75, fig. 6.

1972 *Anchicodium magnum* Endo - Homann, p. 175-177, pl. 2, fig. 13 (cum synonymy)

Remarks. *Anchicodium magnum* was described originally by Endo (1951), with illustrations of 3 specimens in pl. 11, figs. 3-5, but without designation of the holotype. The specimen, illustrated in fig. 3 by him is strongly re-crystallized in the inner part and does not show the character of the medullar zone. Specimen, illustrated in fig. 5 by him, is a well-preserved one and shows the internal structure of the thallus. Endo indicated the "diameter" (= thickness) of the thallus of *A. magnum* as 0.4689 mm to 2.1882 mm. He lists, in table on p. 126, the D with 0.7294-1.5630 mm and d with 0.3647-0.5210 mm. We could not understand what he meant by the "d". He notes (pl. 126) the "diameter of ordinary pores from 0.0521 to 0.0782 mm and that of fine terminal branches about 0.02 mm".

Anchicodium magnum was described and illustrated several times by Endo (see synonymy). Specimen illustrated by him (1954) in pl. 19, fig. 4 is not clearly recognizable, because there are different objects. Also his (1957) specimen in pl. 41, fig. 4 is uncertain, but the specimen in pl. 42, fig. 2 seems to be a budded specimen showing clearly the tape-like shape of this alga.

Homann (1972) described *Anchicodium magnum* from the Lower Permian of Carnic Alps, Austria and gave biometrical data, which are moderately different from the original description (see Tab. 1). Specimen illustrated by Homann in pl. 2, fig. 13 is internally re-crystallized and its determination as *A. magnum* is questionable. The oblique section on this specimen shows, however, the tape-like thallus of the species. Homann discussed the similarities of the genera *Anchicodium*, *Eugonophyllum*, *Calcifolium*, and *Ivanovia*. According to him *Anchicodium* and *Ivanovia* Khvorova are probably synonyms.

Here we treat *A. magnum* beside other species of the genus, although it was replaced and attributed to the genus *Eugonophyllum* by Konishi & Wray (1961).

Occurrence. *A. magnum* was described originally from the Lower Carboniferous and Lower Permian of Japan by Endo (1951). A detailed discussion about this and similar species and its occurrence were given by Homann (1972: 176).

Anchicodium nodosum Johnson, 1946

1946 *Anchicodium nodosum* n. sp. - Johnson, p. 1099, pl. 3, fig. 5.

Remarks. Only one specimen of this species was illustrated by Johnson (1946: pl. 3, fig. 5). The internal part of the thallus is re-crystallized and the details are not recognizable. Apparently, this species was established by Johnson (1946) based on "swellings, buds or incipient branches". Swellings or buds also occur in other species of *Anchicodium* and are not species characteristic. Johnson gave the diameters of the thallus of this species as 0.22-0.55 mm (average 0.44 mm) and the diameters of branches from 0.016 mm to 0.04 mm.

Occurrence. Up to present time, *A. nodosum* is known only from the Upper Pennsylvanian of Donphan County, Kansas.

Anchicodium permianum Johnson, 1946

1946 *Anchicodium permianum* n. sp. - Johnson, p. 1100, pl. 7, figs. 3, 7.

Remarks. Johnson (1946: 1100) gave the following and very short description for this species: "Thallus of this form, which pinches and swells, is rather slender. Calcification weak and usually limited to narrow outer crust. Branches fine, have diameter of 0.007-0.009 mm. Diameter of thallus 0.275-0.32 mm."

Occurrence. The species is known only from the Americus member of the Foraker Limestone (Lower Permian), Marshall County, Kansas.

Anchicodium plumosum Johnson, 1946

1946 *Anchicodium plumosum* n. sp. - Johnson, p. 1099, pl. 2, fig. 6, pl. 7, fig. 4.

Remarks. Johnson (1946) has illustrated two specimens of *A. plumosum* with short description. Nothing is to add.

Occurrence. Ervine Creek member, Deer Creek Limestone (Upper Pennsylvanian), Chautauqua County, Kansas.

Anchicodium sindbadi Elliott, 1970

1970 *Anchicodium sindbadi* n. sp. - Elliott, p. 327-328, pl. 61, fig. 3-4.

Remarks. *Anchicodium sindbadi* was established by Elliott (1970: pl. 61, fig. 3, magnification in fig. 4), based on only one well-preserved specimen from the Permian boulders within the Cretaceous Hawasina Formation. According to the illustrated specimen and its parallel oriented and undulate branches (threads) this species should be classified as *Paraepimastopora* Roux (1979).

Occurrence. The species is known only from the Permian of the Middle East.

Anchicodium undulatum Johnson, 1946

1946 *Anchicodium undulatum* n. sp. - Johnson, p. 1099, pl. 7, fig. 2.

Remarks. Like other species of the genus this species is also poorly described and illustrated by only a broken specimen by Johnson (1946). Characteristics of the species, as "thallus long and undulating" are not recognizable in his illustrated specimen in pl. 7, fig. 2. "Diameter" (= thickness) of the thallus is given as 0.286-0.33 mm, that of the branches as only 0.0154 mm by Johnson (1946). Because of very poor description and illustration of the species we propose to limit the species name only to Johnson's specimen illustrated in pl. 7, fig. 2.

Occurrence. Up to date *Anchicodium undulatum* Johnson is known only from the "type locality" (Big Spring Member of Lecompton Limestone, Upper Pennsylvanian), Jefferson County, Kansas.

Anchicodium iranicum nov. sp.

(Pl. 1, figs B-C, E-G, Pl. 2, figs A-D, Pl. 4, figs B-C, E, Text-figs. 4-6)

Derivatio nominis. Named for the occurrence in Iran.

Holotype. Specimen illustrated in Pl. 1, fig. B (Magnifications in Pl. 1, figs E-G). Thin-section number 5/1.

Paratypes. Pl. 1, figs C, Pl. 2, figs A-D, Pl. 4, figs B-C, E.

Locus typicus. Kuh-e Bagh-e Vang, north of the town of Tabas (see Text-fig. 1-2).

Stratum typicum. Permian.

Diagnosis. Undulating, curved or straight, tape- or ribbon-like thallus with pith sponge-like appearance. Multibranched threads originate from the center of thallus and are oriented perpendicular to the thallus surface. Thallus surface is with swellings and buds.

Material. In several thin-sections (illustrated specimens in sections 5/1, 10/4a, 10/4/b, 1/1, 10/4, 12/2/1, 12/4).

Description. Thallus of this species is undulating, curved or straight, tape- or ribbon-like, reaching thicknesses of 0.6-0.9 mm. Direct near the budding or swelling the thicknesses of the thalli increase moderately. The length of thallus is variable and most specimens seem to be broken. Threads originate from the center of the thallus and are oriented more or less parallel to others, ending perpendicular to the thallus surface. Diameters of threads range between 0.2 mm and 0.4 mm and are branched toward the thallus surfaces. After branch the diameter of the threads become successively

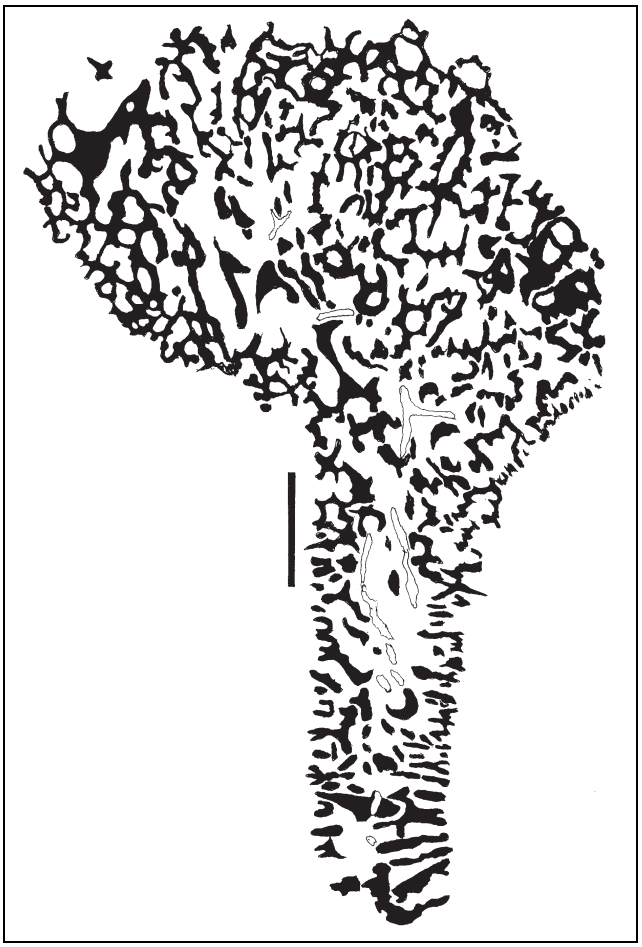

Fig. 4 - *Anchicodium iranicum* nov. sp. Oblique section through a specimen showing the thallus cut perpenticular to the plate (lower part) and parallel to the plate (upper part) (drawn from Pl. 4, fig. B). Scale 0.5 mm.

Fig. 5 - *Anchicodium iranicum* nov. sp. Section through a specimen showing the same size of skeletal elements on both sides of the thallus (drawn from Pl. 4, fig. E). Scale 1 mm.

smaller. Thallus surface exhibits swellings or buds. The thickness of the thallus, including the swelling is up to 2.3 mm.

The holotype, illustrated in Pl. 1, fig. B, is a long and undulating specimen reaching a length of at least 34 mm. It is a specimen, which is at the end of thin-section and is cut on both its ends. The specimen shows several buddings or swellings (Pl. 1, fig. B: large arrows). Thallus is usually 0.3-0.8 mm thick, increasing near the swellings up to 2.3 mm. Some swellings seem to be hollow (Pl. 1, fig. B/1, magnification in fig. G), which could be an indicative for hosting of reproductive organs during lifetime. The medullar zone of the holotype is re-crystallized, but the relatively well-preserved cortical zone shows the multibranched tufts of threads clearly (Pl. 1, figs E-F). Some of paratypes (Pl. 2, figs A-B) exhibit well-preserved medullar zone and the pattern of origination of threads.

Near the holotype, a second undulating and large species is cut, and shows the same characteristics with swellings (Pl. 1, fig. B: small arrows) like the holotype. A large and undulating specimen is illustrated in Pl. 1, Fig. C, exhibiting some swellings like the holotype.

Comparison. *A. iranicum* nov. sp. differs from all known species (listed in Tab. 1) by its large threads or primary pores. According to this feature it is comparable with *A. ankarensis* Bilgütay, but the latter has much thicker thallus than *A. iranicum*.

Occurrence. *A. iranicum* was found only in the Permian Jamal Formation of the type locality (Kuh-e Bagh-e Vang).

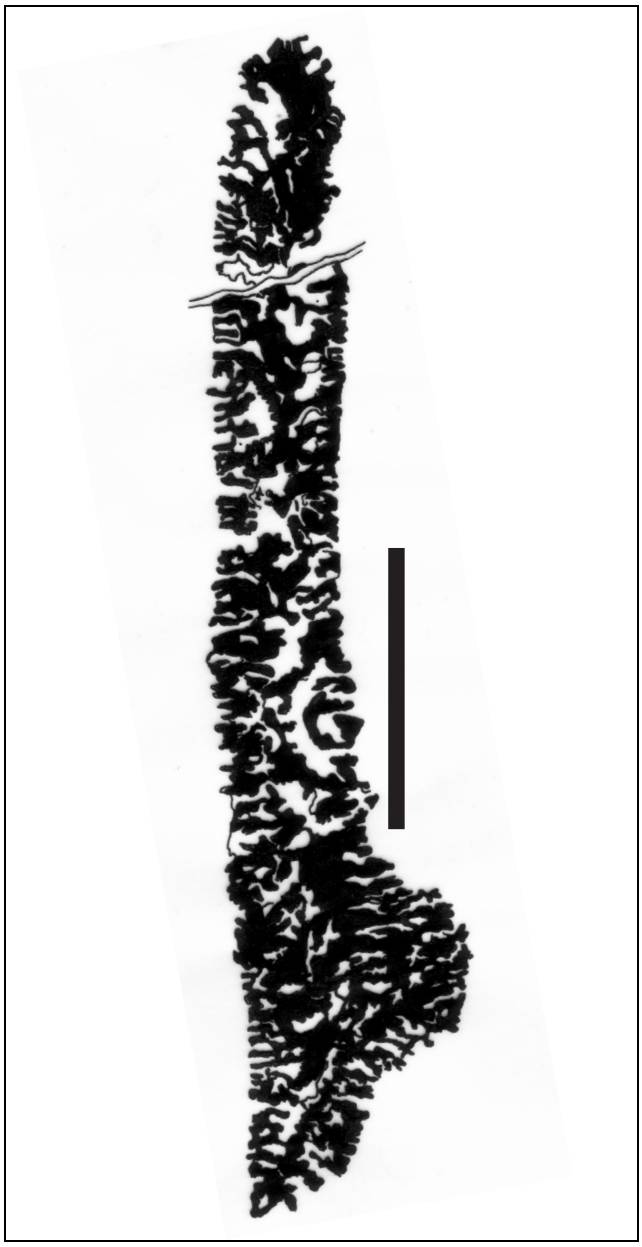

Fig. 6 - *Anchicodium iranicum* nov. sp. Section through a specimen showing the coarse skeletal element in the medullar zone, and fine and parallel oriented equally elements on both sides of the thallus. At the right side of the thallus is a swelling with fine skeletal elements (drawn from Pl. 2, fig. D). Scale 1 mm.

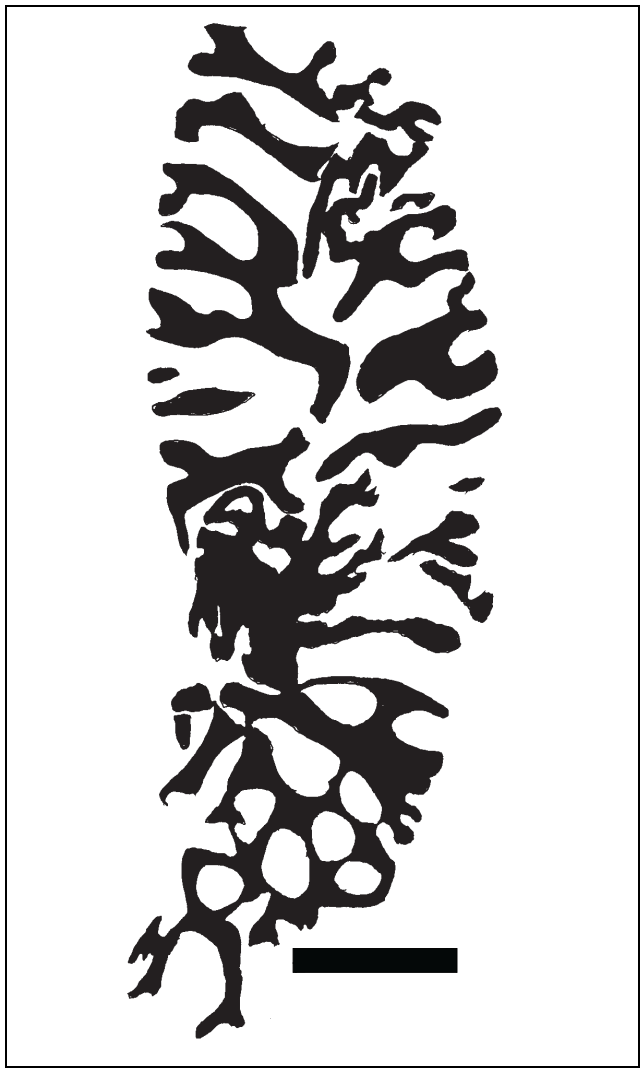

Fig. 7 - *Anchicodium maximum* nov. sp. Drawn from the holotype in Pl. 4, fig. F. The thallus exhibits large skeletal elements (large multi-branched threads and the thick skeletal walls between them). Scale 1 mm.

Anchicodium maximum nov. sp.

(Pl. 4, figs F-G, Text-fig. 7)

Derivatio nomins: Maximus (lat. = largest). Named for the thick thallus and large skeletal elements.

Holotype. Specimen illustrated in Pl. 4, fig. F. Thin-section DM29.

Paratype. Specimen illustrated in Pl. 4, fig. G.

Locus typicus. Kuh-e Bagh-e Vang (see Fig. 1-2).

Stratum typicum. Jamal Formation, Permian (Bolorian in the Tethyan scale, Kungurian in the Global scale).

Diagnosis. Specimen of *Anchicodium* with the largest thickness of the thallus and skeletal elements among the known species.

Material. Three specimens in thin-sections Bs29/1, Bs29/2, Ba29.

Description. Three specimens of this species of *Anchicodium* are available. One of paratypes, illustrated in Pl. 4, fig. G, was apparently growing between two other organisms (sponges) and reached a thallus length of about 8 mm, and a thickness of 3 mm. The holotype (Pl. 4, fig. F, compare Text-fig. 7) reaches a length of at least 7 mm with a thickness of 2.2 mm. It shows the branching pattern of the threads in medullar and cortical zones. The threads in the medullar zone reach a diameter of 0.3 mm, those of the cortical zone about 0.1 mm. The walls between threads are coarse, reaching thicknesses of up to 0.3 mm. The biometrical data of the thallus and thallus elements are given in Tab. 1.

Comparison. All known species of the genus *Anchicodium* are listed in Tab. 1, with their thallus diameters and other specific data. *A. maximum* n. sp. differs from all other known species by the large thickness of the thallus. Also the skeletal elements, like the large threads of the first and second order, large thickness of the wall between the threads differentiate the new species from all other known species of the genus described in the literature.

Occurrence. *A. maximum* nov. sp. was found only in the type locality (Kuh-e Bagh-e Vang).

Genus *Iranicodium* nov. gen.

Type species: *Iranicodium asymmetricum* nov. sp.

Derivatio nominis. Named from Iran and *codium* an abundant suffix in codiacean genera.

Diagnosis. Straight or curved tape-like thallus with swellings and different skeletal elements (threads and the wall between the threads) in opposite surface of the thallus. One side, with small threads is usually thicker and the threads are oriented perpendicular to the thallus surface; the other side is usually thinner and the threads and the walls between them are coarse and arranged irregularly (spongy).

Comparison. *Iranicodium* nov. gen. is similar to *Anchicodium* Johnson (1946) but differs from it in development of different skeletal elements at both sides (or surfaces) of the thallus.

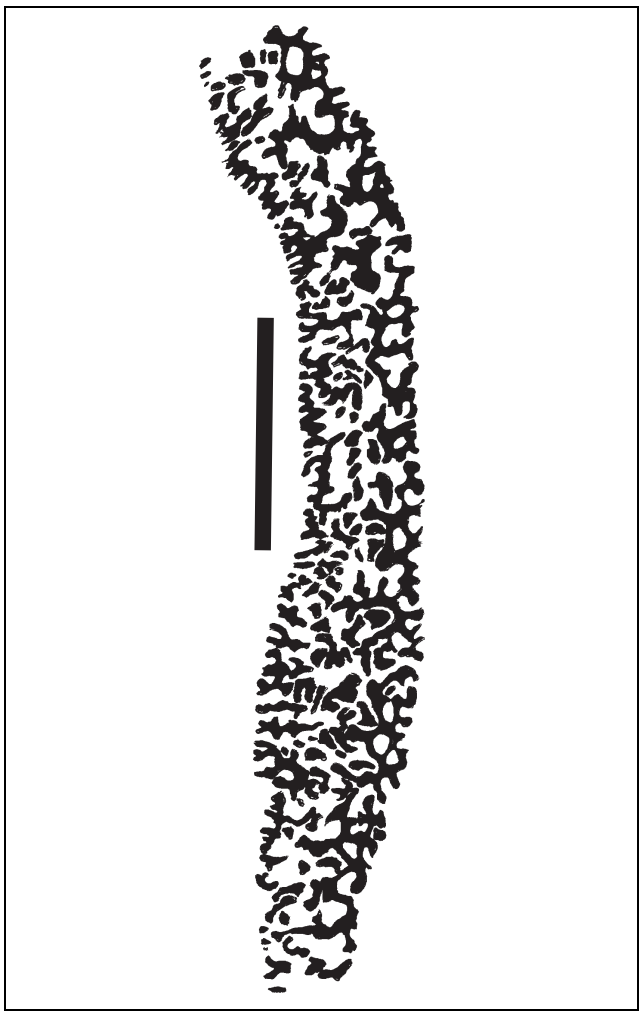

Fig. 8 - *Iranicodium asymmetricum* nov. gen., nov. sp. The specimen shows the different-sized skeletal elements (fine in left surface, coarse in right surface) on both sides of the thallus (holotype, drawn from Pl. 3, fig. C). Scale 1 mm.

Iranicodium asymmetricum nov. sp.

(Pl. 1, fig. A, Pl. 3, figs. A-D, Pl. 4, figs. A, D, Text-fig. 8-10)

Derivatio nominis. Because of the different skeletal elements at the both side of the thallus.

Holotype. Specimen illustrated in Pl. 3, Fig. C. Thin-section DM9 (compare Text-fig. 8).

Paratypes. All specimens illustrated in Pl. 1, fig. A, Pl. 3, figs. A-B, D, Pl. 4, figs. A, D.

Locus typicus. Deh-e Mohammed locality (see Text-fig. 1).

Stratum typicum. Jamal Formation, Permian.

Diagnosis. As diagnosis of the genus.

Material. In several thin-sections from Kuh-e Bagh-e Vang (illustrated specimens in: 1/2, 5/1, 10/4a, 10/7, DM/9, 2/2, 10/5).

Description. The straight or curved and tape-like thallus of this species reaches thicknesses of 0.4-1 mm. The specimens reach lengths of at least 4 mm. The most characteristic feature of this alga is the development of different skeletal elements (threads and the walls between them) on the two sides (both surfaces) of the thallus. The side containing the small threads and the

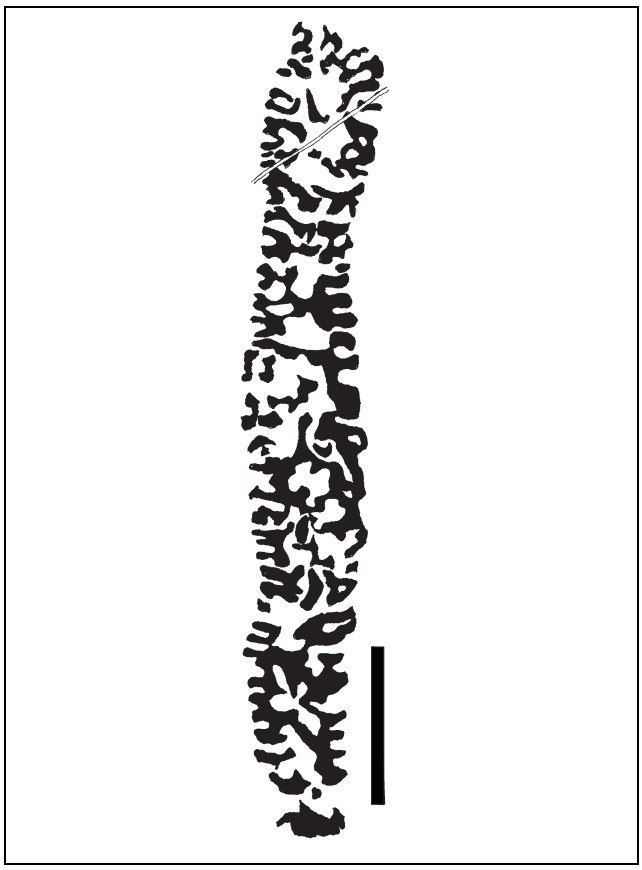

Fig. 9 - *Iranicodium asymmetricum* nov. gen., nov. sp. (compare Pl. 1, fig. A). The specimen exhibits different-sized skeletal elements (fine and parallel oriented at the left side, coarse and irregularly oriented at the right side). Scale 0.5 mm.

thin walls between them is usually thicker (0.2-0.6 mm) than the side with coarse threads. The small threads are arranged more or less parallel to each other and perpendicular to the thallus surfaces (or to the axis of the thallus in section). The threads of this part reach diameters between 0.01 mm and 0.02 mm. The other side with large threads and thick walls between them is usually thinner (0.1-0.2 mm) and the threads are irregular. The primary and secondary threads of both sides are clearly recognizable. Primary threads reach diameters between 0.2 mm and 0.4 mm, and diameters of secondary threads are between 0.01 mm and 0.05 mm at the periphery of the thallus. The boundary between the two sides is marked usually by a dark undulating line. The biometrical data of *I. asymmetricum* nov. sp. are listed in Tab. 2.

The holotype (Pl. 3, fig. C, compare Text-fig. 8) is a specimen that reaches a length of 2.9 mm, with the thallus thickness of about 0.3 mm. It shows, at least at two points (Pl. 3, fig. C: arrows) swellings, where the skeletal elements are similar, more or less the same size.

Ecological limitation of *Anchicodium* Johnson and *Iranicodium* nov. gen. in Permian Jamal Formation

Both genera, *Anchicodium* Johnson and *Iranicodium* nov. gen., occur in reef or reefal limestones together with sponges (Senowbari-Daryan et al. 2005, 2006), bryozoans (Ernst et al. 2009), rare corals, problematic algae (*Tubiphytes obscurus* Maslov, *Tubiphytes carinthiacus* (Flügel), *Pseudovermiporella* ssp., *Lercaritubus problematicus* Flügel, Senowbari-Daryan & Di Stefano, *Archaeolithoporella hidensis* Endo, and different crust-building algae), rare fusulinids etc. and are associated with some specimens of dasycladacean algae *Mizzia* sp., *Imperiella* sp., and *Epimastopora* sp. All other dasycladales, which occur abundantly in lagoonal facies of the Jamal Formation, do not occur in the Kuh-e Bagh-e Vang section together with *Anchicodium* or *Iranicodium* nov. gen.

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Tab. 2 - Biometrical data of some specimens of *Iranicodium asymmetricum* nov. gen., nov. sp. TT) thallus thickness, TFSE) thickness of the side with fine skeletal elements, TCSE) thickness of the side with coarse skeletal elements, DPPBS) diameter of primary threads of both sides of the thallus, DSPFS) diameter of secondary threads at periphery of the side with fine skeletal elements, DSPCS) diameter of secondary threads at periphery of the side with coarse skeletal elements. All measurements are in mm. *) Differences between TFSE+TCSE and TT is the cavity in the axial region of the thallus, which was not measured.

Thin-section	TT	TFSE	TCSE	DPPBS	DSPFS	DSPCS
11C	0.75-1.7	-	-	-	-	-
12/2/1	0.5*	0.25	0.1	0.03-0.1	0.01	0.01-0.02
12/2/1	0.5	0.3	0.2	0.04-0.07	0.01	0.01-0.02
12/2/1	0.4-0.5	0.35	0.15	0.03-0.04	0.01	0.01-0.015
12/4	0.5-0.55	0.3	0.2	0.03	0.01	0.01
13/2	0.5	0.28	0.15	0.04	0.01	0.02-0.05
1/6	0.5	0.4	0.1	0.03-0.05	0.01	0.01-0.015
10/7	0.5	0.33	0.15	0.03-0.04	0.01	0.01-0.05
10/7	0.4-0.7	032-0.45	0.12-0.2	0.03-0.05	0.01	0.01-0.04
1/2	0.6	0.25-0.3	0.2	-	0.01	0.01-0.05
DM9*	0.5-0.8	0.2-0.3	0.2-0.3	0.04-0.1	0.1-0.15	0.02-0.06

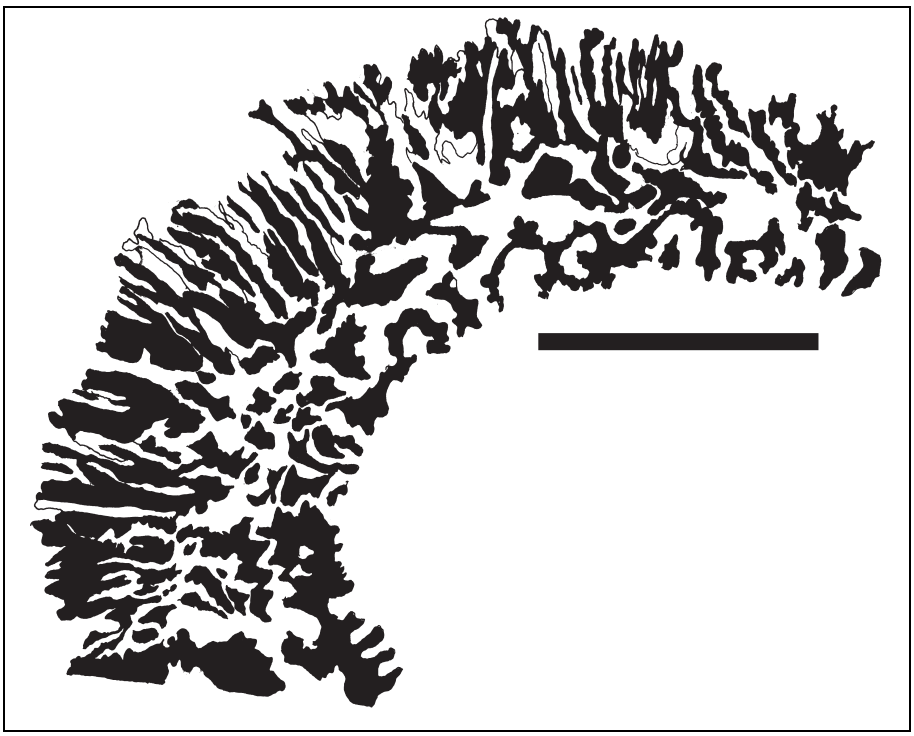

Fig. 10 - *Iranicodium asymmetricum* nov. gen., nov. sp. The different-sized skeletal elements (fine in upper surface, coarse in lower surface) on both sides of the thallus are clearly recognizable (drawn from Pl. 4, fig. A). Scale 0.5 mm.

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PLATE 1

Fig. B-C, E-G) *Anchicodium iranicum* nov. sp. and A, D) *Iranicodium asymmetricum* nov. gen. nov. sp. Scale in B 4 mm, in all others 1 mm.

A) *Iranicodium asymmetricum* nov. gen., nov. sp. Section through a specimen showing the coarse thallus elements at the right side of the photograph and the finer thallus elements at the left side of the photograph. The second order of the threads at the left side is arranged parallel and perpendicular to the thallus surface. For details compare Text-fig. 9. Thin-section 10/4/6.

B) *Anchicodium iranicum* nov. sp. Section through two specimens (H: holotype, P: paratype) of curved and undulated thalli with some swellings at the right side in the largest specimen (large arrows) and in the small specimen (small arrows). The large specimen (holotype) is about 30 mm long. The skeletal elements of the thallus are everywhere symmetrical at both sides of the "middle line". Skeletal elements are arranged parallel to each others and oriented perpendicular to the surface of the thallus. For magnification of the dark-lined rectangles 1-2 see Figs. E-G. Thin-section 5/1.

C) *Anchicodium iranicum* nov. sp. Section through a large specimen. A second specimen is cut at the upper left corner of the photograph. Arrow indicates a swelling. Thin-section 10/4a.

D) *Iranicodium asymmetricum* nov. gen. nov. sp. Section through a curved specimen showing the different-sized skeletal elements at both sides of the "middle line". The skeletal elements of the upper part are coarser and the threads are irregular; the skeletal elements of the lower part are finer and the threads are running parallel to each others and are arranged perpendicular to the thallus surface. Thin-section 10/4b.

E) *Anchicodium iranicum* nov. sp. The magnification of quadrangle 2 in Fig. A shows the skeletal elements (threads and the walls between them) of equal size and arrangement. The multi-branching threads are clearly recognizable in part. Arrow indicates a small organism colonized on the "bottom" of the alga. Thin section 5/1.

F) Enlargement of Fig. E shows the branching pattern of the threads and the equal size of the skeletal elements on both sides of the thallus.

G) *Anchicodium iranicum* nov. sp. The magnification of quadrangle 1 in Fig. A shows a swelling, which is open in the middle. Thin section 5/1.

PLATE 2

Figs. A-D) *Anchicodium iranicum* nov. sp. Permian Jamal Formation of Kuh-e Vagh-e Vang, Shotori Mountains, northeast Iran. Scale 1 mm.

A) Section through a straight specimen showing the equally-sized skeletal elements on both sides of the thallus. The threads are regular and arranged parallel, more or less perpendicular to the thallus surface. The medullar zone is weakly calcified and marked with a dark and undulating line. Thin-section 1/4.

B) Section through a specimen showing the equally-sized skeletal elements on both sides of the "middle line" of the thallus. Thin-section 5/1.
C) Section through a curved specimen showing clearly the equally-sized skeletal elements on both sides of the thallus. Because of re-crystallization of the medullar zone the skeletal elements in the axial region are not well recognizable. Thin-section 5/1.
D) Section through a well-preserved specimen showing clearly defined skeletal elements on both sides of the thallus. At the right side is a swelling with fine skeletal elements. For details see Text-fig. 6. Thin-section 10/4a.

PLATE 3

Fig. A-D: *Iranicodium asymmetricum* nov. gen., nov. sp. from the Permian Jamal Formation of the Shotori Mountains, northeast Iran. Scale 1 mm.

A) Section through a curved specimen showing the large skeletal elements on the "bottom" and the finer elements on the upper part of the thallus. Thin-section 10/4a.
B) Specimen similar to Fig. A exhibiting similar characteristics of the thalllus. Thin-section 10/7.
C) Holotype. The specimen shows clearly the different skeletal elements on both sides of the "middle line" of the thallus. The skeletal elements of the lower part are large and irregular, those of the upper part are finer and the threads are oriented parallel to others and perpendicular to the thallus surface (for details see Text-fig. 8). Thin-section DM9.
D) Section through a curved specimen showing the different skeletal elements (coarse on the lower part and fine on the upper part). White arrow points to the branching pattern of the threads. Thin-section 2/2.

PLATE 4

Iranicodium asymmetricum nov. gen., nov. sp. (A, D), *Anchicodium iranicum* nov. sp. (B-C, E), and *Anchicodium maximum* nov. sp. (F-G) from the Permian Jamal Formation, Shotori Mountains, northeast Iran. Scale in A, D and E is 0.5 mm, in all others is 1 mm.

A) Section through a curved and well-preserved specimen clearly showing the different sized skeletal elements at both sides of the "middle line" of the thallus. The threads of upper left part are arranged parallel to each other and are perpendicular to the thallus surface. The skeletal elements and the threads of the lower right part are coarse and irregular. This part is much thinner than the upper left part. Thin-section 10/5.
B) Section that is cut perpendicular and parallel to the tape showing the skeletal elements in both direction. Thin-section 12/2/1.
C) Sections though two curved thalli showing the threads arranged perpendicular to the thallus surface. Thin-section 12/4.
D) Section showing the large sized and irregularly arranged skeletal elements at the left side of the photograph and small and parallel running elements at the right side. The right part with regular threads is thicker than the left part. Thin-section 12/4.
E) Section through a partly re-crystallized specimen with equally-sized skeletal elements on both sides (for details see Text-fig. 3) Thin-section 10/5.
F) Holotype. The section shows the coarse skeletal elements of modular zone, which are multi-branched to the cortical zone. The white-appearing wall between the threads is also thick. For details see Text-fig. 7. Thin-section BA29.
G) Specimen showing the coarse skeletal elements like the holotype in Fig. F. The specimen has grown between other organisms. Thin-section BA29/1.

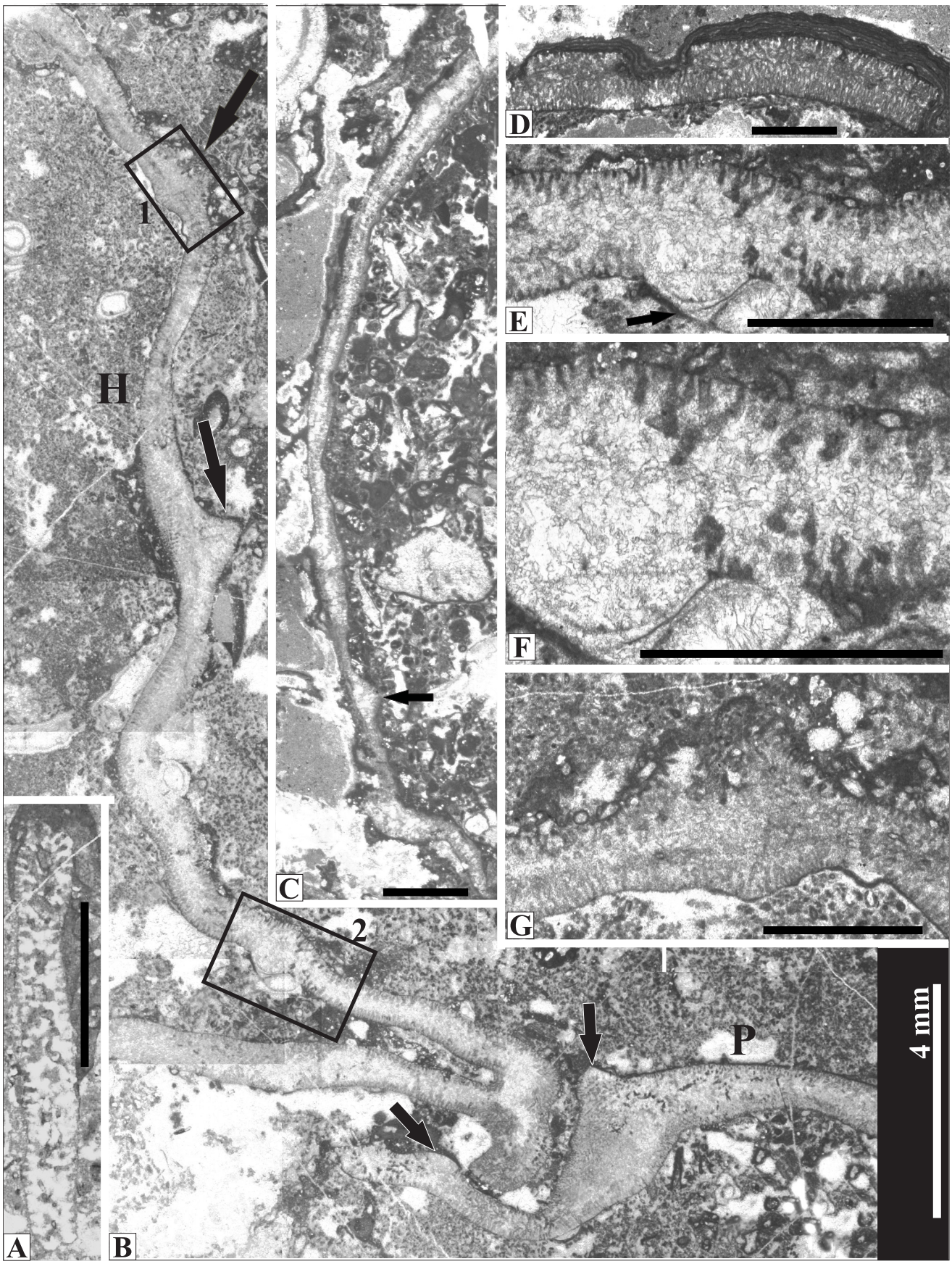

PLATE 1

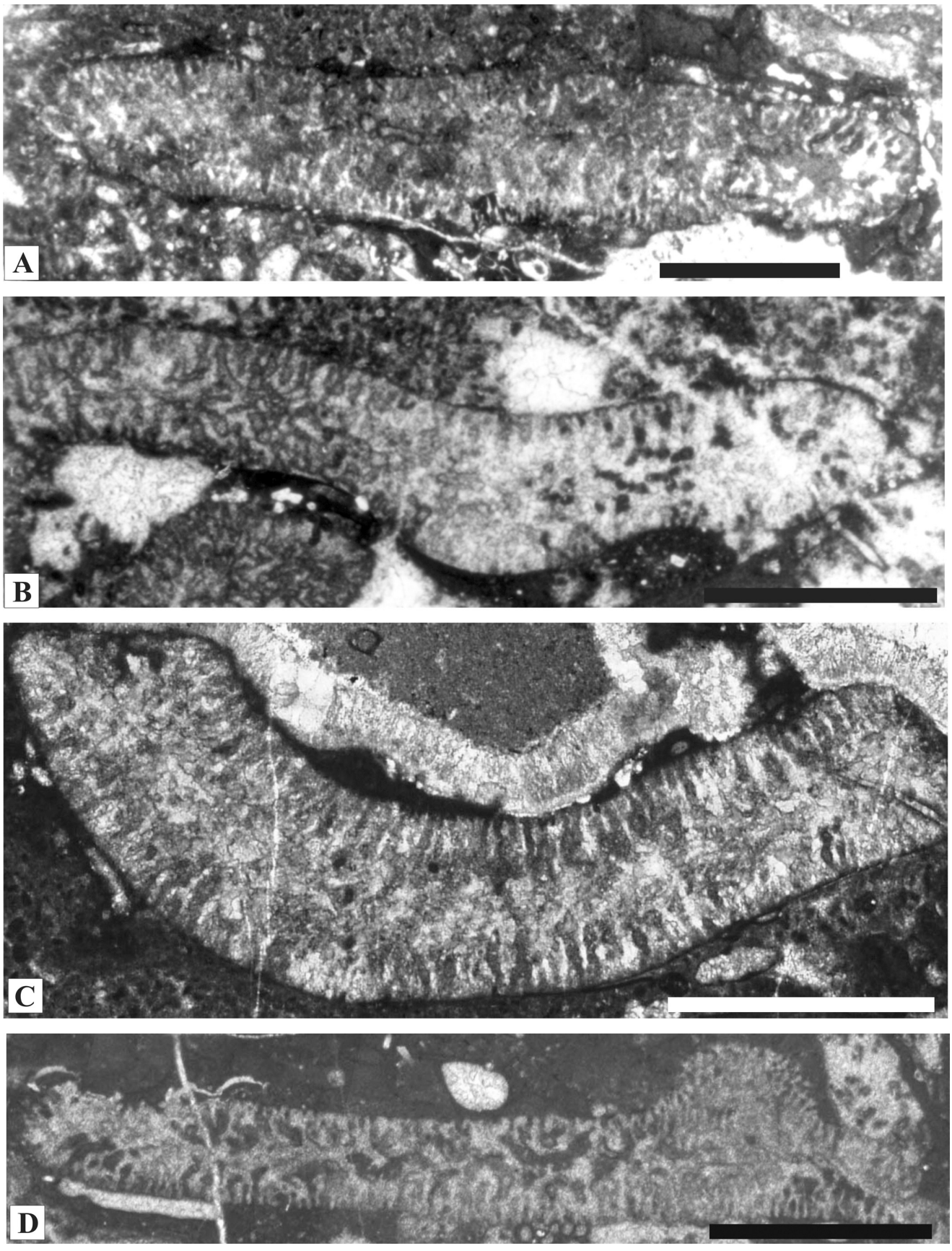

PLATE 2

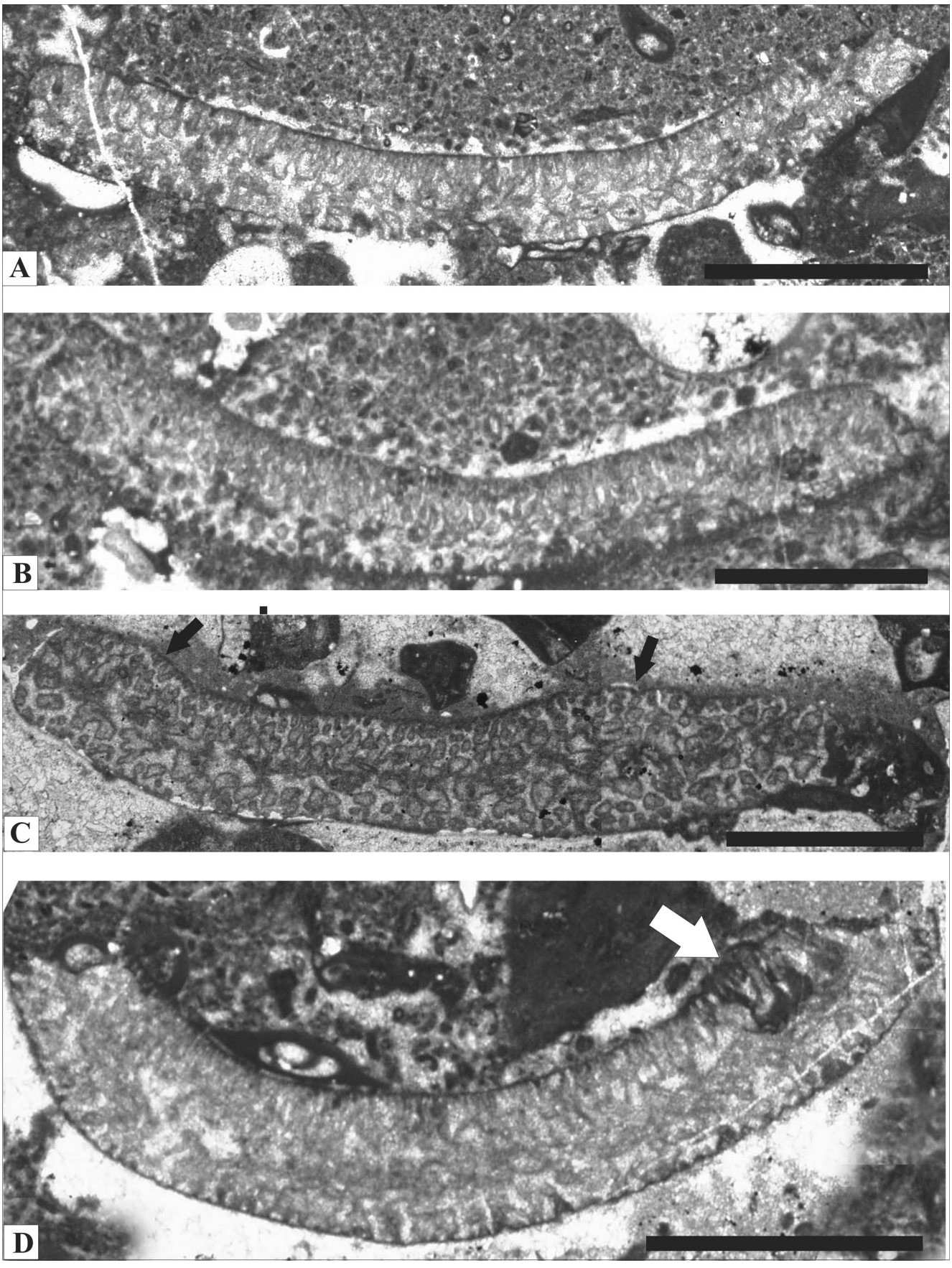

PLATE 3

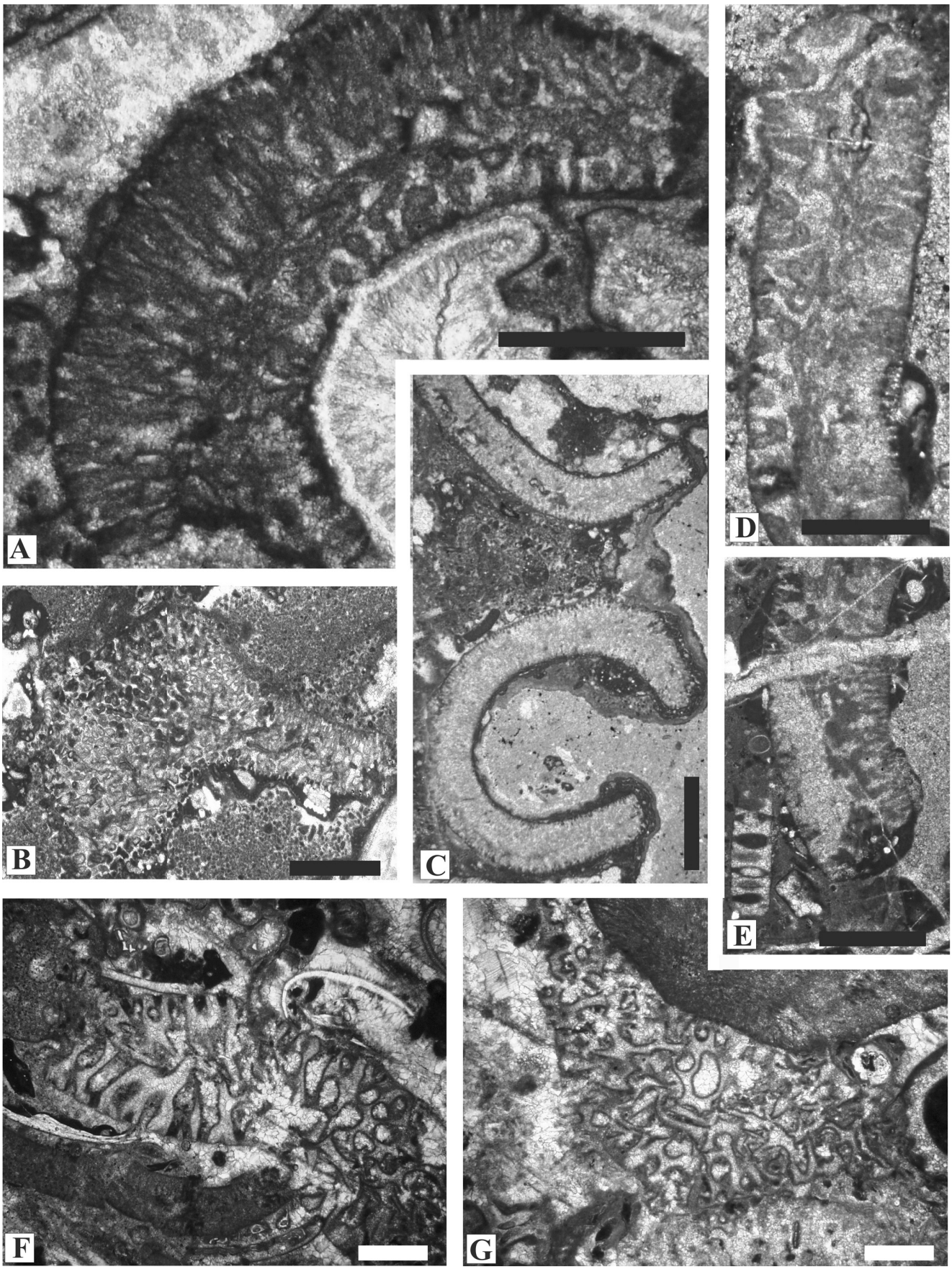

PLATE 4

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