

First report of Devonian corals from the Bitlis-Pötürge Massif (SE Turkey): a rare occurrence of corals on the northern margin of Gondwana

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ABSTRACT

The Bitlis-Pötürge Massif of SE Turkey is a metamorphic belt separating the Arabian Plate from the Taurides. It includes a non-metamorphic Palaeozoic sequence that contains locally fossiliferous strata. Here is reported for the first time an assemblage of Upper Devonian rugose and tabulate corals from the Meydan Formation, composed of the rugose *Frechastraea schafferi* (PENECKE), *Peneckiella* cf. *teichertii* HILL, *Pseudopexiphyllum supradevonicum* (PENECKE), and *Macgeea desioi* VON SCHOUPPÉ, and the tabulate *Thamnopora reticulata* (DE BLAINVILLE), *Alveolites* ex. gr. *suborbicularis* and *Scoliopora* sp. The rugose corals suggest a Late Frasnian age. The palaeobiogeographic affinities of corals are discussed. The species *F. schafferi* and the genus *Pseudopexiphyllum* –so far only reported from Turkey, Iran and Afghanistan– are probably limited to the northern margin of Gondwana and therefore diagnostic for this palaeogeographic area. Until now, the northern margin of Gondwana yielded very few Upper Devonian corals so this occurrence in SE Turkey is particularly important to estimate the relationship between these corals and the ones from the northern margin of the Palaeotethys Ocean.

KEYWORDS | Arabian Plate; Frasnian; *Frechastraea*; Rugosa; Tabulata.

INTRODUCTION

Devonian corals have rarely been reported from Turkey, and only few of them have received a proper description. Heritsch and Gaertner (1929) and Charles (1933) reported some tabulate and rugose corals from the Yılanlı Formation, NW Turkey, mostly of Lower-Middle Devonian age, later Kullmann (1973) reported small solitary undissepimented rugose corals from Lower-Middle Devonian deep-water sediments in the Istanbul area. The first and yet the only comprehensive study of Devonian corals from NW

Turkey was provided by Birenheide and Kaya (1987) who described a diverse coral fauna of Eifelian age (Middle Devonian) from Adapazarı. Tchiatcheff (1897) cited some corals from southern Turkey in the faunal list of his monography, and Penecke (1903) was the first to describe corals from southern Turkey based on material collected by Schaffer (1901) in Hadschin near Feke. Heritsch (1928) and Ünsalaner (1951) reported some colonial rugose and tabulate corals from the Taurides (in the vicinity of Yedi Oluk and of Saimbeyli respectively) but most of those species are *nomen oblitum*. Flügel (1955) and Flügel

and Flügel (1961) described some rugose and tabulate corals, along with stromatoporoids and chaetetid sponges, from Yahyalı (Aladağ Mts.), probably collected in Middle Devonian formations. Hubmann (1991, 1992) described the fauna collected by Kiratlıoğlu (1959) near Feke. This fauna is younger than the one described by Flügel and Flügel (1961) and attributed to the upper Givetian and Frasnian (Middle-Upper Devonian) by Kiratlıoğlu (1959). Oekentorp and Schröder (2001) reported a single occurrence of rugose coral in the Frasnian (Upper Devonian) in the Sultan Dağ in the Geyik Dağ Unit. Coen-Aubert *et al.* (2013) reported a Frasnian coral fauna composed of cosmopolitan genera also from the Geyik Dağ, in the Kozan area near Adana.

Here, we document for the first time the Devonian coral fauna from the Meydan Formation in the Bitlis-Pötürge Massif (SE Turkey, Fig. 1) and discuss its age and affinities.

GEOLOGICAL SETTINGS

The Bitlis-Pötürge Massif forms an arcuate metamorphic belt, about 30km wide and 500km long, rimming the Arabian Platform in SE Turkey. It is separated from the Arabian Platform by a narrow belt of Upper Cretaceous to Eocene flysch and ophiolitic mélangé, and Miocene sediments (Oberhanslı *et al.*, 2010) (Fig. 1). The massif includes a Precambrian basement and an overlying

Phanerozoic sequence (Cavazza *et al.*, 2018; Okay *et al.*, 1985). In an early description, Tolun (1953) interpreted the metamorphic rocks of the Bitlis-Pötürge complex as forming the basement of the region. According to Kellogg (1960) and Göncüoğlu and Turhan (1984) the Bitlis-Pötürge metamorphics are the equivalents of the Arabian autochthonous succession and, accordingly, a Devonian to Upper Cretaceous age was assigned for the metasediments.

The Paleozoic rocks of the Bitlis-Pötürge Massif are grouped into two stratigraphic rock associations that are separated by an angular unconformity (Fig. 1). The lower association (Hizan Group) comprises metamorphic rocks including micaschists, paragneisses, amphibolites and eclogites (Ustaömer *et al.*, 2012).

The upper association (Mutki Group) is a greenschist facies sedimentary succession represented by quartzites, limestones and dolomite lenses, metaclastics and metavolcanics (Okay *et al.*, 1985; Ustaömer *et al.*, 2012) (Figs. 1; 2). Fossils from the metasediments indicate a Middle Devonian age for the lower part of the succession (Göncüoğlu and Turhan, 1984). The base of this rock group is composed of the Devonian Meydan Formation comprising meta-conglomerates, quartzites and greenschists with limestone interlayers, “reef” limestones and albite-chlorite actinolite-chloritoid schists of probably volcanogenic origin (Oberhanslı *et al.*, 2010). The following fossils have

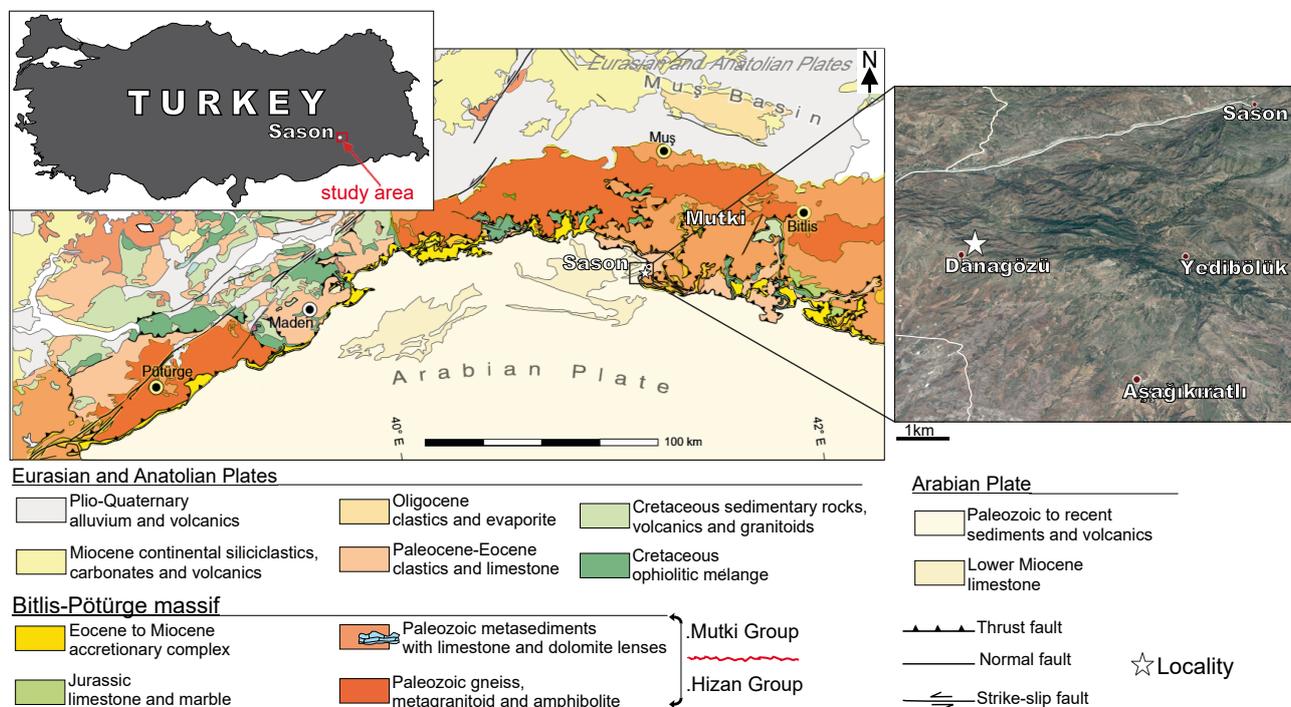


FIGURE 1. Geological map of the Bitlis-Pötürge Massif, SE Turkey, showing the situation of the sampled section (modified from Cavazza *et al.*, 2018). The sampling outcrop coordinates are 38°14'34.31"N 41°19'17.26"E.

been recognised in the Meydan Formation in the east of the Bitlis-Pötürge: *Actinostroma* spp., *Thamnopora* sp., *Favosites* sp. and crinoid fragments. According to these fossils the unit is Givetian-Frasnian in age (Göncüoğlu and Turhan, 1984).

During the Devonian, the Eastern Taurides –including areas that are now part of the Bitlis-Pötürge Massif– were situated along the northern margin of Gondwana, south of the later Cimmerian Terranes rifting line. Wehrmann *et al.* (2010), based on detailed sedimentological and stratigraphic work, suggested that the Upper Devonian strata of the Eastern Taurides were deposited in a shallow-water, mixed carbonate and siliciclastic shelf. Preliminary data on the Meydan Formation are in agreement with previously published interpretations.

RESULTS

Coral association

The coral specimens studied here were found in the Meydan Formation during a geological survey in the western regions of the Bitlis city, in the Bitlis-Pötürge

collision zone of Turkey (Fig. 1). The corals are from the middle part of the Meydan Formation (Fig. 2A, B) in the Danagözü section, located approximately 7km southwest of Sason. All specimens come from a single clayey limestone bed, 20-30cm-thick, which yielded a very poor fossil assemblage but relatively well preserved compared to the fossils occurring in the recrystallized limestone. The fossiliferous limestone is a bioclastic floatstone with a weathered ferruginous dolomitic matrix. Besides corals, crinoids, brachiopods and bryozoans are abundant (Fig. 2C). The assemblage is dominated by colonial rugose corals, represented by the cerioid *Frechastraea schafferi* (PENECKE, 1903), the fasciculate *Peneckiella* cf. *teichertii* HILL, 1954 and the dendroid *Pseudopexiphyllum supradevonicum* (PENECKE, 1903). The tabulate corals are represented by the ramose *Thamnopora reticulata* (DE BLAINVILLE, 1830) and *Scoliopora* sp. and the massive *Alveolites* ex. gr. *suborbicularis* (Figs. 3; 4). Solitary rugose corals are under-represented in the sample with the occurrence of a single specimen of *Macgeea desioi* VON SCHOUPPE, 1965. This specimen is very similar, however slightly smaller, than those described by Rohart (1999) from the Frasnian of eastern Iran. It is rather weathered and serves as an anchorage for a small *Frechastraea* colony.

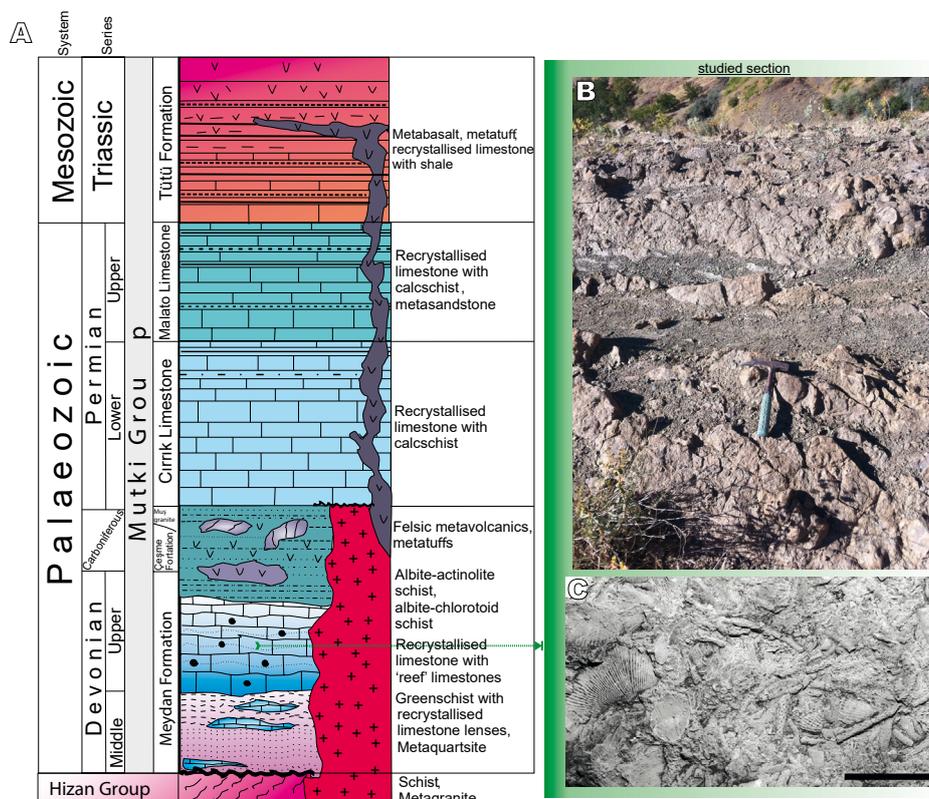


FIGURE 2. A) Palaeozoic stratigraphic section of the Bitlis-Pötürge Massif (modified from Göncüoğlu and Turhan, 1984). B) Field view of the fossiliferous horizon in the Meydan Fm., (hammer for scale). C) Bed surface with abundant brachiopods and bryozoan debris (scale bar: 10mm).

SYSTEMATIC PALAEOONTOLOGY

The fossil material was deposited in the Animal and Human Palaeontology collection of University of Liège, Belgium, under prefix ULg.PA.BM.

Class: Anthozoa EHRENBERG, 1834

Subclass: Rugosa MILNE-EDWARDS AND HAIME, 1851

Order: Stauriida VERRILL, 1865

Family: Phillipsastreidae ROEMER, 1883

***Peneckiella* cf. *teichertii* HILL, 1954**

? 1999 *Peneckiella* cf. *cylindrica* (YOH, 1937), Rohart, p. 60, Pl. 10, figs 1-2.

? 2003 *Peneckiella* *abnorma* HE IN FAN *et al.*, p. 222,

Pl 3, fig 1a-b.

Figs. 3A-B

Material. One single fragment of colony (ULg.PA.BM.6) c. 10cm high and 10cm large, 2 transverse sections and 2 longitudinal thin sections.

Description. Fasciculate colony with lateral offsets. Corallites cylindrical, 6-6.5mm in diameter (tabularium 4-5mm). Twenty to twenty-two septa of each order. Major septa long, commonly reaching the axis where some are joined, but withdrawn in more mature stages, thin with a cuneiform base. Cardinal major septum shorter in some mature corallites. Minor septa short, entering slightly into the tabularium. Dissepimentarium comprising one

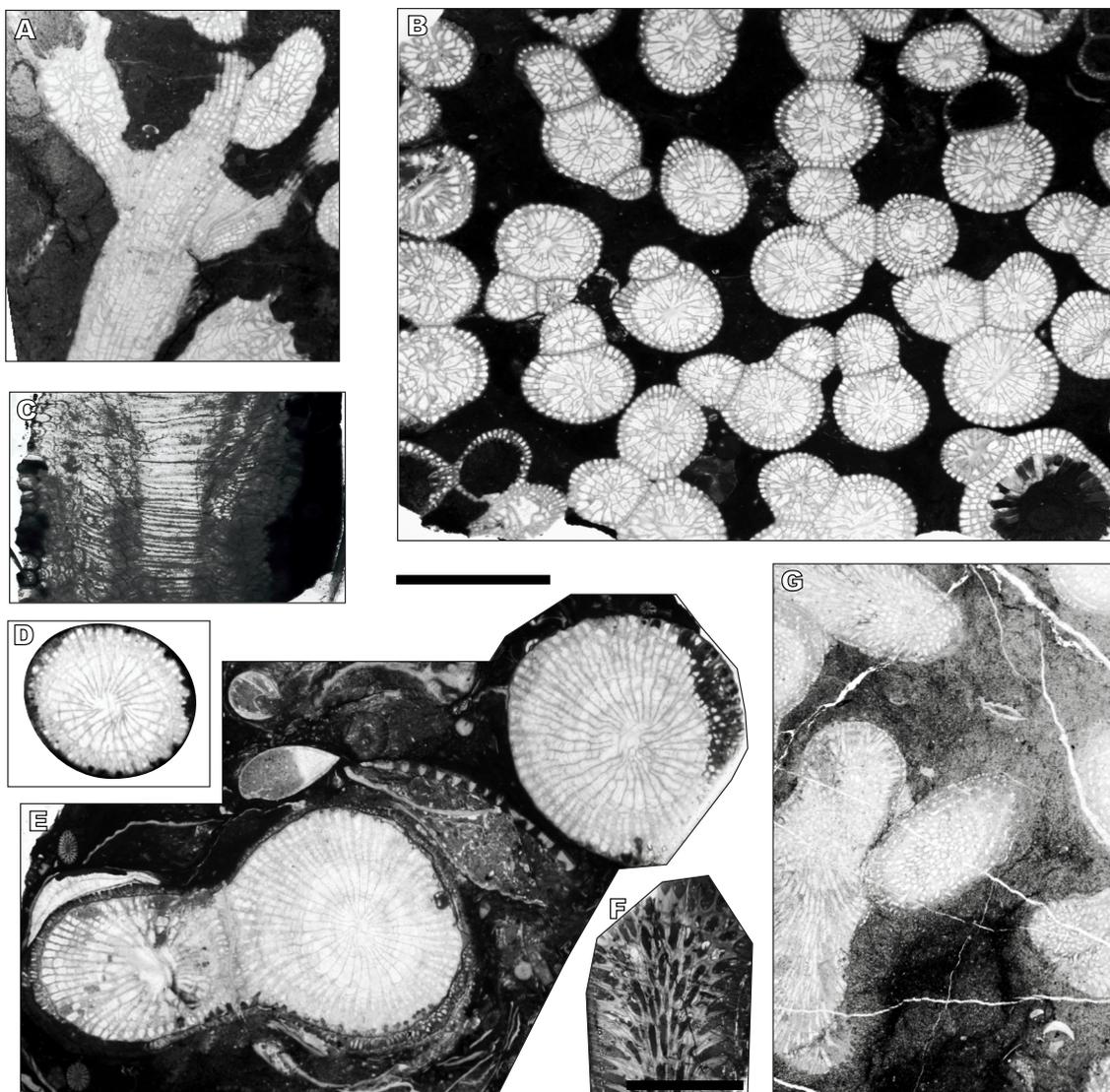


FIGURE 3. Frasnian rugose and tabulate corals from the Meydan Fm. A-B) *Peneckiella* cf. *teichertii* (A: longitudinal section, B: transverse section), specimen ULg.PA.BM.6. C-E) *Pseudopexiphyllum supradevonicum* (C: longitudinal section, D-E: transverse sections), specimen ULg.PA.BM.1; F) *Thamnopora reticulata*, longitudinal section, specimen ULg.PA.BM.2. G) *Scoliopora* sp., specimen ULg.PA.BM.3. Scale bars: 10mm.

complete and occasionally an additional incomplete row of concentric dissepiments, usually thickened. Dissepiments peneckielloid and regular in size in longitudinal section. Scattered horseshoe dissepiments appear in larger corallites. Tabulae complete, domed, with some irregularly-spaced lateral tabellae. Outer wall thick and locally festooned.

Discussion. This colony is similar to *Peneckiella minima* (ROEMER, 1855) (=“*Cyathophyllum minus*” in PENECKE, 1903) that was previously reported from the Turkish Taurides by Penecke (1903), Flügel (1956) and Oekentorp and Schröder (2001) but has larger corallites and longer septa. It shows many similarities with *Peneckiella isylica* (BULANKER, 1958), including size but the present species has shorter minor septa and very few dissepiments (one or two rows) whereas *P. isylica* has a larger dissepimentarium. From Pakistan, von Schouppé (1965) described *Disphyllum casepitosum tricyclum* n.sp. that most probably is a *Peneckiella* with larger corallites (8-13mm in diameter and 28 septa of each order) and that developed a third order of septa. From Western Australia, Brownlaw and Jell (2008) reported *Peneckiella teichert* HILL, 1954 which has slightly smaller corallites (4-6mm in diameter and 17-22 septa of each order) but having, like the present species, scattered horseshoe dissepiments. A slightly larger species was described by Fan *et al.* (2003) from Xizang under the name *Peneckiella abnormalis* HE IN FAN *et al.*, 2003 which has dimensions similar to the Turkish colony (6-8mm in diameter), similar number of septa (20-22 thin septa of each order) and a single row of dissepiments, peneckielloid to horseshoe in shape. *P. abnormalis*, together with the present material, probably enters in the range of variability of the Australian species *P. teichert* HILL, 1954, but additional material is needed to validate the synonymy. Similarly, the isolated corallites described from the Frasnian strata of the Albroz Mountains (Iran) by Rohart (1999) under the name *Peneckiella?* cf. *cylindrica* (YOH, 1937), could possibly be included in that species. Hence, the Turkish colony is provisionally referred with some doubts to *P. teichert* HILL, 1954.

Occurrence. Small-sized species of *Peneckiella* occur widely in the Frasnian strata (see MacLean, 2005 for a recent review). *P. teichert* HILL, 1954 was described in the Canning Basin (Western Australia) by Hill (1954) then additional material was described by Hill and Jell (1970) and Brownlaw and Jell (2008) from the upper part of the Frasnian (Virgin Hill and Pillara formations). The possible synonyms *P. abnormalis* Fan *et al.*, 2003 and *P.?* cf. *cylindrica* (YOH, 1937) are also Frasnian in age.

***Pseudopexiphyllum supradevonicum* (PENECKE, 1903)**

*1903 *Thamnophyllum supradevonicum* n.sp., PENECKE, p. 144, Pl. 4, fig. 1.

1949 *Macgeea* (*Macgeea*) *supradevonica* (PENECKE),

von Schouppé, p. 168, Pl. 12, figs 51-52.

non 1953 *Macgeea* aff. *supradevonica* (PENECKE), Rózkowska, p. 29, Pl. 3, fig. 11.

1991 *Pseudopexiphyllum supradevonicum* (PENECKE, 1903), Hubmann, p. 161, fig. 8, Pl. 2, figs 3-6.

Figs. 3C-E

Diagnosis. After Penecke (1903), colony dendroid with cylindrical corallites bearing strong rugae, 10-14mm in diameter, having 24-28 septa of each order. Major septa withdrawn from the axis, leaving a free space up to 1/5 of the corallite diameter. Minor septa half as long as the major ones. Dissepimentarium composed of three zones: an external zone of small dissepiments steeply inclined towards the periphery, a single row of horseshoe dissepiments and several rows of smaller and flatter dissepiments becoming more declined towards the tabularium. Tabularium complete, made of sub-horizontal tabulae slightly depressed axially.

Material. One colony (ULg.PA.BM.1), 4 transverse thin sections and 2 longitudinal thin sections.

Description. Fragment of a small dendroid colony with cylindrical corallites and many offsets, encrusted by bryozoans (Fig. 3E). Corallites 12-18mm in diameter (tabularium 7-8mm), having 28-32 septa of each order. Major septa long, almost reaching the axis but leaving an empty zone of 1-2mm-wide, straight and thick in the dissepimentarium, thin and wavy in the tabularium, some being hooked in the central part of the tabularium. Minor septa long, reaching the inner margin of the dissepimentarium, thinner than the major septa. Both orders of septa carinate in the outer dissepimentarium. Dissepimentarium divided in three zones: an outer zone made of 1-2 rows of large globular dissepiments declined towards the periphery (concavity towards the periphery in transversal section), commonly filled with sediment; a middle zone of thickened horseshoe dissepiments with rounded shape in longitudinal section; an inner zone of 4-8 rows of small densely-packed concentric dissepiments declined towards the tabularium, the innermost row being sub-vertical in longitudinal section. Tabularium made of flat-topped or slightly concave regularly-spaced mesa-shaped tabulae. Outer wall relatively thin but commonly weathered out.

Discussion. This specimen is very similar to those described by Hubmann (1992) from localities close to the type locality of the species (Penecke, 1903). The major difference resides in the thickening of the septa, more intensely developed in the present colony compared to Hubmann's and Penecke's colonies. However, in juvenile corallites, the thickening and carination are not so pronounced. *Pseudopexiphyllum occultum* SCHRÖDER,

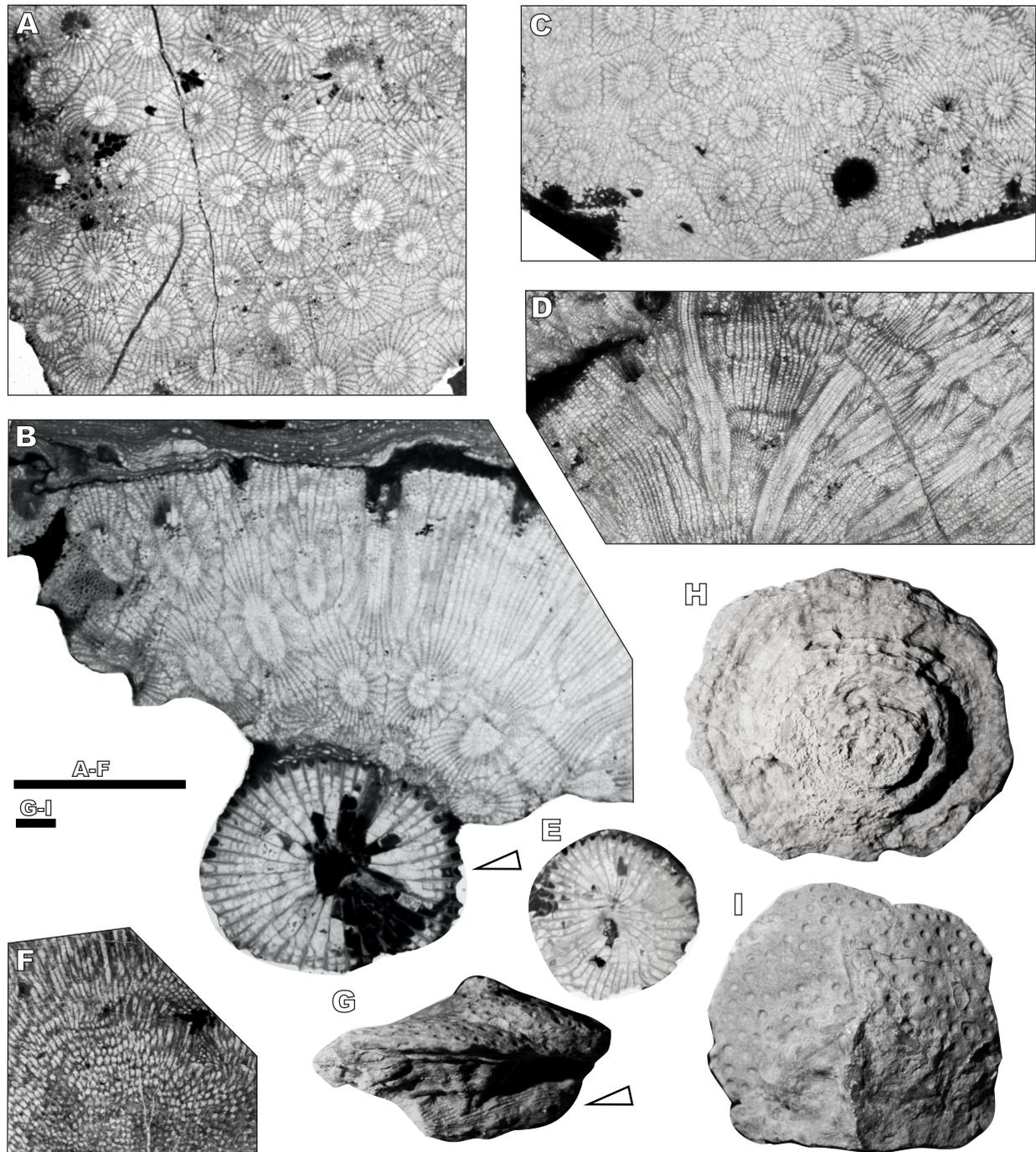


FIGURE 4. Frasnian rugose and tabulate corals from the Meydan Fm. A-D, G-I) *Frechastraea schafferi* (A and C transverse sections, D longitudinal section, G external lateral view of the colony, H external view of aboral face, I external view of oral face), A-B, G) specimen ULg.PA.BM.5.I; C-D, H-I) specimen ULg.PA.BM.4; note the corallite of *Macgeea* serving as anchorage for the colony (arrows); B, E) *Macgeea desioi* in transverse section, specimen ULg.PA.BM.5.III; F) *Alveolites* ex. gr. *suborbicularis*, specimen ULg.PA.BM.5.II. Scale bars: 10mm.

2004 differs from *P. supradevonicum* (PENECKE, 1903) by having larger corallites (20-25mm), but has similar number of septa (29-33). The genus *Pseudopexiphyllum* HUBMANN, 1992 can be regarded as a colonial *Macgeea* WEBSTER, 1899 with which it shares many structural elements, notably the multizonal dissepimentarium (see

Hubmann, 1992; Schröder, 2004). MacLean (2005) however considered that these characters are not sufficient to discriminate *Pseudopexiphyllum* HUBMANN, 1992 from *Thamnophyllum* PENECKE, 1894 as they appear occasionally in large-sized species of *Thamnophyllum*. Because the specimens of *Pseudopexiphyllum* spp.

are rare, further studies would be required to confirm that *Pseudopexiphyllum* HUBMANN, 1992 is synonym of *Thamnophyllum* PENECKE, 1894 or it has evolved from *Macgeea* WEBSTER, 1899 and therefore would be homeomorphic with *Thamnophyllum*.

Occurrence. *P. supradevonicum* is, so far, only documented from the Frasnian of the type area (Feke, SE Turkey; Hubmann, 1992; Penecke, 1903), in the Aladağ tectonostratigraphic unit.

***Frechastraea schafferi* PENECKE, 1903**

*1903 *Phillipsastraea schafferi* n. sp. – PENECKE, p. 147, Pl. 6, figs 1-2, Pl. 7, fig. 1.

non 1958 *Phillipsastraea schafferi* PENECKE – Bulvanker, p. 121, Pl. 58, fig. 2, Pl. 59, fig. 1a-b.

1959 *Phillipsastraea schafferi* PENECKE – Kiratlıoğlu, p. 17, 22.

1992 *Mixogonia schafferi* PENECKE – Hubmann, p. 159, Pl. 6, figs. 1-2.

Fig. 4A-D, G-I

Diagnosis. After Penecke, 1903, cerioid colonies with corallites 5-6mm in diameter having 26-28 septa. Major septa reaching the axis where they commonly fused in bundles of 2-3 septa. Minor septa confined in the dissepimentarium, no longer than half of the corallite radius. Septa rather constant in thickness in the dissepimentarium but thin in the tabularium. Axial ends of septa joined by axial part of the tabulae. Thickened inner row of dissepiments forming an inner wall. Dissepiments large and horizontal in periphery, smaller and more declined towards the axis, commonly vertical at the tabularium-dissepimentarium boundary. Tabulae dome-shaped in the axial part of the corallite.

Material. Two colonies (ULg.PA.BM.4 and ULg.PA.BM.5.I), 6 transverse thin sections and 2 longitudinal thin sections.

Description. Massive low-dome colonies with concave base and marked growth striae. Corallum pseudocerioid limited by a zigzag septotheca locally broken into segments, with polygonal corallites. Corallites 4-5mm wide with a tabularium 1.8-2.4mm in diameter. Thirteen to sixteen septa of both orders. Major septa long reaching the axis where they joined in bundles or connect to the upturned tabulae, locally forming an aulos-like structure open towards the cardinal fossula or completely close. Minor septa short, limited to the dissepimentarium or entering very shortly into the tabularium. Both orders of septa spindle-shaped thickened in the dissepimentarium, reaching a maximum thickness at the tabularium-dissepimentarium boundary. Both orders of septa locally carinate (yardarm carina). Major septa thin and straight in the tabularium. Dissepiments in

3-4 rows, the innermost being thickened in contact with the septa. In longitudinal section, dissepiments globose, larger and horizontal in the outer dissepimentarium, smaller and sub-vertical in the inner dissepimentarium. No horseshoe dissepiments. Tabulae slightly concave, with axial tabellae upturned towards the axis, occasionally forming an aulos-like column. Trabecular fan in the thickened part of the inner dissepimentarium.

Discussion. The present specimens, are very similar to those described by Penecke (1903) under the name *Phillipsastraea schafferi*. Penecke's plate VI, figure 2a is indeed very similar to the present Figure 4A both displaying an aulos-like structure. The present material differs from *Frechastraea crassiseptata* TSIEN, 1978, with which it shares similar dimensions and number of septa, by the relatively limited septal thickening and by the higher development of carinae. Hubmann (1992) attributed his material to Penecke's species but consider it to belong to the genus *Mixogonaria* KONG in Kong and Huang (1978). However, this genus is characterized mainly by asymmetrical trabecular fans expanding throughout the dissepimentarium, whereas Hubmann's plate 2, figure 2 shows poorly expressed trabecular fans seemingly situated in the inner dissepimentarium. Consequently, it is suggested to replace Penecke's species in the genus *Frechastraea* SCRUTTON, 1968, based on the pseudocerioid habitus, the underdevelopment of horseshoe dissepiments and the occurrence of tight trabecular fans near the tabularium-dissepimentarium boundary (see McLean (1989) for discussion of that genus). The aulos-like structure is documented by Hubmann (1992) in his material but also in Penecke (1903) original description. Hubmann (1992) suggested a close relationship between *F. schafferi* PENECKE, 1903 and *Phillipsastraea bethunei* TSIEN, 1978 (= *Frechastraea crassiseptata* Tsien, 1978) but the latter is smaller and has some isolated horseshoe dissepiments but not the aulos-like structure. McLean (1994a) considers Penecke's species to be placed in *Hexagonaria* GÜRICH, 1896 based on the arrangement of the trabeculae that appear more or less perpendicular to the dissepiments on the original figures (plate VI, figure 1b). However, on Penecke's plate VI, figure 2b, the arrangement of the trabeculae is less clear and this possibly led Hubmann to include the species in *Mixogonaria* rather than in *Frechastraea*. In the present material, the trabeculae are arranged in a fan extending in the inner third of the dissepimentarium (see Fig. 4D), allowing to place the species within the genus *Frechastraea* SCRUTTON, 1968 in the sense of McLean (1994b).

Occurrence. *F. schafferi* is present in the Frasnian of the vicinity of Feke (SE Turkey) (Penecke, 1903; Hubmann, 1992). The specimens reported from the Frasnian of the Kuznetsk Basin by Bulvanker (1958) belongs to a distinct taxon.

DISCUSSION

Although Early and early Middle Devonian rugose corals show provincialism, they are strongly cosmopolitan in the Frasnian, at least at the genus-level (Oliver and Pedder, 1979) with almost no endemism (Oliver, 1973). However, at the species-level –or at least group-species-level– differences exist and could be used in palaeogeographic approaches.

The coral assemblage recovered from the middle part of the Meydan Fm. in the Danagözü section, notably the concomitant occurrence of the genera *Frechastraea*, *Macgeea* and *Peneckiella*, suggests an upper Frasnian age. Similar assemblages are known in the upper Frasnian strata of Western Europe (e.g. Pickett, 1967; Scrutton, 1968), Eastern Europe and Urals Mountains (e.g. Soshkina, 1951; Wrzolek, 1992), Australia (Brownlaw and Jell, 2008; Hill and Jell, 1970), North America (e.g. McLean, 2005; Sorauf, 1998) and South China (Liao and Ma, 2007). Species of the rather rare genus *Pseudopexiphyllum* have, so far, a poor palaeobiogeographic signature as they have been reported only from two localities, one in Turkey and other in Karakorum, Pakistan, (Schröder, 2004). The occurrences cited by Hubmann (1992) in Iran, Afghanistan and Tibet are not supported by the literature. Further comparisons with time-equivalent coral associations of Northern Gondwana are imprecise as only scattered data have been published so far. In addition to the Turkish occurrences cited above, some upper Frasnian corals were reported from Iran by Ghods (1982) and Rohart (1999, 2000), from Pakistan by Reed (1922), von Schouppé (1965) and Schröder (2004), from Nepal by Flügel and Tintori (1993) and from Afghanistan by Brice (1970). In Western Australia, upper Frasnian coral associations were abundantly described by Hill (1954), Hill and Jell (1970) and Brownlaw and Jell (2008). In all cases, the genera *Frechastraea*, *Macgeea* and *Peneckiella* are represented by distinct and mostly local –if not endemic– species (Fig. 5). Hence, there is no marker typical of the northern margin of Gondwana. However, Flügel and Tintori (1993) suggested that the depauperate Frasnian coral fauna from these areas could correspond to a distinct province covering the northern margin of Gondwana. This assertion would require an in-detail revision of the coral fauna from the Gondwanian parts of Asia, which is not the aim of the present paper. Based on the close relationship of Upper Devonian conodonts, brachiopods and arthropods from Eastern Taurides with those of Europe, Yalçın *et al.* (2012) and Gourvenec and Hoşgör (2015) suggested that the Rheic Ocean separating Laurussia and Gondwana was very narrow (Wehrmann *et al.*, 2010). Hence, local species could have evolved on an isolated block of the Cimmerian terranes, off Gondwana and separated by wide seas that acted as faunal barriers (Fig. 5) (Schröder, 2004; Talent *et al.*, 1987).

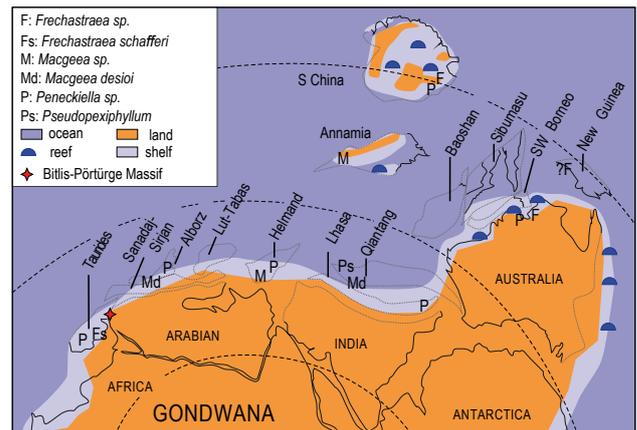


FIGURE 5. Palinspastic map (Frasnian, 370Ma) of the northern margin of Gondwana and Cimmerian terranes (rifting northwards during the Permian), Laurussia omitted. Occurrences of some rugose coral genera and species are indicative but not representative of the entire coral fauna of Gondwana. Map modified from Torsvik and Cocks (2013). Occurrences in Taurides (Turkey) after Penecke (1903), Oekentorp and Schröder (2001), Hubmann (1992); Alborz and Sanadaj-Sirjan (Iran) after Ghods (1982) and Rohart (1999, 2000); Helmand Block (Afghanistan) after Brice (1970); Qiantang Block (Pakistan) after Reed (1922), von Schouppé (1965) and Schröder (2004); Western Australia after Hill (1954), Hill and Jell (1970) and Brownlaw and Jell (2008); Lhasa Block (Xizang) after Fan *et al.* (2003); Annamia (“Indochina”) after Fontaine (1961); New Guinea after Oliver *et al.* (1995); S. China after Liao and Ma (2007).

CONCLUSIONS

The discovery of the corals *Alveolites* ex. gr. *suborbicularis*, *Frechastraea schafferi*, *Macgeea desioi*, *Peneckiella* cf. *teichertii*, *Pseudopexiphyllum supradevonicum*, *Scoliopora* sp. and *Thamnopora reticulata* in the middle part of the Meydan Fm. allows to precise the age of this unit as upper Frasnian. During the early Late Devonian, most corals were cosmopolitan at least at the genus level, local species, however, can be useful to constrain the palaeobiogeography. The species *F. schafferi* and *P. supradevonicum*, originally described in the Taurides, suggest a palaeobiogeographic relationship between the Bitlis-Pörtürge Massif and the Taurides terranes that in the Devonian were not yet rifted off the margin of Gondwana.

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REFERENCES

- Birenheide, R., Kaya, O., 1987. Stratigraphy and Middle Devonian corals of the Adapazari area, NW Turkey. *Senckenbergiana lethaea*, 68, 263-303.

- de Blainville, H.M.D., 1830. Zoophytes. Paris, Dictionnaire des Sciences naturelles, tome 60, 546pp.
- Brice, D., 1970. Etude paléontologique et stratigraphique du Dévonien de l'Afghanistan, contribution à l'étude des brachiopodes et des polypiers rugueux. Notes et mémoires sur le Moyen-Orient, Muséum national d'Histoire naturelle, 9, 1-365.
- Brownlaw, L.S., Jell, J., 2008. Middle and Upper Devonian rugose corals from the Canning Basin, Western Australia. *Memoirs of the Association of Australasian Palaeontologists*, 35, 1-126.
- Bulvankar, E.Z., 1958. Devonskie chetyrekhluचेवye korally okrain Kuznetskogo basseina (in Russian). *Vsesoiuznyi nauchno-issledovatel'skii geologicheskii institut*, 212pp.
- Cavazza, W., Cattò, S., Zattin, M., Okay, A.I., Reiners, P., 2018, Thermochronology of the Miocene Arabia-Eurasia collision zone of southeastern Turkey. *Geosphere*, 14, 2277-2293. DOI: <https://doi.org/10.1130/GES01637.1>
- Charles, F., 1933. Contribution à l'étude des terrains paléozoïques de l'Anatolie du Nord-Ouest (Asie mineure). *Mémoire de la Société géologique de Belgique*, 7, 54-152.
- Coen-Aubert, M., Gourvenec, R., Monod, O., Plusquellec, Y., Tourneur, F., 2013. Frasnian rugose and tabulate corals from the eastern Taurus (Kozan region, Turkey). *Geodinamica Acta*, 26, 68-93.
- Ehrenberg, C.G., 1834. Beiträge zur physiologischen Kenntniss der Corallenthiere im allgemeinen, und besonders des Rothen Meeres, nebst einem Versuche zur physiologischen Systematik derselben. *Abhandlungen der Preussischen Akademie der Wissenschaften*, 1832, 225-380.
- Fan, Y., Yu, X., He, Y., 2003. The Late Palaeozoic Rugose corals of Xizang (Tibet) and adjacent regions and their palaeobiogeography. *Hunan Science and Technology Press*, 679pp.
- Flügel, H., 1955. Zur Paläontologie des Anatolischen Paläozoikums. II. Mitteldevonfauna von Yahyali (NE Ala Dag, Taurus). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 101, 267-280.
- Flügel, H., 1956. Kritische Bemerkungen zum Genus *Peneckiella* Soshkina. *Neues Jahrbuch für Geologie und Paläontologie*, 8, 355-365.
- Flügel, E., Flügel, H., 1961. Stromatoporen und Korallen aus dem Mittel-Devon von Feke (Anti Taurus). *Senckenbergiana lethaea*, 42, 377-409.
- Flügel, H., Tintori, A., 1993. Late Devonian (Frasnian) corals from central Dolpo, Nepal. *Rivista Italiana di Paleontologia e Stratigrafia*, 99, 3-26.
- Fontaine, H., 1961. Les madréporaires paléozoïques du Viêt-Nam, du Laos et du Cambodge. *Archives Géologiques du Viêt-Nam*, 5, 1-276.
- Ghods, P., 1982. Rugose Korallen des Givetium und Frasnium im Elburz-Gebirge (Nord-Iran). PhD Thesis. Hamburg, Universität Hamburg, 172pp.
- Göncüoğlu, M.C., Turhan, N., 1984. Geology of the Bitlis metamorphic belt. In: Tekeli, O., Göncüoğlu, M.C. (eds.). *Geology of the Taurus Belt*. Ankara, Proceedings of the International Symposium on the Geology of the Taurus Belt, 237-244.
- Gourvenec, R., Hoşgör, I., 2015. Brachiopods and crinoids from the Middle–Upper Devonian boundary beds in the Darende–Gürün and Van–Zincirli areas (Eastern Taurus, Turkey). *Bulletin of Geosciences*, 90, 577-600.
- Gürich, G., 1896. Das Palaeozoicum im Polnischen Mittelgebirge. *Verhandlungen der Russisch-kaiserlichen Mineralogischen Gesellschaft zu St. Petersburg*, series 2, 32, 1-539.
- Heritsch, F., 1928. Devonversteinerungen aus dem Antitaurus. *Neues Jahrbuch für Geologie und Paläontologie, Abteilung B*, 59, 300-303.
- Heritsch, F., Gaertner, H.R., 1929. Devonische Versteinerungen aus Paphlagonien. *Sitzungsberichte der mathematisch-naturwissenschaftlichen Klasse, Akademie der Wissenschaften*, 138, 189-209.
- Hill, D., 1954. Coral faunas from the Silurian of New South Wales and the Devonian of Western Australia. *Bulletin of the Bureau of Mineral Resources, Geology and Geophysics*, 23, 1-51.
- Hill, D., Jell, J.S., 1970. Devonian Corals from the Canning Basin of Western Australia. *Geological Survey of Western Australia*, 121, 1-158.
- Hubmann, B., 1991. Die Korallenfauna aus dem Devon von Feke (Antitaurus, SE-Türkei). I: Tabulata. *Mitteilungen der Österreichische Geologische Gesellschaft*, 84, 355-372.
- Hubmann, B., 1992. Die Korallenfauna aus dem Devon von Feke (Antitaurus, SE-Türkei). II. Rugosa. *Geologisch-Paläontologische Mitteilungen Innsbruck*, 18, 151-169.
- Kellogg, H.E., 1960. Stratigraphic report, Hazro area, petroleum district V. SE Turkey. *American Overseas Petroleum (AMOSEAS) Report*, 126, 1-42.
- Kiratlıoğlu, E., 1959. Das Paläozoicum der Umgebung von Feke (NO Adana) SO-Türkei. PhD Thesis. Graz, Karl-Franzens Universität Graz, Unpublished, 47pp.
- Kong, L., Huang, Y.M., 1978. Part I: Rugosa. Atlas of southwest China. *Ghuizou volume*. Beijing, Geological Publishing House, 37-160.
- Kullmann, J., Kaya, O., 1973. Goniatite-coral associations from the Devonian of Istanbul, Turkey. In: Kaya, O. (ed.). *Paleozoic of Istanbul*. Ege Üniversitesi Fen Fakültesi Kitaplar Serisi, Jeoloji, 40, 97-116.
- Liao, W.H., Ma, X.P., 2007. The assemblage sequences and characteristics of the Devonian Givetian and Frasnian rugose corals in near-shore facies from South China. *Acta Palaeontologica Sinica*, 46, 213-224.
- McLean, R.A., 1989. Phillipsastreidae (Rugosa) in the Frasnian of western Canada. In: Jell, P.A., Pickett, J.W. (eds.). *Fossil Cnidaria 5. Memoirs of the Australasian Palaeontologists*, 8, 239-249.
- McLean, R.A., 1994a. Frasnian rugose corals of western Canada, part 3A: the massive Phillipastreidae *Phillipastrea*, *Chaunbeiphylum*. *Palaeontographica Abteilung A*, 230, 39-76.
- McLean, R.A., 1994b. Frasnian rugose corals of western Canada. Part 3B: the massive Phillipsastreidae *Pachyphylum*,

- Smithicyathus, Frechastraea*. *Palaeontographica Abteilung A*, 230, 77-96.
- McLean, R.A., 2005. Phillipsastroid corals from the Frasnian (Upper Devonian) of Western Canada: Taxonomy and biostratigraphic significance. Ottawa (Ontario, Canada), National Research Council Press, 109pp.
- Milne-Edwards, H., Haime, J., 1851. Monographie des Polypiers fossiles des terrains paléozoïques. *Archives du Muséum d'Histoire Naturelle*, 5, 1-502.
- Oberhansli, R., Candan, O., Bousquet, R., Rimmel, G., Okay, A., Goff, J., 2010. Alpine high pressure evolution of the eastern Bitlis complex, SE Turkey. In: Stephenson, R.A., Kaymakci, N., Sosson, M., Starostenko, V., Bergerat, F. (eds.). *Sedimentary Basin Tectonics from the Black Sea and Caucasus to the Arabian platform*. London, Geological Society, 340 (Special Publications), 461-483. DOI: <https://doi.org/10.1144/SP340.20>
- Oekentorp, K., Schröder, S., 2001. Korallen (Rugosa; Tabulata) aus dem Paläozoikum des SW Sultan Dag, Türkei. In: Weiss, R.H. (ed.). *Contributions to geology and palaeontology of Gondwana in Honour of Helmut Wopfner*. Institute of Geology, University of Cologne, 369-381.
- Okay, A., Arman, M.B., Göncüoğlu, M.C., 1985. Petrology and phase relations of the kyanite-eclogites from Eastern Turkey. *Contributions to Mineralogy and Petrology*, 91, 196-204.
- Oliver, W.A.Jr., 1973. Devonian coral endemism in Eastern North America and its bearing on palaeobiogeography. *Special Papers in Palaeontology*, 12, 318-319.
- Oliver, W.A.Jr., Pedder, A.E.H., 1979. Biogeography of Late Silurian and Devonian rugose corals in North America. In: Gray, J., Boucot, A.J. (eds.). *Historical biogeography, plate tectonics and the changing environments*. Corvallis, Oregon State University Press, 131-145.
- Oliver, W.A.Jr., Pedder, A.E.H., Weiland, R.J., Quarles van Ufford, A., 1995. Middle Palaeozoic corals from the southern slope of the Central Ranges of Irian Jaya, Indonesia. *Alcheringa*, 19, 1-15.
- Penecke, K.A., 1894. Das Grazer Devon. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt*, 43, 567-616.
- Penecke, K.A., 1903. Das Sammelergebnis Dr. Franz Schaffer's aus dem Oberdevon von Hadschin im Antitaurus. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt*, 53, 141-152.
- Pickett, J.W., 1967. Untersuchungen zur Familie Phillipsastroidae (Zoantharia, rugose). *Senckenbergiana lethaea*, 48, 1-89.
- Reed, F.R.C., 1922. Devonian fossils from Chitral and the Pamirs. *Geological Survey of India Memoirs, Paleontologica Indica (new series)*, 6, 1-134.
- Roemer, F.A., 1855. Beiträge zur geologischen Kenntniss des nordwestlichen Harzgebirges. *Palaeontographica*, 3, 1-67.
- Roemer, C.F., 1883. *Lethaea geognostica oder Beschreibung und Abbildung der für die Gebirgs-Formationen bezeichnendsten Versteinerungen. I. Theil, Lethaea palaeozoica*. Zweite Lieferung, Stuttgart, 324-543.
- Rohart, J.-C., 1999. Palaeozoic rugose corals from central and eastern Iran (A.F de Lapparent and M. Zahedi collections). *Annales de la Société géologique du Nord*, 7, 47-70.
- Rohart, J.-C., 2000. Frasnian rugose corals from Chah-Rishe (Esfahan Province, Central Iran). *Annales de la Société géologique du Nord*, 8, 67-71.
- Rózkowska, M., 1953. Pachyphyllinae et *Phillipsastraea* du Frasnien de Pologne. *Palaeontologica Polonica*, 5, 1-89.
- Schaffer, F., 1901. Geologische studien im südöstlichen Kleinasein. *Sitzungsberichte der mathematisch-naturwissenschaftlichen Klasse, Akademie der Wissenschaften*, 109, 498-525.
- von Schouppé, A., 1949. Die «Thamnophyllen» und ihre Beziehung zur Gruppe des *Cyathophyllum caespitosum*. *Palaeontographica Abteilung A*, 97, 99-180.
- von Schouppé, A., 1965. Die Mittel- bis Oberdevonische Korallenfauna von Kuragh (Chitral). In: Amuot, A., Ciry, R., Fantini Sestini, N., Premoli Silva, I., Rossi Ronchetti, C., Sartenaer, P., Vandercammen, A., von Schouppé, A., Buri, C.Z. (eds.). *Italian expeditions to the Karakorum (K2) and Hindu Kush, Scientific Report IV. Paleontology-Zoology-Botany*, 13-53.
- Schröder, S., 2004. Devonian rugose corals from the Karakorum Mountains (northern Pakistan). *Rivista Italiana di Paleontologia e Stratigrafia*, 110, 605-641. DOI: <https://doi.org/10.13130/2039-4942/5828>
- Scrutton, C.T., 1968. Colonial Phillipsastroidae from the Devonian of South-East Devon, England. *Bulletin of the British Museum of Natural History, Geology*, 15, 183-281.
- Sorauf, J.E., 1998. Frasnian (Upper Devonian) rugose corals from the Lime Creek and Shell Rock Formations of Iowa. *Bulletin of American Paleontology*, 113, 1-159.
- Soshkina, E.D., 1951. Podznedevonskie korally Rugosa, ikh systematika i evolutsiya. *Trudy Paleontologicheskogo Instituta, Akademiya Nauk SSSR*, 34, 1-121.
- Talent, J.A., Gratsianova, R.T., Yolkin, E.A., 1987. Prototethys: fact or phantom? Paleobiogeography in relation to the crustal mosaic for the Asia-Australian hemisphere in Devonian-Early Carboniferous times. In: McKenzie, K.G. (ed.). *Proceedings of the International Symposium on shallow Tethys*, 87-111.
- Tchiatcheff, P., 1897. *Asie Mineure, IV: géologie*. Paris, 694pp.
- Tolun, N., 1953. Contributions à l'étude géologique des environs du sud et sud-ouest du Lac de Van. *Turkey Mineral Research and Exploration Institution Bulletin*, 44-45, 77-112.
- Torsvik, T.H., Cocks, L.R.M., 2013. Gondwana from top to base in space and time. *Gondwana Research*, 24, 999-1030.
- Tsien, H.H., 1978. Rugosa massifs du Dévonien de la Belgique. *Mémoires de l'Institut géologique de l'Université de Louvain*, 29, 197-229.
- Ünsalner, C., 1951. Some Upper Devonian corals and stromatoporoids from South Anatolia. *Türkiye Jeoloji Bülteni*, 3, 131-146.
- Ustaömer, P.A., Ustaömer, T., Gerdes, A., Robertson, A.H.E., Collins, A.S., 2012. Evidence of Precambrian sedimentation/magmatism and Cambrian metamorphism in the Bitlis Massif, SE Turkey utilizing whole-rock geochemistry and U-Pb LA-ICP-MS zircon dating. *Gondwana Research*, 21, 1001-1018. DOI: <https://doi.org/10.1016/j.gr.2011.07.012>

- Verrill, A.E., 1865. Classification of polyps (Extract condensed from a synopsis of the polypi of the North Pacific Exploring Expedition, under captains Ringgold and Rogers, U.S.N.). *Communications of the Essex Institute*, 4, 145-149.
- Webster, C.L., 1889. Description of a new genus of corals from the Devonian rocks of Iowa. *The American Naturalist*, 23/272, 710-712.
- Wehrmann, A., Yılmaz, I., Yalçın, M.N., Wilde, V., Schindler, E., Weddige, K., Saydam Demirtaş, G., Özkan, R., Nazik, A., Nalcioğlu, G., Kozlu, H., Karşlıoğlu, Ö., Jansen, U., Ertuğ, K., 2010. Devonian shallow-water sequences from the North Gondwana coastal margin (Central and Eastern Taurides, Turkey): Sedimentology, facies and global events. *Gondwana Research*, 17, 546-560.
- Wrzosek, T., 1992. Rugose corals from the Devonian Kowala Formation of the Holy Cross Mountains. *Acta Palaeontologica Polonica*, 37, 217-254.
- Yalçın, M.N., Wehrmann, A., Schindler, E., Yılmaz, I., Wilde, V., Nazik, A., Bozdoğan, N., Özkan, R., Kozlu, H., Brocke, R., 2013. Devonian. In: Gönçüoğlu, M.C., Bozdoğan, N. (eds.). *Paleozoic of Northern Gondwana and its petroleum potential - A field workshop, Kayseri, Turkey*. Turkish Association of Petroleum Geologists, 7 (Special Publications), 100-114.
- Yoh, S.S., 1937. Die Korallenfaunades Mitteldevons aus der Provinz Kwangsi, Südchina. *Palaeontographica Abteilung A*, 87, 45-76.

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