Geopersia ***4*** *(2), 2014, PP. 237-257*

Description of some rugose corals from the Givetian and Lower Frasnian of the Eastern Alborz Mountains, NE Iran

Mohammad Ali Abbasi[1*], Kaveh Khaksar[2], Alireza Ashouri[1]
[1] *Department of Geology, Faculty of Science, Ferdowsi University of Mashhad, Iran*
[2] *Institute of Scientific Applied Higher Education of Jihad-e-Agriculture, Manager of Soil and Water Department, Education and Extension Organization. Karaj, Iran*
**Corresponding author, e-mail: Abbassi709@gmail.com*
(*received: 25/09/2014 ; accepted: 08/12/2014*)

Abstract
Thirteen species of rugose corals, belonging to nine genera are described from the Givetian and Lower Frasnian rocks of the Khoshyeilagh Formation in the Eastern Alborz Mountains (northeastern Iran). *Glossophyllum ceratites* (Goldfuss), *Glossophyllum* sp., *Keriophyllum* cf. *maillieuxi* (Tsien), *Pseudozaphrentis* sp., *Temnophyllum imperfectum* Coen-Aubert, *Temnophyllum occidentale* Hill and Jell, *Temnophyllum* sp., *Aristophyllum luetti* Coen-Aubert and *Spinophyllum blacourti* (Rohart) come from the Givetian rocks and *Neotemnophyllum* sp., *Sinodisphyllum* cf. *posterum* (Ivania), *Sinodisphyllum kielcense* (Rozkowska) and *Charactophyllum*? *nanum* (Hall & Whitfield) belong to the Lower Frasnian strata. In spite of more or less remarkable endemism, the Givetian coral faunas of northeastern Iran show similarities with rugose corals of Germany, Belgium and Poland while the Lower Frasnian faunas reveal affinities with Eastern Asia as well as Europe corals.

Keywords: *Alborz Mountains, Devonian, Khoshyeilagh Formation, Rugose, Iran.*

Introduction

Thick carbonate successions of the Middle to Upper Devonian in the Eastern Alborz Mountains are characterized by rich rugose coral faunas. These strata which are named the Khoshyeilagh Formation have been widely distributed in northeastern parts of Iran. The formation is a heterogeneous sequence of carbonate rocks, marl, shale and siliciclastic deposits with abundant and diverse fossil groups including corals, brachiopods, trilobites, pelecypods, conodonts and ostracods.

Devonian rugose corals of the Alborz Mountains have been poorly documented. After the work of Ghods (1982) who studied the Givetian and Frasnian coral faunas of four exposures in the Western, Central and Eastern Alborz Mountains, the papers of Ashouri *et al*. (2008), Abbasi *et al*. (2014a) and Abbasi *et al*. (2014b) represented some Givetian and Frasnian rugose corals of the Khoshyeilagh Formation in the Eastern Alborz Mountains. This article is also devoted to study of the Givetian and Lower Frasnian rugose coral faunas, collected from the Khoshyeilagh Formation in the vicinity of Till Abad village, approximately 76 km northeast of city of Shahrood in northeastern Iran.

Due to rarity of reliable biostratigraphic framework about the Till Abad Section, our sampling and biostratigraphy were based on correlation with lithological divisions and boundaries, applied by Wendt *et al*. (2005, Fig. 10) for the type section of the formation, about 10 km southwest of the present worked section.

The material described and illustrated in this study are stored at the museum of Geology Department of Science Faculty, Ferdowsi University of Mashhad, Iran.

Geological and stratigraphic setting

The Alborz Mountains are extended about 2,000 km from the Lesser Caucasus of Armenia and Azerbaijan Republic in the northwest to the Paropamisus Mountains of North Afghanistan to the east in north of Iran (Alavi, 1996). Geologically and geographically, the Alborz Mountains are divided into some blocks. The Eastern Alborz Mountains as a geographic term implies to the eastern prolongation of the Alborz Range in northeastern of Iran.

It is believed that Iran was located at the northern banks of the Gondwana during the Paleozoic (Golonka *et al*., 1994) excepting a small area in the northeast of the country, situated at the southern margin of the Laurasia (Wendt *et al*., 2005). During this time, a shelf sea covered the Gondwanian part of Iran (Wendt *et al*., 2005). Characteristically, the Lower Devonian deposits are not traced in vast parts of west and northwest of

Iran due to the Caledonian event. Paleontological and lithological evidences show that a drop of sea level at Silurian-Devonian boundary caused establishment of a siliciclastic shelf in the Early Devonian of Iran (Wendt *et al*., 2005). In the Middle Devonian, rise of sea level led to deposition of fully marine strata, persisted into Frasnian and early Late Carboniferous (Wendt *et al*., 2005). These marine rocks with thickness about 1,200 m which consist of limestone, dolomite, marl, shales and siliciclastic deposits are labeled the Khoshyeilagh Formation (Bozorgnia, 1973) in the Eastern Alborz Mountains.

Stratigraphy and paleontology of the formation in different localities have been studied and reviewed by many workers. Basal beds of the Khoshyeilagh Formation have been dated as Eifelian (Bozorgnia, 1973) or Early Emsian to Eifelian (Hamdi and Janvier, 1981; Ashouri, 2001). The age attributed to the basal parts was also discussed by Weddige (1984), Brice *et al*. (1974; 1978), Stampfli (1978), Ashouri (1990) and Wendt *et al*. (2005), arguing that the first cycle of the completely marine sediments could be assigned to earliest Givetian. The formation is extended in age into Famennian (Bozorgnia, 1973), latest Famennian to Late Tournaisian (Ashouri, 1990; 1994) and Early Tournaisian (Wendt *et al*., 2005). Based on the studies of Wendt *et al*. (2005) the Khoshyeilagh Formation is divided into three members, including the Lower Carbonate Member (Givetian and Early Frasnian), Siliciclastic Member (Middle Frasnian) and Upper Carbonate Member (Late Frasnian to Early Tournaisian) at its type section.

One of the outcrops of the Khoshyeilagh Formation is exposed in the west of village of Till Abad. Here, the formation covers the Emsian-Eifelian Padeha Formation and is overlain by the Late Tounaisian/ Visean Mobarak Formation. Despite shortage in biostratigraphic information it is possible to establish an exact lithostratigraphic correlation between the present locality (Till Abad Section) and the type section, exposed 10 km southwest of the village of Till Abad. Compared to the type section, the three members of the Khoshyeilagh Formation, introduced by Wendt *et al*. (2005) have similar lithological compositions in the present worked section. The coral faunas illustrated herein come from the Lower Carbonate Member. Wendt *et al*. (2005, Fig. 10) divided the Lower Carbonate Member into 12 lithological units (units 16-27) at the type section. According to this division, units 16 to 18 are considered Givetian in age and the remaining units (units 19-27) imply to the Lower Frasnian age. The Eifelian-Givetian boundary (boundary between the Padeha and the Khoshyeilagh Formations) at the basal part of unit 16 is marked by appearance of skeletal limestones, crowded by brachiopods, tentaculitids, bryozoans, rugose corals, and trilobites. These lithological units can be followed in the Till Abad Section with high degrees of confidence.

Locality, description of outcrop and fossil distribution

The investigated section is exposed in north of the Shahrood-Azadshahr road, 4 km west of village of Till Abad, approximately 76 km northeast of city of Shahrood in northeastern of Iran (Fig. 1).

Like the type section, appearances of the skeletal limestones with numerous skeletal remains, underlain by barren, non-skeletal carbonate and siliciclastic rocks of the Padeha Formation imply to basal beds (unit 16) of the Khoshyeilagh Formation in the Till Abad Section. The studied section is 510 m thick (Fig. 2) and consists of:

35 m: alternations of thin to thick-bedded limestone and intercalations of marl. The limestones are predominantly skeletal and bioclastic, including rich fauna of brachiopods, rugose corals, tentaculitids and fragments of trilobites. This interval is correlated with the lower beds of unit 16 from divisions of Wendt *et al*. (2005). *Glossophyllum ceratites*, *Glossophyllum* sp., *Temnophyllum* sp. and *Pseudozaphrentis* sp. were collected from this interval.

30 m: corresponding to the upper beds of unit 16 from divisions of Wendt *et al*. (2005), this interval consists mainly of fine and well-bedded limestone with numerous layers of marl. The limestones are rarely skeletal and sometimes argillaceous and contain brachiopods and rugose corals. *Temnophyllum occidentale* and *Spinophyllum blacourti* are present here.

40 m: thick-bedded dolomite and dolomitic limestone with some intercalations of limestone and marl. Coral faunas and the other skeletal remains are rare here. These layers are correlated with unit 17 from divisions of Wendt *et al*. (2005). *Temnophyllum imperfectum* was collected from this interval.

85 m: corresponding to unit 18 from divisions of Wendt *et al*. (2005) and containing *Aristophyllum luetti* and *Keriophyllum* cf. *maillieuxi*, this interval consists mainly of brecciated limestone and some intercalations of marl and shale with very rare faunas. The boundary between Givetian and Frasnian was arbitrarily selected at the top of this interval by Wendt *et al*. (2005).

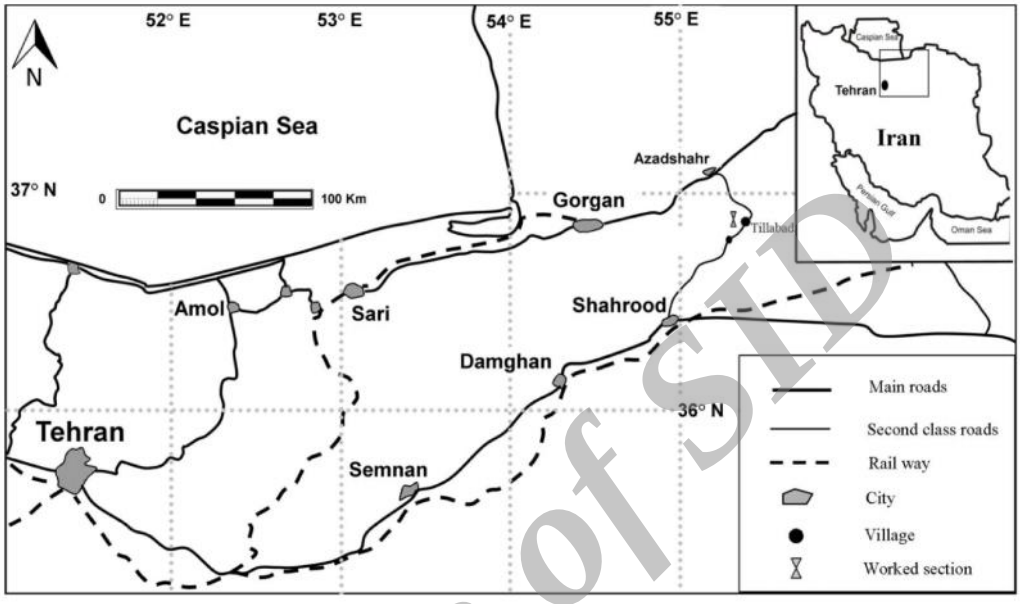

Figure 1. Locality map of the studied section and area

60 m: thick-bedded limestone in the basal parts and alternations of medium to thick-bedded limestone and abundant intercalations of marl in the upper parts. Here, the limestones are sometimes skeletal and fossil remains are rare. These layers are correlated with units 19 to 21 from divisions of Wendt *et al*. (2005). *Sinodisphyllum kielcense* and *Charactophyllum*? *nanum* come from this interval.

210 m: alternations of limestone and marl with intercalations of shale. The limestones are locally skeletal and argillaceous. More or less rich and diverse faunas of brachiopods, rugose corals and tentaculitids are present. The interval is corresponded to units 22 to 26 from divisions of Wendt *et al*. (2005). *Sinodisphyllum* cf. *posterum* was collected from these layers.

50 m: corresponding to unit 27 from divisions of Wendt *et al*. (2005), this interval consists of medium to thick-bedded skeletal and non-skeletal limestones with some layers of marl, containing brachiopods and rugose corals. *Neotemnophyllum* sp. is present here.

Systematic paleontology

Order Rugosa Milne-Edwards and Haime, 1851

Family Cyathophyllidae Dana, 1846

Glossophyllum Wedekind, 1924

Type species. By subsequent designation of Lang *et al*., 1940, p. 63, *Glossophyllum dohmi* Wedekind, 1924.

Diagnosis. Solitary tetracorals. Septa in two orders. Septa thin, generally smooth but sometimes weakly carinate. Major septa commonly long, reaching to the axis or slightly withdrawn. Cardinal septum short. Fossula developed in the late stages of growth. Tabularium broad and incomplete.

Glossophyllum ceratites (Goldfuss, 1826) (Figs. 3A–D)

1826 *Cyathophyllum ceratites* Goldfuss, p. 57, pl. 17, Fig. 2.

1981 *Glossophyllum ceratites* Hill, Treatise on Invertebrate paleontology. F, text-Fig. 195/2b- d.

1998 *Glossophyllum* cf. *ceratites* Schröder, p. 32, pl. 3, Fig. 12.

1999 *Glossophyllum ceratites* Schröder and Kazmierczak, p. 99, pl. 2, Fig. 6.

non 2006 *Glossophyllum ceratites* Khaksar *et al*., p. 58, pl. 1, Fig. 3.

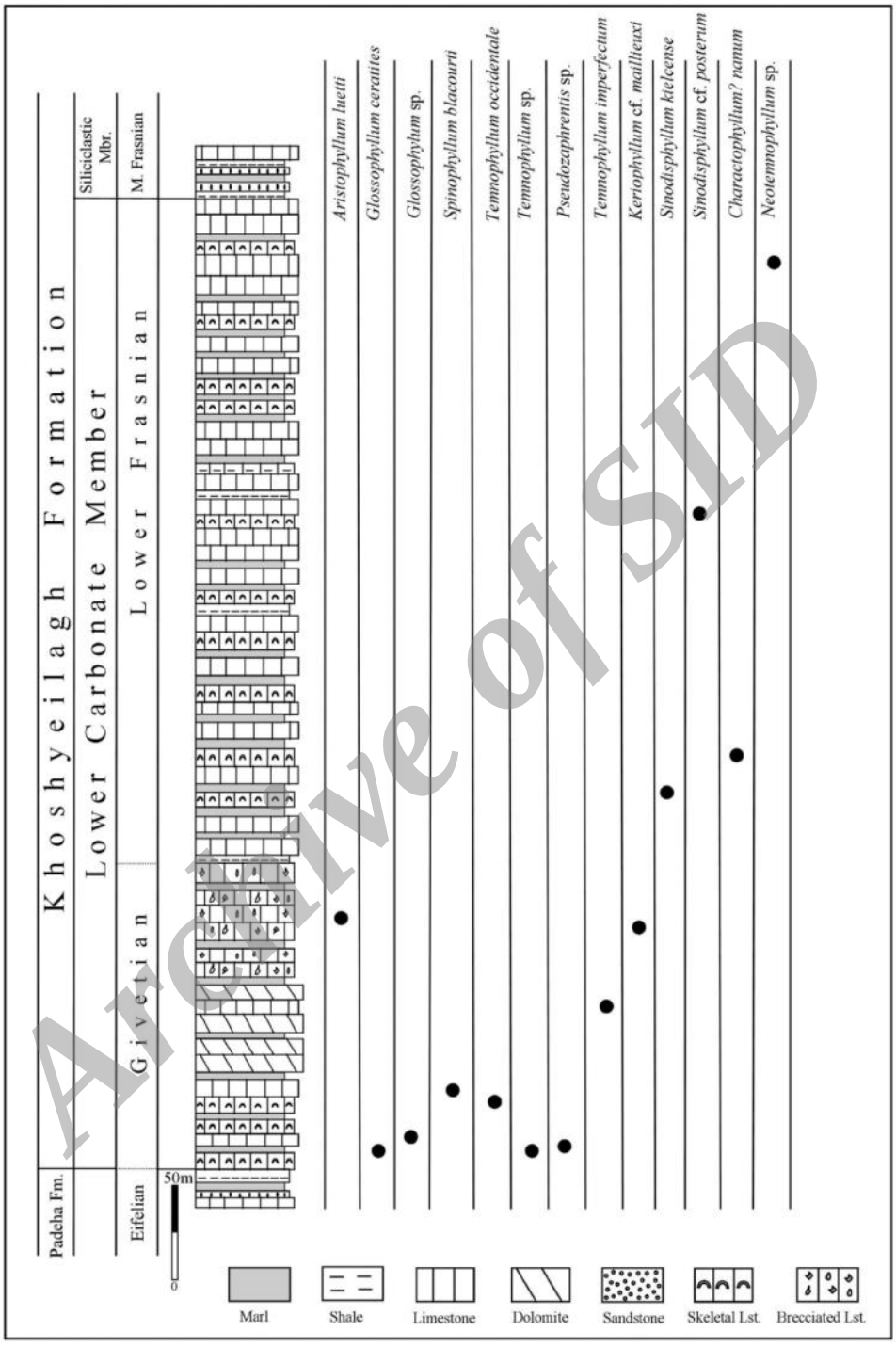

Figure 2. Stratigraphic log of the studied section and distributions of described rugose corals

Lectotype. See Lütte (1987, p. 441).

Material. Two specimens, No. Ti-A/57 and Ti-A/24

Description. The corallites are large and cylindrical with tendency to develop trochoid form in the early stages of growth. The calice is moderately deep and growth lines and longitudinal ribs are strongly developed. The diameters of corallites are 29 and 30 mm.

The septa are developed in major and minor orders. Both orders of the septa are generally thin but the major septa in one specimen are dilated in the tabularium (Fig. 3C). The major septa range in number from 35 to 37. They are extended about 3/4 (Fig. 3A) to 5/6 (Fig. 3C) of the corallite radius. The septa are smooth but some bear very weak spinose carinae. The minor septa are slightly slender than the majors and a few ones are discontinuous axially (Fig. 3A). The minor septa are about 1/2 of the corallite radius in length. One of the major septa is shorter than the adjacent septa. It is assumed to be the cardinal septum, situated in a marked fossula (Fig. 3C). The septa are arranged bilaterally around the mentioned fossula. The assumed cardinal septum and fossula are not very well developed in the other specimen but a short septum is situated within a pseudofossula (Fig. 3A).

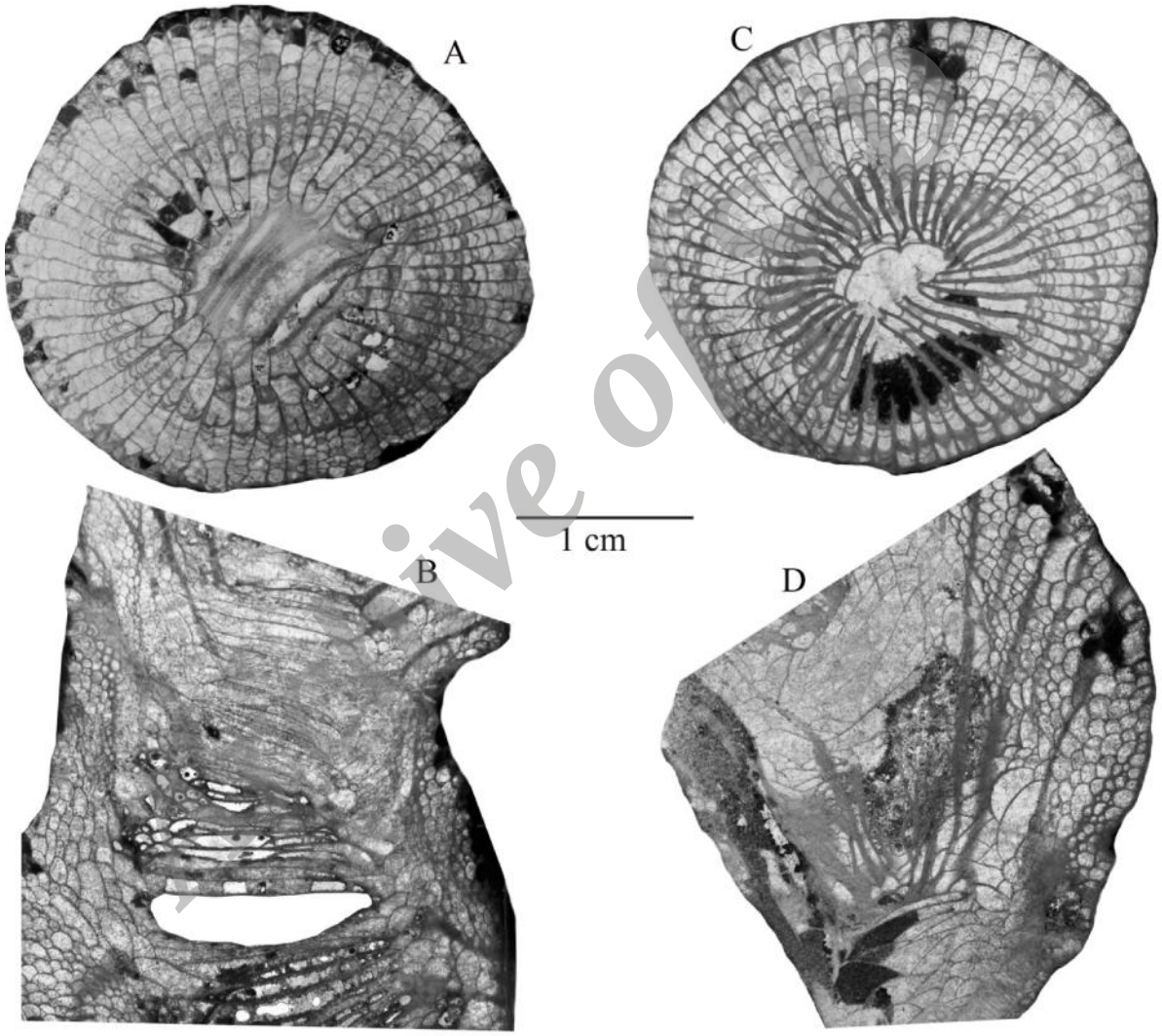

Figure 3. A–D) *Glossophyllum ceratites*; A) transverse section of Ti-A/57. B) longitudinal section of the same. C) transverse section of Ti-A/24. D: longitudinal section of the same.

The dissepiments are generally small, globose to subglobose. They become smaller in size axially. The specimens have about 10 to 14 rows of dissepiments. The tabularium is broad. The tabulae are incomplete, consisted of the closely-spaced and wide axial tabellae and the steeply inclined lateral tabellae.

Remarks. The lectotype of *Cyathophyllum ceratites* Goldfuss, 1826 was selected by Birenheide (1969, p. 30). Later, in his paper, Lütte (1987, p. 441) transferred this species to *Glossophyllum* Wedekind, 1924. Relation of

Cyathophyllum ceratites to *Glossophyllum* has been discussed by Birenheide (1969). Based on the material, figured by Lütte (1987), *Glossophyllum ceratites* can be distinguished from *Glossophyllum soetenicum* (Schlüter, 1885) by longer septa, wider dissepimentarium, closely-spaced tabulae, well-developed fossula and short cardinal septum. Differences between the two discussed species have been illustrated in detail by Schröder (1998, p. 35-36; 2005, p. 99-100).

Though the fossula it is not very prominent in one of the Iranian specimens (Fig. 3A), its assumed cardinal septum is short. In the other specimen (Fig. 3C), the septa are dilated in the tabularium and its fossula and the cardinal septum are well developed. Structures of the tabularium in the Iranian corallites are well within descriptions of *Glossophyllum ceratites*. Our specimens have fewer septa (35 to 37 major septa) than the type material of the species but we believe that they are corresponded to *Glossophyllum ceratites* in corallite diameter, septal morphology, structure of the tabularium, presence of fossula (Fig. 3C) and assumed short cardinal septum. *Glossophyllum ceratites* was described from the Lower Givetian rocks of the Bahram Formation in south of the Ozbak Kuh in the Eastern Iran by Khaksar *et al*. (2006, pl. 1, Fig. 3). This specimen is excluded from the synonymy of *Glossophyllum ceratites* due to fewer septa (32 major septa), absence of the fossula and dilated septa in the tabularium.

Distribution. Givetian of Germany, Morocco and Iran. Middle Devonian? of China.

***Glossophyllum* sp**. (Figs. 4 A–B)

Material. One corallite, No. Ti-A/5.

Description. The corallite is small and conical with a diameter of 19 mm and height of 44 mm. Depth of the calice is about 4 mm. Longitudinal ribs and septal grooves are faintly developed.

The septa are in two orders. Number of the major septa is 32. The major septa are extended to 2/3 of the corallite radius, leaving a more or less extensive open area in the center of the tabularium. The minor septa are about 1/2 to 1/3 of the majors in length. Some of the minor septa enter into the tabularium or are withdrawn from border of the dissepimentarium, replaced by a few rows of angulated dissepiments. The septa are non-carinate but some bear weak knobby carinae. The septa are rather dilated in the dissepimentarium and their axial ends become thicker in the tabularium. The fossula is present. One of the major septa, situated in the fossula is shorter than the rest septa. It is assumed to be the cardinal septum.

The dissepiments are small and globose. They are locally obscured by stereome. The dissepimentarium is narrow, consisted of 3 to 5 rows of dissepiments. The wide tabularium is incomplete and in two regions. The axial tabellae are nearly flat and sometimes convex or concave while the periaxial tabellae are seen as axially inclined plates.

Remarks. With smooth and rather thin septa, presence of a fossula, short assumed cardinal septum and wide tabularium, the Iranian corallite is within morphological variation, observed in *Glossophyllum*. We believe that the specimen can fit well in this genus but due to limited material, its specific assignment is impossible. *Glossophyllum schouppei*, introduced by Lütte (1990, figs. 20-24) from the Givetian strata of N Eifel, Germany is distinguished from the Iranian species by fewer septal number and less thicker septa.

Keriophyllum Wedekind, 1923

Type species. *Keriophyllum heiligensteini* Wedekind, 1923.

Diagnosis. Solitary rugose corals. Septa in two orders and carinate with numerous zigzag carinae. Septa generally thin or less dilated in dissepimentarium. Major septa long and minor septa as long as dissepimentarium. Dissepimentarium wide, consisting of several rows of small and globose dissepiments. Tabularium incomplete. Fossula present.

Keriophyllum* cf. *maillieuxi (Tsien, 1969) (Figs. 4C–D)

1969 *Cyathophyllum maillieuxi* nov. sp., Tsien, p. 132, pl. 46, Fig. 8; pl. 47, Figs. 12-14.

1996 *Keriophyllum maillieuxi* Coen-Aubert, p. 28, pl. 1, Figs. 6, 8; pl. 2, Figs. 4-6.

Holotype. Pl. 47, fig. 12 in Tsien 1969. Specimen no. 8. 708a (85)-Co2d-27. 924. Pl. 2, Fig. 6 in Coen-Aubert 1996. Basal part of Givetian?, Mont d'Hanonet Formation, south of the Dinant Synclinorium, Belgium.

Material. One specimen, No. Ti- C/33.

Description. The corallite is solitary, large and ceratoid. The calice is not preserved. Maximum diameter of the corallite is 25 mm and its height is

65 mm. Longitudinal ribs and growth lines are moderately strong.

The septa are in two orders. The corallite contains 35 major septa. The major septa are rather long, extending about 4/5 of the corallite radius. They leave 5 mm open space in the center of the tabularium. The minor septa traverse the entire dissepimentarium but a few ones are shorter, replaced by some rows of herringbone dissepiments. In general, both orders of the septa are thin. The septa are locally and slightly dilated in the dissepimentarium. Some of the minor septa are interrupted at periphery and a small area of lonsdaleoid dissepiments is formed. Both orders of the septa are carinate in the dissepimentarium. Carinae are mostly zigzag and elbow-shaped. Some knobby carinae are also present on the thickened parts of the septa. One of the septa is shorter than the rest of the septa. It is assumed to be the cardinal septum, positioned in a pseudofossula.

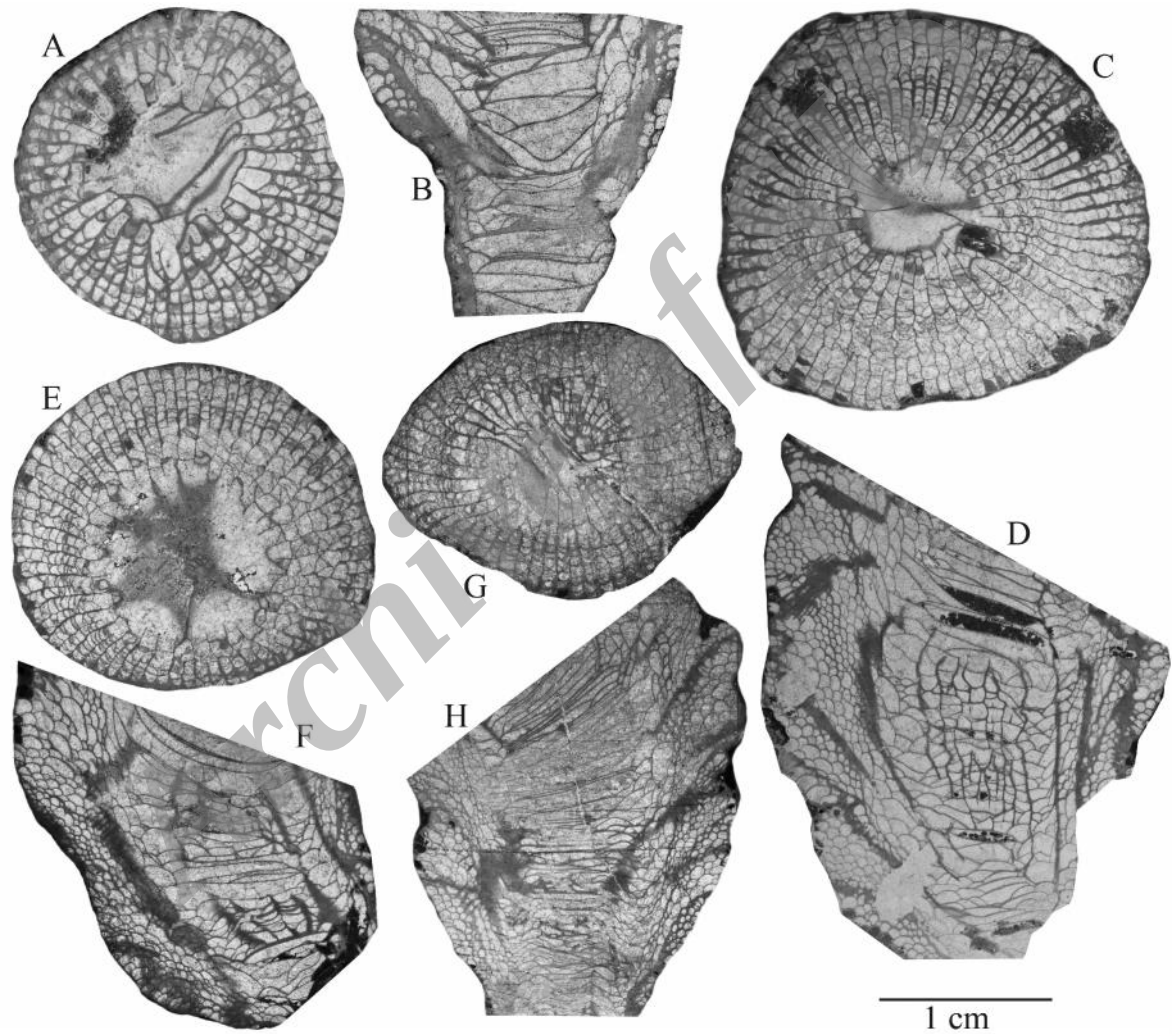

Figure 4. A–B) *Glossophyllum* sp.; A) transverse section of Ti-A/5. B) longitudinal section of the same. C–D) *Keriophyllum* cf. *maillieuxi*; C) transverse section of Ti-C/33. D) longitudinal section of the same. E–F) *Aristophyllum luetti*; E) transverse section of Ti-C/40. F) longitudinal section of the same. G–H) *Pseudozaphrentis* sp.; G) transverse section of Ti-A/2. H) longitudinal section of the same.

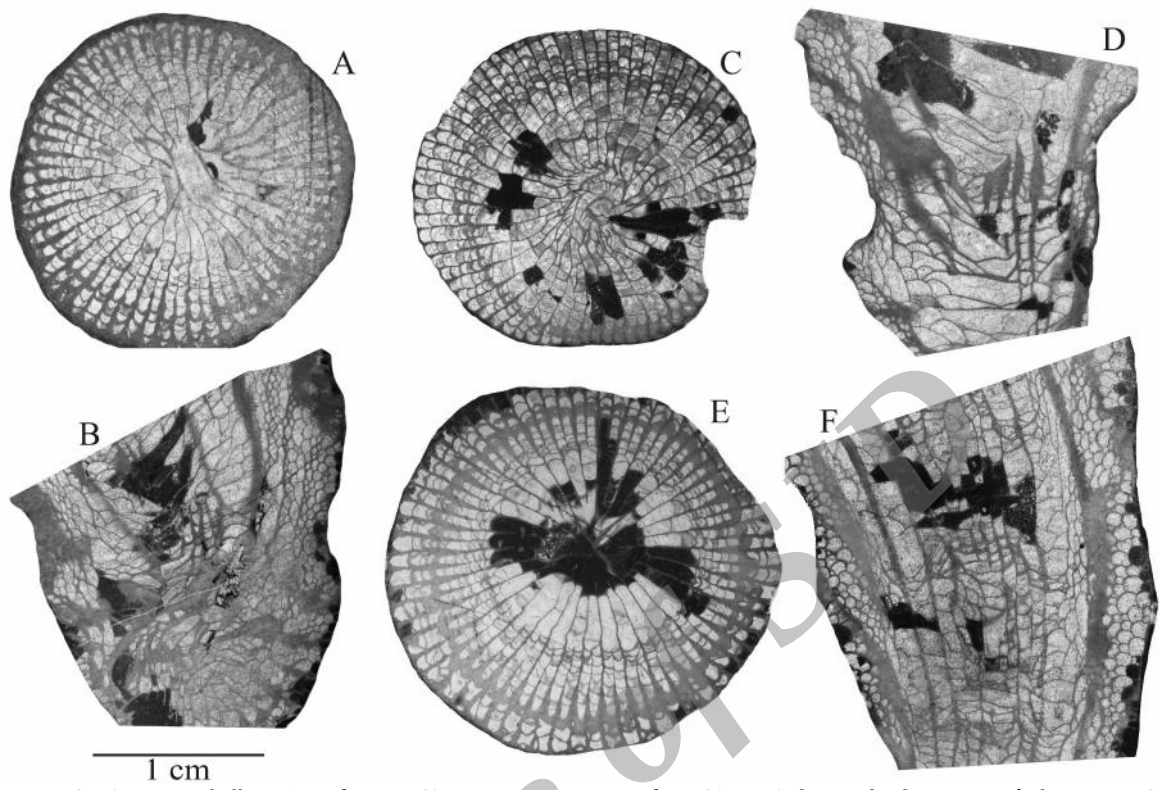

Figure 5. A–B) *Temnophyllum imperfectum*; A) transverse section of Ti-C/25. B) longitudinal section of the same. C–D) *Temnophyllum occidentale*; C) transverse section of Ti-B/104. D) longitudinal section of the same. E–F) *Temnophyllum* sp.; E) transverse section of Ti-A/44. F) longitudinal section of the same.

The dissepimentarium is relatively wide, consisting of about 15 rows of dissepiments. The dissepiments are small and globose, arranged horizontally at the periphery. The tabularium is incomplete. The axial tabellae are horizontal and peripheral ones are axially inclined to convex.

Remarks. *Keriophyllum heiligensteini* Wedekind, 1923 is type species of *Keriophyllum* Wedekind, 1923. Birenheide (1962, p. 108; 1963, p. 390) included this species in synonymy of *Peripaedium turbinatum* (Goldfuss, 1826), type species of *Peripaedium* Ehrenberg, 1834. Coen-Aubert (1996, p. 27 and 28) challenged this synonymy and compared two mentioned species. McLaren in McLaren and Norris (1964, p. 18) suggested that *Keriophyllum* can be merged with *Peripaedium* while during recent years, both genera have been independently discussed (e.g. Coen-Aubert 1996; Schröder 1998; Schröder 2004).

Our specimen shows minor differences from descriptions of *Keriophyllum maillieuxi*, given by Tsien (1969) and Coen-Aubert (1996). Compared to *Keriophyllum maillieuxi*, the Iranian corallite has a few more septa and weaker carination but based on corallite diameter, septa dilation and morphology, development of zigzag carinae and presence of pseudofossula, the discussed species is closely comparable to *Keriophyllum maillieuxi*.

***Distribution*.** Givetian of Belgium and Iran.

Family Disphyllidae Hill, 1939

Aristophyllum Bulvanker, Spassky and Kravtsov, 1975 in Besprozvannykh *et al*., (1975).

Type species. *Aristophyllum terechovi* Bulvanker, Spassky and Kravtsov, 1975 in Besprozvannykh *et al*., (1975). 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 and thin in tabularium. Major septa withdrawn from the axis, leaving a considerable free axial space. Minor septa traversing the entire dissepimentarium. Narrow dissepimentarium composed of a few rows of small and globose dissepiments. Tabularium broad and incomplete with wide axial tabulae.

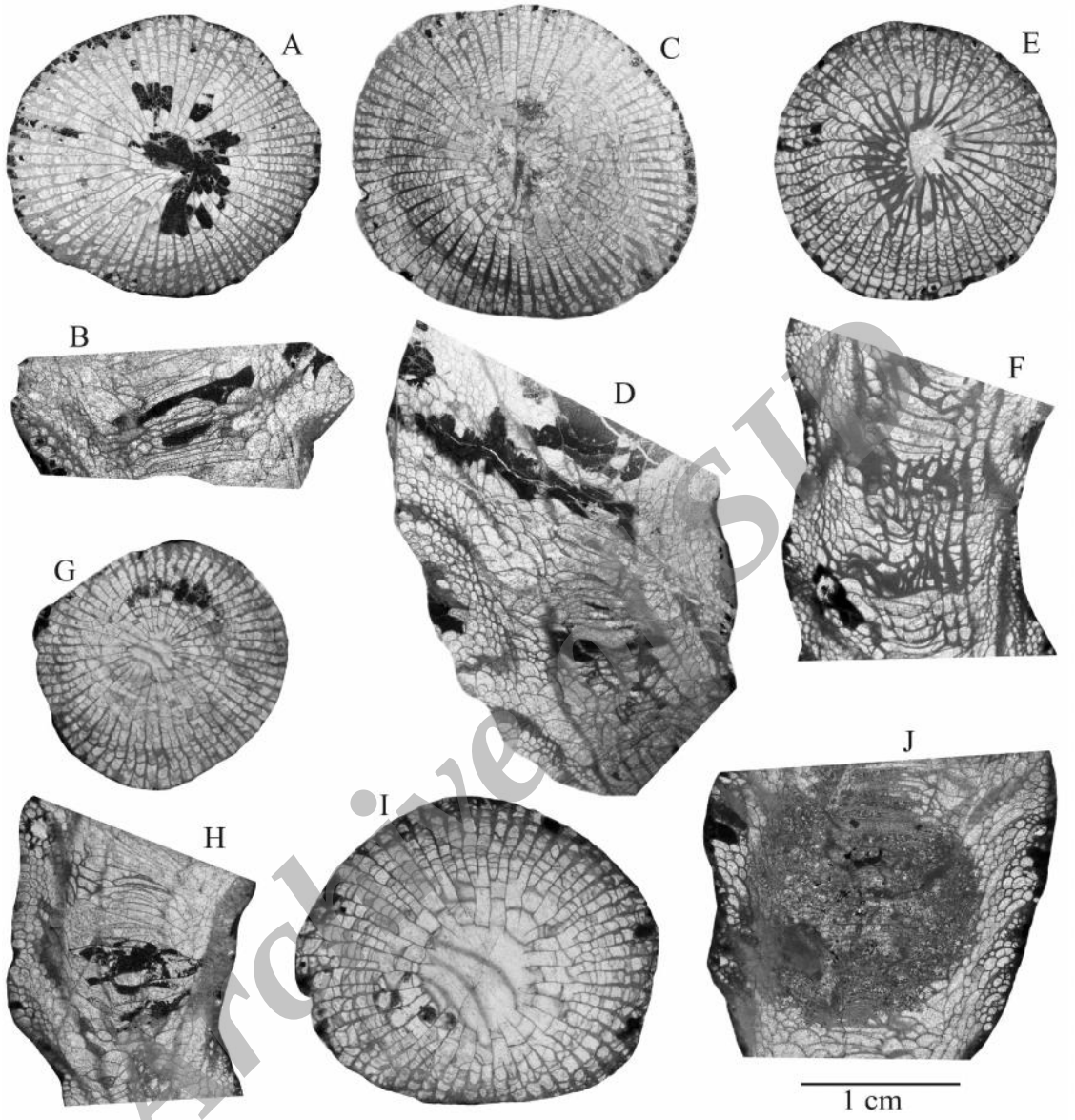

Figure 6. A–D) *Spinophyllum blacourti*; A) transverse section of Ti-B/1. B) longitudinal section of the same. C) transverse section of Ti-B/121. D) longitudinal section of the same. E–F) *Charactophyllum*? *nanum*; E) transverse section of Ti-C/55. F) longitudinal section of the same. G–H) *Sinodisphyllum kielcense*; G) transverse section of Ti-C/70. H) longitudinal section of the same. I–J) *Sinodisphyllum* cf. *posterum*; I) transverse section of Ti-D/18. J) longitudinal section of the same.

Aristophyllum luetti Coen-Aubert, 1997 (Figs. 4E-F)

1997 *Aristophyllum luetti* nov. sp., 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.

2014a *Aristophyllum luetti* Abbasi *et al*., p. 131, Figs 5i-j, 6a-d.

Holotype. Pl. 2, Figs. 1-2 in Coen-Aubert 1997. Specimen no. IRScNB a10553. Givetian, Hanonet Formation, Pondrôme, Belgium.

Material. One specimen, No. Ti- C/40.

Description. The specimen is a solitary and trochoid in form with a diameter of 21 mm and height of 67 mm. The corallite shows well-preserved growth lines and longitudinal ribs.

The septa are in major and minor orders and radial in arrangement. The corallite contains 36

major septa. Septal length varies from 1/2 to 1/3 of the corallite radius. The major septa are withdrawn from axis, leaving an extensive open space in the center of the tabularium. The minor septa are different in length, varying from 1/3 to 4/5 of the majors. The minor septa are locally replaced by herringbone dissepiments. Both orders of the septa are thin throughout their length. Peripheral ends of the septa are faintly dilated and a very narrow thickening is formed against the wall. The septa bear some weak zigzag carinae.

The dissepimentarium consists of 5 to 8 rows of small dissepiments. The dissepiments are globose and subglobose. They are steeply inclined or nearly vertical near the tabularium. The tabularium is wide, differentiated into two parts. There are a few rows of the steeply inclined tabellae in the peripheral parts of the tabularium. The axial region of the tabularium consists of the wide and nearly flat tabellae. These axial tabellae are locally broken into smaller plates.

Remarks. With fewer septa and more dissepiments, *Aristophyllum luetti* Coen-Aubert, 1997 differs from *Aristophyllum terechovi* Bulvanker, Spassky and Kravtsov, 1975 the type species of the genus *Aristophyllum*. The specimen described here, has the same features as are seen in *Aristophyllum luetti*, figured by Coen-Aubert (1997, pl. 1, Figs. 5-7; pl. 2, Figs. 1-4) and the authors believe that the Iranian corallite is conspecific with the species. The septal number, corallite diameter, septal length, range of dissepiments and morphology of septa are similar to the material, described by Coen-Aubert (1997).

Distribution. Givetian of Belgium, Germany and Iran.

Pseudozaphrentis Sun, 1958

Type species. By original designation, *Pseudozaphrentis difficile* Sun, 1958.

Diagnosis. Solitary tetracorals. Septa in major and minor orders, smooth or sometimes carinate. Major septa withdrawn from axis, leaving a considerable open area in the axial part. Minor septa variable in length, traversing the entire dissepimentarium or withdrawn from border of dissepimentarium, replaced by rows of herringbone dissepiments. Tabularium incomplete

***Pseudozaphrentis* sp.** (Figs. 4G–H)

Material. One specimen, No. Ti-A/2.

Description. The corallite is solitary, ceratoid to conical and slightly abraded. The corallite is oval-shaped in transverse section with maximum and minimum diameters of 21 and 16.5 mm, respectively. Longitudinal ribs and growth lines are well developed. The calice is not preserved and wall is thin.

The septa are in two orders; majors and minors. Number of the major septa is 38. The major septa are more or less different in size, leaving a considerable open area in the axial part. The minor septa are also different in length. They are seen as short ridges, replaced by several rows of angulated and herringbone dissepiments or as long as the dissepimentarium. Both orders of the septa are generally smooth but some are faintly carinate. The septa are thin in the dissepimentarium but become slightly thick in the tabularium. Some of the septa are more or less dilated in border of the dissepimentarium.

The dissepiments are small, globose, subglobose and locally thickened. They are arranged horizontally at the outer row where wall is well preserved and steeply inclined in the inner rows and near the tabularium. There are about 5 to 9 rows of dissepiments. The incomplete tabularium is developed in axial and periaxial regions. The tabellae are mostly inclined towards the tabularium in the periaxial regions and horizontal and closely-spaced in the axial regions. The axial tabellae are sometimes laterally intersected. Proximally, there are arch-shaped accessory tabellae, developed on the peripheral ends of the axial tabellae.

Remarks. Following the work of Sun (1958), many of coral workers considered *Pseudozaphrentis* as an independent and valid genus (e.g. Coen-Aubert, 1995, 2003; Schröder and Salerno, 2001; Schröder, 2004) while the genus has been discussed as synonym of *Temnophyllum* Walther, 1929 (Hill, 1981; McLean, 1993) and *Paracanthus* Merriam, 1973 (Zhen & Jell, 1996). Coen-Aubert (2003, p. 19 and 20) compared *Pseudozaphrentis* with *Temnophyllum* and *Paracanthus*.

The Iranian corallite shows a considerable free axial area in the tabularium, reduction of the minor septa, replaced by herringbone dissepiments and axially dilation of the some septa. These features convinced the authors to consider the specimen as *Pseudozaphrentis*. The Iranian coral is distinguished from *Pseudozaphrentis zamkowae* (Wrzolek, 1993) by more septa, shorter minor septa

and closely-spaced axial tabellae. *Pseudozaphrentis Sirius*, introduced by Schröder (2004, p. 616) from Upper Givetian? of the Karakorum Mountains, northern Pakistan differs from the present specimen by slightly thicker septa, fewer dissepiments rows and fewer septal number. With fewer septa, wedge-shaped septal dilation and less developed minor septa, *Pseudozaphrentis difficilis* is differentiated from the Iranian specimen.

Family Charactophyllidae Pedder, 1982

Temnophyllum Walther, 1929

Type species. *Temnophyllum latum* Walther, 1929, p. 123, 124, text-Fig. 14. Late Givetian, Sauerland, Germany. Subsequent designation by Lang *et al*., 1940, p. 132.

Diagnosis. Solitary rugose coral. Septa in two orders, non-carinate or sometimes weakly carinate, typically dilated in the outer dissepimentarium, forming an irregular, complete or partial stereozone. Major septa reaching to the axis or slightly withdrawn. Minor septa traversing the entire dissepimentarium. Dissepiments globose, small, arranged horizontally at the periphery. Tabularium incomplete, with lateral and axial tabellae.

Temnophyllum imperfectum Coen-Aubert, 2002

(Figs. 5A–B)

2002 *Temnophyllum imperfectum* nov. sp., Coen-Aubert, p. 13, pl. 2, Figs. 1-10.

Holotype. Pl. 2, Figs. 1-2 in Coen-Aubert 2002. Specimen no. IRScNB a11727. Middle part of Givetian, Mont d'Haurs Formation, south of the Dinant Synclinorium, Belgium.

Material. One corallite, No. Ti-C/25.

Description. The corallite is solitary, trochoid to conical and medium in size. The corallite diameter and height are 20 mm and 68 mm, respectively. The calice is shallow and septa grooves and longitudinal ribs are well developed.

The septa are in major and minor orders and radial in arrangement. The major septa are extended to 4/5 of the corallite radius, leaving a moderately small open space in the center of the tabularium. Number of the major septa is 31. The minor septa traverse the entire dissepimentarium but a few ones enter into the tabularium. The septa are variably dilated in the dissepimentarium and rather thick in the tabularium. Dilation of the septa forms a stereozone in the outer dissepimentarium and against the wall. This stereozone is incomplete. The septa are carinate with more or less weak knobby carinae in the dissepimentarium.

The dissepiments are small, globose to subglobose, in 8 to 11 rows. Inner rows of the dissepiments are steely inclined or nearly vertical. The dissepiments are generally thickened by stereome. The tabularium is incomplete with steeply inclined lateral tabellae and flat axial tabellae.

Remarks. *Temnophyllum imperfectum* was introduced and discussed by Coen-Aubert (2002, p. 13-15) from the Givetian Mont d'Haurs Formation in Belgium. The Iranian specimen corresponds well with material of *Temnophyllum imperfectum*, figured and illustrated by Coen-Aubert (2002) except a slightly weaker stereozone in the former. Diameter of the corallite, septal number and morphology of the septa in our corallite are closely similar to the Belgian material.

Distribution. Givetian of Belgium and Iran.

Temnophyllum occidentale Hill and Jell, 1970

(Figs. 5C–D)

* 1970 *Temnophyllum occidentale* Hill and Jell, p. 59, pl. 14, Figs. 1-9.

e.p. 1993 *Temnophyllum occidentale* Wrzolek, p. 233, Figs. 10A-H.

2005 *Temnophyllum* cf. *occidentale* Schröder, p. 44, 45, pl. 9, Figs. 1-4.

Holotype. Pl. 15, Figs. 7a-c in Hill and Jell 1970. Specimen no. SWA F5931/7, late Givetian, Pillara Limestone, Western Australia.

Material. One specimen, No. Ti-B/104.

Description. The corallite is trochoid with a diameter of 20 mm. The corallite height is 55 mm and depth of the calice reaches to 5 mm. Septal grooves and longitudinal ribs are fully developed.

The septa are in two orders; majors and minors. Number of the major septa is 35. The septa are rather long, slightly withdrawn from axis, leaving a small open area in the axial part. Axial parts of the major septa are weakly rotated and some of them are fused. The septa are faintly thickened in the dissepimentarium and become thicker at the inner border of dissepimentarium. Dilation of the septa is decreased in the inner dissepimentarium. The major septa are rather thickened in the tabularium. The minor septa traverse the entire dissepimentarium, reaching to 1/3 of the majors in length. The minor septa are slender than the major septa. Some of the septa are faintly carinate with spinose carinae in the dissepimentarium and smooth in the tabularium.

There are local deposits of stereoplasmic thickening against of the some septa.

The dissepiments are small, globose to subglobose. They are more or less arranged horizontally in the outer row and inclined in the inner rows. The dissepiments are locally thickened. Number of the dissepiments row is 6 to 7. The incomplete tabularium is differentiated into two parts. The axial tabellae are wide and nearly flat. The lateral tabellae are developed as large steeply inclined plates.

Remarks. The Iranian corallite is closely similar to *Temnophyllum occidentale* Hill and Jell, 1970, introduced from the Givetian rocks of Australia. Compared to our specimen, the type material of *Temnophyllum occidentale*, figured by Hill and Jell (1970, pl. 15, Figs. 1-9) has fewer septa. Morphological features, named as "bow-ties" in the descriptions of Hill and Jell (1970, p. 59) are also absent in the transverse thin section of the Iranian coral. With regard to the corallite size, septal length, dilation of septa in the dissepimentarium and tabularium, there are strong similarities between the Iranian and Australian specimens. These resemblances are supported by structure of the tabularium.

Some assignments of Wrzolek (1993, Figs. 10D, F, H) to *Temnophyllum occidentale*, described from the Givetian rocks of the Holy Cross Mountains, Poland are excluded from the synonymy of the species due to presence of more or less heavy stereozone. This stereozone are not seen in the type material, described by Hill and Jell (1970).

Distribution. Late Givetian of Australia and Givetian of Poland and Iran.

***Temnophyllum* sp.** (Figs. 5E–F)

Material. One specimen, No. Ti-A/44.

Description. The corallite is ceratoid with a height of 48 mm and a diameter of 23 mm. The calice is moderately deep. Septal grooves and longitudinal ribs are weakly developed. The wall is thin.

The septa are radial in arrangement and in two orders. Number of the major septa is 34. The major septa are extended to 4/5 of the corallite radius, leaving an open area in the axial part. One of the major septa is shorter than the other septa and its opposite septum is longer than the rest septa. The minor septa traverse the entire dissepimentarium.

The septa are dilated in the dissepimentarium and thin in the tabularium. Thickening of the septa produces a stereozone in the middle parts of dissepimentarium. This stereozone is complete and rather strong. The septa are smooth but some are carinate with weak knobby carinae in the outer dissepimentarium. Peripheral ends of the septa are thickened and a thin stereozone is developed against the wall.

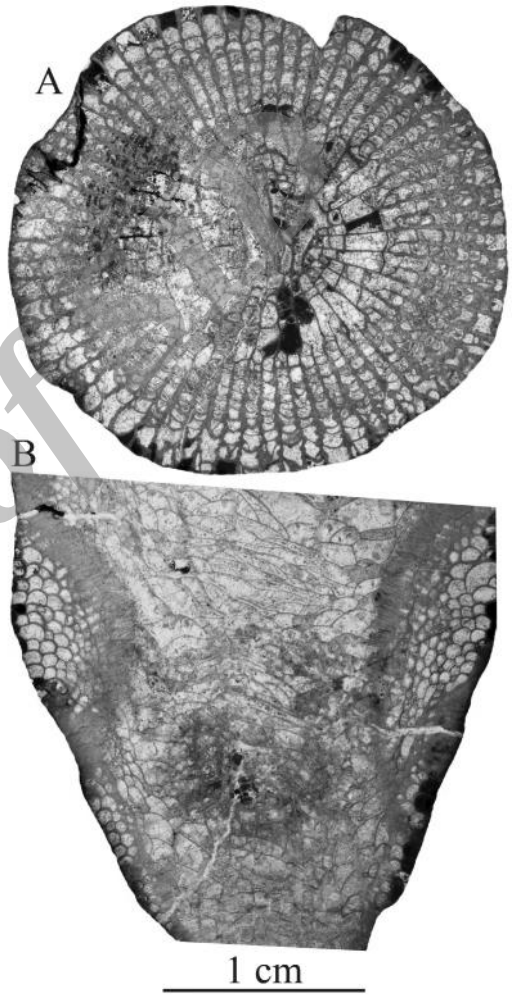

Figure 7. A–B) *Neotemnophyllum* sp.; A) transverse section of Ti-D/50. B) longitudinal section of the same

The dissepiments are generally small, globose to subglobose. The dissepiments are locally obscured by stereome. The dissepimentarium has about 10 rows of the dissepiments. The tabularium is incomplete and in two regions. The tabellae are steeply inclined in the periaxial region of the tabularium while structure of the axial tabellae is unknown due to an oblique thin section.

Remarks. Due to the presence of a stereozone in the dissepimentarium, this corallite corresponds

well with genus *Temnophyllum*. So far, many species of *Temnophyllum* with prominent stereozone have been introduced. Because of the limited material, specific assignment of the Iranian corallite is impossible but it is similar to some forms. *Temnophyllum wellinense* Coen-Aubert, 2003 from the Early Givetian rocks of Belgium is distinguished from our coral by narrow and incomplete stereozone, smaller size, wider free axial space and fewer septa. The Iranian coral differs from *Temnophyllum imperfectum* Coen-Aubert, 2002, introduced from the Givetian beds of Belgium by larger corallite diameter and complete stereozone in the middle parts of the dissepimentarium. More septa, larger size and presence of a complete stereozone exclude the discussed specimen from the synonymy of *Temnophyllum occidentale* Hill and Jell, 1970. A more or less complete and strong stereozone is developed within the dissepimentarium of *Temnophyllum* sp. A, reported by Schröder (1998, pl. 8, Figs. 45-47) from the Givetian Loogh and Cürten Formations, Eifel region, Germany. The German specimen is differentiated from the Iranian coral by its strong dilation of peripheral tips of septa against the wall.

Spinophyllum Wedekind, 1922

Type species. By monotypy, *Campophyllum spongiosum* Schlüter, 1889. Givetian, Büchel Formation, Germany.

Diagnosis. Solitary rugose corals with two orders of septa. Septa more or less dilated in dissepimentarium and outer tabularium and thin in inner tabularium. Septa heavily or irregularly carinate with yardarm and zigzag carinae. Major septa extending to the axis of corallite or slightly withdrawn. Minor septa traversing the entire dissepimentarium. Dissepimentarium composed of some rows of small and globose dissepiments. Tabularium incomplete, differentiated in axial and peripheral regions.

Spinophyllum blacourti (Rohart, 1988) (Figs. 6A–D)

1988 *Truncicarinulum blacourti* nov. sp., Rohart, p. 277, pl. 35, Figs. 3-4.

2002 *Spinophyllum blacourti* Coen-Aubert, p. 16, pl. 3, Figs. 8-14.

2004 *Spinophyllum blacourti* Barchy *et al*., pl. 1, Fig. 5.

2006 *Spinophyllum blacourti* Khaksar *et al*., p. 60, pl. 2, Fig. 3.

Holotype. Pl. 35, Fig. 3 in Rohart, 1988. Specimen no. GFCL 4556. Middle part of Givetian, Blacourt Formation, Bance Noir quarry at Ferques, Boulonnais, France.

Material. Two specimens. No. Ti-B/1 and Ti-B/121.

Description. The corallites are trochoid with diameter of 20 and 22 mm and height of 45 and 46 mm,

respectively. The calice is not preserved. Longitudinal ribs and septal grooves are weakly developed.

The septa are in two orders and radial in arrangement. The corallites contain 34 and 38 major septa, respectively. The major septa are more or less long, reaching to 5/6 of the corallite radius. They leave 3 to 5 mm open area in the axial part. The major septa faintly swirl in the tabularium. The minor septa are about half of length of the majors, replaced commonly with a few row of the herringbone dissepiments (Fig. 6C). The major septa are thickened in the outer and middle dissepimentarium and become thin in the inner dissepimentarium and tabularium. Peripheral ends of the septa are weakly dilated and a narrow stereozone is formed against the wall. Both orders of septa bear a few spinose and knobby carinae, especially in the thickened parts of the septa in the outer dissepimentarium.

The dissepimentarium consists of 12 to 15 rows of dissepiments. The dissepiments are small in size and commonly globose and subglobose. They are horizontally arranged near the wall and inclined or nearly vertical in inner rows. The tabularium incomplete and consists of the axial and peripheral tabellae. The peripheral tabellae are relatively large plates with axially inclined arrangement. The axial tabellae are more or less horizontal, concave, convex and slightly depressed. The trabeculae are rather coarse and arise upwardly and inwardly at angle with the corallite wall.

Remarks. Variations of *Spinophyllum blacourti* and comparison of the species with similar forms have been discussed by Coen-Aubert (2002, p. 16 and 17) who transferred it to *Spinophyllum*. Before the studies of the mentioned author, the species was erected as *Truncicarinulum blacourti* by Rohart (1988, p. 277) who collected the species from the Givetian Blacourt Formation in Boulonnais,

France. *Truncicarinulum* Yu and Kuang, 1982 has been considered as synonym of *Spinophyllum* by McLean (1993, p. 110), Wrzolek and Wach (1994, p. 53) and Coen-Aubert (2002, p. 16).

Compared to the *Spinophyllum blacourti*, described by Rohart (1988, pl. 35, Figs. 3-4) and Coen-Aubert (2002, pl. 3, Figs. 8-14) from the Givetian rocks of France and Belgium, respectively, the Iranian coral shows a close similarity to these material. Regard to the quantitative measurements, including corallite diameter and number of septa, our specimen is similar to the Belgian specimens. Based on diagnosis of Coen-Aubert (2002, p. 17) the septa are slightly carinate in *Spinophyllum blacourti*. This weak carination is also seen in the Iranian coral. Septal morphology and dilation are the same in both forms.

Distribution. Givetian of France, Belgium and Iran.

Charactophyllum Simpson, 1900

Type species. *Campophyllum nanum* Hall and Whitfield, 1873, p. 232, Frasnian, Lime Creek Formation, Rockford, Iowa, USA.

Diagnosis. Solitary rugose corals with charactophyllid trabeculae. Septa in two orders, denticulate, variable in length and dilation in dissepimentarium. Septa moderately to strongly dilated in tabularium. Dissepimentarium in some rows of small and globose dissepiments, arranged horizontally at the periphery. Incomplete tabularium composed of horizontal or slightly concave and convex axial tabellae and numerous steeply inclined peripheral tabellae.

Charactophyllum*? *nanum (Hall and Whitfield, 1873) (Figs. 6E–F)

1873 *Campophyllum nanum* Hall and Whitfield, p. 232.

1900 *Charatophyllum nanum* Simpson, p. 209. Fig. 28.

1945 *Charactophyllum nanum* Smith, p. 17. pl. 1, Figs. 6. 7. 8a. 8b; pl. 31, Figs, la-li.

non1982 *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.

2014a *Charactophyllum nanum* Abbasi *et al.*, p. 135, Figs. 7a-c.

Holotype. Hall and Whitfield 1873, p. 232 as *Campophyllum nanum*. Simpson 1900. p. 209-210, text-Fig. 28 as *Charactophyllum nanum*.

Material. One specimen, No. Ti-C/55.

Description. The corallite is ceratoid with a diameter of 18 mm and height of 57 mm. The calice is not preserved. Septal grooves and longitudinal ribs are well-developed.

The septa are in major and minor orders. Number of the major septa is 32. The septa show a weak bilateral arrangement in the tabularium. The major septa are long, leaving a small open area in the axial part. Axial tips of some of the major septa are fused. The major septa are slightly swirled around the axis of the corallite. The minor septa are about 1/2 of the major septa in length. They are confined to the dissepimentarium but some replaced by a few rows of herringbone or angulated dissepiments. The septa are slightly dilated in the dissepimentarium. The major septa are moderately to strongly dilated in the tabularium with swollen axial tips. Both orders of the septa are weakly carinate with knobby carinae in the dissepimentarium.

The dissepiments are small, globose and subglobose. There are 7 to 12 rows of dissepiments. The tabularium is incomplete and in two regions. The tabellae are nearly flat or slightly concave and convex in the axial region and axially inclined in the periaxial region.

Remarks. Pedder (1982, p. 562) and McLean (1993, p. 109) discussed *Charactophyllum* in detail. One of the most complete descriptions of *Charactophyllum nanum* has been given by Sorauf (1998, p. 54-56). McLean (1993, p. 110) noticed that the septa are dilated in tabularium in large populations of *Charactophyllum* and axial dilation of septa is a rare characteristic in charactophyllids. *Charactophyllum burdekinense*, Zhen and Jell, 1996, erected from the Givetian beds of Australia shows septal dilation in tabularium. Axially thickened septa in the species has been figured by Sorauf (1988, pl. 24, Figs. 1-15; pl. 25, Figs. 1-12; pl. 26, Figs. 1-2).

The Iranian specimen is assigned to *Charactophyllun* due to strong dilation of the septa in the tabularium. Microstructure of the septa is unknown and we tentatively assigned the specimen to this genus but number of septa, diameter of corallite, morphology and dilation of septa are similar to the material of *Charactophyllum nanum* described by Sorauf (1998) from the Frasnian rocks

of Iowa. The Iranian specimen differs from *Charactophyllum burdekinense*, Zhen and Jell, 1996 by larger diameter and more septa. Dilation of the septa in the tabularium is not observed in the material of Ghods (1982, pl. 5, Figs. 1-3) and the authors exclude these specimens from the synonymy of *Charactophyllum nanum.*

Distribution. Frasnian of USA and Iran.

Sinodisphyllum Sun, 1958

Type species. By original designation, *Disphyllum* (*Sinodisphyllum*) *variabile* Sun, 1958. Frasnian, Shaitienchiao Formation, Hunan, China.

Diagnosis. Solitary tetracorals. Septa in two orders, rather long, slightly dilated in dissepimentarium and thin in tabularium. Septa non-carinate or faintly carinate. Minor septa traversing the entire dissepimentarium. Septal stereozone 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.

Sinodisphyllum kielcense (Rozkowska, 1979) (Figs. 6G–H)

1979 *Ceratophyllum kielcense* nov. sp., 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 and Coen-Aubert, p. 44, pl. 1, Fig. 8; pl. 2, Figs. 11-13; pl. 3, Figs. 1-3.
2014a *Sinodisphyllum kielcense* Abbasi *et al*., p. 133, Figs. 6e-f.

Holotype. Pl.3, Fig. 10 in Rozkowska, 1979. Specimen no. TcI/9. Frasnian, Holy Cross Mountains, Poland.

Material. One specimen. No. Ti-C/70.

Description. The corallite is ceratoid with a diameter of 16 mm and height of 40 mm. The specimen is slightly abraded and longitudinal ribs and septal grooves are faintly developed. Depth of the calice is about 5 mm.

The septa are in major and minor orders. The corallite contains 31 major septa. The major septa are extended to 5/6 of the corallite radius and leave a small open space in the axial part. The minor septa are confined to the dissepimentarium. The septa are non-carinate but some bear a few weak knobby carinae. The septa are slightly dilated in the dissepimentarium and become thin in the tabularium. Axial tips of the major septa are slightly thickened.

The dissepimentarium is more or less narrow with 4 to 5 rows of dissepiments. The dissepiments are small, globose and subglobose. They are larger and horizontally arranged at the periphery and smaller and inclined in the inner rows. The tabularium is broad and incomplete. The axial tabellae are nearly flat, arch-shaped and laterally intersected. The periaxial tabellae are formed as axially inclined small plates.

Remarks. *Ceratophyllum kielcense* was first described by Rozkowska (1979, p. 22) from the Frasnian rocks of the Holy Cross Mountains, Poland, followed by Federowski (2003, p. 93). By discussing on *Ceratophyllum* Gürich, 1896, Rohart (2002, p. 116) transferred the species to *Sinodisphyllum* Sun, 1958.

Boulvain *et al*., (2005) assigned material of *Mansuyphyllum elongatum* (Rozkowska, 1970), figured by Boulvain and Coen-Aubert (1998, pl. 3, Figs. F-K) to *Sinodisphyllum kielcense*. It was based on study of probable Middle Devonian *Cyathophyllum annamiticum* Mansuy, 1913, the type species of *Mansuyphyllum* Fontaine, 1961 which differs from the species of *Sinodisphyllum* by narrow tabularium and very wide dissepimentarium, composed of several rows of small and globose dissepiments. These differences convinced Boulvain *et al*., (2005) to make such decision.

The Iranian specimen is very similar in septal number, corallite diameter, morphology of septa and development of the tabularium to the material, described by Boulvain and Coen-Aubert (2006, pl. 1, Fig. 18; pl. 2, Figs. 11-13; pl. 3, Figs. 1-3) from the Frasnian Bieumond Member of the Grands Breux Formation in south side of the Dinant Synclinorium, Belgium. Compared to the latter, the Iranian coral shows a slightly smaller free axial area and absence of stereozone.

Distribution. Frasnian of France, Belgium, Poland and Iran.

Sinodisphyllum* cf. *posterum (Ivania, 1965) (Figs. 6I–J)

1965 *Charactophyllum posterum* nov. sp. Ivania, p. 103, pl. 102, Figs. 440-442.
2006 *Sinodisphyllum posterum* Boulvain and Coen-Aubert, p. 43, pl. 3, Figs. 4-11.

Holotype. Pl. 102, Figs. 440-442 in Ivania, 1965. Specimen no. 239/8. Frasnian, Solomino Beds, Kuznetsk Basin, Russia.

Material. One specimen. No. Ti-D/18.

Description. The corallite is ceratoid to conical with a diameter of 23 mm and height of 47 mm. Depth of the calice is 6 mm and septal grooves and longitudinal ribs are weakly developed.

The septa are differentiated into two orders and radial in arrangement. Number of the major septa is 30. The major septa are withdrawn from axis, leaving a more or less a wide open area in the center of the tabularium. They are faintly thickened in the dissepimentarium and become thin in the tabularium. The minor septa traverse the entire dissepimentarium but some enter into the tabularium. Both orders of the septa are smooth but some bear weak knobby carinae in the outer dissepimentarium. Trace of a pseudofossula is also observed.

The dissepiments are mainly small and subglobose. Elongated dissepiments are also present. The dissepiments are different in size and mostly inclined. The dissepimentarium consists of 6 to 9 rows of dissepiments. The incomplete tabularium is more or less wide. The axial tabellae are slightly wide, flat, closely-spaced and laterally intersected while the lateral tabellae are developed as axially inclined plates.

Remarks. *Charactophyllum posterum* was first introduced from the Frasnian rocks of the Kuznetsk Basin in Russia by Ivania (1965). According to McLean (1993), *Charactophyllum* Simpson, 1900 is characterized by axially dilated septa and then this species transferred to *Sinodisphyllum*, Sun, 1958 by Boulvain *et al*. (2005) and Boulvain and Coen-Aubert (2006). *Sinodisphyllum posterum* has been discussed by Boulvain and Coen-Aubert (2006, p. 43 and 44).

The present corallite is closely comparable with *Sinodisphyllum posterum* from the Frasnian La Boverie Member (in south side of the Dinant Synclinorium, Belgium), figured by Boulvain and Coen-Aubert (2006, pl. 3, Figs. 4-11). Compared to the Belgian material, the Iranian specimen has slightly lesser number of septa but shows similar septal length, not extending to the axis. In addition, morphology of septa and development of tabularium, including more or less wide and closely-spaced arrangement of the axial tabellae are the same in the Iranian and Belgian corallites.

Distribution. Frasnian of Belgium, Russia and Iran.

Neotemnophyllum Yu and Kuang, 1984

Type species. *Neotemnophyllum furcatum* Yu and Kuang, 1984. p. 145, pl. 3, Fig. 1, text-Fig. 5, Upper Frasnian, Liujing, central Guangxi, China.

Diagnosis. Solitary rugose coral. Septa in two orders. Major septa long. Both orders of septa formed by monacanthine trabeculae. The septa dilated and carinate in dissepimentarium. Dissepimentarium of numerous rows of globose to subglobose dissepiments. Tabularium composed of vesicular and arched axial tabellae.

***Neotemnophyllum* sp.** (Figs. 7A–B)

Material. One specimen. No. Ti-D/50.

Description. The corallite is solitary and conical. The calice is not preserved. Diameter of the corallite is 25 mm and its height is 54 mm. Growth lines are strongly developed.

The septa are in two orders and radial in arrangement. There are 33 major septa. The major septa are relatively long, leaving 4 mm open space in the axial part of the corallite. They are rather thick in the dissepimentarium but attenuate in the tabularium. Peripheral parts of septa are sometimes degenerated and lateral dissepiments are present in some places. The minor septa are as long as dissepimentarium, about 1/2 of corallite radius. Both orders of the septa are moderately to strongly carinate, bearing yardarm and knobby carinae in the dissepimentarium.

The dissepimentarium consists of about 8 to 11 rows of dissepiments. The dissepiments are small and globose but nearly vertical in inner rows. They are horizontal at the periphery row and sometimes thickened in some places. Width of the tabularium reaches to 14 mm in adult stage. The tabularium is incomplete and vesicular. The axial tabellae are small, closely-spaced and arch-shaped while the periaxial ones are large axially inclined blister.

Remarks. *Neotemnophyllum* with type species *Neotemnophyllum furcatum* has been erected as a charactophyllids by Yu and Kuang (1984) from the Frasnian rocks of central Guangxi, China. As a carinate genus, *Neotemnophyllum* is similar to *Truncicarinulum* Yu and Kuang, 1982, *Charisphyllum* Oliver and Sorauf, 1988 and *Spinophyllum* Wedekind, 1922. Wrzolek and Wach (1994) believed that the genus is junior synonym of *Spinophyllum*. McLean (1993, p. 115) regarded

Neotemnophyllum as synonymous with *Piceaphyllum* Rozkowska, 1979. *Neotemnophyllum* has been considered as independent solitary rugose coral by Coen-Aubert (2005, p. 72). We believe that *Neotemnophyllum* is differentiated from other carinate genera by vesicular and arch-shaped development of tabularium.

The discussed specimen is distinguished from the type species *Neotemnophyllum furcatum* Yu and Kuang, 1984, descried from the Frasnian rocks of China by its larger corallite, less dilated septa and larger open area in the axial parts. *Neotemnophyllum mirabile* Yu and Kuang, 1984, collected from the Frasnian beds of China, differs mainly from the Iranian coral by smaller diameter and locally reduced minor septa. *Neotemnophyllum liujingense* Yu and Kuang, 1984 which has been also reported from the Frasnian rocks of China is differentiated from our material by smaller corallite size and more septal number. Coen-Aubert (2005, p. 72-73) introduced and described two species of *Neotemnophyllum* from the Upper Givetian rocks of Morocco; *Neotemnophyllum* sp. and *Neotemnophyllum breve*. Compared to the Iranian coral, the former has larger corallite diameter and a few more septa. The latter is more or less similar to the Iranian specimen in diameter and septal number but the Moroccan species shows thicker septa and larger free axial area.

Biogeographic implications and faunistic connections

Our knowledge about the coral composition of the Alborz Mountains, especially the Eastern Alborz during the Middle and Upper Devonian is very insufficient. This rare knowledge comes from a few works, appeared in Ghods (1982), Ashouri *et al*. (2008), Abbasi *et al*. (2014a), Abbasi *et al*. (2014b) and the present work. Undoubtedly, more reliable biogeographic and faunistic conclusions need much more researches.

Examination of the generic distribution of the Givetian and Lower Frasnian coral faunas in the Alborz Mountains reveals that these faunas are mostly characterized by genera as *Disphyllum*, *Spinophyllum*, *Temnophyllum*, *Macgeea*, *Hexagonaria*, *Glossophyllum* and *Chostophyllum*. This cosmopolitan composition is explained by high faunal exchange in the Givetian and Lower Frasnian (Oliver, 1977; Pedder and Oliver, 1990). Absence of many cosmopolitan taxa (e.g. *Grypophyllum*, *Acanthophyllum* and *Mesophyllum*) in the Alborz Mountains may be due to limited material or general rarity of some genera. This has been previously explained by Schröder (2004) for the coral faunas of the Karakorum Mountains in northern Pakistan. Generic composition of the coral faunas in the Alborz Mountains is represented by Old World Realm (OWR) taxa but Ghods (1982) reported genera (*Heliophyllum* and *Aulacophyllum*) which are typical for the Eastern America Realm (EAR). It seems that these assignments are questionable and his material needs to be revised.

At the species level, endemism is more or less remarkable among the Devonian corals of the Alborz Mountains. *Glossophyllum* sp., *Pseudozaphrentis* sp., *Temnophyllum* sp., and *Neotemnophyllum* sp. which have been described herein are forms which are confined to the Eastern Alborz Mountains. Abbasi *et al*. (2014b) reported *Temnophyllum* sp. 1 and *Temnophyllum* sp. 2 from the Givetian beds of the type section of the Khoshyeilagh Formation. These taxa are unique for Iran and show endemism in the studied areas.

As mentioned by Schröder (2004) and Abbasi *et al*. (2014), in spite of more or less similar generic composition, no faunistic link can be traced at the species level between the Middle and Upper Devonian coral faunas of the Alborz Mountains and the neighboring Karakorum Block, situated in the northern parts of Pakistan. Base on the present and previous works on rugose corals, a striking faunistic similarity or relation cannot be considered between faunas of the Alborz Mountains and neighboring regions such as Turkey, Helmand Block and Pamir (Tajikistan).

Occurrences of *Glossophyllum ceratites* described herein and the other taxa including *Spinophyllum arduum*, *Spinophyllum longiseptatum*, *Aristophyllum luetti* and *Glossophyllum ceratites* from the Givetian strata of the formation in the different outcrops, reported by Abbasi *et al*. (2014a) and Abbasi *et al*. (2014b) show a faunistic link between the Alborz Mountains and the Eifel region, Germany during the Givetian time. Presences of *Spinophyllum blacourti*, *Temnophyllum imperfectum* and *Aristophyllum luetti* indicate faunistic affinity of the Givetian corals of the Alborz Range to the faunas, reported from south of Belgium. Weak faunistic link to the Canning Basin and Queensland, Australia can be considered by occurrences of

Temnophyllum occidentale, illustrated here and *Chostophyllum gregorii* and *Temnophyllum occidentale* (Abbasi *et al*., 2014b).

Sinodisphyllum is one of the main components of the Frasnian coral faunas of the Alborz Mountains. This genus has been mostly reported from South China (e.g. Sun, 1958; Liao and Birenheide, 1989) and Russia (e.g. Ivania, 1965). Presence of *Sinodisphyllum* has also been documented from Pakistan (Reed, 1922), Iran (Rohart, 1999; Abbasi *et al*., 2014), Belgium (Boulvain and Coen-Aubert, 2006) and Poland (Rohart, 2002). At species level, due to occurrence of *Sinodisphyllum kielcense* in the Frasnian rocks of the Holy Cross Mountains in Poland, south of Belgium and Boulonnais in France, faunistic connection can be considered between the Alborz Mountains and the mentioned area in Frasnian. Based on presences of *Sinodisphyllum variable* and *Sinodisphyllum litvinovitshae*, reported from the Frasnian rocks of the type section of the Khoshyeilagh Formation in northeastern Iran, Abbasi *et al*. (2014a) indicated a faunistic affinity with south of China and Russia. *Neotemnophyllum* is a genus, confined mostly to China but it has been described from the Upper Givetian rocks of Morocco in north of Africa (Coen-Aubert, 2005). Morphologically, it seems that the Iranian species of *Neotemnophyllum* is more similar to the Chinese specimens than the Moroccan ones.

Acknowledgments

We thank Dr. Marie Coen-Aubert for her comments and suggestions on some taxa, described in this article.

References

Abbasi, M. A., Khaksar, K., Ashouri, A. R., 2014a. Some rugose corals from the Devonian (Givetian and Frasnian) of Northeastern Iran. Neues Jahrbuch für Geologie und Paläontologie, 271(2): 123-139.

Abbasi, M. A., Ashouri, A. R., Khaksar, K., 2014b. Solitary rugose corals from the Givetian of the Khoshyeilagh Formation (Eastern Alborz Mountains, NE Iran). Palaeodiversity, 7: 1–21.

Alavi, M., 1996. Tectonostratigraphic synthesis and structural style of the Alborz mountain system in northern Iran. Journal of Geodynamics, 21: 1-33.

Ashouri, A. R., 1990. Devonian and Carboniferous conodont faunas from Iran. Ph. D. thesis, University of Hull, UK. 351 pp.

Ashouri, A. R., 1994. The stratigraphical position of members 1 and 6 of Khoshyeilagh Formation based on conodont fauna and introducing of three conodont zones from member 6. GeoSciences Scientific Quarterly Journal, 13: 64-71 [in Persian].

Ashouri, A. R., 2001. Middle Devonian-Early Carboniferous conodont faunas from the Khoshyeilagh Formation, Alborz Mountains, north Iran. 15th International Senckenberg Conference, Joint Meeting IGCP 421/SDS, May 2001, Abstracts. Frankfurt am Main.

Ashouri, A. R., Ghadimi, B. M., Khaksar, K., 2008. Introduction of Frasnian corals from Chahar- Borj Section, NW Esfaraein, Eastern Alborz Mountains. Iranian Journal of Geology, 7: 71-80 [in Persian with English abstract].

Besprozvannykh, N. I., Dubatolov, V. N., Kravtsov, A. G., Latypov, Yu. Ya., & Spassky, N. Ya., 1975. Devonskie rugozy Taymyro-Kolymskoy provintsii. Trudy Instituta Geologii I Geofiziki, Akademiya Nauk SSSR, Sibirskoe Otdelenie, 228: 1-172.

Birenheide, R., 1962. Die Typen der Sammlung Wedekind aus den Familien Cyathophyllidae und Stringophyllidae (Rugosa). Senckenbergiana lethaea, 43(2): 101-123. Frankfurt am Main.

Birenheide, R., 1969. Typen mittel - und oberdevonischer Rugosa aus der Sammlung Golffuss. Senckenbergiana lethaea, 50 (1): 37-55. Frankfurt am Main.

Boulvain, F., Coen-Aubert, M., 1998. Le monticule frasnien de la Carrière du Nord à frasnes (Belgique): sédimentologie, stratigraphie séquenteille et coraux. Service Géologique de Belgique, Professional Paper, 1997/3 (285): 1-47.

Boulvain, F., Demany, B., Coen-Aubert, M., 2005. Frasnian carbonate buildups of southern Belgium: the Arche and Lion members interpreted as atolls. Geologica Belgica, 8: 69-89.

Boulvain, F., Coen-Aubert, M. 2006. A fourth level of Frasnian carbonate mounds along the south side of the Dinant Synclinorium (Belgium). Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre, 76: 31-51.

Bozorgnia, F., 1973. Paleozoic foraminiferal biostratigraphy of Central and East Alborz Mountains, Iran. National Iranian Oil Company, Geological Laboratories, 4: 1–185.

Brice, D., Lafuste, J., de Lapparent, A. F., Pillet, J., Yassini, I., 1974. Etude de deux gisements paleozoiques (Silurien et Devonien) de l'Elbourz oriental (Iran). Annales de la Societe Geologique du Nord, 93: 177-218.

Brice, D., Jenny, J., Stampfli, G., Bigey, F., 1978. Le Devonien de l'Elbourz oriental: Stratigraphie, paleontologie

(brachiopodes et bryozoaires), paleogeographie. Rivista Italiana di Paleontologia e Stratigrafia, 84: 1-56.
Coen-Aubert, M., 1995. Contribution à l'ètude des rugueux frasniens de la Province du Hunan en Chine. Bulletin de la Sociètè belge de Gèologie, 103: 161-169.
Coen-Aubert, M., 1996. Siphonophrentides et Cyathophyllides pre Ás de la limite Eifelien-Givetien aÁ Resteigne (Ardenne, Belgique). Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre, 66: 19-36.
Coen-Aubert, M., 1997. Rugueux solitaires près de la limite Eifelien-Givetien à Pondrôme (Belgique). Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre, 67: 5-24.
Coen-Aubert, M., 2002. Temnophyllids and Spinophyllids (Rugosa) from the Givetian Mont d'Haurs Formation in Belgium. Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre, 72: 5-24.
Coen-Aubert, M., 2003. Description of a few rugose corals from the Givetian Terres d'Haurs Formation in Belgium. Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre, 73: 11-27.
Coen-Aubert, M., 2005. Fasciculate and solitary rugose corals from the Upper Givetian of the Tafilalt and the Ma'der (Morocco). Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre, 75: 67-85.
Dana, J. D., 1846. Genera of fossil corals of the family Cyathophyllidae. American Journal of Science and Art, 1 (2): 178-189. Philadelphia.
Ehrenberg, C. G., 1834. Beitrage zur physiologischen Kenntnis der Corallenthiere im allgemeinen, und besonders des rothen Meeres, nebst einem Versuche zur physiologischen Systematik derselben: KgI. Akad. Wiss. Berlin Abh. (1832), p. 225-380.
Federowski, J., 2003. Typ Coelenterata, Gromada Anthozoa Ehrenberg, 1834, Podgromady: Rugosa Milne Edwards & Haime, 1850-Dividocorallia Fedorowski, 1991. In Malinowska, L. (ed.) Budowa Geologiczna Polski, tom 3, Atlas Skamienialosci przewodnich i charakterystycznych, czesc 1b-z.1, Dewon. Panstwowy Instytut Geologiczny, Warszawa, 49-124 and Atlas.
Fontain, H., 1961. Les madreporaires Paleozoiques du Viet-nam, du Laoset du Cambodge. Archives Geologique du Viet-nam, 5: text, 276 pp.
Ghods, P., 1982. Rugose Korallen des Givetium und Frasnium im Elburz-Gebirge (Nord-Iran). Ph. D. thesis, University of Hamburg, Germany. 171 pp.
Goldfuss, G. A., 1826-1833. Petrefacta germaniae (Arnz ed.), 252 pp. Düsseldorf.
Golonka, J., Ross, M. I., Scotese, C. R. 1994. Phanerozoic paleogeographic and paleoclimatic modeling maps. In: A. F. Embry, B. Beauchamp & D. J. Glass (Eds), Pangea: Global environments and resources. Canadian Society of Petroleum Geology, Memoir, **17**: 1-47.
Gürich, G., 1896. Das Palaeozoicum im polnischen Mittelgebirge. Verhandlungen der Russischen Kaiserlichen Mineralogischen, Gesettschaft, series 2, 32, 540 p.
Hall, J., Whitfield, R. P., 1873. Descriptions of new species of fossils from the Devonian rocks of Iowa. 23rd Annual Report. New York State Cabinet of Natural History, 223-239.
Hamdi, B., Janvier, P., 1981. Some conodonts and fish remains from Lower Devonian (lower part of the Khoshyeylaq Formation) north east Shahrud, Iran. Geological Survey of Iran, Report 49: 195-210.
Hill, D., 1939. The Devonian rugose corals of Lilydale and Loyola, Victoria. Proceeding of the Royal Society of Victoria, new series, 51: 219-256.
Hill, D., Jell, J. S., 1970. Devonian corals from the Canning Basin. Western Australia. Geological Survey of Western Australia Bulletin, 121: 1 -158.
Hill, D., 1981. Treatise on Invertebrate Paleontology, Part F. Coelenterata. Supplement I. Rugosa and Tabulata. 378 pp.
Ivania, V. A., 1965. Devonskie korally Sayano-Altayskoy gornoy oblasti. Izd. Tomskogo Universiteta. Tomsk. 398 pp.
Khaksar, K., Rafatbahari, T., Ashouri, A. R., 2006. Devonian Rugose Corals from Bahram Formation, South of Osbak - Kuh (Iran). GeoSciences Scientific Quarterly Journal, 59: 56-69. [in Persian with English abstract].
Lang, W. D., Smith, S., Thomas, H. D., 1940. Index of palaeozoic coral genera. British Museum (Natural History): VIII, 231 pp.
Liao, W. H., Birenheide, R., 1989. Rugose corals from the Frasnian of Tushan, Province of Guizhou, South China. Courier Forschungsinstitut Senckenberg, 110: 81–103.
Lütte, B. P., 1987. *Glossophyllum*-Arten aus dem Mitteldevon der Eifel (Rugosa; Rheinisches Schiefergebirge). Senckenbergiana lethaea, 67 (5/6): 433-457. Frankfurt am Main.
Lütte, B. P., 1990. Horn-und kegelförmige rugose Korallen aus dem Mitteldevon der Eifel. Senckenbergiana lethaea, 70 (4/6): 297-395. Frankfurt am Main.
Mansuy, H., 1913. Paleontologie de l' Annam et du Tonkin. Mèmoires du Service Gèologique de l' Iindochine, 2 (3) : 1-48.
McLean, R., 1993. The Devonian rugose coral family Charactophyllidae Pedder. In Proceedings of the VI International Symposium on Fossil Cnidaria and Porifera. P. Oekentorp-Küster. ed. Courier Forschungsinstilut Senckenberg, 164: 109-118.

Mclaren, D. J., Norris, A. W., 1964. Fauna of the Devonian Horn Plateau Formation, District of Mackenzie. Geological Survey of Canada Bulletin, 114, 74 p.

Merriam, C. W., 1973. Middele Devonian Rugose Corals of the Central Great Basin. Geological Survey of U. S. Professional Paper, 799, 53 pp.

Oliver, W. A., 1977. Biogeography of late Silurian and Devonian rugose corals. *Palaeogeography, Palaeoclimatology,* Palaeoecology, 22 (2): 85–135.

Oliver, W. A., Sorauf, J. E., 1988. *Heliophyllum* Hall and *Charisphyllum* n. gen. (Devonian rugose corals) of the Cantabrian Mountains (NW Spain). Trabajos de Geologica, Uinversidad de Oviedo, 17: 3-17.

Pedder, A. E. H., 1982. *Chostophyllum*, a new genus of charactophyllid corals from the Middle Devonian of western Canada. Journal of Paleontology, 56 (3): 559-582. Ithaka.

Pedder, A. E. H., Oliver, W.A., 1990. Rugose coral distribution as a test of Devonian palaeogeographic models. In: McKerrow W.S., Scotese C.R. (Eds.) Palaeozoic Palaeogeography and Biogeography. Geological Society of London, Memoir, 12: 267-275.

Reed, F. R. C., 1922. Devonian fossils from Chitral and Pamirs. Geological Survey of India. Palaeontologia Indica, 6 (2): 1–134.

Rohart, J. Cl., 1988. Rugueux Givetiens et Frasniens de Ferques (Boulonnais - France). In: BRICE, D. (Editor), Le Devonien de Ferques, Bas-Boulonnais (N. France*).* Biostratigraphie du Paleozoique, 7: 231-297.

Rohart, J. Cl., 1999. Palaeozoic rugose corals from Central and Eastern Iran (A.F. LAPPARENT and M. ZAHEDI collections). Annales de la Société Géologique du Nord, T. 7: 47-70.

Rohart, J. Cl., 2000. Frasnian rugose corals from Chah- Riseh (Esfahan Province, central Iran). Annales de la Société Géologique du Nord, T. 8: 67-71.

Rohart, J. Cl., 2002. Coraux rugueux du Membre des Pâtures, Formation de Beaulieu (Frasnien de Ferques, Boulonnais*).* Annales de la Société Géologique du Nord, 9: 111-128.

Rozkowska, M., 1979. Contribution to the Frasnain Tetracorals from Poland. Palaeontologica Polonica, 40: 3-56.

Schlüter, C., 1885. Über einige neue Anthozoen aus dem Devon. Verh. Naturhist. Verhandlungen des Naturhistorischen Vereins der Preussischen Rheinlande und Westfalens, 44: 114-151.

Schlüter, C., 1889. Anthozoen des rheinischen Mitteldevon. Abhandlungen zur geologischen Specialkarte von Preusen und den thuringischen Staaten, 8 (4): I-X, 259-465.

Schröder, S., 1998. Rugose Korallen und Stratigraphie des oberen Eifelium und unteren Givetium der Dollendorfer Mulde/Eifel. (Mitteldevon; Rheinisches Schiefergebirge). Courier Forschungsinstitut Senckenberg, 208: 1-135.

Schröder, S., 2004. Devonian rugose corals from the Karakorum Mountains (northern Pakistan). Rivista Italiana di Paleontologia e Stratigrafia, 110: 605-641.

Schröder, S., 2005. Stratigraphie und Systematik rugoser Korallen aus dem Givetium und Unter-Frasnium des Rheinischen Schiefergebirges (Sauerland/Bergisches Land). Zitteliana, B25: 39-116. München.

Schröder, S., Kazmierczak, M., 1999. The Middle Devonian „coral-reef" of Quihlane (Morroco) – New data on the geology and rugose coral fauna. Geologica et Palaeontologica, 33: 93-115. Marburg.

Schröder, S., Salerno, C., 2001. Zur Korallenfauna und Fazies untergivetischer (Cürten-/Dreimühlen-Formation) Kalksteinabfolgen der Dollendorfer Mulde (Rheinisches Schiefergebirge/Eifel). Senckenbergiana lethaea, 81 (1): 111-133. Frankfurt am Main.

Simpson, G. B., 1900. Preliminary descriptions of new genera of Paleozoic rugose corals. New York State Museum. Bulletin, 39: 199-222.

Smith, S., 1945. Upper Devonian corals of the Mackenzie River region, Canada. Geological Society of America, Special Paper, 59: 1-126.

Sorauf, J. E. 1998. Frasnian (Upper Devonian) rugose corals from the Lime Creek and Shell Rock Formation of Iowa. Bulletins of American Palaeontology, 113 (355): 159.

Stampfli, G. M., 1978. Étude géologique générale de l'Elburz oriental au S de Gonbad-e-Qabus Iran N-E. Thèse présentée à la Faculté des Sciences de l'Université de Genève. 329 pp.

Sun, Y. C., 1958. The Upper Devonian coral faunas of Hunan. Palaeontologia Sinica, 144 (new series, B, 8): 1-28.

Tsien, H. H., 1969. Contribution à l'étude des Rugosa du Couvinien dans la région de Couvin. Mémoires de l'Institut Géologique de l'Université de Louvain, 25: 17.

Yu, C. M., Kuang, G. D., 1982. Late Middle Devonian rugose corals from Liujing, Heng Xian, Guangxi and their paleoecological significance. Bulletin of the Nanjing Institute of Geology and Palaeontology, Academia Sinica, 4: 241–278.

Yu, C. M., Kuang, G. D., 1984. Tetracorals from MiddleUpper Devonian boundary beds and Upper Devonian in Liujing, Heng Xian of Central Guangxi. Bulletin of the Nanjing Institut of Geology and Palaeontology, Academia, Sinica 7: 127-164.

Walther, C., 1929. Untersuchungen über die Mitteldevon - Oberdevongrenze. Zeitschrift der deutschen geologischen

Gesellschaft, Abhandlungen, (A) 80: 97-152.
Wedekind, R., 1922. Zur Kenntnis der Stringophyllen des oberen Mitteldevon. Sitzungsberichte der Gesellschaft zur Beforderung der Gesamten Naturwissenschaften zu Marburg, 1921 (1): 1-16.
Wedekind, R., 1923. Die Gliederung des Mitteldevons auf Grund von Korallen. Sitzungsberichte der Gesellschaft zu Befo Èrderung der gesamten Naturwissenschaften zu Marburg, 1922: 24-35.
Wedekind, R., 1924. Das Mittledevon der Eifel. Eine biostratigraphische Studie. I. Teil. Die Tetrakorallen des unteren Mitteldevon. Schr. Ges. Beförderung ges. Naturwiss. Marburg, 14 (3): 1-93.
Weddige, K., 1984. Zur Stratigraphie und Paläogeographie des Devons und Karbons von NE-Iran. Senckenbergiana Lethaea, 65: 179-223.
Wendt, J., Kaufmann, B., Belka, Z., Farsan, N., Bavandpur, A., 2005. Devonian/Lower Carboniferous stratigraphy, facies patterns and palaeogeography of Iran. Part II. North and central Iran. Acta Geologica Polonica, 55 (1): 31–97.
Wrzolek, T., 1993. Rugose corals from the Devonian Kowala Formation of the Holy Cross Mountains. Acta Palaeontologica Polonica, 37 (2-4): 217-254.
Wrzolek, T., Wach, P., 1994. Tetracoral genus *Spinophyllum* in the Devonian of the Holy Cross Mountains, Poland. Geologia, 12/13: 47-63.
Zhen, Y. Y., Jell, J. S., 1996. Middle Devonian rugose corals from the Fanning River Group, North Queensland, Australia. Palaeontographica A, 242 (1-3): 15-98.