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ORIGINAL ARTICLE

Middle Permian calcareous algae and microproblematica (Dalan Formation, Dena Mountain, High Zagros, SW Iran)

Tahere Parvizi · Koorosh Rashidi · Daniel Vachard

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Abstract Calcareous algae and microproblematica have been studied in the Middle Permian part of the Dalan Formation in Dena Mountain, Zagros, southwest Iran. Murgabian (=Wordian) microfossils are the most diversified. The assemblages encompass, among the dasycladales, *Anthracoporella spectabilis, Epimastopora piae*, *Epimastoporella japonica*, *E. likana, Paraepimastopora*? cf. *densipora* n. comb., *Gyroporella* cf. *nipponica*, *G.*? aff. *fluegeli* n. comb., *G.*? aff. *symmetrica, G.*? aff. *digitula* n. comb., *Mizzia yabei*; among the gymnocodiaceans, *Gymnocodium bellerophontis, G. nodosum, Permocalculus* cf. *digitatus, P. forcepinus, P.* cf. *fragilis, P. plumosus*, *P.* cf. *solidus*, *Tauridium*? sp.; among the "phylloid algae" *Eugonophyllum*? sp.; among the other incertae sedis algae *Stacheoides* sp., *Ungdarella uralica, Fourstonella* (*Efluegelia*) *johnsoni,* and among some microproblematica alternatively assigned to foraminifers or algae *Aeolisaccus dunningtoni, Tubiphytes obscurus, Pseudovermiporella nipponica, P. sodalica,* and *P. longipora*. Each taxon is briefly characterized, whereas a more detailed analysis of the epimastoporacean algae is given. Among them, the genera *Epimastopora* and *Epimastoporella* are emended. All the described microfossils have a relatively broad stratigraphic distribution in the Permian period but they are paleoecologically important. They are indeed confident micropaleontological Middle Permian proxies, particularly for shallow-marine, warm, well-oxygenated and relatively high-energy environments. They were affected by the end-Guadalupian crisis because they strongly decrease in the upper carbonate unit of the Dalan Formation and are not found in the Triassic sediments of the area.

Keywords Calcareous algae · Microproblematica · Taxonomic revision · Permian carbonates · Dalan Formation · Dena Mountain · Iran

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Introduction

Middle Permian algae are generally very productive, relatively well known, and cosmopolitan. The most abundant algae are the Gymnocodiaceae *Permocalculus* Elliott, 1955 and *Gymnocodium* Pia, 1920, and the dasycladale *Mizzia* Schubert, 1909. Some Early Permian forms persist such as *Epimastopora* (see below for the exact designation of the authors of this taxon) and *Gyroporella* Gümbel, 1872. Some other microorganisms, occasionally assigned to algae, are also rather common: *Aeolisaccus* Elliott, 1958, *Tubiphytes* Maslov, 1956b, *Pseudovermiporella* Elliott, 1958, as well as rare algosponges (i.e., incertae sedis algae), especially *Ungdarella* Maslov, 1956a.

In the literature, other Permian calcareous algae, such as the codiaceans, are poorly known. The codiaceans appeared in the Ordovician and were numerous and diverse in back-reef environments during the Late Silurian and Early to Middle Devonian (Rothpletz 1908; Poncet 1982, 1990; Mamet and Préat 1994; Vachard 1994) but unquestionable representatives are very rare during Carboniferous and Permian times (e.g., Vachard et al. 1989b, 2001).

Moreover, some forms assigned to the Permian codiaceans belong in fact to the Gymnocodiaceae; a confusion due to the resemblance, after diagenesis, of the undivided sites of the laterals and siphons of the former with the files of cells of the second group. That is especially obvious in *Succodium* Konishi, 1955, *Aphroditicodium* Elliott, 1970, *Tauridium* Güvenç, 1966, and *Thaiporella* Endo, 1969 which, although described as codiaceans, rather belong to gymnocodiaceans. Although attributed to the red algae by the genial paleophycologist Julius von Pia in 1937 (principal arguments being, the presence of cellular files and conceptacles), the gymnocodiaceans were recently transferred to the green algae by some authors such as Mu Xinan and Riding (1983), Chuvashov et al. (1987), Bucur (1994), Radoičić (2004), and Schlagintweit and Sanders (2007). We continue to favor an assignment to the galaxauracean red algae (shape and subcortical location of the conceptacles, long files of cells and not unicellular siphons, etc.). Inversely, it seems possible that some so-called Paleozoic "codiaceans" belong, in fact, to red ancestral gymnocodiaceans. Nevertheless, the unique Devonian species formally assigned to the group, "*Gymnocodium*" *devonicum* Mamet et al., 1993, is most probably a fossil ulotrichale (according to the criteria proposed by Kozlowski and Kazmierczak 1968). However, these discussions about the botanical assignment of gymnocodiacean at least document the difficulty to distinguish various fossil green and red algae (for other examples see Vachard and Cózar 2010).

Compared with *Mizzia* and *Gyroporella*, the other Permian genera of dasycladales are generally rare and endemic. There are *Atractyliopsis* Pia, 1937, *Anthracoporella* Pia, 1920, *Clavaporella* Kochansky-Devidé and Herak, 1960 emend. Vachard, 1980, *Eoclypeina* Emberger in Vachard, 1985, *Goniolinopsis* Milanović, 1966b, *Imperiellla* Elliott and Süssli, 1975, *Kochanskyella* Milanović, 1974, *Likanella* Milanović, 1966a (non-1965); *Nanjinoporella* Mu and Elliott, 1982, *Pseudotabasoporella* Rashidi and Senowbari-Daryan, 2010, *Salopekiella* Milanović, 1965a (non-1965b), *Sinoporella* Yabe, 1949, *Uragiellopsis* Vachard in Vachard and Montenat 1981, *Tabasoporella* Rashidi and Senowbari-Daryan, 2010, and *Velebitella* Kochansky-Devidé, 1964. The Lopingian (i.e., Late Permian) algal assemblages seem to be restricted to *Mizzia*, *Permocalculus*, and *Gymnocodium*, except in Armenia (formerly Transcaucasia) with the very poorly known genera *Johnsonia* Kordé, 1965 and *Endoina*, Kordé 1965; Greece with *Clavaporella* and *Macroporella* Pia, 1912 (Vachard et al. 1993a, b, 1995, 2003), or in northern Italy with *Atractyliopsis lastensis* Accordi, 1956, "*Physoporella*", and "*Macroporella*" (Accordi 1956; Praturlon 1963; Noé 1987).

The gymnocodiacean alga *Gymnocodium* has its first acme during the Midian (with *G. exile* Mu, 1981, *G. bellerophontis* (Rothpletz, 1894) Pia, 1920, and *G. nodosum* Ogilvie-Gordon, 1927), whereas *Permocalculus* is abundant since the Kubergandian (Vachard, 1980) or perhaps as soon the Artinskian or even the Sakmarian (Vachard and Moix, unpublished data; Krainer, Lucas and Vachard, unpublished data).

"Phylloid algae" are relatively rare in our material. They constitute, in fact, a composite group, the representatives of which have been assigned to the codiaceans, ancestral corallinales, and algospongia (Vachard et al. 1989a, b, 2001; Vachard and Cózar 2010; Granier 2012) or considered as a result of complex biological interactions (Vachard et al. 1989a, b, 2001). For example, the *Eugonophyllum* illustrated by Forsythe et al. (2002) or specimens of *Ivanovia* illustrated by Torres (2002) are comparable with recrystallized, peripherically microbored blades of an ancestral corallinale, the red alga *Archaeolithophyllum* Johnson, 1956. This transition between *Archaeolithophyllum* and "phylloid algae" is peculiarly conspicuous in the Midian deposits of Tunisia (Vachard et al. 1989a).

Within the reefal ecosystems, the Cisuralian (early Early Permian) reefs with the giant calcareous red alga *Palaeoaplysina* Krotov 1988, well known in Arctic regions of Canada, Russia, and Norway (Morin et al. 1994; Hüneke et al. 2001; Weidlich 2002a, b; Reid et al. 2007; Anderson and Beauchamp 2010; Blomeier et al. 2011) disappear and are replaced in the Middle Permian by the CAC: calcisponge-algal-cement reefs of Flügel et al. (1984) (see also Weidlich 2002a, b). The transitional period, Artinskian and Kungurian, is generally poorly known (see Flügel and Flügel-Kahler 1980 in the Trogkofelkalk of the Carnic Alps) but it seems accepted that the end-Early Permian reef crisis is due to a general cooling (due to a glaciation, increasing paleobathymetry, change from tropical to temperate climate, upwelling, or "Auernig paradox") or a general rise of the sea level related to the end of the LPIA (great Gondwanan glaciation) (see James 1997; Samankassou 1999, 2002; Soreghan et al. 2008) with a generalized change of photozoan assemblages to heterozoan ones.

A special, or at least especially developed during the Permian, micro-ecosystem is constituted by "algal biscuits"; large oncoids or complex biopisoliths with cyanobacteria, *Claracrusta* Vachard and Montenat, 1981, *Ellesmerella* Mamet and Roux in Mamet et al., 1987 (e.g., Henbest 1963; Vachard 1980; Flügel and Flügel-Kahler 1980; Roux 1985; Toomey et al. 1988; Sanders and Krainer 2005; Gaetani et al. 2009). Some incorporated "oncoid-dwelling" microfossils in the sense of Schlagintweit and Gawlick (2009a) are represented by the algosponge *Fourstonella* (*Efluegelia*) and the rare dwarf foraminifer *Tetrataxis*.

Other peculiar Permian constructions are those of *Tubiphytes* (non *Shamovella* Rauzer-Chernousova, 1950), a microfossil generally considered as an alga (Razgallah and Vachard 1991; Riding and Barkham 1999; Fagerstrom and Weidlich 2005) but also of a hyperspecialized foraminifer as well as of *Pseudovermiporella* (Vachard and Krainer 2001a, b).

Permian calcareous algae and problematic microfossils were described from numerous Tethyan localities (Table 1). For additional references concerning the genera and species of Upper Paleozoic dasycladales, see the compilations of Pia (1920), Kochansky-Devidé and Gusic (1971), Emberger (1976), Bassoullet et al. (1979), Vachard (1980, 1985), Roux (1985), Deloffre (1988), Riding and Guo (1992), Deloffre and Granier (1991), Granier and Deloffre (1995), Granier and Grgasović (2000), Pille (2008), Pille et al. (2010), Cózar et al. (2009), and Mamet and Préat (2010). Calcareous algae and problematic microfossils, including dasycladaleans and other algal groups, have not been well studied in Iran, particularly in the Permian of Zagros. Golesstaneh (1979) reported the occurrence of 15 algal genera and numerous species of Permian dasycladales from the Zagros Mountains, southeast Iran, without, however, giving a detailed description and illustration.

In central, southwestern, and northern Iran, several authors have reported, in the last 50 years, previously known algal genera (e.g., Flügel 1963; Kalantari 1986; Vaziri et al. 2005; Gaillot and Vachard 2007; Kolodka et al. 2012). New algal taxa were introduced by Elliott and Süssli (1975) and Rashidi and Senowbari-Daryan (2010), and Senowbari-Daryan and Rashidi (2010, 2011). Elliott and Süssli (1975) described the genus *Imperiella*, with the type species *I. iranica*, from the Permian Ruteh limestone of the Alborz Mountains in northern Iran. Senowbari-Daryan and Rashidi (2010, 2011) reported dasycladales and the codiacean genera *Anchicodium* Johnson, 1946 and *Iranicodium* Senowbari-Daryan and Rashidi, 2010, as well as *Lercaritubus problematicus* Flügel et al. 1990 and *Vangia telleri* (Flügel in Flügel et al. 1984), two problematic organisms from the Permian Jamal Formation of Shotori Mountains in Central Iran (Senowbari-Daryan and Rashidi 2011). Nevertheless, *Iranocodium* is very difficult to characterize, and *Vangia* is probably a junior synonym of *Bacinella* Radoičić, 1959.

The most important environments and microfossils from a paleobathymetrical point of view are described more accurately in the following paragraphs. Overall, more than

Table 1 List of calcareous algae and problematic microfossils from Tethyan localities and from some selected localities of the Americas

Area	References
Italy	Gortani (1906), Accordi (1956), Praturlon (1963), Noé (1987) and Flügel et al. (1991)
Austria	Pia (1920, 1937), Flügel (1966, 1980, 2004), Flügel and Flügel-Kahler (1980), Homann (1972), Krainer (1995), Krainer et al. (2003a), Schönlaub and Forke (2007), Krainer (2007a, b) and Krainer and Vachard (2007)
Former Yugoslavia	Herak and Kochansky-Devidé (1960), Kochansky-Devidé and Herak (1960), Kochansky-Devidé (1970a) and Sremac (2007)
Greece	Vachard et al. (1993a, b, 1995, 2003)
Tunisia	Glintzboeckel and Rabaté 1964; Vachard in Termier et al. (1977a, b) and Vachard (1985)
Saudi Arabia	Rezak (1959), Okla (1992), Vachard et al. (2005) and Hughes (2005)
Oman	Vachard et al. (2001)
Turkey	Bilgütay (1959, 1960) and Güvenç (1966, 1969, 1972)
Iraq	Elliott (1955, 1968a)
Iran	Flügel (1963), Elliott and Süssli (1975), Golesstaneh (1979), Vaziri et al. (2005), Mohtat-Aghai and Vachard (2005), Gaillot (2006), Gaillot and Vachard (2007), Senowbari-Daryan and Rashidi (2010, 2011), Rashidi and Senowbari-Daryan (2010) and Kolodka et al. (2012); this work
Afghanistan	Vachard (1980) and Vachard and Montenat (1981)
Pakistan	Dragastan et al. (1990)
Himalaya	Lys et al. (1978)
Japan and Southeast Asia	e.g., Endo (1951, 1969)
Former USSR	Maslov (1956a), Chuvashov (1974), Kulik (1978), and Vennin (2007a, b)
South China	Mu (1981, 1982), Mu and Riding (1983), and Wendt (1996)
USA	Johnson and Dorr (1942), Johnson (1946, 1951, 1963), Roux (1979), Kirkland (1995), Kirkland and Chapman (1990), Krainer et al. (2003b, 2005, 2007), Fagerstrom and Weidlich (2005), and Lucas et al. (2011)
Mexico	Vachard et al. (1993c)
Guatemala	Vachard et al. (1997)

30 genera of cyanobacteria, true algae (dasycladales and rhodophycophyta), incertae sedis algae or protista (algospongia), and microproblematical species were found in the Permian deposits of Dena Mountain.

Geological setting

The Iranian plateau extends over a number of continental fragments welded together along suture zones of oceanic character. The fragments are delineated by major boundary faults, which appear to be inherited from older geological periods. Each fragment differs in its sedimentary succession, nature, and age of magmatism and metamorphism, and its structural character and intensity of deformation (Berberian and King 1981; Heydari 2008). These fragments are exposed in the following structural provinces: (1) Zagros; (2) Sanandaj-Sirjan; (3) Urumieh-Dokhtar; (4) Central Iran; (5) Alborz; (6) Kopet Dagh; (7) Lut; and (8) Makran (Fig. 1).

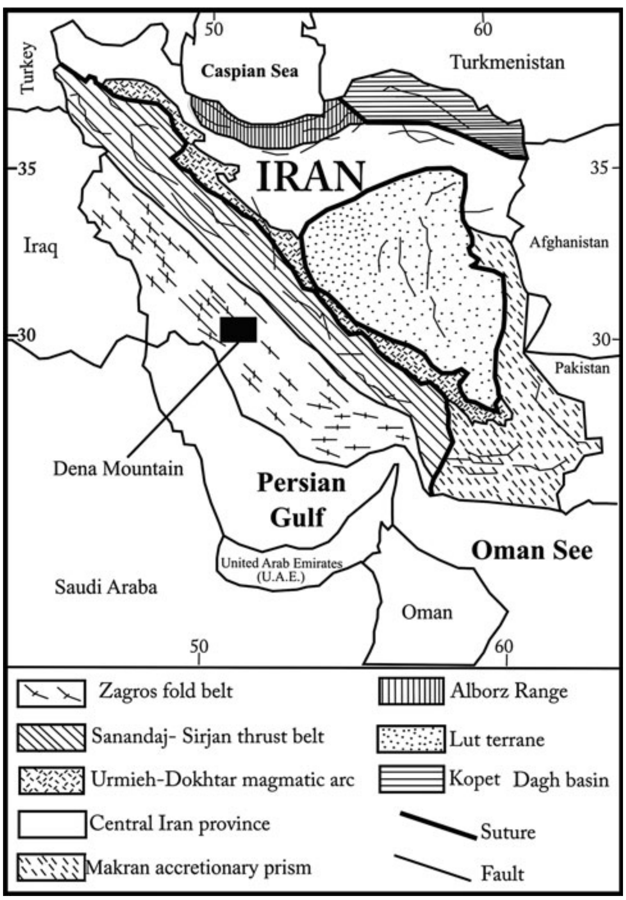


Fig. 1 General map of Iran showing the eight geologic provinces. Dena Mountain is located in the Zagros province (adopted from Heydari et al. 2003)

The Late Permian to Early Triassic periods were characterized in the Zagros Mountains by marine carbonate sedimentation (Setudehnia 1978; Koop and Stoneley 1982). These deposits, known as the Dalan and Kangan Formations, correspond to the Khuff Formation in Saudi Arabia, Kuwait, UAE, and Qatar (Szabo and Kheradpir 1978; Vaslet et al. 2005; Hughes 2005).

The Permian Dalan and Khuff Formations contain extensive gas reservoirs in the Greater Persian Gulf area (Kashfi 1992). The Dalan Formation corps out in some mountains at the base of Zagros zone in southwestern Iran such as Zard-Kuh (Setudehnia 1976), Dena (Setudehnia 1976; Baghbani 1997; Insalaco et al. 2006; Gaillot and Vachard 2007), Gakhum (Insalaco et al. 2006; Kolodka et al. 2012), and Oshtoran-Kuh and Surmeh (Sharland et al. 2001; Gaillot and Vachard 2007).

In 1976, the Stratigraphic Committee of Iran adopted a new term for the Permian succession in southern Iran, the Deh Ram Group, which was named after a village on the southwestern flank of the Kuh-e Surmeh in southern Iran.

Subsequently, the Deh Ram Group was divided into three formations: the Lower Permian Faraghan Formation, the Upper Permian Dalan Formation, and the Lower Triassic Kangan Formation (Kashfi 2000) (Fig. 2). The Dalan Formation is equivalent to (a) the Jamal Formation (Stöcklin et al. 1965; Partoazar 1995; Aghanabati 2004) in the Shotori Range of the Tabas area (eastern Iran); (b) the Surmaq, Abadeh, and Hambast Formations (Taraz 1969, 1974; Iranian-Japanese Research Group 1981; Partoazar 1995, 2002; Baghbani 1996; Kobayashi and Ishii 2003) in the Abadeh region (Central Iran); (c) the Ali Bashi and Jolfa Formations (Partoazar 1995; Baghbani 1996) in the Jolfa region (northwestern Iran), and (d) the Nesen and Ruteh Formations (Assereto 1963; Glaus 1964; Vachard et al. 1993a, b, c) in the Alborz Range (northern Iran) (Fig. 3). The Dalan Formation is conformably underlain by the Faraghan Formation and disconformably overlain by the thin-bedded limestone of the Kangan Formation (Szabo and Kheradpir 1978; Gaillot 2006; Gaillot and Vachard 2007).

The objective of our research has been the study of the Dalan Formation in a section located 58 km northwest of Yasouj city (the center of the Kohgilouye and Boyerahmad province) and approximately 7 km northwest of Sisakht town, at the southern flank of the Kuh-e Dena hill (coordinates 30°55′52″ N, 51°25′24″ E; Fig. 4). The Dalan Formation in this section, the Dena section, is 325.7 m thick and can be divided into three rock units: Lower Dalan Member, Nar Member, and Upper Dalan Member. The Lower Dalan Member is Murgabian to late Midian in age (Szabo and Kheradpir 1978; Johnson 1981; Gaillot 2006; Gaillot and Vachard 2007); the Nar Member is dated as latest Midian (Baghbani 1988; Vachard et al. 2002; Insalaco et al. 2006; Gaillot 2006); and the Upper Dalan

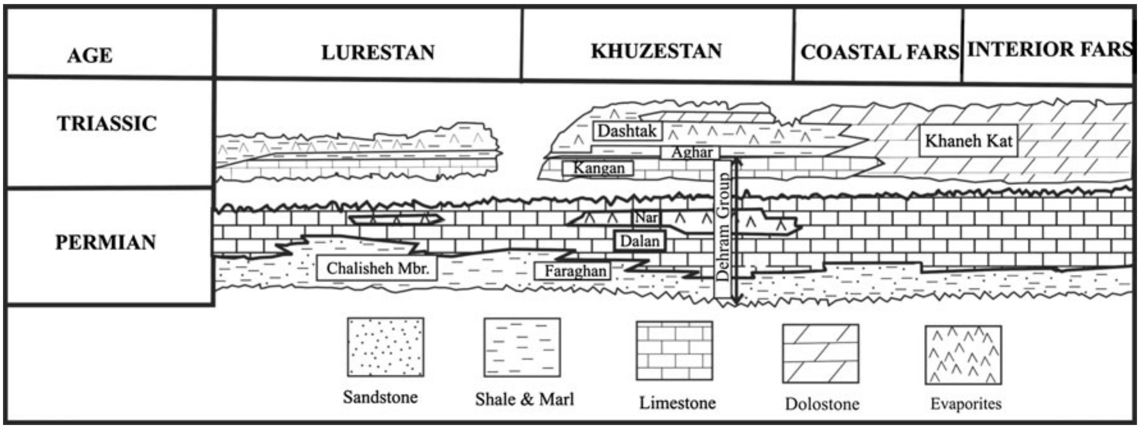


Fig. 2 Permian–Triassic stratigraphy of the Zagros basin, slightly modified from James and Wynd (1965)

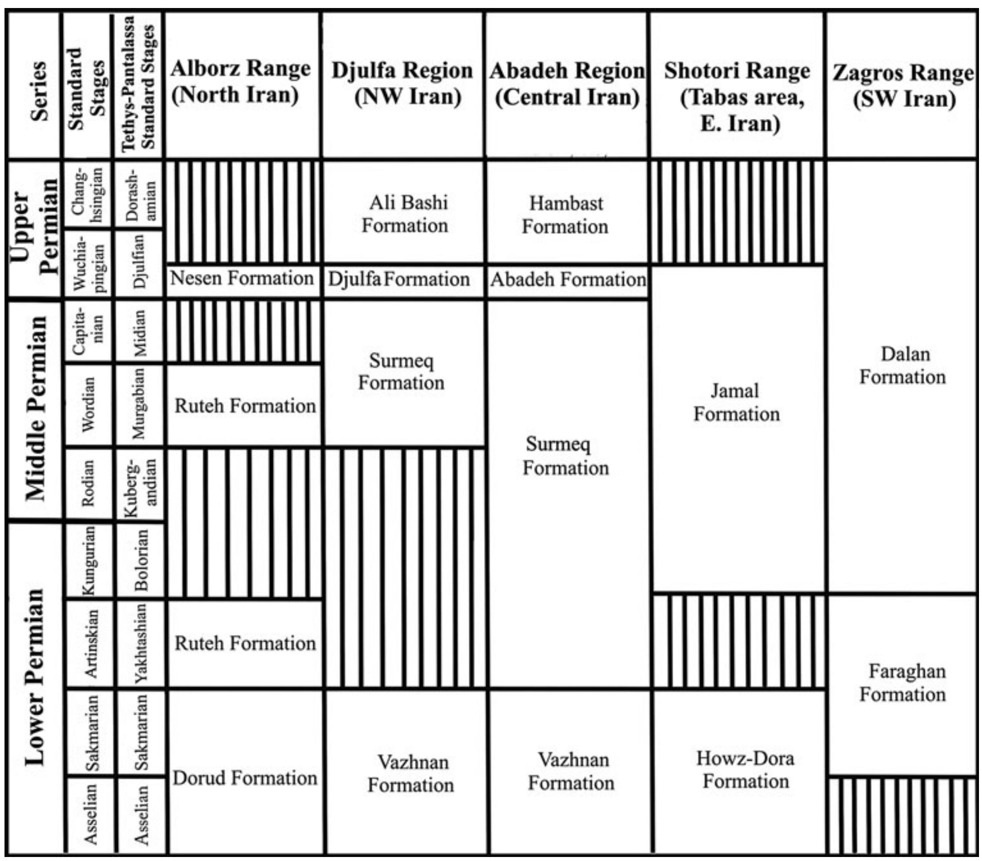


Fig. 3 Stratigraphic correlation chart of the Permian rocks units of Iran (adopted from Vaziri et al. 2005)

Member is Djulfian to Dorashamian in age (Insalaco et al. 2006; Gaillot 2006; Gaillot and Vachard 2007). The Lower Dalan Member yields rare trilobites, sponges, corals, gastropods, brachiopods, bryozoans (Ernst et al. 2011), and various foraminifers (Baghbani 1997; Insalaco et al. 2006; Gaillot 2006; Gaillot and Vachard 2007), calcareous algae, and microproblematica. In Dena Mountain, the evaporites of the Nar unit are replaced by thick beds of sandstone (Aghanabati 2004), and the age of the Dalan Formation is Murgabian (=Wordian) to early Djulfian (=Wuchiapingian). As the Upper Dalan Member has been accurately described by Gaillot (2006), the aim of this paper is to describe the microproblematica and algae of the Lower Dalan Member (Fig. 5).

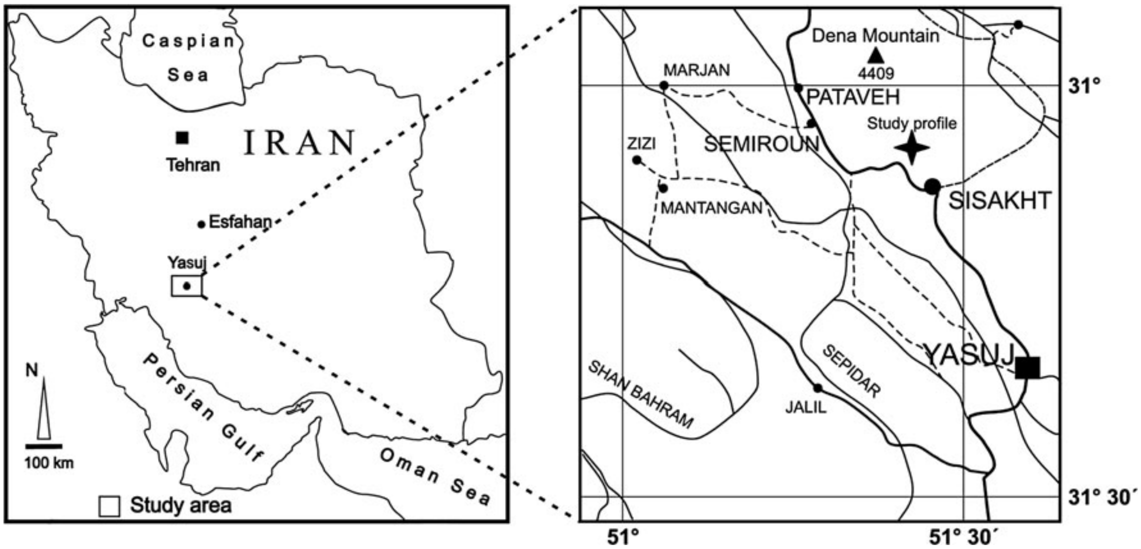


Fig. 4 Location of the study area in southwestern Iran

Systematic paleontology

Abbreviations: L = length; D = outer diameter; d = inner diameter; s = thickness of wall; p = diameter of pores (= diameter of laterals); ip = interval between two pores (i.e., two laterals).

Phylum Chlorophycophyta Papenfuss, 1955
Class Chlorophyceae Kützing, 1843
Order Dasycladales Pascher, 1931
Family Seletonellaceae (Kordé, 1973) Bassoullet et al., 1979
Tribe ?Dasyporelleae Pia, 1920
Genus *Anthracoporella* Pia, 1920
Anthracoporella spectabilis Pia, 1920
Fig. 6a

1920 *Anthracoporella spectabilis* n. gen. n. sp.—Pia: 15, text-fig. 3, pl. 1, figs. 7–11
1968a *Anthracoporella spectabilis* Pia—Elliott: 21, pl. 2, figs. 1–2
2000 *Anthracoporella spectabilis* Pia—Granier and Grgasović: 11 (cum syn.)
2001 *Anthracoporella spectabilis* Pia—Vachard et al.: 385, 387, figs. 12.1–12.10

Description All the specimens observed in the lower carbonate unit of the Dena section have the form of straight and long fragments. They can be differentiated from epimastoporacean fragments by the acrophore or slightly phloiophore, aspondyl, more or less parallel, simple or rarely bifurcated laterals.

Dimensions $L = 200–2.26$ mm; $s = 0.40–0.60$ mm; $p = 0.03–0.04$ mm; ip = 0.04–0.06 mm.

Comparison See Vachard et al. (2001, p. 385).

Occurrence See Vachard et al. (2001, p. 385, 387). Discovered in the Murgabian (Middle Permian) part of the Dena section.

Tribe Epimastoporaceae Vachard et al., 2012
Subtribe Epimastoporellinae Cózar and Vachard, 2004
Genus *Epimastopora* (Pia, 1937) Kochansky-Devidé and Herak, 1960
emend. Vachard in Perret and Vachard 1977, re-emended herein

Synonym *Gyroporella* (partim; sensu Gortani 1906).

Type species *Epimastopora alpina* Kochansky-Devidé and Herak, 1960 (=*Epimastopora* sp. sensu Pia 1937, pl. 97, fig. 4).

Discussion The genus *Epimastopora* of Pia (1922) and Pia (1937) does not follow the rules for creating a taxon as no type species has been defined. Moreover, both names of Pia are not really identical because the first one (1922) refers informally to a species "?*Gyroporella* n. f." sensu Gortani (1906) that will become an *Epimastoporella* (see below), whereas the second one (1937) corresponds more to the first valid description of the genus with the description of *E. alpina*. Before the typification of this latter species by Kochansky-Devidé and Herak (1960), Johnson (1946), Kordé (1951), and Endo (1959) had created successively some species of epimastoporaceans. Nevertheless, all are very remote from the type area (the Austrian–Italian border) and therefore do not correspond to the intentions of Pia (1922 or 1937). Furthermore, the taxon of Kordé was renamed *Globuliferoporella* Chuvashov, 1974 and that of Johnson *Paraepimastopora* Roux, 1979. Although the material of Gortani (1906) has been revised and re-described as *Epimastopora alpha* and *E. beta*, respectively by Elliott (1956), it is difficult to attribute the authorship of *Epimastopora* to this author because he did not understand the nature of this taxon very well. Indeed, (a) *Epimastopora* "*alpha*" Elliott 1956 might be a *Globuliferoporella* (also present among the unpublished topotypes of Vachard and Argyriadis and those of Krainer); (b) *E.* "*beta*" Elliott 1956 is an *Epimastoporella* according to Roux (1979) and Granier and Grgasović (2000), (c) *E. minima* Elliott, 1956, which is evidently a gymnocodiacean and not a dasycladale (Elliott 1968a; Granier and Grgasović 2000; Vachard et al. 2012), and (d) *E. malaysiana* Elliott, 1968b resembles many things but no an epimastoporean. Furthermore, according to Granier (pers. comm. September 2012), the 1988 edition of the International Code of Botanical Nomenclature states in Article 23.6 that "The following are not to be regarded as specific epithets: (b) ordinal adjectives used for enumeration, for instance, alpha, beta, gamma, etc."

Consequently, the nomenclatural proposals as "*Epimastopora* Pia ex Kordé 1951, emend. Roux 1979" or "*Epimastopora* (Pia 1922) Elliott, 1956" cannot be accepted. Hence, we suggest here the name *Epimastopora* (Pia, 1937) Kochansky-Devidé and Herak, 1960 emend. Vachard in Perret and Vachard, 1977 (see also Gaillot 2006; Vachard et al. 2012). Indeed, the emended diagnosis and the designation of *Epimastopora alpina* (=*Epimastopora* sp. sensu Pia 1937, pl. 97, fig. 4) as type by Kochansky-Devidé and Herak (1960) are most consistent with the intentions of Pia (1937). We will explain below why the name "*Epimastopora*" sensu Pia (1922) can be abandoned and replaced by *Epimastoporella* Roux, 1979.

Occurrence As already indicated by Johnson (1963), the distribution of this cosmopolitan alga is Middle Pennsylvanian–Late Permian; the other species of the genus, recorded from the late Bashkirian to Jurassic, have been erroneously assigned to the genus as re-described here.

Epimastopora piae Bilgütay 1960
Fig. 6b, d

1960 *Epimastopora piae* n. sp.—Bilgütay: 55–57, text-fig. 2a–c, pl. 2, figs. 1–4
2000 *Epimastopora piae* Bilgütay—Granier and Grgasović: 57 (with synonymy list)

Description A few specimens of this alga have been observed in the lower carbonate unit of Dena section. The thalli are broken in elongate fragments. The laterals are simple, cylindrical, acrophorous, parallel, and relatively wide.

Dimensions $L = 1.73$–2.29 mm; $s = 0.34$–0.55 mm; $p = 0.05$–0.10 mm; ip = 0.01–0.03 mm.

Comparison Our specimens have smaller interpores than the type of specimens from Turkey studied by Bilgütay (1960).

Occurrence Early Permian of Turkey, Carnic Alps (Austria), Italy, Slovenia, Urals, Sumatra, Xizang/Tibet. Discovered in the Murgabian (Middle Permian) of the Dena section.

Genus *Epimastoporella* Roux, 1979 emend. herein.

Synonym *Pseudoepimastopora* sensu Homann (1972).

Type species *Epimastopora japonica* Endo, 1951 [=*Epimastopora* "*alpha*" Elliott, 1956= "?*Gyroporella* n. f." Gortani, 1906 (partim)].

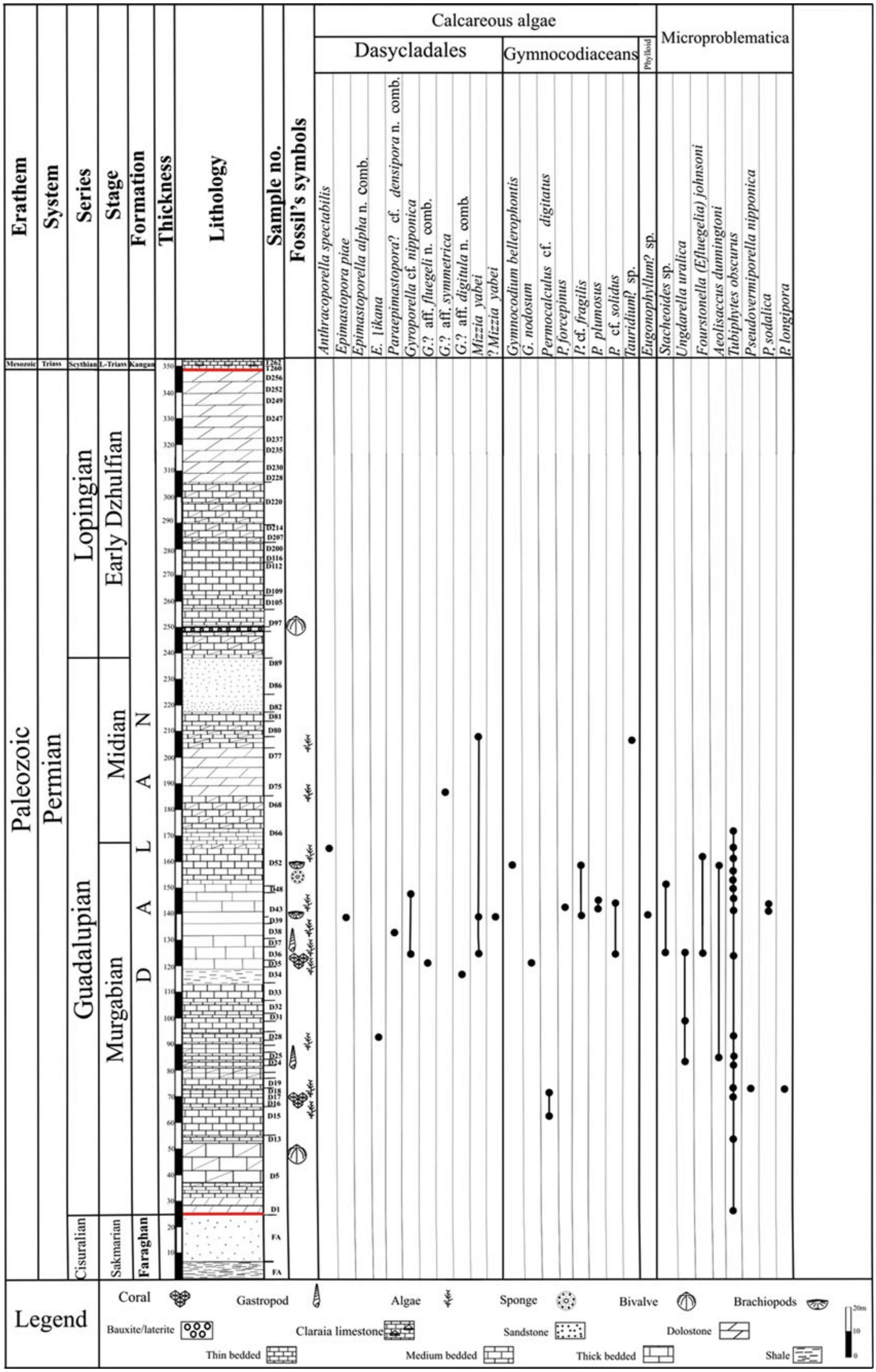
Description *Epimastoporella* differs from *Epimastopora* emend. herein by inflated laterals, either ellipsoidal or acrophorous at the two extremities with a vesiculifer median part.

Discussion The invalid taxon "?*Gyroporella* n. f." Gortani (1906) was initially included in "*Epimastopora*" Pia, 1922. Elliott (1956) described two species in the material of Gortani, *Epimastopora alpha*, and *E. beta*. Consequently, one of these species could appear as the type species of *Epimastopora*. Nevertheless, these species were subsequently neglected; probably because, as indicated by Granier and Grgasović (2000), these names are invalid with reference to article 23.6 of the ICBN (see above). *Epimastopora japonica* Endo, 1951 is generally regarded as a synonym of "?*Gyroporella* n. f.". As *E. japonica* is also the type species of *Epimastoporella*, we suggest that (1) *Epimastoporella japonica* is the first valid name of "?*Gyroporella* n. f." Gortani (1906); (2) the name *Epimastoporella* Roux, 1979 emend. herein must replace *Epimastopora* (Pia 1922), a nomen nudum; (3) from now on, the name *Epimastopora* corresponds only to *Epimastopora* (Pia 1937) Kochansky-Devidé and Herak, 1960, emend. Vachard in Perret and Vachard, 1977, re-emend herein.

Occurrence Late Pennsylvanian-Middle Permian. *Epimastoporella* emend. appears after and disappears before *Epimastopora* emend.; both genera are cosmopolitan.

Epimastoporella japonica (Endo, 1951) Roux, 1979
Fig. 6g

1906 ?*Gyroporella* n. f.—Gortani: 7, pl. 1, fig. 2 only (non pl. 1, fig. 1 = *Epimastopora beta* = *Globuliferelloporella*?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System
Series
Stage
Formation
Thickness
Lithology
Sample no.
Fossil's symbols
Calcareous algae
Dasycladales
Gymnocodiaceans
Phylloid
Microproblematica
Anthracoporella spectabilis
Epimastopora piae
Epimastoporella alpha n. comb.
E. ikana
Paraepimastopora? cf. densipora n. comb.
Gyroporella cf. nipponica
G.? aff. fluegeli n. comb.
G.? aff. symmetrica
G.? aff. digitula n. comb.
Mizzia yabei
? Mizzia yabei
Gymnocodium bellerophontis
G. nodosum
Permocalculus cf. digitatus
P. forcepinus
P. cf. fragilis
P. plumosus
P. cf. solidus
Tauridium? sp.
Eugonophyllum? sp.
Stacheoides sp.
Ungdarella uralica
Fourstonella (Efluegelia) johnsoni
Aeolisaccus dunningtoni
Tubiphytes obscurus
Pseudovermiporella nipponica
P. sodalica
P. longipora
Mesozoic
Triass
Scythian
L-Triass
Kangan
Paleozoic
Permian
Lopingian
Early Dzhulfian
Guadalupian
Midian
Murgabian
DALAN
Cisuralian
Sakmarian
Faraghan
Legend
Coral
Gastropod
Algae
Sponge
Bivalve
Brachiopods
Bauxite/laterite
Claraia limestone
Sandstone
Dolostone
Thin bedded
Medium bedded
Thick bedded
Shale

◀ **Fig. 5** Stratigraphic column with distribution and abundance of Dasycladales, red algae, and problematic microfossils of the studied Dalan Formation in Dena Mountain

1951 *Epimastopora japonica* n. sp.—Endo: 124, pl. 11, figs. 1–2
1956 *Epimastopora alpha* n. sp.—Elliott: 327
1979 *Epimastoporella japonica* (Endo) n. comb.—Roux: 809
1987 *Epimastoporella japonica* (Endo) n. comb.—Mamet et al.: 34, pl. 15, figs. 6–12, pl. 6, figs. 1–3 (partim; the proposed synonyms of *E. likana* excluded)
2000 *Epimastopora alpha*—Granier and Grgasović: 59
2000 *Epimastoporella japonica* (Endo) Roux—Granier and Grgasović: 62 (with synonymy, but a part of the citations should be assigned to *E. likana*)

Description This taxon is abundant in thin-sections of the lower carbonate unit of the Dena section. It is characterized by regularly placed ellipsoidal laterals.

Dimensions $L = 2.36$–2.38 mm; $s = 0.19$–0.30 mm; $p = 0.08$–0.13 mm; ip = 0.03–0.09 mm.

Occurrence Early Permian of Japan, Carnic Alps, Serbia, Thailand, Philippines, Canada. Discovered in the Murgabian (Middle Permian) part of the Dena section.

Epimastoporella likana (Kochansky-Devidé and Herak 1960)
Fig. 6h

1960 *Epimastopora likana* n. sp.—Kochansky-Devidé and Herak: 78, pl. 4, figs. 5–10
2000 *Epimastoporella japonica* (Endo) Roux—Granier and Grgasović: 62 (with synonymy list, 21 references erroneously assigned to *E. japonica*)

Description The elongate fusiform shape of the laterals is characteristic and differs from those of *E. japonica* in contrast to the opinion of Mamet et al. (1987).

Dimensions $L = 2.12$ mm; $s = 0.27$ mm; $p = 0.075$ mm; ip = 0.10 mm.

Occurrence Late Pennsylvanian–Late Permian. Croatia, Slovenia, Montenegro, Carnic Alps Austria-Italy), Greece, Turkey, Urals (Russia), Iran (Azerbaijan, eastern Alborz), Oman, Afghanistan, New Mexico, Guatemala. Discovered in the Murgabian (Middle Permian) of the Dena section.

Genus *Paraepimastopora* Roux, 1979 emend. Krainer and Vachard, 2002.

Type species *Epimastopora kansasensis* Johnson, 1946.

Discussion *Paraepimastopora* is probably the most abundant dasycladale in the North American Carboniferous limestone (Johnson 1946; Roux 1989; Krainer et al. 2005; Gómez-Espinosa et al. 2008). This genus is well defined and easy to identify (Roux 1989; Krainer and Vachard 2002) due to (1) its wide axial cell; (2) its abundant, thin, parallel, acrophorous and aspondyl laterals; and (3) its oblique well-developed intusannulations. Nevertheless, previous numerous reciprocal misinterpretations between *Paraepimastopora* and *Orthriosiphon* Johnson and Konishi 1956 exist in the literature. For example, *Orthriosiphon* sp. of Maslov (1973, pl. 11, fig. 6) is a typical *Paraepimastopora* with a characteristic imperforate intusannulation (bottom, left).

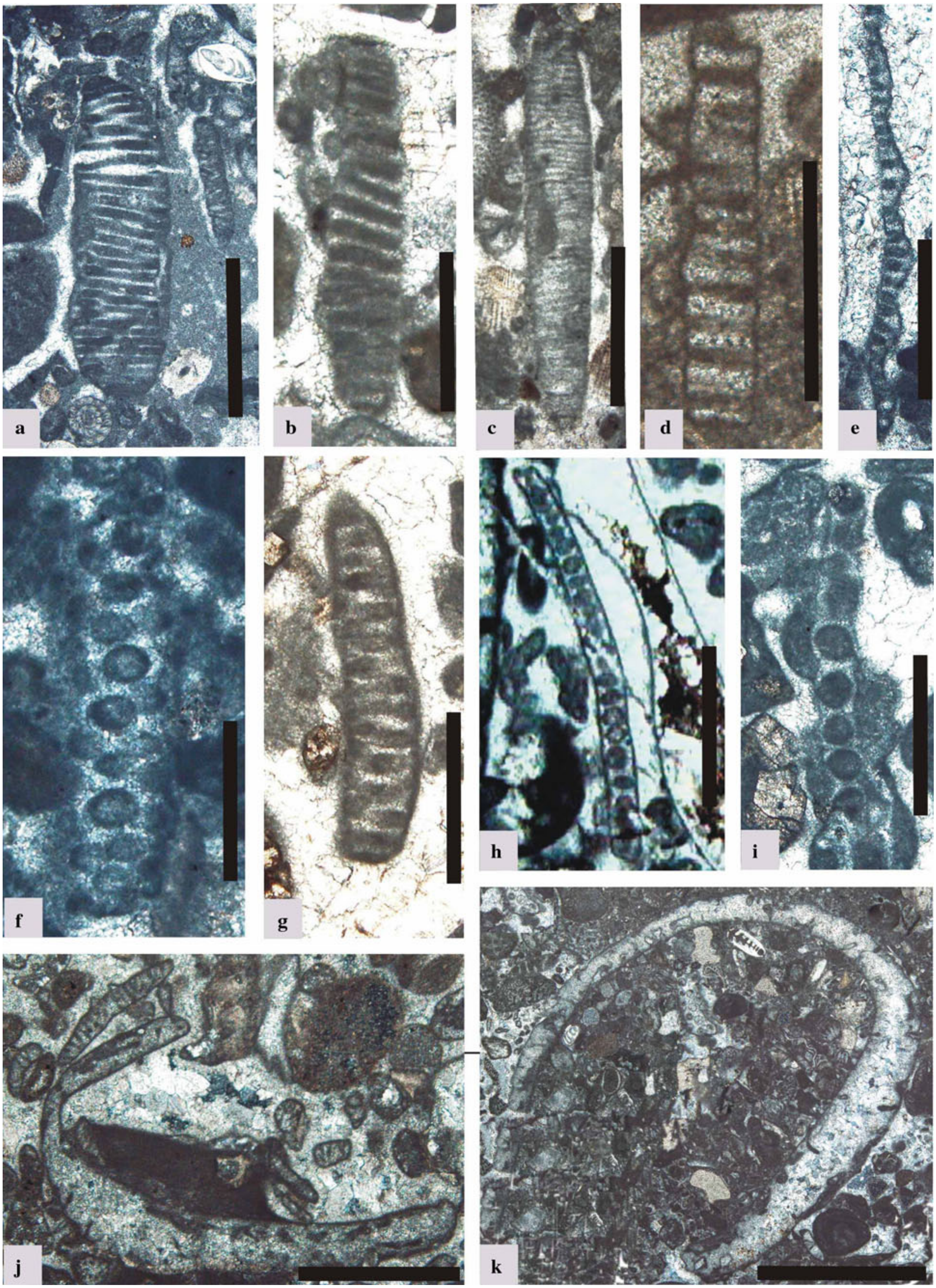
Occurrence The genus appeared first in the Tethys in the late Viséan (Sánchez-Chico et al. 1995; Cózar and Somerville 2004; Cózar et al. 2005; Pille 2008). It is then known in the early Serpukhovian of Austria (Krainer and Vachard 2002), ?Bashkirian of Bolivia (Mamet 1994), and Moscovian of Tunisia (Glintzboeckel and Rabaté 1964, pl. 12, fig. 2, pl. 16, figs. 1–2) and the Urals (Ivanova 2008, pl. 28, figs. 8–9; under the name *Epimastopora grandis* Chuvashov and Anfimov, 1988, correctly assigned to *Paraepimastopora* by Mamet and Préat 2010, p. 34–35). The genus appeared in North America during the Moscovian (Mamet et al. 1987) or perhaps as soon as the late Bashkirian (Groves 1984, text-fig. 7, p. 289). Its cosmopolitan acme occurred during the middle-late Virgilian/Gzhelian (Roux 1989; Krainer et al. 2005). It last appeared in the Early Permian (Sakmarian) (Mamet et al. 1987; Roux 1989; Mamet 1991; Vachard and Krainer 2001b; Vachard et al. 2012). The present study shows that it survived in the Murgabian of southern Iran.

Paraepimastopora? cf. densipora (Endo 1969) n. comb.
Fig. 6c

1969 *Epimastopora densipora* n. sp.—Endo: 80, Pl. 42, figs. 1–2
cf. 2000 *Epimastopora densipora* Endo—Granier and Grgasović: 55 (with synonymy)

Description This alga is rare in the lower carbonate unit of Dena section. Its fragments are curved and their thickness remains the same across their length. The interval between pores is very small. The Dena profile specimen has larger pore diameters than the specimens studied by Endo (1969).

Dimensions $L = 2.50$ mm; $s = 0.38$ mm; $p = 0.05$ mm; ip = 0.02 mm.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◀ **Fig. 6** Primitive dasycladales and "phylloid algae" of the Dena section. *Scale bars* 1 mm. **a** *Anthracoporella spectabilis*; longitudinal section; sample D58. **b**, **d** *Epimastopora piae*; longitudinal section; sample D41. **c** *Paraepimastopora*? cf. *densipora* n. comb.; longitudinal section; sample D38. **e** *Gyroporella*? aff. *digitula* n. comb.; longitudinal section; sample D34. **f** *Gyroporella nipponica*; longitudinal section; sample D36. **g** *Epimastoporella japonica*; longitudinal section; sample D34. **h** *Epimastoporella likana*; longitudinal section; sample D28. **i** *Gyroporella*? aff. *fluegeli* n. comb.; longitudinal section; sample D35. **J–k** *Eugonophyllum*? sp.; longitudinal section; sample D41

Occurrence Middle Permian of Thailand, Japan, Slovenia, Iran (Tabas area). Discovered in the Murgabian (Middle Permian) of the Dena section.

Tribe Gyroporelleae Pal, 1976 emend. Bassoullet et al., 1979
Genus *Gyroporella* Gümbel, 1872 emend. Kochansk-Devidé, 1970b
Gyroporella nipponica Endo and Hashimoto, 1955
Fig. 7f

1952 *Gyroporella* sp.—Konishi: 157, pl. 14, figs. 15–16
1955 *Gyroporella nipponica* n. sp.—Endo and Hashimoto: 705, fig. 1
1959 *Gyroporella igoi* n. sp.—Endo: 190, pl. 34, figs. 1–5, pl. 35, figs. 1–5, pl. 40, fig. 3, pl. 41, figs. 7–8
2000 *Gyroporella nipponica* Endo and Hashimoto—Granier and Grgasović: 75 (with synonymy)

Description Abundant longitudinal and oblique sections of the species have been found in the lower carbonate unit of the Dena section. This alga exhibits a particularly typical cylindrical thallus and vesiculiferous laterals. The ratio of outer to inner diameter is 0.75. The specimens from Dena Mountain are nearly similar to the specimen described and illustrated by Endo and Hashimoto (1955) from the Permian of Japan, but the Dena samples are larger.

Dimensions $D = 1.20–2.74$ mm; $d = 0.72–2.06$ mm; $s = 0.16–0.27$ (0.83) mm; $p = 0.11–0.16$ (0.36) mm.

Occurrence Late Pennsylvanian-Permian. Japan, Spain, Croatia, Montenegro, Carnic Alps, Urals, Turkey, Iran (Central Iran), South China, Thailand, SW Canada, NW USA. Murgabian (Middle Permian) of the Dena section.

Gyroporella? aff. *fluegeli* (Kulik 1978) n. comb.
Fig. 7i

aff. 1978 *Epimastopora fluegeli* n. sp.—Kulik: 198, pl. 5, figs. 4–5
aff. 2000 *Epimastopora fluegeli* Kulik—Granier and Grgasović: 56 (with synonymy)

Description Rare oblique sections of the Faxon have been found in the lower carbonate unit of the Dena section. The alga is cylindrical with vesiculiferous laterals, i.e., it belongs more probably to *Gyroporella* or a similar genus (e.g., *Gyroporella* cf. *prisca* sensu Krainer et al. 2005, fig. 6.13). The distal extremities of these laterals are very inflated, and as the proximal acrophore extremity is not calcified the laterals appear almost spherical.

Dimension $D = 1.20–2.74$ mm; $s = 0.16–0.27$ mm; $p = 0.11–0.16$ mm; ip = 0.025–0.05 mm.

Occurrence Early Permian of Russia and Italy. Murgabian (Middle Permian) of the Dena section.

Gyroporella? aff. *symmetrica* Johnson 1951
Fig. 6f

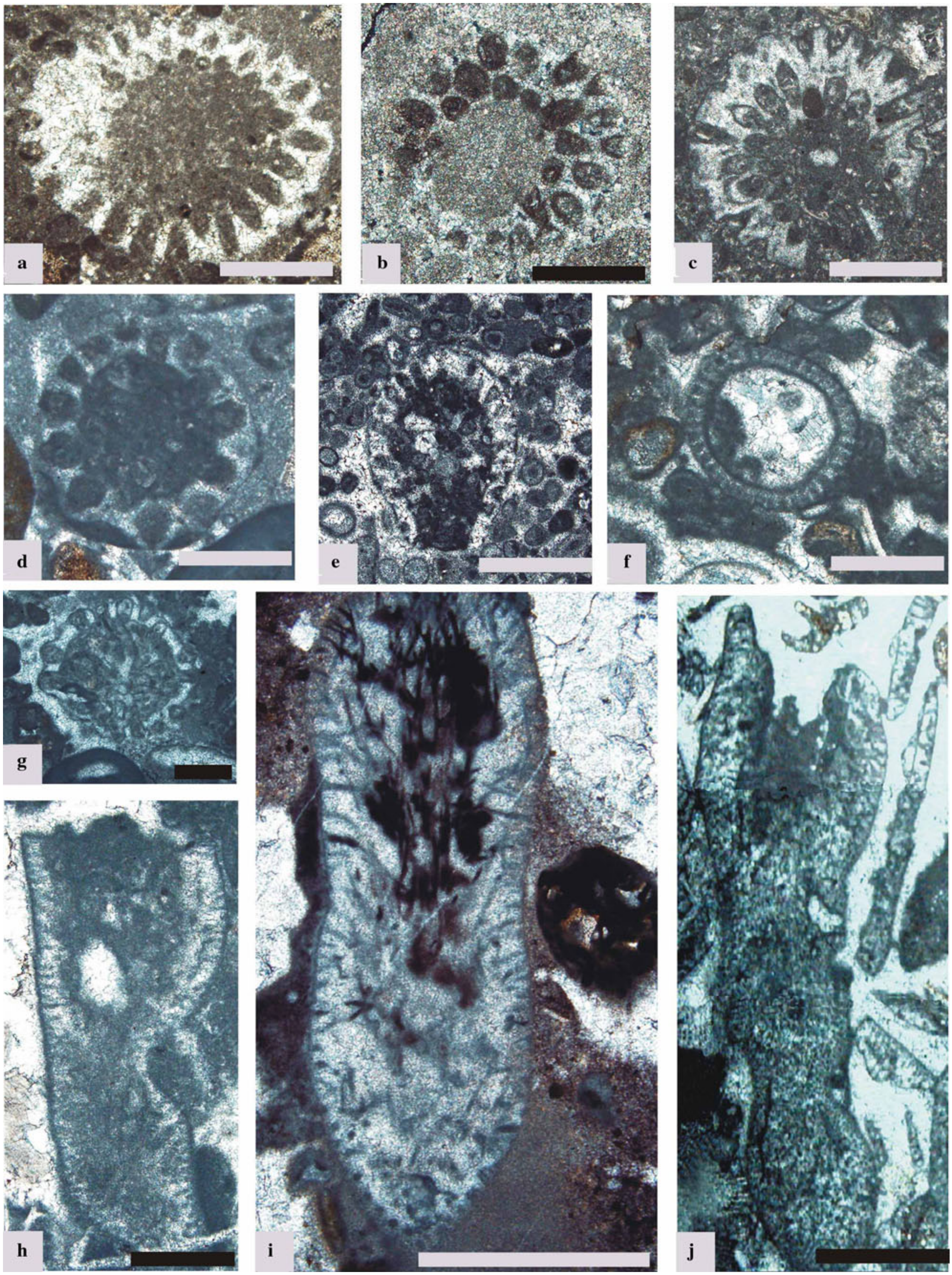
aff. 1951 *Gyroporella symmetrica* (sic) n. sp.—Johnson; 25, pl. 8, fig. 7, pl. 10, figs. 1–5
aff. 1974 *Globuliferoporella symmetrica* n. gen. n. comb.—Chuvashov: 27, pl. 12, figs. 1–8
aff. 1979 *Epimatopora symmetrica* n. comb.—Roux: 807
aff. 2000 *Epimastotopora symmetrica* (Johnson) Roux—Granier and Grgasović: 63, (with synonymy)
aff. 2004 *Epimastopora symmetrica* (Johnson) Roux—Mamet and Villa: 157

Description A poor material of this alga has been observed in the lower carbonate unit of the Dena section. The alga is cylindrical or slightly undulating. The branches are closely arranged and the distance between pores is relatively narrow for a true *Gyroporella*. The specimen investigated in this study has larger pores and smaller interpores than the specimens studied by Johnson (1951). In fact, this taxon is very ambiguous. pl. 10, figs. 1–2, and 5 of Johnson probably corresponds to a *Gyroporella*, whereas pl. 10, fig. 3 is a *Gymnocodium* and pl. 8, fig. 7 and pl. 10, fig. 4 possibly are diploporaceans. In the past, the taxon has been assigned to *Globuliferoporella* and "*Epimastopora*" sensu Roux (1979). It is possibly also related to *Gyroporella microporosa afghanica* Vachard in Vachard et Montenat (1981), an unquestionable *Gyroporella*.

Dimensions $L = 2.38$ mm; $D = 0.60$ mm; $p = 0.19$ mm; ip = 0.03–0.11 mm.

Occurrence Permian of Texas, Turkey, Afghanistan, and Tunisia. Midian (Middle Permian) of the Dena section.

Gyroporella? aff. *digitula* (Chuvashov and Anfimov 1988) n. comb.
Fig. 6e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◀ **Fig. 7** Dasycladales and Gymnocodiaceae of the Dena section. *Scale bars* = 1 mm. **a-c, d**? **e, g**? *Mizzia yabei*; **a** oblique section; sample D41; **b** oblique section; Sample D79; **c** oblique section. Sample D36e; **d** cross section; sample D41; **e** longitudinal section; sample D36; **g** cross section; sample D47. **f** *Gyroporella* aff. *symmetrica*; cross to oblique section; sample D74. **h–j** *Permocalculus plumosus*; **h** longitudinal section; sample D47; **i** longitudinal section; sample D43; **j** longitudinal section; sample D44

aff. 1988 *Epimastopora digitula* n. sp.—Chuvashov and Anfimov: 62, pl. 25, figs. 4–5

Description This taxon is very rare in our material and apparently unpublished. Only the Moscovian species *Epimastopora digitula* seems to have some resemblance by its wide, regularly parallel vesiculiferous laterals and the beginning of segmentation of the test, with a more or less triangular pseudo-annulation. Nevertheless, it is evident that this species is not an *Epimastopora* and corresponds more likely to a *Gyroporella*. More material might permit to describe it as a new taxon.

Dimensions $L = 2.83$ mm; $s = 0.20$ mm; $p = 0.07$ mm; ip = 0.01/0.05 mm.

Occurrence Type material described from the late Moscovian (Middle Pennsylvanian) of the Urals (Russia). Murgabian (Middle Permian) of the Dena section.

Family Dasycladaceae Kützing, 1843
Tribe Coniporelleae Pia, 1920 emend. Bassoullet et al., 1979
Subtribe Mizziinae Bassoullet et al., 1979
Genus *Mizzia* Schubert, 1909
Mizzia yabei (Karpinsky, 1909) Pia, 1920
Fig. 7a–c, d?, e, g?

1909 *Stolleyella Yabei* n. sp.—Karpinsky: 268, text-fig. p. 1055
1920 *Mizzia* cf. *yabei* (Karpinsky) n. comb.—Pia: pl. 1, figs. 4–6
1960 *Mizzia Yabei* (Karpinsky)—Herak: 91
1970 *Mizzia*—Canuti et al.: 30, text-fig. 9
1973 *Mizzia* sp.—Bozorgnia: pl. 48, fig. 12
1993b *Mizzia yabei* (Karpinsky)—Vachard et al.: pl. 1, fig. 3, pl. 2, fig. 6
2000 *Mizzia yabei* (Karpinsky) Pia—Granier and Grgasović: 107 (with synonymy)
2001 *Yabeites yabei* (Karpinsky)—Chuvashov: 102, text-figs. 1d–e, 3b
2005 *Mizzia velebitana* Schubert—Hughes: pl. 1, figs. 21–23

Description Numerous specimens of this species were found. *M. yabei* is apparently the only species of the genus present in the section. For example, neither *M. velebitana* Schubert 1909 nor *M. cornuta* Kochansky-Devidé and Herak, 1960 were truly identified, although some specimens resemble these species (Fig. 7d, g, respectively). *M. yabei* is characterized by club-shaped articles and the drum-stick-shaped laterals. *M. velebitana* differs by wider spherical articles, and *M. cornuta* by “horny” protuberances at the extremities of the laterals. These differences are clearly specific during all transitional stages, and cannot justify the creation of the genus *Yabeites* Chuvashov, 2001 for *M. yabei* and *Cornutella* Chuvashov, 2001 for *M. cornuta*. Furthermore, in our material, atypical specimens are occasionally similar to *Mizzia bramkampi* Rezak, 1959 and/or the genera *Eogoniolina* Endo, 1953 or *Permoplexella* Elliott, 1968a.

In general, in the Near and Middle East, the most common species of *Mizzia* seems to be *M. yabei*, whereas *M. velebitana* (well characterized by Pia 1920; Vachard 1980; and Flügel et al. 1984) is rare or absent. In particular, in our opinion *Mizzia velebitana* as illustrated by Elliott (1968a) and Hughes (2005) belong unquestionably to *M. yabei*.

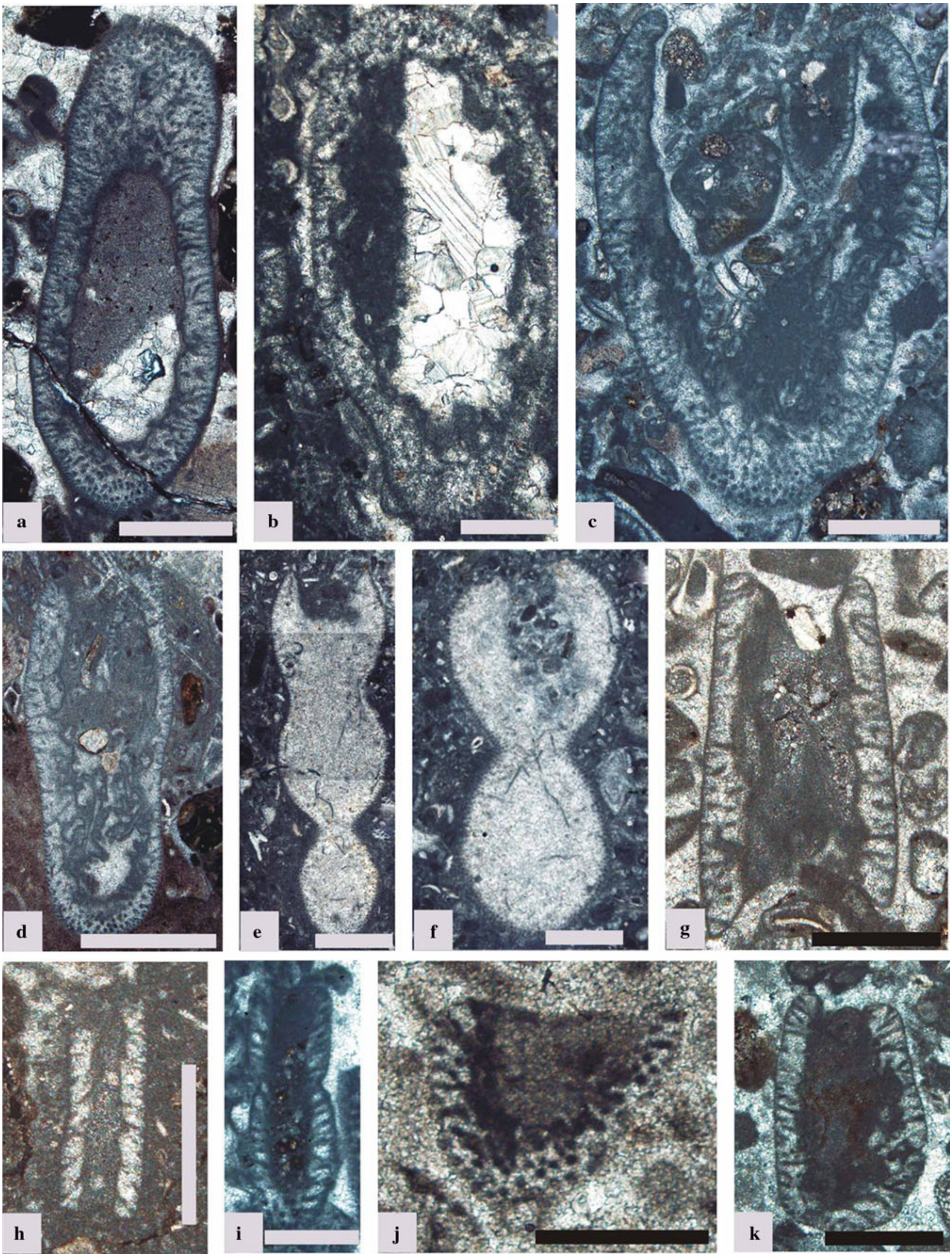
The transverse sections are difficult to distinguish (Fig. 7a–d, g) but the axial sections are characteristic (Fig. 7e). Some specimens in our material exhibit relatively prominent lateral extremities (Fig. 7g). This feature is generally due to a weak, differential abrasion of the outer surface and should not be confused with *M. cornuta*.

Dimensions $D = 1.30–2.30$ mm; $d = 0.80–0.130$ mm; $s = 0.16–0.68$ mm; $p = 0.16–0.38$ mm.

Occurrence Permian of Japan, South China, Guatemala, southwestern USA, Thailand, Malaysia, Pakistan, Afghanistan, Iran (Alborz, Zagros; Bozorgnia 1973; Kolodka et al. 2012 (no 2006); this study), Saudi Arabia, Tunisia, Turkey, Greece, Carnic Alps, Hungary, Slovenia, Croatia, Montenegro. Murgabian and Midian (Middle Permian) of the Dena section.

Class Rhodophyta Wettstein, 1901
Order Nemalionales Schmitz in Engler, 1892
Family Gymnocodiaceae Elliott, 1955
Genus *Gymnocodium* Pia, 1920 emend. Elliott, 1955
Gymnocodium bellerophontis (Rothpletz, 1894) Pia, 1920 emend. Elliott, 1955
Fig. 8h

1894 *Gyroporella bellerophontis* n. sp.—Rothpletz: 24, fig. 4
1912 *Macroporella bellerophontis* (Rothpletz) n. comb.—Pia: 34, text-fig. 3, pl. 2, figs. 7–12
1920 *Gymnocodium bellerophontis* (Rothpletz) n. comb.—Pia: 34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◀ **Fig. 8** Gymnocodiaceae of the Dena section. *Scale bars* 1 mm. **a, d** *Permocalculus* cf. *solidus*; **a** longitudinal-oblique section; sample D36; **d** longitudinal section; sample no. D44. **b, c** *Permocalculus* cf. *fragilis*; two oblique sections; **b** sample D52; **c** sample D42. **c, g, k** *Permocalculus* cf. *digitatus*; **c** (small specimen); sample D42; **g** longitudinal section; sample D18; **k** longitudinal-oblique section; sample D15. **e–f** *Permocalculus forcepinus*; two longitudinal sections; sample D45. **h** *Gymnocodium bellerophontis*; longitudinal section; sample D35. **i** *Gymnocodium nodosum*; longitudinal section; sample D79. **j** *Tauridium*? sp.; longitudinal-oblique section; sample D15

1991 *Gymnocodium bellerophontis* (Rothpletz) Pia—Roux: 138, pl. 1, fig. 1 (with synonymy)

Description This alga has been sporadically found in the lower and upper carbonate unit of the Dena section. The specimens are perfectly similar to an illustration of Partoazar (1995, pl. 5, fig. 1), but differ from the type material of Pia by a more regularly cylindrical thallus, which is weakly curved, with the files of cells smaller and less marked through the wall. In one specimen, the rounded conceptacle has a diameter of 0.096 mm. The specimens studied by Rezak (1959) have broader pore diameters than those of the Dena specimens. Conversely, the latter have larger pores and thicker walls than the specimens studied by Elliott (1955).

Dimensions $L = 1.22–1.76$ mm; $D = 1.14–1.18$ mm; $d = 0.56–0.86$ mm; $s = 0.33–0.40$ mm; $p = 0.05–0.09$ mm.

Occurrence Middle-Late Permian of Europe (Slovenia, Serbia, Bosnia, Montenegro, Italy, Austria, Greece, Hungary), Tunisia, Urals, Near and Middle East [Turkey, Caucasus, Saudi Arabia, Oman, Iraq, Armenia, and Iran (Lys et al. 1978; Partoazar 1995; Vaziri et al. 2005; Kolodka et al. 2012)], central and southwestern Asia (Pakistan (Salt Range), Afghanistan, Uzbekistan (Pamir), Tibet, South China, Thailand, Malaysia, Japan; New Zealand; ?Guatemala. Murgabian (Middle Permian) of the Dena section.

Gymnocodium nodosum Ogilvie Gordon, 1927
Fig. 8i

1927 *Gymnocodium nodosum* n. sp.—Ogilvie Gordon: 71, pl. 9, fig. 9, pl. 13, fig. 5
1991 *Gymnocodium nodosum* (Rothpletz)—Roux: 144, pl. 1, fig. 5 (with synonymy)
1992 *Permocalculus plumosus* Elliott—Okla: 46, figs. 1–2

Description This species is larger than *G. bellerophontis* with marked thallus undulations. *G. nodosum* was mentioned but not illustrated by Jenny (1977, p. 159, 160) from the Nesen Formation of eastern Alborz. As corrected by Mu (1982), *G. nodosum* sensu Wang (1974) is a *G. bellerophontis*.

Dimensions $L = 2.96$ mm; $D = 1.48$ mm; $d = 0.96$ mm; $s = 0.60$ mm; $p = 0.05–0.09$ mm.

Occurrence Late Permian of Italy, Austria, Turkey, ?Tunisia, Saudi Arabia, Armenia, Iran, and Ladakh (Himalaya). Midian (Middle Permian) of the Dena section.

Genus *Permocalculus* Elliott, 1955
Permocalculus cf. *digitatus* Elliott, 1955
Fig. 8c, g, k

cf. 1955 *Permocalculus digitatus* n. sp.—Elliott: 86, pl. 3, fig. 6
cf. 1991 *Permocalculus digitatus* Elliott—Roux: 149, 152
cf. 1992 *Gymnocodium bellerophontis* Pia—Okla: pl. 46, figs. 3–5

Description The alga is found in the lower and middle carbonate units of the Dena section. The thallus is cylindrical or finger-shaped. The medullar zone is always completely uncalcified, and the cellular files in the cortical zone are few abundant and resemble acrophorous laterals. These cortical files of cells are arranged slightly oblique to the wall and are occasionally divided into two or three branches with diameters of 0.052–0.068 mm. Their density in the cortex is moderate. Rare conceptacles were observed (Fig. 8k). Contrary to the opinion of Elliott (1955), this species cannot be the basal portion of a *Permocalculus fragilis* because both species are morphologically very different in our material.

Dimensions $L = 1.37–2.29$ mm; $D = (0.37)–1.35–1.40$ mm; $d = (0.18)–0.76–0.94$ mm; $s = 0.12–0.24$ mm; $p = 0.03$ mm.

Occurrence Murgabian (Middle Permian) of the Dena section. This alga has been found sporadically in thin-sections of the lower and middle units of the Dena section, associated with *Permocalculus* spp. and *Gyroporella* spp.

Permocalculus forcepinus (Johnson, 1951)
Fig. 8e–f

1951 *Gymnocodium forcepinum* n. sp.—Johnson: 28, pl. 9, figs. 3, 9
1991 *Permocalculus forcepinus* (Johnson)—Roux: 152, pl. 2, fig. 3 (with synonymy)

Description Species characterized by the deep segmentation of its thallus; i.e., a "waxing-and-waning" outline [consequently, *P. fragilis* forma *moniliformis* (Pia) sensu Kochansky-Devidé et Slisković (1969) and *P. anatoliensis* Güvenç, 1966 are probably junior synonyms]. The thallus is generally extensively calcified with disappearance of skeletal details.

Dimensions $L = 4.22$–6.76 mm; $D = 2.14$–2.58 mm; $s = 0.33$–0.60 mm; $p = 0.05$–0.09 mm.

Occurrence Middle Permian of Texas, Iraq, Armenia, ?Turkey. Murgabian (Middle Permian) of the Dena section.

Permocalculus cf. *fragilis* (Pia, 1937) Elliott, 1955
Fig. 8b–c

cf. 1937 *Gymnocodium fragile* n. sp.—Pia: 70, pl. 12, figs. 1–2
cf. 1955 *Permocalculus fragilis* (Pia)—Elliott: 86, pl. 1, figs. 1–2
cf. 1960 *Permocalculus fragilis* (Pia)—Herak and Kochansky-Devidé: 188, pl. 2, fig. 1–4, pl. 3, figs. 1–8
cf. 1963 *Permocalculus fragilis* (Pia)—Herak and Kochansky-Devidé: 65, pl. 3, figs. 2–9, pl. 4, fig. 1
cf. 1977 *Permocalculus fragilis* (Pia)—Vachard in H. Termier et al.: 10, pl. 1, figs. 1–3, 5–6
non 1983 *Permocalculus* cf. *fragilis* (Pia)—Schäfer and Senowbari-Daryan: 116, pl. 8, fig. 7
cf. 1991 *Permocalculus fragilis* (Pia)—Roux: 152, pl. 2, figs. 4–5 (with synonymy)

Description This alga is common in the lower and middle carbonate units of the Dena section. The thallus, when well preserved, is ovoid to spherical. The uncalcified medullar zone is large and the cortical zone thin. The density of the cortical file of cells is variable but occasionally high. They exhibit 3 or 4 ramifications in the cortical zone. Rare conceptacles located at the boundary between the medullar and cortical zones have been observed (Fig. 8c).

Dimensions $L = 1.69$–4.70 mm; $D = (0.52)$–1.14–2.50 mm; $d = 1.00$–2.16 mm; $s = (0.06)$–0.14–0.20 mm; $p = 0.03$–0.085 mm.

Occurrence Murgabian (Middle Permian) of the Dena section. This alga co-occurs with *Mizzia* sp., *Permocalculus* sp., and *Epimastoporella* spp.

Permocalculus plumosus Elliott, 1955
Fig. 7h–j

1955 *Permocalculus plumosus* n. sp.—Elliott,: 87, pl. 3, figs. 2–5
1982 *Permocalculus* aff. *plumosus* Elliott—Mu: 214, pl. 1, fig. 3
1991 *Permocalculus plumosus* Elliott—Roux: 158, pl. 2, figs. 11–12 (with synonymy)

Description A number of longitudinal and oblique sections have been found in thin-sections the lower and middle carbonate units of Dena succession. The thallus is slightly segmented with ovoid-elongate elements. Some specimens exhibit a preserved medulla and relatively numerous conceptacles as dark oval cavities with diameters of 0.46–0.66 mm (Fig. 7h–j). The cortex is well calcified and the files of cells, almost perpendicular to the wall, often show three to four ramifications. The specimens from the Dena Mountain have generally larger diameters than those described by Elliott (1955).

Dimensions $L = 2.63$–5.53 mm; $D = 1.22$–3.06 mm; $d = 0.53$–2.26 mm; $s = 0.13$–1.05 mm; $p = 0.02$–0.035 mm.

Occurrence Murgabian (Middle Permian) of the Dena section. This alga co-occurs with *Mizzia yabei* and *Permocalculus* spp.

Permocalculus cf. *solidus* (Pia 1937) Elliott, 1955
Fig. 8a, d

cf. 1937 *Gymnocodium solidum* n. sp.—Pia: 28, pl. 9, fig. 1?, pl. 13, figs. 1–2
cf. 1955 *Permocalculus solidus* (Pia)—Elliott: 86, pl. 2, figs. 5—6
cf. 1969 *Permocalculus fragilis* forma *solidus* (Pia)—Kochansky-Devidé and Slisković: 106, pl. 2, fig. 2
cf. 1991 *Permocalculus solidus* (Pia) Elliott—Roux: 158, pl. 2, fig. 3
cf. 1992 *Succodium difficile* Kordé—Okla: pl. 46, figs. 6–8

Description The cylindrical to finger-shaped thalli are very well preserved in the cortical zone but also in the medullar one (Fig. 8d). Consequently, these specimens are almost at the stage of *Pyrulites* Mu, 1981 where the medullar zone is entirely preserved. Other evidence that *Pyrulites* is only a stage and no a genus or subgenus is its presence in the Cretaceous (Bucur 1994; Schlagintweit and Sanders 2007).

Dimensions $L = 2.22$–2.76 mm; $D = 2.74$–2.88 mm; $s = 0.33$–0.60 mm; $p = 0.02$–0.05 mm.

Occurrence Late Permian of the Carnic Alps, Saudi Arabia, Iraq, Tunisia, Pakistan. Murgabian (Middle Permian) of the Dena section.

Genus *Tauridium* Güvenç, 1966
Tauridium? sp.
Fig. 8j

? 1992 *Succodium* sp.—Okla: pl. 46, figs. 8–9

Description According to Vachard et al. (2005), *Tauridium* is another preservational stage of *Permocalculus* where the files of cells are remarkably preserved. We have observed one specimen with this characteristic.

Dimensions $L = 2.76$ mm; $D = 2.18$ mm; $d = 1.76$ mm; $s = 0.17–0.20$ mm; $p = 0.075–0.09$ mm.

Occurrence The genus has been recorded from the late Middle and Late Permian of Turkey, Iraq, and Saudi Arabia. The form from Turkey, illustrated by Flügel (1990, pl. 4, fig. 7), is in fact an algosponge. This is the first, albeit doubtful, record of the genus from Iran.

Algae incertae sedis
Phylloid algae (green and/or red algae)

Description Phylloid algae are present in our material as sparitized fragments with micro-perforations. The latter are interpreted either as siphons of codiaceans (e.g., Chuvashov et al. 1987; Mamet 1991) or as secondary small tunnels bored by possible bacteria (Vachard et al. 1989a). Different forms of siphons or microborings permit the distinction of several morphogenera, in particular *Eugonophyllum* Konishi and Wray, 1961 and *Ivanovia* Khvorova, 1946.

Remarks We agree with Schlagintweit (2010) and Granier (2012) to consider the phylloid algae as an informal botanical group. *Calcifolium* and the calcifoliids differ totally (Vachard and Cózar 2010). Nevertheless, other forms such as *Archaeolithophyllum*, *Anchicodium*, *Ivanovia*, *Eugonophyllum*, and *Neoanchicodium* remain botanically and diagenetically related according to the scenarios previously proposed by Vachard et al. (1989a, 2001, 2012).

Occurrence Middle Pennsylvanian-Middle Permian, cosmopolitan.

Genus *Eugonophyllum* Konishi and Wray, 1961
Eugonophyllum? sp.
Fig. 6j–k

Description Two particular longitudinal sections have been observed in the lower carbonate unit of the Dena profile. They resemble some *Eugonophyllum* of the literature but might also correspond to gastropod and/or bivalve fragments perforated by microendolithic cyanobacteria or algae. The fragments are broad and irregularly arcuate. Their lengths range from 0.17 to 0.43 mm. On the surface, there are small and elongate tunnels, siphons or microborings with diameters of 0.03–0.07 mm and a length of 0.11–0.46 mm. The inner parts do not show a crystallized and structural medulla and cortex. *Eugonophyllum*? sp. is the only "phylloid alga" observed in the Dena section.

Occurrence Murgabian (Middle Permian) part of the Dena section. This taxon has been found in high-energy carbonates associated with *Permocalculus* spp, and the foraminifer *Pachyphloia* spp.

Class Algospongia G. Termier et al. 1977a, b emend. Vachard and Cózar, 2010
Order Aoujgaliida G. Termier et al., 1975 emend. Vachard and Cózar, 2010
Family Aoujgaliidae G. Termier et al., 1975 nom. translat. Vachard and Cózar, 2010
Genus *Stacheoides* Cummings, 1955
Stacheoides sp.
Fig. 9e–f

Description In the lower carbonate unit of the Dena section, some *Stacheoides* sp. were found. They are attached, and consist of concentric rows of hemispherical cells or chambers. No aperture or connexion visible. Wall calcitic, yellowish, and hyaline. This species seems to be similar to that mentioned from Afghanistan by Vachard (1980).

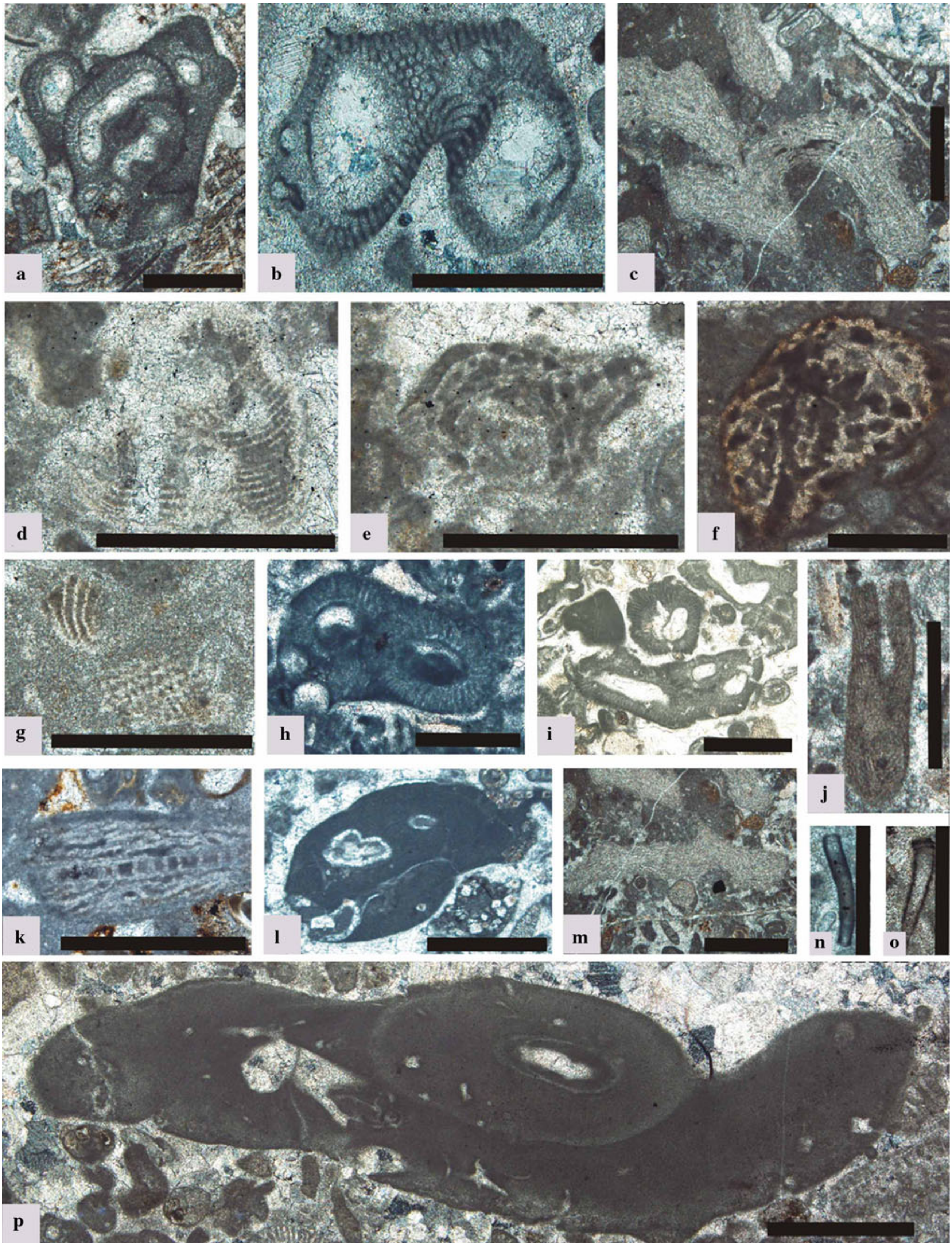
Dimensions $L = 1.30–1.80$ mm; cell dimensions = 0.03–0.05 mm × 0.05–0.10 mm; cell wall thickness = 0.01–0.03 mm.

Occurrence Late Middle Mississippian-Late Permian (see references in Vachard and Cózar 2010). Cosmopolitan up to the Early Permian; after that limited to the shelves of the Paleo- and Neotethys. Murgabian (Middle Permian) part of the Dena section.

Family Ungdarellidae Maslov, 1956a emend. Vachard and Cózar, 2010

Description Aoujgaliida showing an attached-to arborescent shape, cylindrical and branched, and embracing rows of the chambers. Occasionally, the initial stage is attached, similar to *Stacheoides*, followed by an erect stage. The endoskeleton is composed of conical to paraboloid concentric laminae growing upward or downward in continuous rows of chambers, and perforated pillars, transverse, perpendicular to each lamina, acting as communications between the chambers (Vachard 1980, fig. 74). Bifurcations of the laminae and thallus have the same orientation as the growth direction contrary to e.g., *Komia* Kordé, 1951. Wall calcitic, yellowish, and hyaline.

Occurrence Middle Mississippian (late Visean zone MFZ14) to Late Permian (Vachard and Cózar 2010). Cosmopolitan up to the Early Permian; after that restricted to the Palaeo- and Neotethys.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◀ **Fig. 9** Incertae sedis algae and microproblematica of the Dena section. *Scale bars* 1 mm. **a-b** *Pseudovermiporella sodalica*; typical specimens; **a** sample D44; **b** sample D45. **c, j-k, m** *Ungdarella uralica*; typical specimens; **c** sample D36; **j** sample D24; **k** sample D31; **m** sample D36. **d, g** *Fourstonella* (*Efluegelia*) *johnsoni*; typical specimens; **d** sample D36; **g** sample D54. **e–f** *Stacheoides* sp., typical specimens; **e** sample D49; **f** sample D 36. **h** *Pseudovermiporella nipponica*; typical specimen; sample D19. **i** *Pseudovermiporella longipora*; typical specimen; sample D19. **l, p** *Tubiphytes obscurus*; different specimens; **l** sample D24; **p** sample D25. **n–o** *Aeolisaccus dunningtoni*; typical specimens; **n** sample D25; **o** sample D52

Genus *Ungdarella* (Maslov, 1950) Maslov, 1956a
Ungdarella uralica Maslov, 1956a
Fig. 9c, j–k, m

1950 *Ungdarella uralica* n. gen. n. sp.—Maslov: 75, fig. 1
1956a *Ungdarella uralica* Maslov—Maslov: 73, pl. 21, figs. 2–3, pl. 23, figs. 1–4, 18–19
1972 *Ungdarella uralica* Maslov—Homann: 155, pl. 1, fig. 4
1972 *Ungdarella uralica* Maslov—Mamet and Rudloff: 91. pl. 9, figs. 1–5
1973 *Ungdarella uralica* Maslov—Ivanova: pl. 21, fig. 8, pl. 28, figs. 4–5, pl. 34, fig. 7
1977 *Ungdarella* cf. *uralica* Maslov—Mamet and Roux: 229, pl. 6, fig. 3

Description This microfossil has been observed sporadically in lower and middle parts of the Dena profile. The thallus is rod-shaped, branched, with an apparently cellular construction. Due to the generally strong recrystallization, only yellow or cream-colored indistinct bodies are seen.

Dimensions $L = 1.39–4.16$ mm; $D = 0.46–0.81$ mm; height of cell laminae = 0.01–0.017 mm and width of cells = 0.017–0.022 mm.

Comparison Many species of *Ungdarella* exist in the literature. Several authors, however, consider that only the very polymorphic *U. uralica* should be recognized.

Occurrence As for the genus, Permian representatives are relatively common in the Carnic Alps, Russia, Turkey, Armenia, Iraq, Afghanistan, Himalaya, and Iran (e.g., Kolodka et al. 2012). Murgabian (Middle Permian) part of the Dena section.

Family Stacheiidae Loeblich and Tappan, 1961
nomen translat. Vachard and Cózar, 2010

Description Attached *Aoujgaliida*, showing many rows of quadratic cells or chamberlets with a uniserial, partly overlapping growth. Chamberlets square or higher than wide with distal and proximal, curved sides, and rectilinear lateral sides.

Occurrence Late Viséan-Late Permian, probably cosmopolitan (especially *Efluegelia*).

Genus *Fourstonella* Cummings, 1955
Subgenus *Efluegelia* Vachard in Massa and Vachard, 1979

Type species *Cuneiphycus johnsoni* Flügel, 1966.

Discussion *Efluegelia* can be synonymized with *Fourstonella* (see discussion in Vachard and Cózar 2010) or considered as a subgenus of *Fourstonella* because it replaces definitively the true *Fourstonella* at the end of the Moscovian and is the unique representative of the stacheiids during Late Pennsylvanian and Permian times (Vachard et al. 2012; this work). The subgenus is currently monospecific, although some undescribed new species exist in the Middle Pennsylvanian of Iran and Russia (Vachard, unpubl, data). *Fourstonella* (*Efluegelia*) differs from *F.* (*Fourstonella*) by the absence of axial symmetry of the thallus, some differences in the cell walls (Vachard et al. 1989b), and a difference in age. During the Permian, it has been commonly reported from Austria, Russia, Tunisia, Afghanistan, Oman, and Iran (Kolodka et al. 2012) and is well known in the USA (Toomey et al. 1988; Groves 1983; Mamet et al. 1987; Krainer et al. 2003b, 2009; Vachard et al. 2012).

Occurrence Late Visean-Late Permian with an acme in the Late Pennsylvanian and Early Permian; cosmopolitan.

Fourstonella (*Efluegelia*) *johnsoni* (Flügel, 1966) emend. Vachard in Massa and Vachard, 1979
Fig. 9d, g

1966 *Cuneiphycus johnsoni* n. sp.—Flügel: 17, pl. 2, figs. 1–5
1971 *Cuneiphycus johnsoni* Flügel—Lys and Lapparent: 91
1979 *Eflugelia johnsoni* (Flügel) n. gen. n. comb.—Massa and Vachard: 34

Discussion Scattered specimens have been found in thin-sections from the lower unit of the Dena section. The yellowish thallus can display numerous morphological variations. It develops on different substrates, which are often not preserved, and is mostly found as fragments. Most of its structure is not quite recognizable due to recrystallization.

Dimensions $L = 0.68–0.98$ mm; $w = 0.86$ mm; cell width = 0.01–0.02 mm; cell height = 0.015–0.025 mm; cell wall thickness = 0.005–0.01 mm.

Occurrence As for the genus, Murgabian (Middle Permian) part of the Dena section.

Microproblematica and foraminifera/cyanobacteria
Order uncertain
Genus *Aeolisaccus* Elliott, 1958
Aeolisaccus dunningtoni Elliott, 1958
Fig. 9n–o

1958 *Aeolisaccus dunningtoni* n. gen. n. sp.—Elliott: 422, 424, pl. 3, figs 5–6, 8–9
2006 *Earlandia dunningtoni* (Elliott)—Krainer and Vachard: 69, pl. 2, figs. 8, 11–12, 17–18, pl. 6, fig. 8 (with synonymy)
2012 *Aeolisaccus dunningtoni* Elliott—Hughes: pl. 4, figs. 1–15

Description A few representatives of this microfossil have been found in thin-sections from the lower parts of the Dena section. It consists of carbonate tubes apparently open at both ends, although Gaillot and Vachard (2007) and Krainer and Vachard (2011) have encountered very rare specimens with a closed and slightly inflated extremity, which has been compared with to the proloculus of foraminifers by these authors. For other authors (e.g., Hughes 2012), the wall differs from that of the foraminifer *Earlandia*.

Dimensions $L = 0.84–0.90$ mm; $D = 0.06–0.14$ mm; $d = 0.04–0.12$ mm; $s = 0.018–0.02$ mm.

Occurrence The microfossil was first reported from Late Permian rocks of Iraq and subsequently from other parts of the world such as Afghanistan, Europe, and Iran (Gaillot and Vachard 2007). Murgabian (Middle Permian) part of the Dena section.

Family Tubiphytidae Vachard et al., 2012

Description Consortial associations between foraminifers Miliolata (Vachard and Krainer 2001b; Vachard et al. 2010) with cyanobacterial algae. Poorly transformed chambered tubes were called *Cordiformis* Güvenç, 1965 (nom. nud.; see also Vachard and Montenat 1981, pl. 13, fig. 10; Vachard and Ferrière 1991, pl. 1, fig. 4), Foraminifer gen. et sp. indet. by Senowbari-Daryan and Flügel (1993, pl. 3, figs. 7–10, pl. 4, figs. 5–6), etc. Typical forms appear as masses of a rounded, thick-walled taxon with a small, rounded cavity (e.g., Razgallah and Vachard 1991; Senowbari-Daryan and Flügel 1993; Fig. 9l, p). The family crosses the Permio-Triassic boundary.

Occurrence Late Middle Pennsylvanian (Late Moscovian)-Early Cretaceous. For Pennsylvanian forms, see Vachard and Moix (2011) and Vachard et al. (2012), and for the Mesozoic forms, see Senowbari-Daryan et al. (2008) and Schlagintweit and Gawlick (2009b). True *Tubiphytes* are limited to Permian strata (Vachard et al. 2012).

Genus *Tubiphytes* Maslov, 1956b
Tubiphytes obscurus Maslov, 1956b
Fig. 9l, p

1949 Trubchatye vodorosli (tubular algae) *Tubiella*—Rauzer-Chernousova: 10, 14
?1950 *Shamovella*—Rauzer-Chernousova: 17, pl. 3, figs. 1–2
1956a *Tubiphytes obscurus* n. gen. n. sp.—Maslov: 82, text-fig. 22, pl. 25, figs. 1, 3, pl. 26, pl. 27, figs. 1–3
1960 Corallinaceae ind.—Bilgütay: 53, pl. 1, figs. 1–2
1972 *Tubiphytes obscurus* Maslov—Homann: 254, pl. 10, figs. 71, 75–76
1977 *Tubiphytes obscurus* Maslov—Flügel: table 2: 318, pl. 2, figs. 2–4
1977 *Tubiphytes obscurus* Maslov—Vachard in H. Termier et al.: 16, pl. 4, fig. 14b only (non pl. 3, fig. 2)
1977 *Tubiphytes obscurus* Maslov—Jenny: 150, 151, 160
1978 *Tubiphytes obscurus* Maslov—Stampfli: 95, 98?, 104, 108
2003 *Tubiphytes* ex gr. *obscurus* Maslov—Vachard et al.: pl. 4, figs. 1, 4–5

Description Common in thin-sections from the lower and middle carbonate units of the Dena section. In general, these remains are common in material from Iran, where they are very diversified, and vary from morphotypes looking like foraminifers (compare Vachard et al. 1993b, pl. 3, fig. 4) to small domes with one or several cavities (compare Vachard et al. 1993b, pl. 3, fig. 1). Typical specimens were found at Kuh-e Gakhum (Zagros, Iran) by Gaillot (2006) in the Lower Dalan Formation. In contrast, *Tubiphytes* of the Dena section are commonly irregularly cylindrical in shape, with smooth external surface and characteristic dark walls. They are segmented and each segment has a spherical, oval, cylindrical, or annulated cavity that is filled with sparite.

Dimensions Outer diameter = 0.45–0.55 mm, diameter of the central cavity = 0.10–0.125 mm, wall thickness = 0.075–0.15 mm. Typical forms attain 5–6 mm in length (Elliott 1962).

Occurrence Throughout the Permian, from the earliest Wolfcampian to the latest Changhsinghian (Lys et al. 1978; Altiner and Özkan-Altiner 1998; Vachard et al. 2003, 2012). This microfossil has been reported from the Urals, Japan, Indonesia, Afghanistan, Himalaya, Guatemala, Mexico, USA, Algeria, Turkey, Iraq, Greece, Oman, China (Mu et al. 2005), and Iran (Vaziri et al. 2005; Kolodka et al. 2012). Its range is Midian-Wuchiapingian in the Zagros Mts (Gaillot 2006). Murgabian (Middle Permian) part of the Dena section.

Genus *Pseudovermiporella* Elliott, 1958
Pseudovermiporella nipponica (Endo in Endo et Kanuma, 1954)
Fig. 9h

1954 *Vermiporella nipponica* n. sp.—Endo in Endo and Kanuma: 191, pl. 13, figs. 2–5
2007 *Pseudovermiporella nipponica* (Endo)—Gaillot and Vachard: 82, pl. 58, fig. 16, pl. 59, figs. 4, 19 (with synonymy)

Description The species is characterized by a moderately thick wall; pits straight, of small diameter.

Dimensions L = up to 2.00 mm; D = 0.40–0.65 mm; d = 0.10–0.45 mm; s = 0.07–0.12 mm; pits diameter = 0.005–0.01 mm.

Occurrence Relatively common and cosmopolitan from the Sakmarian (Vachard and Krainer 2001a; Krainer et al. 2003b, 2009) to the Changsinghian. Already mentioned in Zagros by Gaillot (2006) and Gaillot and Vachard (2007). Murgabian part of the Dena section.

Pseudovermiporella sodalica Elliott, 1958
Fig. 9a,b

1958 *Pseudovermiporella sodalica* n. sp.—Elliott: 419, pl. 1, figs. 1–6, pl. 2, figs. 2–6, pl. 3, figs. 1–4, 7
2007 *Pseudovermiporella sodalica* (Elliott)—Gaillot and Vachard: 83, pl. 34, fig. 18, pl. 57, figs. 2–6 (with synonymy)
2009 *Mizzia* sp.—Gaetani et al.: figs. 16.14–16.15

Description The microfossil includes some tubular skeletons with circular, oval, or irregular transverse sections. Pits are perpendicular to the central chamber and are polygonal or rounded in tangential sections.

Dimensions L = 0.96–2.74 mm; D = 0.56–1.08 (2.20) mm; d = 0.52–1.16 mm; s = 0.08–0.31 (0.69) mm; pits diameter = 0.02–0.06 mm (with a wall of 0.01–0.04 mm).

Comparison The species differs from *P. nipponica* and *P. longipora* by the shape and dimensions of the pits. They are shorter and wider in *P. nipponica*, and larger and narrower in *P. longipora*. *Pseudovermiporella sodalica* is often confused with true algae [e.g., *Mizzia*; Gaetani et al. (2009) or *Thaumatoporella*; Schlagintweit (2011)].

Occurrence Middle-Late Permian of Iraq, Oman, Afghanistan, Turkey, Hungary, Greece, Slovenia, Croatia, Armenia, North America, Tunisia, China, and SE Asia (Mu et al. 2005), and Iran (Kolodka et al. 2012). Murgabian (Middle Permian) part of the Dena section.

Pseudovermiporella longipora (Praturlon 1963)
Fig. 9i

1954 *Vermiporella nipponica* var. *longipora* n. var.—Praturlon: 126, pl. 2, figs. 1–7
2003 *Pseudovermiporella* ex gr. *nipponica* (Endo)—Vachard et al.: pl. 4, fig. 3
2007 *Pseudovermiporella nipponica* (Endo)—Gaillot and Vachard: pl. 58, fig. 16, pl. 59, figs. 4, 19 (with synonymy)

Description Some of these microfossils have been found in thin-sections from the lower and middle carbonate units of the Dena section. This microfossil is irregularly cylindrical. The pits are long, curved, relatively narrow, and thin-walled. Some pits divide into two branches outward.

Dimensions L = 0.87–2.37 mm; D = 0.31–0.43 mm; s = 0.05–0.11 mm.

Comparison *Pseudovermiporella longipora* differs from *P. nipponica* and *P. solida* by having more slender, larger, and curved pits (= pores of the authors).

Occurrence Late Permian of Italy, Greece, Turkey, and Oman. Murgabian (Middle Permian) part of the Dena section.

Discussion

The described assemblage is traditional, being dominated by *Mizzia* and *Permocalculus*. We assigned all sections of *Mizzia* to a unique species, *M. yabei*, but we identified several species for our *Permocalculus* because (a) as illustrated our taxa have very different morphologies and (b) attempts to synonymize previous species (but often with the creation of new species) are rare or have never been confirmed (Elliott 1955; Kochansky-Devidé and Sliskovic 1969; Termier et al. 1977a, b; Vachard 1980; Roux 1991). *Gymnocodium* is quite rare in our material, but epimastoporellaceans and gyroporellaceans are relatively abundant and diversified. All these microfossils have a relatively broad distribution in the Permian period but are paleoecologically very important (Elliott 1968a; Vachard 1980; Gaillot 2006; Hughes 2012). They characterize very shallow but somewhat confined environments (with relatively high salinity and moderate water energy) above the fair-weather wave-base.

As light-sensitive organisms and thus indicators for light penetration, they are very important for paleoecological reconstructions. Paleobathymetric considerations for this group are based on the presence of modern dasycladales in the uppermost meters of the water column and in high water temperatures. Dasycladales are a parangon of the shallowest marine depths with a peak abundance at approximately 5–6 m, becoming rare between 10 and 30 m, and exceptional beyond these depths. The deepest ones were found at 90 m, but at a water temperature surpassing 17 °C (Elliott 1968a, 1977; Purser 1983; Roux 1985; Kirkland and Chapman 1990; Bucur and Sasaran 2005). Optimal temperatures of growth are quoted as 25–27 °C (Berger and Kaever 1992; Aguirre and Riding 2005). The dasycladales are all photophile but members of the group have different depth preference.

The modern caulerpales extend to a water depth of 120–150 m but co-dominate the fore-reef from 25–45 to 50–60 m (e.g., Purser 1983; Roux 1985; Blair and Norris 1988; Aponte and Ballantine 2001; Wilson and Vecsei 2005).

Permian true red algae are represented by *Gymnocodium*, *Permocalculus*, and rare solenoporaceans. Modern rhodophyta exhibit a wide depth range (Adey and Macintyre 1973; Purser 1983; Martindale 1992; Aponte and Ballantine 2001; Fagerstrom and Weidlich 2005; Wilson and Vecsei 2005; Perry 2005). Their accumulations or constructions exist between 0 m (algal ridge) to 180 m, with an acme between 60 and 120 m (Adey and Macintyre 1973; Roux 1985; Steneck et al. 1997; Aponte and Ballantine 2001); whereas the deepest Recent crustose coralline red alga was collected at a depth of 268 m (Aponte and Ballantine 2001). Relatively eurybathic, they nevertheless could constitute a high-resolution climate indicator for the mid and high latitude, today (Halfar et al. 2008).

Two groups of incertae sedis algae, very abundant during the Early Carboniferous, are still sporadically present in Permian times: (a) a group of tubular, septate, and ramified tests or thalli considered as green algae, microspongia, or undeterminate protists, which are called moravamminids or Paleoberesellaceae, and (b) a group of laminar, cellular or chambered tests or thalli considered as red algae, microspongia, or undeterminate protists, which are called Aoujgaliids or Ungdarellaceae. Both groups are encompassed in the class Algospongia assigned to incertae sedis algae or protists. According to their interpretations as algae or protists, their paleobathymetric implications are very controversial (e.g., Lees and Miller 1985; Hennebert and Lees 1985; Lees 1997; Vachard and Cózar 2010).

Conclusions

Eight genera and 22 species of calcareous algae and eight genera and five species of microproblematica were recognized in the Dena section, and some of them were investigated structurally in this study. Among the algae and problematic microfossils identified in this study, gymnocodiacean algae, problematic microfossils, and dasycladacean algae had the highest abundance in the lower carbonate unit of the Dena section. In the upper carbonate unit of the section, early Djulfian (= early Wuchiapingian) in age, there is a sharp decrease in the abundance of calcareous algae and problematic microfossils. The calcareous algae studied in this section are widespread in the lower carbonate unit in lagoonal and shallow-water environments. These true algae are accompanied by problematic algae or by consortia with algae or cyanobacteria that are also photophile, including *Tubiphytes obscurus* (with thick external wall) and *Ungdarella uralica* indicating clear water with depths below 25 m. Therefore, the lower carbonate unit of the Dalan Formation in this section formed in an area exposed to light and wave energy.

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