



Some rugose corals from the Devonian (Givetian and Frasnian) of Northeastern Iran

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With 7 figures

Abstract: A rugose coral fauna from Givetian and Lower Frasnian strata of the Khoshyeilagh Formation in the Eastern Alborz Mountains (Northeastern Iran) was studied. In total, eight species belonging to five genera are reported from the Mighan section, northeast of the city of Shahrood. From the Givetian, four species of the genera *Spinophyllum* WEDEKIND, 1922, *Chostophyllum* PEDDER, 1982, and *Aristophyllum* BULVANKER, SPASSKY & KRAVTSOV, 1975, are described. From the overlying Lower Frasnian, four species are recorded, belonging to the genera *Sinodisphyllum* SUN, 1958 and *Charactophyllum* SIMPSON, 1900.

Key words: Rugose corals, Givetian, Frasnian, Khoshyeilagh Formation, Eastern Alborz Mountains, Iran.

1. Introduction

The first investigation of the Devonian coral fauna of the Alborz Mountains was carried out by GHODS (1982), who studied the coral composition of four localities in these mountains including two sections in Azerbaijan and two sections in the Eastern Alborz Mountains (NE Iran). Amazingly, GHODS (1982) attributed the Givetian and Frasnian strata of the Djuifa and Poldasht sections studied in Azerbaijan to the Khoshyeilagh Formation, while it has been documented that the latter formation implies to the Middle and Upper Devonian of the Eastern Alborz Mountains. It would have been better, if GHODS (1982) would have used the Ilanqareh Formation for the studied strata of his sections in Northwestern Iran.

Taxonomically, the Devonian coral fauna of the Alborz Mountains has been rarely studied and our knowledge about this fossil group is confined to a few

papers, in which the presence of the group has only been briefly mentioned from different areas. The Ilanqareh Formation, which represents the Middle and Upper Devonian in Azerbaijan and in the Western Alborz Mountains (NW Iran), contains rugose and tabulate corals such as favositids, thamnoporids, *Hexagonaria*, and *Phillipsastraea* in some of its outcrops (WENDT et al. 2005: 38). Rugose corals also occur in the Upper Devonian Geirud Formation across the Central Alborz. In the Eastern Alborz Mountains, the Padeha and Khoshyeilagh formations imply to the Devonian. The Lower Devonian Padeha Formation is generally poor in macrofauna, while the Middle and Late Devonian deposits of the Khoshyeilagh Formation are characterized by a large number of rugose corals. In the Binalud Mountains, which are considered as an eastern prolongation of the Alborz Mountains, the Bahram Formation represents the Middle and Upper Devonian. In comparison with the Binalud Mountains, exposures

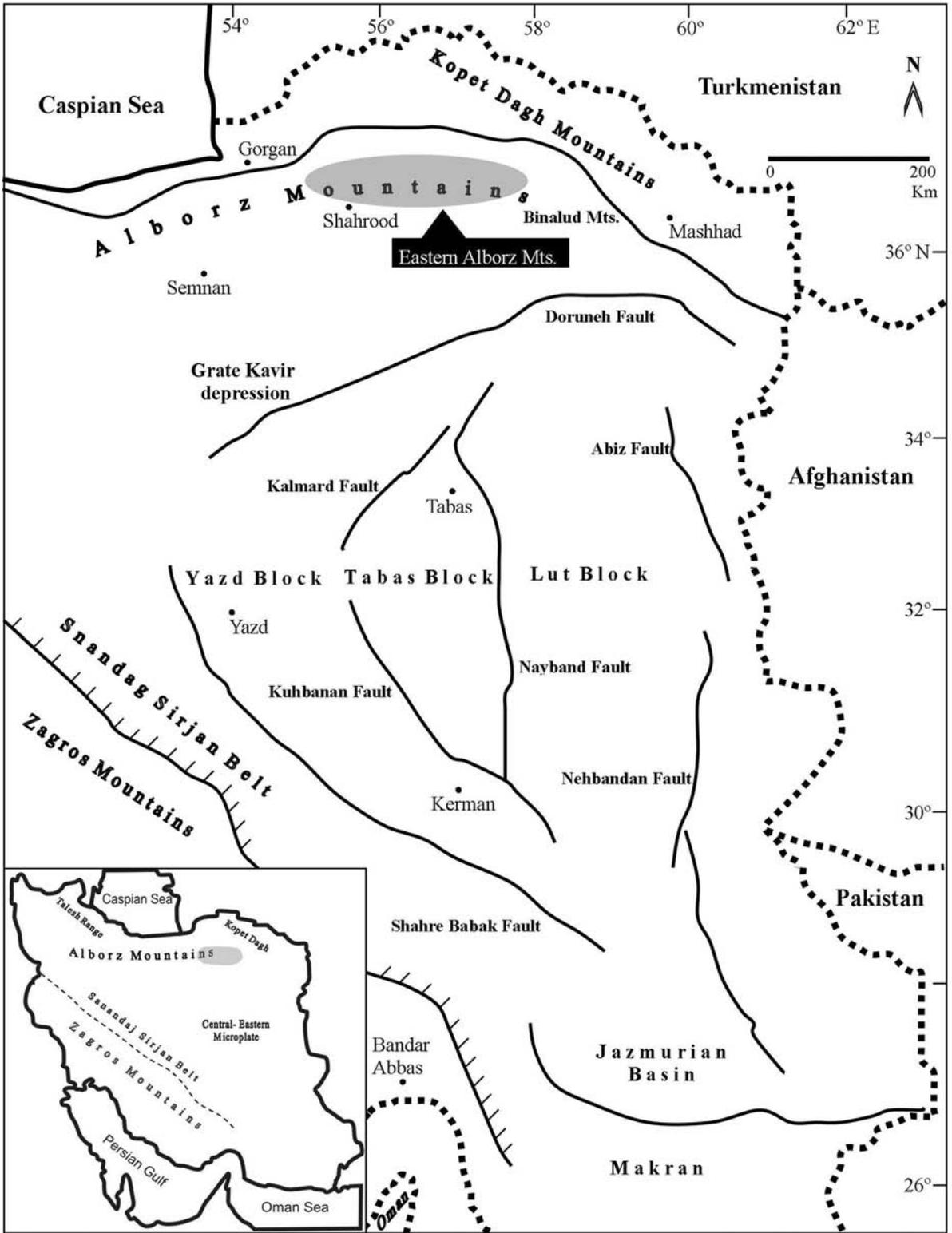


Fig. 1. Simplified map of the structural units in Iran. The map shows structural units in the East, South and Southwest of Iran and also the location of the Eastern Alborz Mountains.

of the Bahram Formation in the Central and Eastern Iran are characterized by considerable abundances of coral faunas.

Structurally and palaeotectonically, the Iran is divided into three main zones including the Northern zone, the Central Iran and the Zagros Mountains (see WENDT et al. 2002, 2005). The Northern zone comprises the Caspian Depression and the Northern Alborz Mountains, being extended towards the West (the Talesh Range or the Western Alborz) and the East (the Kopet Dagh Mountains). The Zagros Mountains in the Southwest and West of Iran is bordered by the Persian Gulf in the Southwest. The Central Iran consists of the Southern Alborz Mountains, being prolonged into the Binalud Mountains in the East, Northwestern Iran (Azerbaijan), the Central-Eastern Microplate, the Great Kavir Depression, and the Sanandaj-Sirjan Belt (Fig. 1). According to the mentioned divisions, the studied area is located in the Eastern parts of the Southern Alborz Mountains, approximately in the Northeast of Iran. The Alborz Mountains are considered as northern folded belt of Central Iran. This assignment is supported by lithostratigraphic and biostratigraphic similarities between two zones. It is noticeable that terms such as “Western”, “Central”, “Eastern” and “Southern”, which are used for subdivisions of the Alborz Mountains, have purely geographical implications. In fact, the Eastern Alborz Mountains comprises the eastern parts of the Alborz Mountains bordered by the Binalud Mountains in the East.

Rugose corals are one of the main components of the macrofauna occurring in the Khoshyeilagh Formation. The formation has a wide distribution in the Eastern Alborz Mountains and was established by BOZORGNIA (1973), who mentioned its age ranging from the Eifelian to Famennian. However, there are still controversies about the age of this formation, especially concerning the lower part of the profile. Based on conodont dating, an Early Emsian to Eifelian age was proposed by HAMDI & JANVIER (1981) for the basal parts of the Khoshyeilagh Formation. WEDDIGE (1984) believed that earliest Givetian must be considered for the lower parts of the formation. STAMPFLI (1978), WEDDIGE (1984) And ASHOURI (1990) showed that the onset of marine sedimentation in the formation is earliest Givetian (*hemiansatus* Zone) in age. According to WENDT et al. (2005), who conducted a detailed research of the Devonian and Carboniferous rocks in Iran, the Khoshyeilagh Formation is divided into three members, including Lower Carbonate, Siliciclastic and Upper Carbonate Members. The age

of the Lower Carbonate Member was determined as Givetian and Early Frasnian (HAMDI & JANVIER 1981; KALANTARI 1981; ASHOURI 2006). According to the occurrences of a different and diverse fauna with brachiopods, trilobites and conodonts, a Late Frasnian to Early Tournaisian age was proposed for the Upper Carbonate Member (BRICE et al. 1974, 1978; ASHOURI 1994, 2004; WENDT et al. 2005). No fossils have been reported from the Siliciclastic Member, and, based on underlying and overlying fossils, its age was regarded as Middle Frasnian.

Alternations of limestones, dolomites and shales of the Lower Carbonate Member are rich in macrofaunas such as rugose corals, brachiopods, tentaculitids and trilobites. In this study, eight species of the solitary rugose corals of the mentioned member are studied northeast of the Iranian city of Shahrood.

2. Previous works on corals

The oldest report about the Givetian and Frasnian coral fauna from the Khoshyeilagh Formation appeared in GHODS (1982), who described some solitary and colonial corals from the type section, approximately 57 km NE of the city of Shahrood. Another study was published by ASHOURI et al. (2008), in which a few Frasnian rugose and tabulate corals from this formation were illustrated from the Chahar-Borj section, northwest of the city of Esfaraein. The Famennian solitary corals were collected in the North of the village of Mighan (present worked section) by M.A. ABBASI, and some new taxa were described by ASHOURI et al. (2010).

3. Geological setting and material

The name of the investigated section (Mighan Section) refers to the village of Mighan, which is located about 25 km northeast of the city of Shahrood and 4 km north of the road connecting Shahrood and Azadshahr. The outcrops of the Khoshyeilagh Formation are located approximately 5 km north of the village, on both sides of a valley (Fig. 2).

Lithofacies and biofacies evidences imply to prevalence of a shallow shelf settlement during the Silurian in the most areas of Iran. These Silurian siliciclastic deposits are widely exposed in the Eastern Alborz Mountains and Central Iran. The shelf settlement and low stand of sea level persisted into Early Devonian. During this time, the siliciclastic rocks are accompanied with sabkha, deltaic and fluvial deposits, named

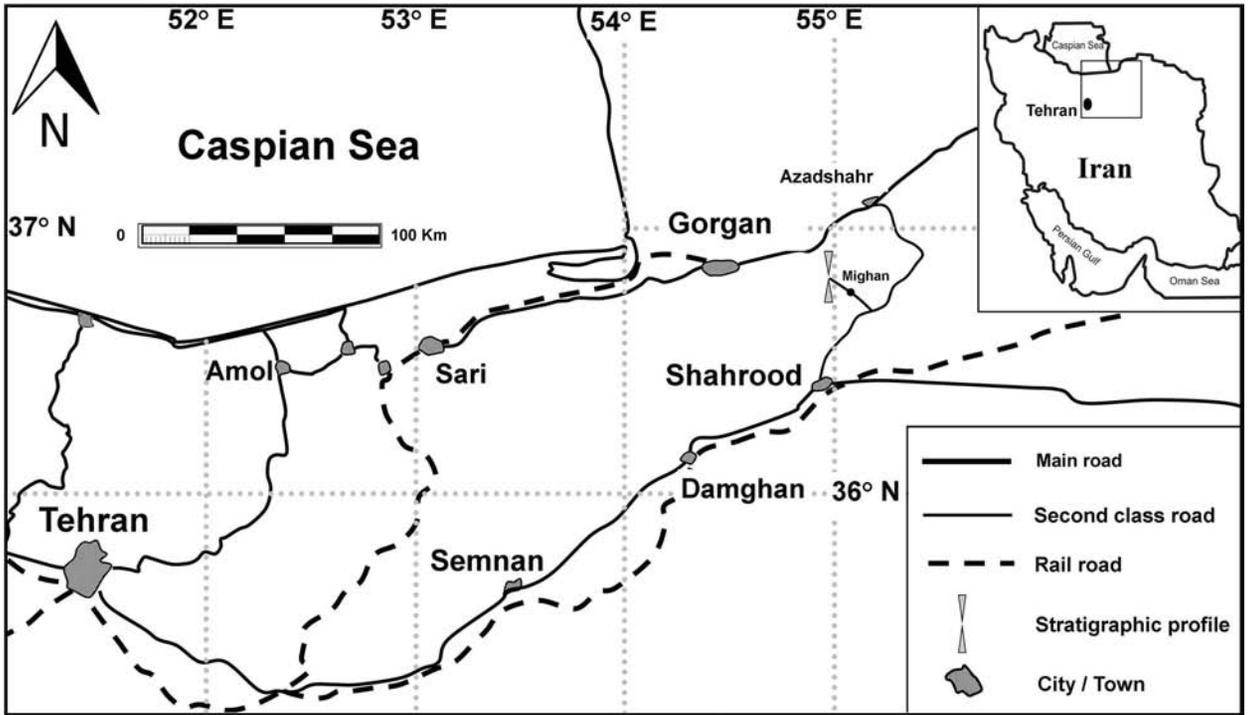


Fig. 2. Location map of the investigated section.

as the Padeha Formation in the Eastern Alborz Mountains and in Central Iran. In Middle Devonian times a considerable sea level rise caused the deposition of fully marine sediments in large parts of Iran. These rather thick and fossiliferous rocks are known as the Khoshyeilagh Formation in the Eastern Alborz Mountains. The fully marine condition prevailed to the early Late Carboniferous.

One of the most complete exposures of the Khoshyeilagh Formation is situated in the North of the village of Mighan (Fig. 3). In that section, the formation covers the Padeha Formation, composed mainly of red to gray siliciclastic deposits and intercalations of mudstones and dolostones. WENDT et al. (2005) assigned the Padeha Formation to the ?Emsian and Eifelian. The Mobarak Formation, which is not older than latest Tournaisian/Visean, overlies the Khoshyeilagh Formation. Similar to the type section, WENDT et al. (2005) divided the Khoshyeilagh Formation exposed in the Mighan section into three members; the Lower Carbonate Member (Givetian to Early Frasnian), the Siliciclastic Member (Middle Frasnian) and the Upper

Carbonate Member (Late Frasnian to Early Tournaisian). Based on WENDT et al. (2005: 45), 41 lithostratigraphic units were assigned to the Padeha Formation (units 1 to 18) and the overlying three members of the Khoshyeilagh Formation (units 19 to 41). The onset of the fully marine sedimentation (boundary between the Padeha and Khoshyeilagh formations = Eifelian/Givetian boundary) was selected in the unit 19 by WENDT et al. (2005: 45) and compared with other workers; these authors believed that their choice is less arbitrary. According to this subdivision, units 19 to 26 were attributed to the Lower Carbonate Member, corresponding to the Givetian (units 19 to 21) and the lower Frasnian (units 22 to 26). The boundary between the Givetian and Frasnian was arbitrary selected.

The coral fauna described in this paper was collected from units 19 to 26. Lithologically, the Lower Carbonate Member consists of an alternation of carbonate rocks and shales with some intercalations of marls. The section is 195 m thick at the worked locality and the occurrence of the skeletal limestones and brachiopods, overlying reddish layers of shales and

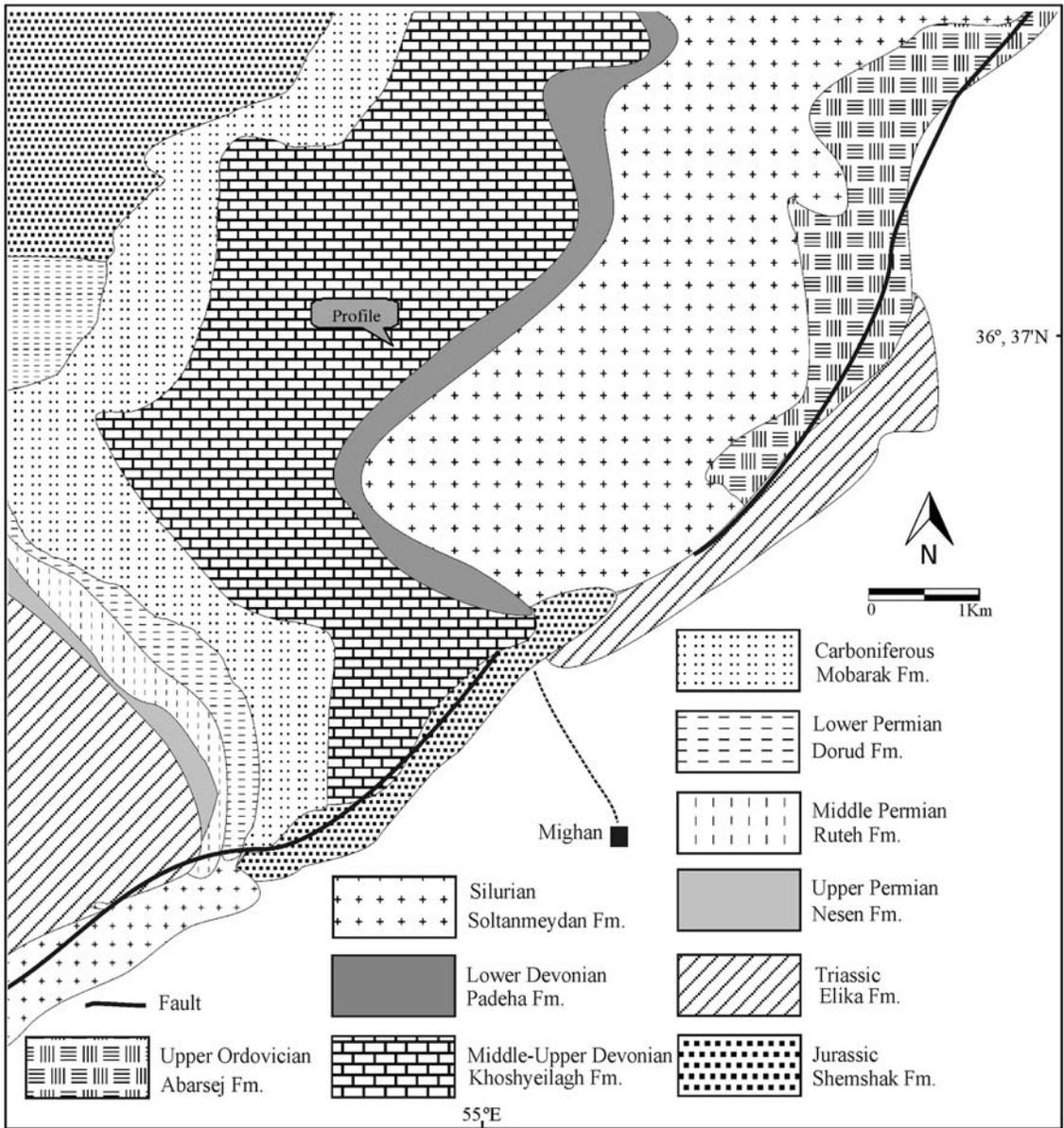


Fig. 3. Simplified geological map of distribution of the Khoshyeilagh Formation and parts of other outcrops in the studied area.

marls of the Padeha Formation is a distinct indication of the basal part of the Khoshyeilagh Formation. The studied section is represented by:

- 15 m: alternations of thin to thick-bedded of skeletal limestones with intercalations of shales and marls. The interval contains numerous brachiopods and few broken fragments of trilobites. The rugose coral fauna is rare. Specimens MC1, MC22, MC42 and MC103 belong to this interval.

- 10 m: alternations of thin to thick-bedded of carbonate rocks and some layers of marls and shales. Limestones are partly skeletal. Compared with the above mentioned interval, these alternations are rather poor in macrofossil remains. This interval and the previous one are correlated with unit 19 of WENDT et al. (2005). Specimens MB25 and MB30 were collected from these alternations.

- 40 m: mainly thick-bedded dolomites with frequent

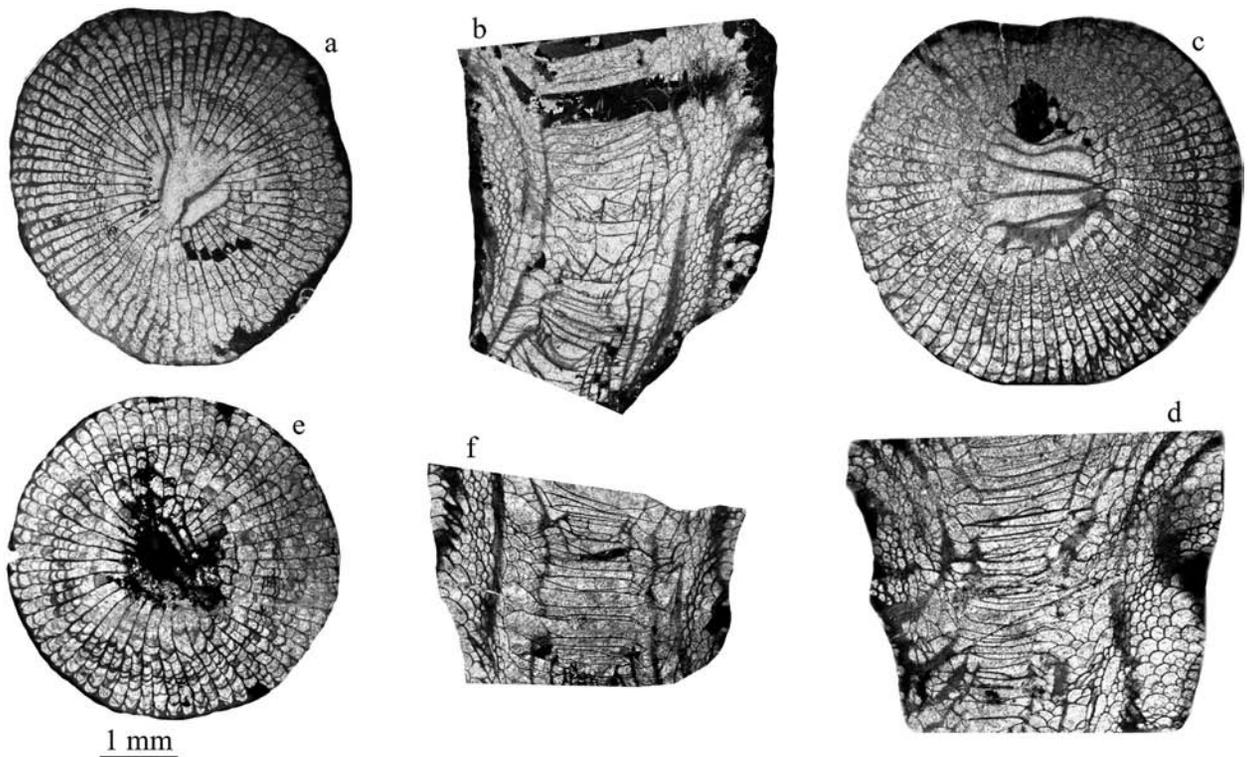


Fig. 4. a-f – *Spinophyllum arduum* (LÜTTE, 1985). MC1: a) transverse section, b) longitudinal section. MC22: c) transverse section, d) longitudinal section. MG22: e) transverse section, f) longitudinal section.

intercalations of thick-bedded limestones. There are a few layers of shales. The limestones are more or less skeletal and poor in rugose corals and brachiopods. The interval is correlated with unit 20 of WENDT et al. (2005) and contains specimen MD15.

- 50 m: corresponding to unit 21 of WENDT et al. (2005), this interval consists predominantly of limestones and some intercalations of shales. Limestones are mainly brecciate and rarely skeletal. Brachiopods are often present. Specimens MG14, MG22, MG23 and MG42 were gathered from the discussed strata. The boundary of the Lower Frasnian was determined at the top of this interval.

- 21 m: alternations of skeletal and non-skeletal limestones and shales containing brachiopods and rugose corals. Specimen MG40 belongs to this interval.

- 24 m: consisting of limestones and shale. The limestones are thin to thick-bedded and partly skeletal. Brachiopods are numerous and coral fauna is rare. There are a few fragments of trilobites. This interval

and the previous one are compared with unit 22 of WENDT et al. (2005).

- 35 m: alternations of carbonate rocks and rather thick layers of shales. Limestones are partly skeletal and rich in fossils, especially brachiopods. The interval is correlated with units 23 to 26 of WENDT et al. (2005) and contains specimens MG45, MG48, MG53 and MG80.

The material and prepared thin sections are deposited in the museum of the Geology Department, Faculty of Sciences, Ferdowsi University of Mashhad, Iran.

4. Systematic palaeontology

Subclass Rugosa MILNE-EDWARDS & HAIME, 1850

Genus *Spinophyllum* WEDEKIND, 1922

Type species: *Campophyllum spongiosum* SCHLÜTER, 1889, p. 46, Givetian, Büchel Formation, Germany; by monotypy.

Diagnosis: Solitary charactophyllid rugose corals. Septa in two orders, showing a peripheral dilation but commonly

developing renewed dilation in the inner dissepimentarium and outer tabularium. Both orders of septa carinate in the forms of yardarm and zigzag carinae. Major septa extend to the corallite axis or may be slightly withdrawn. Minor septa as long as the entire dissepimentarium. Dissepimentarium composed of some rows of globose dissepiments arranged horizontally in the outer row. Tabularium incomplete or compound. Peripheral stereozone weak or absent.

Distribution: Upper Eifelian, Givetian and Frasnian of Eurasia, Frasnian of China.

Spinophyllum arduum (LÜTTE, 1985)

Figs. 4a-f, 5a-b

*1985 *Cyathophyllum* (*Cyathophyllum*) *arduum* LÜTTE, p. 544, figs. 1-2.

1988 *Spinophyllum arduum*. – ROHART, p. 284, pl. 36, figs. 3-4.

Holotype: LÜTTE (1985, pl. 1, fig. 1, specimen no. B2.416.34); Lower Givetian, Kerpen Formation, Sötenich Syncline, Northern Eifel, Germany.

Material: Four specimens with eight thin sections, including MC1, MC22, MC42 and MG22.

Diagnosis: A species of *Spinophyllum* with 36 to 39 major septa at diameter ranging from 21 mm to 25 mm. Septa thin, rather long but withdrawn from axis, leaving an open area in the axial part. Septa faintly and irregularly carinate with zigzag carinae. Yardarm carinae rare. Broad dissepimentarium composed of several rows of small and globose dissepiments. Incomplete tabularium differentiated in flat axial tabellae and axially inclined peripheral tabellae.

Description: The material consists of some complete trochoid and conical specimens with strong to weak longitudinal ribs. Prominent growth lines are observed in all specimens. The diameter of the coralla ranges from 21 mm to 25 mm. The length of corals varies between 32 mm and 43 mm. The outer wall is not well preserved.

Transverse sections: The septa are radial in arrangement. They are straight excepting in one specimen (Fig. 5a) with slight rotation in their axial parts. There are 36 to 39 major septa per corallum. The majors leave a 3mm to 5mm open space in the center of the corallite. They are characteristically thin (Fig. 4e) but sometimes slightly dilated near the dissepimentarium and tabularium boundary (Fig. 5a). Both orders of septa bear weak to strong zigzag carinae (Figs. 4a, 5a) in the dissepimentarium, but some yardarm and spinose carinae are present (Fig. 4a) which are not so prominent. The length of first order septa is about 4/5 to 5/6 of the corallite radius. Minor septa traverse the entire dissepimentarium and are about 1/2 of the corallite radius in length.

Longitudinal sections: The relatively wide dissepimentarium consists of 8 to 15 rows of globose to subglobose dissepiments which are small to medium in size. The dis-

sepiments are larger and more or less horizontal at the periphery, but smaller and inclined in the inner dissepimentarium. The tabularium is incomplete. Axial series of tabellae are more or less flat, closely-spaced and intersected laterally while peripheral ones are large plates which are steeply inclined to the axial parts. The width of the tabularium ranges from 8mm to 14mm. Trabeculae are not clear but sometimes coarse isolate trabeculae can be traced which extend inwards and upwards (Fig. 4d). They are locally contiguous.

Remarks: LÜTTE (1985: 44) introduced *Cyathophyllum arduum* as a new species from the lower Givetian Kerpen Formation in the Northern Eifel (Germany). ROHART (1988) collected slightly larger similar forms together with *Spinophyllum blacourti* (ROHART, 1988) in the Boulonnais (France) and transferred the discussed species to *Spinophyllum*. Among the different species of *Spinophyllum*, which are characterized by rather weak to strong septal dilation and carination, *Spinophyllum arduum* is distinguished by slender septa and poorly developed carinae. Although the Iranian corals have a few more septa and a little larger size, they are very similar to those described by LÜTTE (1985) and ROHART (1988).

Distribution: Outside Iran, this species was described from the lower Givetian Kerpen Formation in the Sötenich Syncline, Northern Eifel, Germany (LÜTTE 1985) and from the Givetian Blacourt Formation in the Boulonnais, France (ROHART 1988).

Genus *Chostophyllum* PEDDER, 1982

Type species: *Chostophyllum metula* PEDDER, 1982, pl. 1, figs. 1-17; pl. 2, figs. 1-11 and 14; text-fig. 3, Givetian, Hare Indian Formation, District of Mackenzie, Northwestern Canada.

Diagnosis: From PEDDER (1982: 566): "Solitary genus of charactophyllid corals. Proximal tip of corallum filled, or almost filled by adaxially expanded septa and lamellar stereome. Cardinal septum short and cardinal fossula well developed in later ontogenetic stages. Counter septum commonly slightly shorter than adjacent major septa through most of the ontogeny, but not as well differentiated as the cardinal septum. In mature stage, major septa short, dissepimentarium narrow, inner wall well formed and tabulae broad".

Distribution: Upper Eifelian and Givetian of Canada and Germany, Givetian of Australia, Iran, and Morocco.

Chostophyllum cf. dollendorfsense SCHRÖDER, 1997

Fig. 5c-d

*1997 *Chostophyllum dollendorfsense* SCHRÖDER, p. 13, pl. 2, figs. 20-24, text-figs. 3-5.

1998 *Chostophyllum dollendorfsense*. – SCHRÖDER, p. 39, pl. 8, fig. 52.

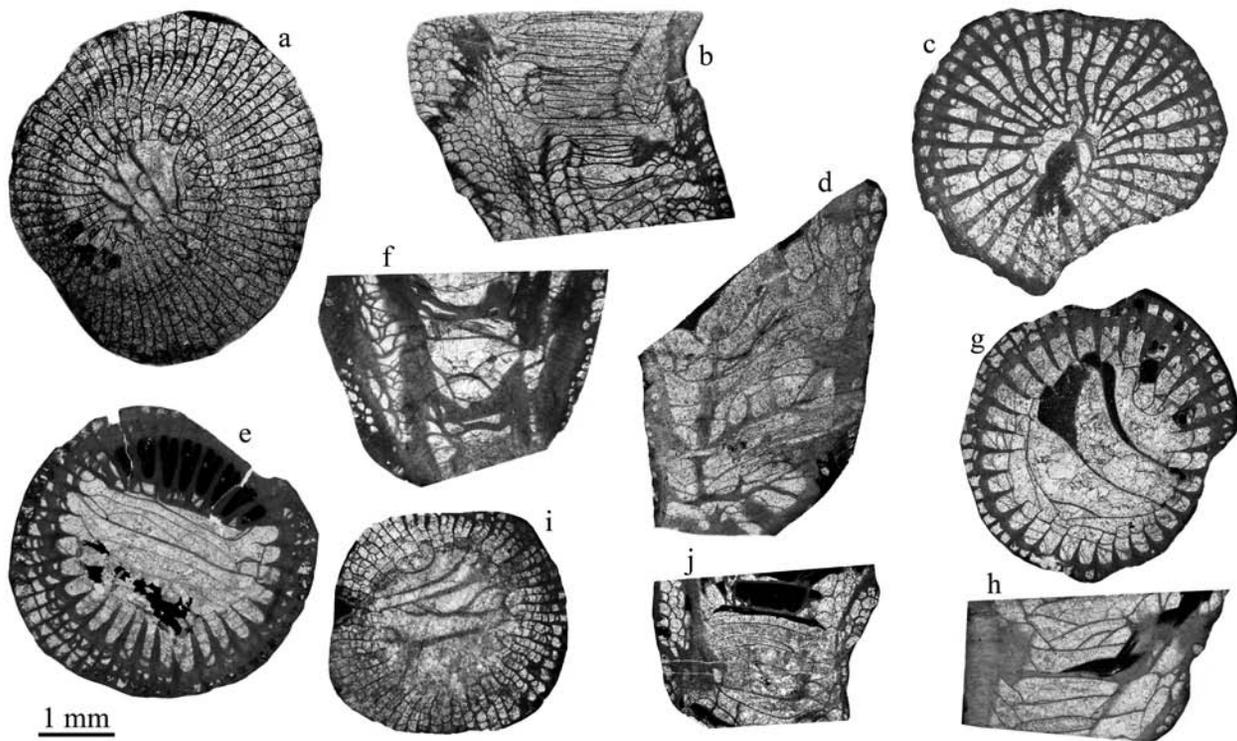


Fig. 5. a-b – *Spinophyllum arduum* (LÜTTE, 1985). MC42: a) transverse section, b) longitudinal section. c-d – *Chostophyllum* cf. *dollendorfsense* SCHRÖDER, 1997. MB25: c) transverse section, d) longitudinal section. e-h – *Chostophyllum metula* PEDDER, 1982. e-f) MG14: e) transverse section, f) longitudinal section. g-h) MC103: g) transverse section, h) longitudinal section. i-j – *Aristophyllum luetti* COEN-AUBERT, 1997. MG23: i) transverse section, j) longitudinal section.

Holotype: SCHRÖDER (1997, pl. 2, fig. 23, specimen no. B2C-38/67-11); Upper Eifelian, Freilingen Formation, Eilenberg Member, Eifel, Germany.

Material: Two corallites with four thin sections including MB25 and MB30.

Diagnosis: A small species of *Chostophyllum* with 28 to 30 major septa at diameter of 14 to 19 mm. Major septa rather long and thickened. Dissepimentarium extremely narrow composed of 2 to 3 rows of small dissepiments. Cardinal septum short and fossula distinct.

Description: Our material consists of slightly abraded coralla which are trochoid. Their diameter is 14 mm and 19 mm. Growth lines and longitudinal ribs are weakly developed. The wall is poorly preserved.

Transverse sections: The septa are differentiated in two orders. The major septa are 28 to 30 in number and slightly different in length. They are relatively long, leaving a small to more or less considerable open space in the center of corallite. The majors are a little wavy in form and their axial parts are weakly rotated. A narrow but distinct stereozone is formed by thickening of peripheral tips of septa near the

wall. The septa are uniformly and strongly thickened in the both dissepimentarium and tabularium. One of the septum (cardinal?) is very short or slightly shorter than others, located in a fossula. An inner wall can be seen at the boundary of the dissepimentarium and the tabularium. The minor septa are short, about 1/4 to 1/5 as long as the majors.

Longitudinal sections: There are 2 to 3 rows of dissepiments in the narrow dissepimentarium. The dissepiments are globose and small. They are more or less obscured by heavy stereome and arranged horizontally in the outer row. The tabularium is broad, about 9mm to 12mm in width. It is divided into two regions. In the axial region, tabulae are wide and arranged horizontally whereas some axially inclined dissepiments-like tabellae are present in the peripheral region of the tabularium.

Remarks: SCHRÖDER (1997) introduced *Chostophyllum dollendorfsense* from the upper Eifelian Freilingen Formation in the Eifel, Germany. According to SCHRÖDER (1997: 14), it differs from the Late Eifelian *Chostophyllum humense* PEDDER, 1982 by smaller corallite size and fewer septa. The specimens illustrated herein closely resemble *Chostophyllum dollendorfsense* in diameter and number of septa. Additionally, the length and the thickening of the septa in the

Iranian corals are very similar to the material from Germany. The specimens from Iran differ from *Chostophyllum dollendorfense* in having a slightly wider dissepimentarium and a trend to develop herring-bone dissepiments. Although the partially abraded Iranian corals are reported from the Givetian rocks; our samples are very close to the material described by SCHRÖDER (1997) and a determination as *Chostophyllum cf. dollendorfense* seems to be appropriate.

Distribution: *Chostophyllum dollendorfense* has been reported from upper Eifelian rocks in the Eifel District, Germany (SCHRÖDER 1997).

Chostophyllum metula PEDDER, 1982

Fig. 5e-h

*1982 *Chostophyllum metula* PEDDER, p. 566, pl. 1, figs. 1-17; pl. 2, figs 1-11, 14; text-fig. 3.

Holotype: PEDDER (1982, pl. 1, figs. 8, 11, 14-16; text-fig. 3A, specimen no. GSC 64688), Givetian, Hare Indian Formation, District of Mackenzie, Northwestern Canada.

Material: Two specimens with four thin sections including MG14 and MC103.

Diagnosis: A species of *Chostophyllum* with 30 major septa at diameter of 18 to 19 mm. Major septa very short and thickened. Narrow dissepimentarium composed of 2 to 3 rows of small and globose dissepiments. Tabularium broad. Cardinal septum short and inner wall formed.

Description: The material consists of small and trochoid forms with diameters of 18 and 19 mm and length of 40 and 42 mm, respectively. One of the corallites is partially abraded. The calice is moderately deep and growth lines and longitudinal ribs are not so prominent. The wall is thin and poorly preserved.

Transverse sections: The septa are differentiated in two orders. Major septal count is as much as 30. The major septa are short, leaving a considerable free space in the axial parts. The length of major septa ranges between 2.5 to 4.5mm, about 1/3 to 1/2 as long as the radius of corallites. Peripheral tips of septa are dilated, forming a narrow but slightly distinct stereozone against the wall. The septa are more or less thickened within the dissepimentarium and strongly dilated at the boundary between the dissepimentarium and the tabularium, forming a strong and distinct inner wall. They are also dilated and wedge shaped in the tabularium. Axial tips of some of the major septa are very thin. One of the major septa is shorter than the others (Fig. 5e) which is possibly the cardinal septum. It is located in a fossula. The minor septa are short about 1/3 to 1/2 as long as the majors, being terminated mostly within the inner wall.

Longitudinal sections: The proximal tip of one of the corallites is partially filled by stereome (Fig. 5f). The dissepimentarium is characteristically narrow, consisting of 2 or 3 rows of dissepiments. The dissepiments are partly (Fig. 5f) or entirely (Fig. 5h) obscured by thick stereome in

some places. They are small and globose in the early stages of growth, increasing in size distally (Fig. 5f). The dissepiments are arranged more or less horizontally at the periphery. The tabularium is broad. The axial tabellae are widely spaced, flat, slightly inclined and sometimes thickened. There are some scattered small to large inclined, lateral tabellae. Trabeculae are monacanthine but not very coarse. They are flat lying, making angles with the horizontal.

Remarks: So far, *Chostophyllum metula* PEDDER, 1982 has been only reported from the Hare Indian Formation of District of Mackenzie, Northwestern Canada. The material from Iran closely resembles *Chostophyllum metula*. This resemblance includes diameter of corallite, number of septa, dilation of septa, septal length, undeveloped dissepimentarium and structure of the tabularium. *Chostophyllum waskasense* (WHITHEAVES, 1892) differs from *Chostophyllum metula* by fewer and more dilated septa, larger size and fewer dissepiments. *Chostophyllum goryanovi* (PEDDER, 1973) is distinguished from *Chostophyllum metula* by more septa and a strong peripheral septal stereozone. *Chostophyllum gregorii* (ETHERIDGE, 1892) is separated from *Chostophyllum metula* by its smaller size and longer septa.

Distribution: Outside Iran, *Chostophyllum metula* has been only reported from the Givetian rocks of the Hare Indian Formation in District of Mackenzie, Northwestern Canada (PEDDER 1982).

Genus *Aristophyllum* BULVANKER, SPASSKY

& KRAVTSOV

in BESPRZVANNYKH et al. (1975)

Type species: *Aristophyllum terechovi* BULVANKER, SPASSKY & KRAVTSOV in BESPRZVANNYKH et al. (1975, p.78, pl. 25, fig. 2; pl. 26, figs. 1-2); Frasnian, Salaga Series, Kolyma Basin, Siberia.

Diagnosis: Solitary rugose corals. Septa in two orders, non-carinate or faintly carinate. Septa thin or slightly dilated in dissepimentarium but thin in tabularium. Major septa short and minors as long as dissepimentarium. Narrow dissepimentarium composed of a few rows of small globose dissepiments arranged horizontally at the periphery. Tabularium wide and incomplete. Axial tabulae often large, flat and wide.

Distribution: Givetian of Gemany, Belgium, Australia, and Iran. Frasnian of Siberia, Poland, Belgium, and France.

Aristophyllum luetti COEN-AUBERT, 1997

Fig. 5i-j, 6a-d

*1997 *Aristophyllum luetti* COEN-AUBERT, p.16, pl. 1, figs. 5-7; pl. 2, figs. 1-4.

1998 *Aristophyllum luetti*. – SCHRÖDER, p. 36, pl. 4, figs. 27-29.

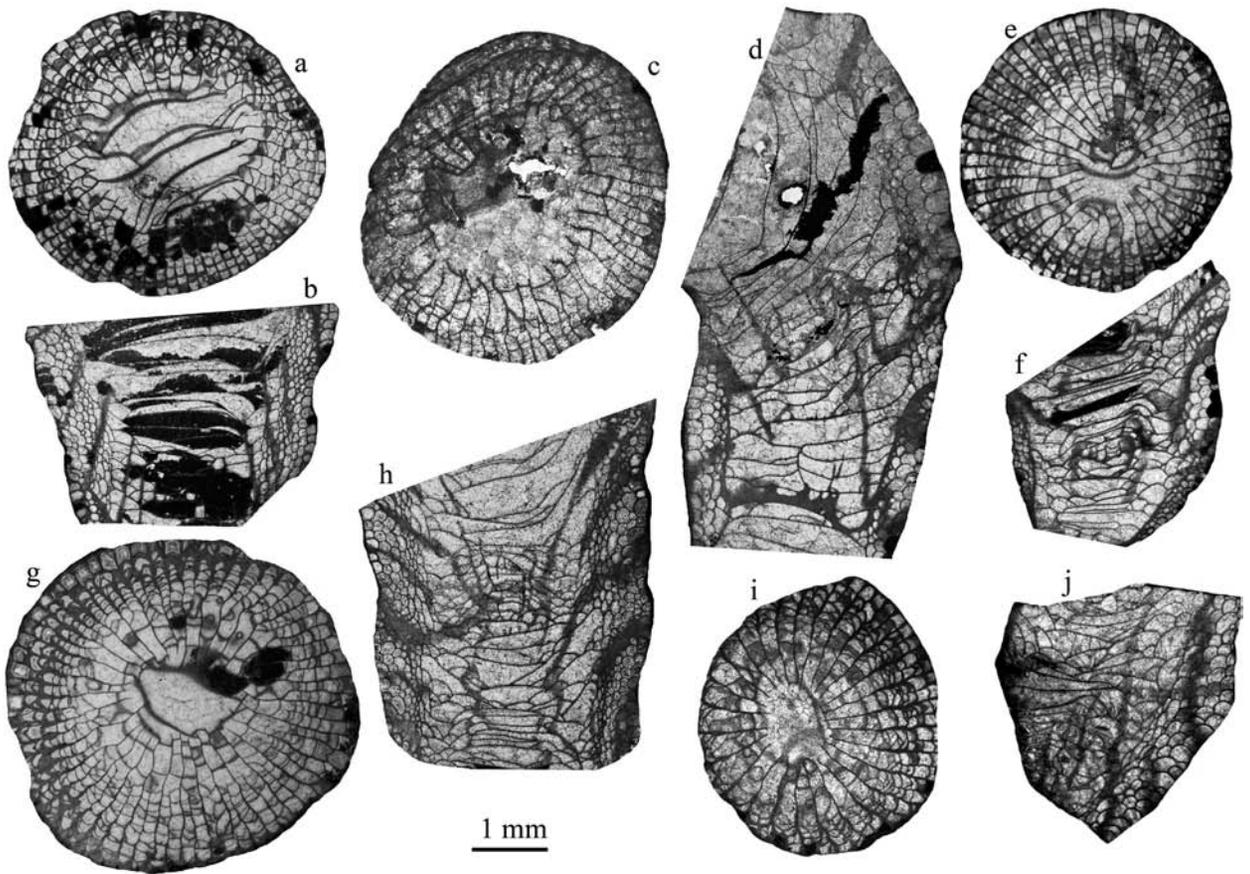


Fig. 6. a-d – *Aristophyllum luetti* COEN-AUBERT, 1997. a-b) MG42: a) transverse section, b) longitudinal section. c-d) MD15: c) transverse section, d) longitudinal section. e-f – *Sinodisphyllum kielcense* (ROZKOWSKA, 1979). MG80: e) transverse section, f) longitudinal section. g-h – *Sinodisphyllum variable* SUN, 1958. MG48: g) transverse section, h) longitudinal section. i-j – *Sinodisphyllum litvinovitshae* (SOSHKINA, 1949). MG53: i) transverse section, j) longitudinal section.

Holotype: COEN-AUBERT 1997, pl. 2, figs. 1-2; specimen no. IRScNB a10553). Givetian, Hanonet Formation, Pondrôme, Belgium.

Material: Three specimens with six thin sections including MG23, MD15 and MG42.

Diagnosis: A species of *Aristophyllum* with 32 to 36 major septa at diameter of 15 to 21 mm. Major septa thin, withdrawn from axis and leaving a considerable open area in the axial part. Dissepimentarium rather narrow composed of few rows of small dissepiments. Tabularium broad, differentiated in wide and flat axial tabellae and some inclined peripheral tabellae.

Description: The Iranian material consists of fragmentary coralla which are trochoid and ceratoid. Their diameter

varies between 15 to 21 mm and their length ranges from 30 mm to 52 mm. Growth lines and longitudinal ribs are fully observed.

Transverse sections: The septa are in two orders and radial in arrangement. There are 32 to 36 major septa per corallum. The septa are thin (Fig. 6a, c) or sometimes slightly thick in the dissepimentarium (Fig. 5i). They are withdrawn from the axis and leave a wide and considerable open area in the center of the tabularium. The length of the major septa is about 1/2 (Fig. 5i) to 2/3 (Fig. 6a, c) of the corallite radius. Both orders of septa are smooth or faintly carinate in the dissepimentarium. The minor septa are thin and predominantly as long as the dissepimentarium. Some of the minor septa become shorter and are replaced by a few rows of herringbone dissepiments (Fig. 6a) whereas others are penetrated into the tabularium. Their length varies from 1/2 to 3/4 of the majors.

Longitudinal sections: The dissepimentarium is relatively narrow and consists of 3 (Fig. 6d) to 5 or even 8 rows (Fig. 6b) of dissepiments. The dissepiments are mostly globose and small but sometimes become larger (Fig. 6d). They are horizontal in the outer row and inclined in inner rows. The tabularium is wide, about 11 to 14 mm in width. It is incomplete, consisting of axial and peripheral tabellae. The axial tabellae are wide, nearly horizontal or slightly concave. They become narrower and break into smaller plates in some places (Fig. 6d). There are some scattered large peripheral tabellae which are inclined adaxially.

Remarks: *Aristophyllum terechovi* BULVANKER, SPASSKY & KRAVTSOV, 1975 which is the type species, is distinguished from *Aristophyllum luetti* COEN-AUBERT, 1997 by more septa and a narrower dissepimentarium. By considering the discussed differences, COEN-AUBERT (1997: 17) believed that *Aristophyllum* sp. (LÜTTE 1984) and *Aristophyllum terechovi* (reported by LÜTTE 1990), both from the Givetian of the Northern Eifel, Germany, should be assigned to *Aristophyllum luetti*. ZHEN (1994: 336) erected *Aristophyllum planotabulatum* from the Givetian of North Queensland, Australia, which differs from *Aristophyllum luetti* by its septa which are more dilated within the dissepimentarium. Although some Iranian specimens possess a few more septa, this material is similar to those described by COEN-AUBERT (1997) and SCHRÖDER (1998).

Distribution: Outside Iran, this species has been reported from the Givetian Hanonet Formation in Pondrôme, Belgium (Coen-Aubert 1997) and the Givetian Cürten and Loogh formations in the Northern Eifel, Germany (Schröder 1998).

Genus *Sinodisphyllum* SUN, 1958

Type species: *Disphyllum* (*Sinodisphyllum*) *variabile* SUN, 1958 (Frasnian, Shaitienchiao Formation, Hunan, China); by original designation.

Diagnosis: Solitary charactophyllid rugose corals. Septa differentiated in two orders, rather long, slightly dilated in dissepimentarium, thin in tabularium. Septa non-carinate or faintly carinate. Minor septa traversing the entire dissepimentarium. Septal sterezone rare or commonly absent. Dissepimentarium composed of several rows of small and globose dissepiments arranged horizontally at the periphery. Tabularium rather wide, incomplete or compound.

Distribution: Upper Givetian and Frasnian of China and Russia, Frasnian of Belgium, France, and Iran.

Sinodisphyllum kielcense (ROZKOWSKA, 1979)

Fig. 6e-f

*1979 *Ceratophyllum kielcense* sp. n. – ROZKOWSKA, p. 22, pl. 3, figs. 7-10.

2002 *Sinodisphyllum kielcense*. – ROHART, p. 115, pl. 6, fig. 3; pl. 7, figs. 1-2.

2006 *Sinodisphyllum kielcense*. – BOULVAIN & COEN-AUBERT, p. 44, pl. 1, fig. 8; pl. 2, figs. 11-13; pl. 3, figs. 1-3.

Holotype: ROZKOWSKA (1979, pl. 3, fig. 10, specimen no. TcI/9); Frasnian, Holy Cross Mountains, Poland.

Material: One specimen with two thin sections. MG80.

Diagnosis: A species of *Sinodisphyllum* with 32 major septa at diameter of 17 mm. Major septa withdrawn from axis, slightly thickened and rarely carinate in dissepimentarium. Minor septa traversing the entire dissepimentarium. Dissepimentarium composed of a few rows of globose dissepiments arranged horizontally in the outer row. More or less wide tabularium formed of flat axial tabellae and inclined lateral tabellae.

Description: The only available specimen is a conical to trochoid form with a diameter of 17 mm and a length of 36 mm. The specimen shows longitudinal ribs and growth lines. The outer wall is very thin and the calice is not preserved.

Transverse section: The septa are radial in arrangement and differentiated in two orders. The number of major septa is 32. They leave a 4 mm open area in the center of the tabularium. The major septa are slightly thickened in the dissepimentarium and thin in the tabularium. Both orders of septa are smooth or bear small and weak knobby carinae. The minor septa are thin and about 1/2 to 1/3 as long as of the majors. They traverse the entire of dissepimentarium, but some of them are slightly withdrawn and replaced by few rows of dissepiments. The inner edges of two septa are fused together, forming a pseudofossula.

Longitudinal section: The relatively narrow dissepimentarium consists of 5 to 7 rows of small and globose dissepiments. They are more or less horizontally arranged in the outer row and slightly inclined in the inner rows. The tabularium is rather wide. It is incomplete and differentiated in two parts. In the axial part, tabellae are flat and closely spaced with downturned edges. The axial tabellae are supplemented by axially inclined to nearly horizontal tabellae in the peripheral part.

Remarks: The single Iranian specimen is closely similar in corallite size, septal number, characteristics of the septa and structure of the tabularium to *Sinodisphyllum kielcense* described from the lower part of the Bieumont Member of the Grands Breux Formation, on the Southern side of the Dinant Synclinorium, Belgium, by BOULVAIN & COEN-AUBERT (2006: pl. 1, fig. 8; pl. 2, figs. 11-13; pl. 3, figs. 1-3).

Distribution: *Sinodisphyllum kielcense* has been reported from the Frasnian strata of the Grands Breux Formation on the Southern side of the Dinant Synclinorium in Belgium (BOULVAIN & COEN-AUBERT 2006), from the Frasnian Beau-lieu Formation in the Boulonnais, France (ROHART 2002), and from the Frasnian of the Holy Cross Mountains (ROZKOWSKA 1979).

Sinodisphyllum variable SUN, 1958

Fig. 6g-h

- *1958 *Sinodisphyllum variable* SUN, p. 12, pl. 4, figs. 1-2; pl. 5, fig. 1; pl. 6, fig. 1.
 1977 *Sinodisphyllum variable*. – LIAO, text-fig. 1.
 1996 *Sinodisphyllum variable*. – LIAO, p. 66, pl. 8.1, figs. 1-2.
 2002 *Sinodisphyllum variable*. – MA et al., p. 382, fig. 8E-G, I.
 ? 2008 *Sinodisphyllum variable*. – ASHOURI et al., p. 76, pl. 1, fig. 4.

Lectotype: As selected by IVANOVSKI (1976: 157) and figured by HILL (1981, fig. 198.2). It was also illustrated by LIAO 1996 (pl. 8.1, fig. 2, Catalogue no. s. 1289); Frasnian, Shaitienchiao Formation, Hunan, China.

Material: Only one specimen with two thin sections. MG48.

Diagnosis: A species of *Sinodisphyllum* with 32 major septa at diameter of 22 mm. Septa thin and smooth, leaving an open space in the axial part. Minor septa traversing the entire dissepimentarium and locally reduced. Dissepimentarium composed of some rows of small and globose dissepiments. Tabularium rather broad and incomplete.

Description: The specimen is cylindrical in form with diameter and length of 22 and 45 mm, respectively. The calice is not preserved and growth lines and longitudinal ribs are strongly developed.

Transverse section: The septa are in two orders and major septa number is 32. The major septa are slightly withdrawn from the axis of the corallite, forming a free space in the center of tabularium. They are commonly thin, rather wavy and smooth but some of them are slightly dilated in the inner parts of the dissepimentarium. Peripheral ends of septa are thickened and a narrow stereozone is formed near the wall. The minor septa are mostly as long as the dissepimentarium. A few of the minor septa penetrate into the tabularium and some of them are slightly shortened. They are about 1/2 of majors in length.

Longitudinal section: The dissepimentarium consists of 5 to 8 rows of dissepiments. They are characteristically horizontal in the outer row but inclined, elongate or nearly vertical in the inner rows. The size of dissepiments decreases axially. The tabularium is rather broad and differentiated into axial and periaxial regions. In the axial region, the tabulae are relatively wide, flat, concave or convex, breaking sometimes into some arched tabellae. The periaxial part of tabularium consists of relatively large and axially steeply inclined tabellae.

Remarks: The investigated specimen is very similar to *Sinodisphyllum variable* SUN, 1958 in dimension of corallite, septal number, smooth and thin septa. These resemblances are strongly supported by the longitudinal thin section of the coral from Iran, which is closely similar to longitudinal sections of the species figured by SUN (1958) and LIAO (1977:

text-fig.1). Although the reduction of the minor septa is seen in some paratypes, this feature is local. This local shortening of the minor septa is more or less visible in the specimen from Iran. *Sinodisphyllum simplex* SUN, 1958 from the Frasnian of Hunan, China, is distinguished from the specimen from Iran by showing more septa, smaller size and rather short minor septa, replaced by herringbone dissepiments. Our specimen differs from *Sinodisphyllum posterum* (IVANOVSKI, 1965) by thinner septa in the dissepimentarium, fewer septa and rare carinae.

Distribution: Outside Iran, *Sinodisphyllum variable* has been reported from the Frasnian rocks of Hunan, China, by SUN (1958) and MA et al. (2002). Moreover, it has been described from the Frasnian of the Khoshyeilagh Formation NW of the city of Esfaraein (Khorasan Province) by ASHOURI et al. (2008).

Sinodisphyllum litvinovitshae (SOSHKINA, 1949)

Fig. 6i-j

- *1949 *Campophyllum litvinovitshae* SOSHKINA, p. 86-88, pls. 38-39; pl. 40, figs. 1-3.
 1977 *Sinodisphyllum litvinovitshae* LIAO, p. 43, pl. 1, figs. 6-8; pl. 3, fig. 3.
 1989 *Sinodisphyllum litvinovitshae*. – LIAO & BIRENHEIDE, p. 88, pl. 1, figs. 1-6.
 2002 *Sinodisphyllum litvinovitshae*. – MA et al., p. 382, fig. 8J, K.
 2003 *Sinodisphyllum litvinovitshae*. – LIAO, pl. 3, figs. 19-21.
 non 2008 *Sinodisphyllum litvinovitshae*. – ASHOURI et al., pl. 1, fig. 5.

Holotype: See SOSHKINA (1949).

Material: One specimen with two thin sections. MG53.

Diagnosis: A species of *Sinodisphyllum* with 27 major septa at diameter of 18 mm. Major septa smooth, rather withdrawn from axis with wedge-shaped thickening in dissepimentarium. Minor septa short and locally replaced by a few rows of herringbone dissepiments. Dissepimentarium rather narrow composed of some rows of globose dissepiments. Tabularium rather broad and incomplete.

Description: The specimen is abraded and trochoid, with a diameter of 18 mm and a length of 37 mm. Growth lines and longitudinal ribs are present and the wall is thin. The calice is not preserved.

Transverse section: The major septa are 27 in number. The septa are radial or weakly pinnate in arrangement and in two orders. The major septa are slightly curved and smooth but not very long, leaving a 4 mm open space in the center of the tabularium. The septa show a little wedge-shaped thickening in the dissepimentarium. They are slightly dilated at the boundary of the dissepimentarium and the tabularium but they are thin in the tabularium. The minor septa are short and weakly different in length. Some

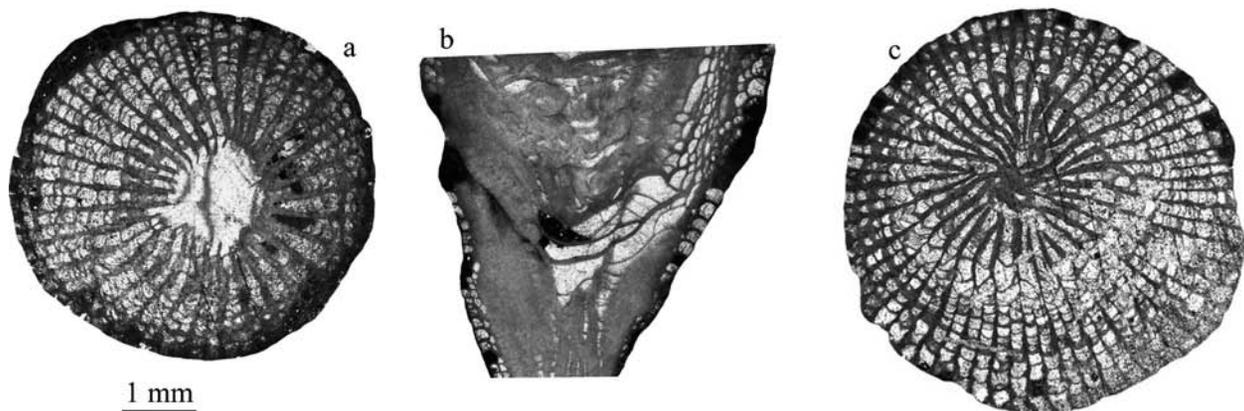


Fig. 7. a-c – *Charactophyllum nanum* (HALL & WHITFIELD, 1873). MG40: a) transverse section, b) longitudinal section. c) MG45: transverse section

of the minor septa are replaced by a few rows of angulated dissepiments.

Longitudinal section: The dissepimentarium is rather narrow, consisting of 4 to 7 rows of globose dissepiments. The dissepiments are moderately small, nearly horizontal at the periphery and inclined near the tabularium. The tabularium is 9mm in adult stage. It is incomplete, consisting of two series. The axial tabellae are concave to convex and the lateral tabellae are large and steeply inclined to the axis.

Remarks: SOSHKINA (1949: 86-88) reported *Campophyllum litvinovitshae* as a new species with large variation from the Ural, Russia. Later, LIAO (1977: 43) found this species in the Dushan District, China, and assigned it to the genus *Sinodisphyllum*. The material figured by LIAO (1977: pl. 1, figs. 6-8; pl.3, fig. 3) and LIAO & BIRENHEIDE (1989: pl. 1, figs. 1-6) shows a wedge-shaped septal dilation in the dissepimentarium, reduced minor septa, and a wide tabularium. These characters are fully observed in the coral from Iran discussed herein as *Sinodisphyllum litvinovitshae*. Reduced minor septa and the presence of herringbone dissepiments are also seen in *Sinodisphyllum simplex* SUN, 1958, but this species differs from *Sinodisphyllum litvinovitshae* by less thickened septa in the dissepimentarium, the scolecoid form and more septa.

Distribution: The species has been reported from the Givetian to Frasnian of Russia (SOSHKINA 1949) and China (LIAO & BIRENHEIDE 1989; LIAO 1977; MA et al. 2002; LIAO 2003).

Genus *Charactophyllum* SIMPSON, 1900

Type species: *Campophyllum nanum* HALL & WHITFIELD, 1873, p. 232 (Frasnian, Lime Creek Formation, Rockford, Iowa, USA).

Diagnosis: Solitary rugose corals with charactophyllid septal structure. Septa in two orders, variable in length and

dilation. Both order of septa moderately to strongly dilated in tabularium. Dissepimentarium with some rows of globose dissepiments arranged horizontally in the outer row. Tabularium composed of flat tabellae in the axial portion and numerous steeply inclined peripheral tabellae. Septa denticulate along their margin.

Distribution: Frasnian of the USA, Spain, and Iran.

Charactophyllum nanum (HALL & WHITFIELD, 1873) Fig. 7a-c

- 1873 *Campophyllum nanum* HALL & WHITFIELD, p. 232.
1900 *Charactophyllum nanum*. – SIMPSON, p. 209, fig. 28.
1945 *Charactophyllum nanum*. – SMITH, p. 17, pl. 1, figs. 6, 7, 8a, b; pl. 31, fig. 1a-i.
non 1982 *Charactophyllum nanum*. – GHODS, p. 68, pl. 5, figs. 1-3.
1998 *Charactophyllum nanum*. – SORAUF, p. 54, pl. 2, figs. 1-4; pl. 24, figs. 1-15; pl. 25, figs. 1-12; pl. 26, figs. 1-2.
non 2008 *Charactophyllum nanum*. – ASHOURI et al., p. 76, pl. 2, fig. 1.

Holotype: HALL & WHITFIELD 1873, p. 232, as *Campophyllum nanum*. SIMPSON (1900: 209-210, text-fig. 28) as *Charactophyllum nanum*.

Material: Two specimens with three thin sections including MG40 and MG45.

Diagnosis: A species of *Charactophyllum* with 31 to 33 major septa at a diameter of 19 to 21 mm. Septa extending to the axis or withdrawn, slightly carinate and dilated in

dissepimentarium, strongly dilated in tabularium. Dissepimentarium with some rows of small and globose dissepiments arranged horizontally at the periphery. Incomplete tabularium composed of flat axial and some inclined periaxial tabellae.

Description: The material consists of trochoid and subcylindrical coralla. Their length varies between 27 and 40 mm and their diameter ranges from 19 to 21mm. The longitudinal ribs are occasionally present but growth lines are very prominent and well developed. The calice is relatively shallow in one corallite (MG40) and not preserved in the other specimen.

Transverse sections: The septa are differentiated in two orders and radial in arrangement. Number of major septa is 31 to 33. The major septa are long, reaching the center of tabularium (Fig. 7c) or leaving a very small open area in the axial part (Fig. 7a). They are slightly swirled in the center of the tabularium. Septal dilation varies in the dissepimentarium. The septa are strongly dilated and swollen in the tabularium. Both orders of septa bear knobby carinae which are more or less strong or weak. The minor septa are about 1/3 to 1/2 as long as the majors and traverse the entire of the dissepimentarium. Some of the minor septa are locally replaced by a few rows of dissepiments (Fig. 7a). The fossula is indistinct.

Longitudinal section: The dissepimentarium mainly consists of 6 to 8 rows of dissepiments. They are small in size, mostly globose and subglobose in shape. The dissepiments are often arranged horizontally in the outer row whereas they are more or less inclined or nearly vertical in the inner rows and locally masked by heavy stereome. The tabularium structure is obscured by heavy stereome but it seems that the tabulae are incomplete, consisting of axial tabellae supplemented by periaxial ones.

Remarks: Based on McLEAN (1993), *Charactophyllum* is a genus of rugose corals with strongly dilated septa in the tabularium. This characteristic feature is seen among most specimens of *Charactophyllum nanum* collected and illustrated from the Frasnian of Iowa by SORAUF (1998). *Charactophyllum burdekinense* ZHEN & JELL, 1996 described from the Givetian of Queensland, Australia, shows septal dilation in the tabularium, but the species from Australia is distinguished from the Iranian one by smaller diameter and less septal number. The material from Iran closely resembles *Charactophyllum nanum* (HALL & WHITFIELD, 1873) reported from Iowa (SORAUF 1998) in septal count, dimension and especially axially thickened septa. The species has also been reported from the other outcrops of the Khoshyeilagh Formation in the Eastern Alborz Mountains. GHODS (1982: pl. 5, figs. 1-3) illustrated this species from the type section, however, his specimens do not show a septal dilation in the tabularium and it seems that they must be included in the genus *Spinophyllum*.

Distribution: Outside Iran, this species has been reported from the Frasnian of the Lime Creek and Shell Rock formations in Iowa, USA (SORAUF 1998).

5. Conclusions

Composition of the Devonian coral fauna of the Alborz Mountains and other localities in Iran is insufficiently known. Hence, the study of the faunistic similarities within these areas can be very hard. Our knowledge about the Devonian rugose corals of the Alborz Mountains, the Eastern and Central Iran is confined to a few works (e.g., GHODS 1982; ROHART 1999, 2000; KHAKSAR et al. 2006; ASHOURI et al. 2008).

On the generic level, cosmopolitan genera including *Sinodisphyllum*, *Temnophyllum*, *Spinophyllum*, *Disphyllum*, *Hexagonaria*, and *Macgeea* were described from the Eastern Alborz Mountains. These taxa were also reported from Central and Eastern Iran. Occurrences of *Temnophyllum*, *Disphyllum* and *Hexagonaria* in the Frasnian of Central Iran (Esfahan Province) were documented by ROHART (2000). *Disphyllum*, *Hexagonaria* and *Temnophyllum* were reported from the Frasnian of the Kerman Province (Eastern Iran) by ROHART (1999). *Sinodisphyllum* and *Macgeea* are present in the Frasnian of the Tabas area (Yazd Province in Eastern Iran) and in the Esfahan Province of Central Iran (ROHART 1999). KHAKSAR et al. (2006) reported *Sinodisphyllum*, *Temnophyllum*, *Spinophyllum*, *Disphyllum* and *Hexagonaria* from the Tabas area of Eastern Iran. On the specific level, faunistic similarities are not very clear between the Eastern Alborz Mountains and the other localities in Central and Eastern Iran, at least due to limited material. *Hexagonaria hexagona* and *Disphyllum caespitosum* were described from the Frasnian of the Khoshyeilagh Formation by GHODS (1982) and from the Frasnian of the Bahram Formation in the Kerman Province of Eastern Iran (DASTANPOUR 1996).

Our limited Givetian corals are specifically similar to some Givetian material described from Germany, and thus a faunistic similarity is possible. *Spinophyllum arduum*, *Aristophyllum luetti* and *Chostophyllum dollendorffense* occur in the Eifel Mountains. The Frasnian strata of the Khoshyeilagh Formation include some taxa which have also been reported from South China and Russia, notably *Sinodisphyllum variable* and *Sinodisphyllum litvinovitshae*.

Compared with Central Asia, it seems that the coral faunas from the Eastern Alborz Mountains are different. SCHRÖDER (2004) described Givetian and Frasnian rugose corals of the Karakorum Mountains in North Pakistan and wrote that the faunistic link between the material from Pakistan and the Iran is not clear. Cosmopolitan genera such as *Spinophyllum*, *Disphyllum* and

Hexagonaria have been recorded both from the Eastern Alborz Mountains and the Karakorum Mountains, but based on that material and the identified species, a study of the similarity is not possible. Rugose coral faunas from Tajikistan are poorly known. SCHRÖDER & LELESHUS (2002) compared their new species *Hexagonaria reedi* from the Pamir Mountains with *Hexagonaria cf. magna* (FENTON & FENTON, 1924), originally reported from the Chah-Rishe area of Central Iran (ROHART 2000), and argued for a possible affinity between the species from Iran and Tajikistan. In general, due to the limited material from both areas, the study of faunistic similarities between coral faunas of the Eastern Alborz Mountains and the Pamir Mountains is still impossible.

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