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Accepted Manuscript

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DOI: 10.22059/GEOPE.2019.275130.648447

Receive Date: 31 January 2019

Revise Date: 18 August 2019

Accept Date: 03 September 2019

On certain Neocomian – Aptian calcareous algae in the West of Kopeh-Dagh (NE-Iran) – Systematics and compared biogeography, focusing on Dasycladales

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(received: 31/01/2019 ; accepted: 03/09/2019)

Abstract

In Western Kopeh-Dagh, the lower Cretaceous carbonate series contains distinctive assemblages of calcareous algae, chiefly Dasycladales which are primarily studied in this work. Based on the significant presence of certain species, the Zard Formation, assigned to the Valanginian and, in its upper part, to the Hauterivian or base of the Barremian, is subdivided into two intervals, respectively A and B. Higher up, the Urgonian-type Tirgan Formation, assigned to the Barremian and Lower Aptian, is subdivided into intervals C and D. On this occasion, the taxonomy and systematics of 17 species of Dasycladales and one *incertae sedis* found in the series are discussed, in relation to some recent standpoints. Out of this inventory, the biogeographic distribution of 11 species is particularly interesting. During the Lower Cretaceous, the Kopeh-Dagh region was quite isolated, northeast of the Izanca, a branch of the Tethys. Assemblages encountered in this region are compared with other areas, encompassing Iberia to the northern margin of West Gondwana. For two species, under any reserve, distribution seems to be related to the genus, therefore with the systematics. On the other hand, the algal habitat, which depending of the species, may be open marine or rather sheltered, appears to be only partially related to biogeography. Finally, the stratigraphic and/or biogeographic distribution of two species appears to be partially related, in one case to the Valanginian OAE1 event, in another case to one or more obstacles in relation to the paleotectonic context.

Keywords: *Early Cretaceous, microfossils, calcareous algae, Kopeh-Dagh basin.*

Introduction

Dasycladalean green algae are common biogenic component of shallow-water carbonates, particularly in bedded limestones of Early Cretaceous deposits. They are known from numerous localities around the world, especially from the Tethyan Realm. In west of Kopeh-Dagh basin, the Lower Cretaceous sedimentary succession is rather monotonous and consists of exclusively shallow-water carbonate rocks, i.e., marl, limestones and dolomites. These sediments accumulated on a shallow-marine platform that limits the occurrence of fully marine organisms, and carbonate producers are restricted to mollusks, foraminifers (e.g. orbitolinids) and calcareous algae. Therefore, considering the scarceness of open-marine organisms (e.g., ammonites, planktonic foraminifera, etc.), which are commonly used in high-resolution biostratigraphy, calcareous algae play an important role in chronological dating of the studied area. Calcareous algae have traditionally been considered as suitable ecological and environmental indices (Wray, 1977; Roux, 1985; Bosence, 1991; Berger & Kaefer, 1992; De Castro, 1997). The study area, due to its rather isolated geographical location in

west of Kopeh-Dagh basin has not attracted the attention of geologists. Indeed, most of works in the recent years focused on the east of Kopeh-Dagh basin, where the sedimentary facies changed from marine carbonates to continental siliciclastic beds (Shourijeh Formation) with its potential for gas reservoir in NE Iran (Moussavi-Harami & Brenner, 1992, 1993). In the present study, Lower Cretaceous sediments (Zard and Tirgan formations) extending in the west of Kopeh-Dagh Basin (Fig. 2), are examined to study the algal distribution, focusing on the Dasycladales. On this occasion, the taxonomy, systematics and biogeographical distribution of some species beyond the study area is also examined.

Geological setting

Iran is a part of Alp-Himalaya orogeny belt, which is compressed between Arabian shield (in the southwest) and Turan plate (in the northeast). The Kopeh-Dagh basin in NE Iran formed after the closure of the Hercynian Ocean following the Middle Triassic orogeny that involved the Iran and Turan plates (Berberian and King, 1981; Ruttner,

1993). More than 7'000 m of carbonate, siliciclastic and evaporitic sediments were deposited in the basin from the Jurassic to the Miocene (Afshar-Harb, 1979, 1994) (Fig. 1), forming five major transgressive–regressive sequences (Moussavi-Harami and Brenner, 1992). Principal formations in the Kopeh-Dagh basin include the Mozduran, Shurijeh, Tirgan, Sarcheshmeh, Sanganeh and Aitamir formations (Fig. 1). At the Late Jurassic to Early Cretaceous transition, due to the retreat of the sea toward the northwest Kopeh-Dagh basin, siliciclastic red beds of the Shurijeh Formation were deposited, forming a fluvial depositional system in

the east. Marine sedimentation continued in the west of the basin, where mainly carbonates and marls of the Zard Formation were deposited. The Tirgan Formation (Urgonian-type deposits) overlies the Shurijeh and Zard formations in the east and west of the basin. The Neocomian sediments have been well studied in east and central part of the Kopeh-Dagh (Afshar-Harb 1969; Moussavi-Harami and Brenner, 1992, 1993; Moussavi-Harami *et al.*, 2009; Mortazavi *et al.*, 2013a, b, c). The Cretaceous sequence consists of the Zard, Tirgan, Sarcheshmeh and Sanganeh formations.

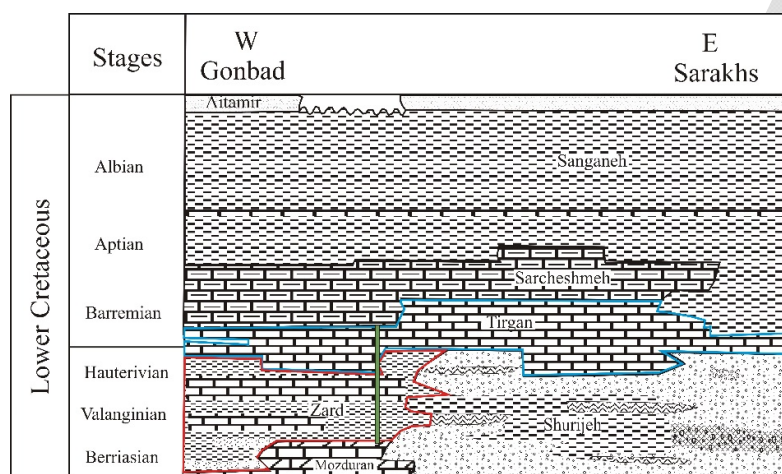


Figure 1. Generalized stratigraphic chart and facies changes in the Kopeh-Dagh basin, showing the Zard (red border) and Tirgan (blue border) formations (Modified after Afshar-harb (1979) and Aghanabati & Rezaie, 2008).

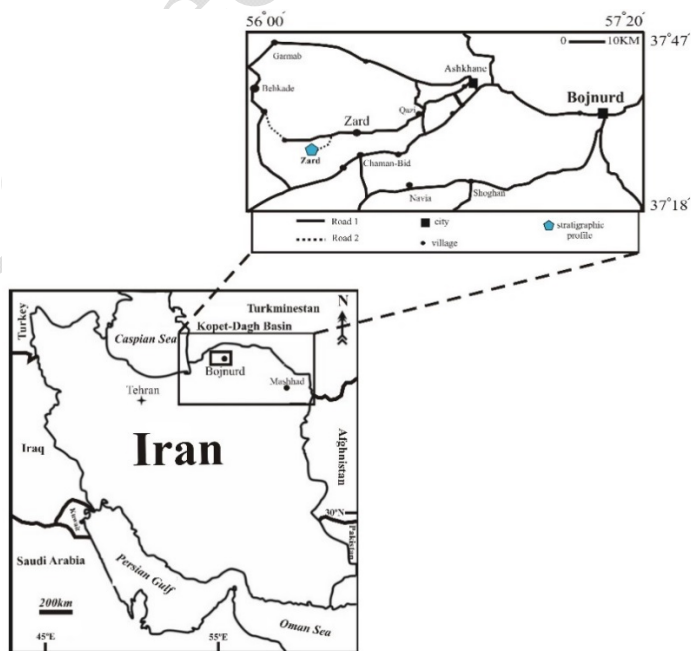


Figure 2. Location map of the study area showing location of measured stratigraphic sections.

The 190m thick Zard Formation is mainly composed of light gray shales and light brown limestones interbedded with thin marl, dolomite and sandstone beds, which overlie the carbonate Mozdouran Formation, and underlies the Tirgan Formation. The Tirgan Formation consists of shallow marine, thick-bedded carbonate (yellow-gray limestone and marl).

Age of the Zard Formation (Zard section) as determined by Afshar-Harb (1979) is Hauterivian-Barremian based on an assemblage of foraminifers comprising *Brotzenia tenuicostata*; *Haplophragmium aeqale*; *Haplophragmoides globose*; *Lenticulina bettenstaedti*; *L. crepidularis*; *L. saxonica*; *L. nodosa*; *Saracenella vestita*; *Triplasia emsladensis*; *Dictyoconus arabicus*; *Gavelinella barremiana*; *Tritaxia tricarinata*. Lower Cretaceous shallow-water carbonates comprising large benthic foraminifera and dasycladalean algae are widely distributed in Iran, e.g., in the Zagros, Alborz, Kopeh-Dagh Mountains and Central Iran (Afshar-Harb 1969; Shakib, 1990; Shirazi, 2008; 2009; Van Buchem *et al.*, 2010; Hosseini, 2014). Micropaleontological studies of these strata in the Kopeh-Dagh basin were undertaken by Bucur *et al.* (2013), and Taherpour Khalil Abad *et al.* (2010a, b, 2013).

The Tirgan Formation in the Kopeh-Dagh is Barremian-Aptian, based on ammonites, algae and foraminifers. In the Shirvan area, some 80 km east of the study area, the algal content of the Tirgan including *Tritaxia tricarinata*, *T. pyramidata*, *Ammobaculites reophacoides*, *Astaculus* cf. *schloenbachi*, *Brotzenia cretosa*, *B. spinulifera polypoides*, *Citharina aptiensis*, *Dentalina distincta*, *Gaudryina dividens*, *Globorodospira djaffaensis*, *Textularia foedu*, *Verneuilinoides subfiliformis*, *Orbitolina kurdica*, *O. discoidea*, and *O. conica* (Taherpour Khalil Abad *et al.*, 2010b; Bucur *et al.*, 2018). Age of Tirgan Formation was also determined as Early Cretaceous (such as near Tirgan village, see Gheiasvand *et al.*, 2019, and the Ali Abad stratigraphic section, see Carević *et al.*, 2013) locally extending as high as the Aptian (Stocklin and Setudehnia, 1991; Taherpour Khalil Abad, 2017; Molaei *et al.*, 2019).

In the present study, the Lower Cretaceous sediments (Zard and Tirgan formations) of the west of Kopeh-Dagh Basin (Fig. 2), were examined to define the algal distribution.

Material and methods

A total of 164 samples were collected from the

Lower Cretaceous succession in the west of the Kopeh-Dagh, to prepare for thin-sections petrography and paleontological analysis (Fig. 3) in the Zard and Tirgan formations. Facies groups based on carbonate grain types, texture and fossil content, mainly Dasycladales, leads to subdividing the studied series into four stratigraphic intervals (A-D), which are presented below. Information on some other species found in the Kopeh-Dagh is included in the discussion.

Systematics, distribution of some of the Dasycladales identified in the Kopeh-Dagh, focusing in the Hauterivian – Aptian

Ordo Dasycladales Pascher, 1931

The following, simple diagnosis applicable to the fossil record is herein proposed, based on terminology adopted by Valet (1969): “Thallus simple, sessile, arising from a rootlike holdfast, branched or anastomosed, made up of stipe supporting one or several orders of lateral offshoots (ramifications). The whole or part of the thallus is covered by a mantle of calcium carbonate. Reproductive organs (cysts) within the stipe, or within the laterals, or between them”.

Family Bornetellaceae Granier & Bucur in Granier *et al.*, 2013

In Granier *et al.* 2012, p. 217: Family Bornetellaceae nov. fam. (basonym *Bornetella*, type species: *B. nitida*), which comprises all goniosporated forms.

Genus *Pseudoactinoporella* Conrad, 1970, emend. Conrad & Peybernès, 1976

In Conrad & Peybernès, 1976: “The thallus consists of a tubular, axial stipe bearing phloiophorous branches building tight whorls, more or less calcified and tipping upwards. Near their basis, branches bear, or are likely to bear, secondary branchlets. In addition, the branchlets themselves bear, or are likely to bear, fertile structures [...]. Considered a junior synonym of *Actinoporella* by Granier (1994). Considered still a distinct taxonomic entity by Bucur (1999). Type-species: *Pseudoactinoporella fragilis* Conrad, 1970, Hauterivian - Aptian. Assignment to the Bornetellaceae is debatable.

Pseudoactinoporella? silvaeregis Bucur, 1981 (Z100; Pl. 1, Fig. m). Interval C, Barremian, Tirgan

Fm.

Although with doubt, the species was originally assigned to the genus *Pseudoactinoporella*. Yet again with doubt, it was assigned by Bucur (1999) to the genus *Falsolikanella* Granier 1987, and by Granier (1994) to the genus *Actinoporella* Gumbel in Alth, 1881. According to Bucur (1992, p. 451 and pl. III, fig. 7; re-illustrated in Bucur 1999, pl. III, fig. 8) the specimens in longitudinal section “exhibits a short globulous primary branch splitting in two phloiophorous branches arranged in a vertical plane”. Besides the laterals start with a short peduncle, then those verging upwards (e.g. second, third, fifth and sixth whorl on the right) exhibit a sort of upward verging “triangular” expansion, those slightly verging downward (second whorl on the left, fourth and seventh on the right) show the “triangular” expansion to set downwards, resulting that all laterals widen regularly outwards. The absence of proximal tangential sections makes difficult to understand if the peduncle corresponds or not to a primary lateral. Therefore, in this paper, the species is, provisionally at least, left in *Pseudoactinoporella*. Distribution: Barremian of Romania and Iranian Kopeh-Dagh. France? (Unconfirmed)

Pseudoactinoporella? iranica Bucur & al., 2012 - (Z102; Pl. 2, Fig. j). Interval C, Barremian, Tirgan Fm. Bucur *et al.* 2018: lower part of the Tirgan Fm, Kopeh-Dagh, Upper Barremian – Lower Aptian.

Original diagnosis: “Relatively large dasycladalean alga with long, phloiophorous-type (funnel-like) laterals. In their proximal area, they contain a small lower protuberance (globular extension). The laterals are slightly compressed (they are more extended in height than in width) and show typical “chess pawn” features in deep tangential sections (as a result of the proximal sectioning of the lateral and of the small globular protuberance). The verticils are closely packed (located close to each other), apparently with the laterals alternating from one verticil to another. Cylindrical thallus with a relatively wide axial cavity. The calcification is more intense around the axial cavity and diminishes towards the distal part of the laterals”. Distribution : Central Iran, Kopeh-Dagh.

Genus *Bakalovaella* Bucur, 1993

The author (p. 100) gives the following diagnosis: “Thallus cylindrical, non-segmented. Axial cavity with a slightly moniliform outline. Primary and secondary ramifications, alternating in adjacent

whorls. At their end the primary, tubular ramifications give rise, on the upper side, to big sub-spheric fertile ampoules, and on the lower one, under the fertile ampoules, to secondary tubular ramifications widening distally. Calcification consists of a thick and compact sheath comprising both primary and secondary ramifications.”. Synonyms; *Barattoloporellospis* Granier *et al.*, 2016. Type-species: *Bakalovaella elitzae* (Bakalova, 1980) Bucur 1993, Hauterivian-Albian.

Bakalovaella elitzae (Bakalova, 1980) Bucur 1993 (Z84, Z98, Z102; Pl. 2, Figs. b, c, d and g). Intervals B, C, Hauterivian, Barremian, top Zard and Tirgan formations. Also: Bucur *et al.* (2018), under *Bakalovaella elitzae*, and Taherpour *et al.* (2010), same area.

The following informal diagnosis is herein proposed, based on Bucur (1993), under *Bakalovaella elitzae*: Thallus thick, strongly calcified by colorless hyaline calcite, cylindrical, bearing verticils of short tubular first order ramifications. Stipe cylindrical or constricted at height of the verticils. Two types of secondaries are clustered at tip of the primaries: (1) one (single) big sub-spherical or egg-like blister (assumed fertile), slightly oblique, tilted upwards to the axis, (2) two slender secondaries, first tubular, widening out at tips, are found below”. Distribution: Hauterivian – Albian. N. & S. margin of the Tethys, in Bulgaria, Romania, Eastern Seberia, continental Italy (Latium), SW Switzerland, Spain, Pacific, Kopeh-Dagh, Zagros, Guatemala.

Synonyms, transfers - Pending further studies, the following taxa are provisionally considered synonyms or are transferred to *B. elitzae*: *Bakalovaella benizarensis* (Jaffrezo, 1978) Bucur, 1993; *Cylindroporella barbui* Dragastan *et al.*, 1989, ex Dragastan, 1978; *Cylindroporella benizarensis* Fourcade *et al.* ex Jaffrezo in Bassoullet *et al.*, 1978; *Cylindroporella elitzae* Bakalova, 1971; *Montiella benizarensis* (Jaffrezo, 1978) Granier, 1990.

Remarks on *Bakalovaella* - According to Bucur *et al.* (2012), the genus *Bakalovaella* Bucur 1993, type-species *B. elitzae*, is a junior synonym of *Montiella*, in agreement with the transfer of *Cylindroporella elitzae* Bakalova to the genus *Montiella* proposed by Radoičić (1980). However, the sterile lower part of *Bakalovaella* is cylindrical, Salpingoporella-like, whereas the upper fertile part, also cylindrical, is larger. In this latter part, the

laterals are calcified as of their proximal part, but do not show a clear differentiation in primary and distally located secondary laterals. Seemingly, only primary laterals were present, each bearing a fertile ampulla attached aside. Shape of thallus and laterals cause *Bakalovaella* to be set apart of *Montiella*, the former agreeing with the dactyloporid model, the latter with the neomerid model.

Anyway, the genus type species *Montiella munieri*, displays a segmented (moniliform) thallus and a large central cavity. The inner surface of the calcareous skeleton (Génot 1987, pl. 31, figs. 7-12 and Génot 1993, pl. 2 figs. 2-3) displays two whorls set in continuity, the lowest made of large pores and the upper one made of smaller pores, respectively corresponding to calcified sterile laterals, and distally closed (calcified), gametangia. According to Génot (1987, 1993), these (sterile and fertile) laterals are of second order, arising from the tip of uncalcified primaries, therefore matching the neomerid model. In one specimen, however (Génot, 1987, pl. 31, fig. 10 and Génot, 1993, pl. 2 fig. 5), the gametangium peduncle of is set horizontally, not bending downward, suggesting the possible presence of a massive, uncalcified primary lateral, thus matching the dactyloporid model. The general aspect makes *Montiella* close to *Cymopolia* and *Barattoloporella* (as to the comparative differences between *Montiella* and the Maastrichtian *Barattoloporella* see Parente 1997, pgs. 108-110).

Recently however, the genus *Bakalovaella* was re-instated by Granier et Bucur (2019). Quoting these authors, "From a phylogenetic point of view, based on the "lifting piston" model, this taxon should be part of a lineage derived from the Diploporaceae." In the future, arguments put forward by these authors will need to be thoroughly considered.

Remarks on *Barattoloporellopsis* - Recently, Granier *et al.* (2016) established their new genus *Barattoloporellopsis* based on the Oxfordian *Cylindroporella? lusitanica* Ramalho 1970. The structure of this alga (only one phloiophorous primary lateral, bearing a single reproductive organ attached proximally) recalls the genus *Bakalovaella*. The scattered occurrence of gametangia (cysts) inside some specimens induce the authors to propose their new genus. We fully agree with Granier *et al.* (2016) that from a strictly botanical point of view, the presence of gametangia vs gametophores is a character at genus level (e.g. *Dasycladus* vs. *Chlorocladus*), but such character

can be hardly proved in the fossil record. Lack of cysts inside *Bakalovaella* does not necessarily means reproductive organs are gametangia and not gametophores. On the other side, the actual structure of possibly close genera (e.g. *Cylindroporella* Johnson) still remains unclarified. Therefore, the genus *Barattoloporellopsis* perhaps needs to be further discussed and the taxonomic value of gametangia vs. gametophores should be taken cautiously in paleoalgebra.

Genus *Terquemella* Munier-Chalmas ex L. & J. Morellet, 1913 (Z84; Pl. 2, Fig. i). Interval B, Hauterivian, top Zard Formation.

We assume that the organ-genus *Terquemella*, which refers to isolated reproductive organs consisting of groups of cysts, corresponds to skeletal remains of large Bornetellacean algae. *Terquemella* is found in all our algal assemblages.

Family Dasycladaceae Kützing, 1841, emend.

Granier *et al.* 2012

Emendation in Granier *et al.* 2012: "Fertile laterals have one gametophore (exceptionally two) in terminal position on their primary segment (choristosporate type). The number of secondary segments of laterals varies from one genus to the other". Representatives of this family are characterized by the presence of reproductive organs sited at the end of the laterals, either the primaries in primitive genera, or higher orders in modern genera; this feature is called the choristosporate type.

Tribus Neomereae (Pia, 1920) Bassoullet *et al.*, 1979

Pending future studies, the following diagnosis given by Deloffre (1988), translated, may be revised: "Thallus cylindrical, claviform or moniliform, only primary ramifications or primary and secondary ramifications, choristosporous, fertile blisters at tip of the primary ramifications".

Genus *Neomeris* Lamouroux, 1816

In Barattolo & Romano, 2001, excerpts: "The alga is characterized by a cylindrical thallus bearing whorls of primary laterals. Each primary lateral bear at its outer end a single ovoid ampulla together with two secondary laterals. The laterals, usually those of secondary order, may produce a conical layer [...] The main diagnostic characters utilized in botanical description of specific rank in extant

Neomeris are: shape of primary laterals; shape of secondary laterals and their distal ends making a cortex or not; shape of fertile ampulla and cyst; shape of the plug set at the connection between primary laterals and ampulla; calcification [...]. Type-species: the extant *Neomeris dumetosa*.

Neomeris? cf. *N. cretacea* Steinmann, 1899 (Z100; Pl. 2, Fig. k). Bucur et al. (2018), Tirgan Fm, Kopeh-Dagh, Upper Barremian and Lower Aptian. In the Upper Hauterivian, we found few poorly preserved remains that can be referred to this species. Simplified description: cylindrical, elongated thallus. Two types of laterals, primary, each bearing two sterile secondaries situated on both sides of a fertile, ovoid to ellipsoidal ampulla. Distribution: Hauterivian – Maastrichtian, possibly Early Danian. Tethyan and beyond in Mexico, Europe, N. Africa, Middle East, Kopeh-Dagh, Central Iran.

Family Polyphysaceae Kützing, 1843

In Granier et al. 2013: “Representatives of this family have either two discrete types of laterals, some sterile and others fertile, alternating along the main axis, or verticils of elongated reproductive organs. However, in modern forms, a single terminal fertile verticil called a cap is common; this last feature is called the umbrellosporate type”.

Genus *Actinoporella* (Gümbel, 1882) Barattolo et al., 2019

Emended diagnosis in Barattolo et al. 2019: “Thallus simple, unbranched, bearing spaced-out whorls of short primary laterals. Second-order laterals are three in number: one upper and one lower corona, both arising from the proximal part of the primary lateral, and one large gametophore arising from the tip of the primary lateral.”

Actinoporella podolica (Alth, 1878) Alth, 1882 – Sources: Bucur et al. (2018), lower part of the Tirgan Fm, Gelian section, Kopeh-Dagh; Taherpour et al. (2010), same area. Type-species of the genus. Diagnostic characters etc: Conrad et al. (1974), p. 7. Distribution: Tithonian – Lower Barremian, Eastern and Western Europe, Italy, North Africa, Oman, Turkey, Western Atlantic, Central Iran (cf.), Kopeh-Dagh.

Family Thyrsoportellaceae Granier et al. 2013
In Granier et al. 2013: Family Thyrsoportellaceae

nov. fam. (basonym Thyrsoportella, type species: *T. cancellata*) with syringosporate forms only.

Tribus Thyrsoportelleae PIA, 1927

Emended diagnosis in Elliott (1977): “Tubular or serial-unit calcified dasycladaceans, medium to thick walled, with verticils each usually containing six to eight branches, which divide distally up to five times, all branches and branchlets thickened or swollen, calcification weak adjacent to stem-cell.”

Genus *Deloffrella* Granier & Michaud, 1987

Original diagnosis translated: “Alga with a cylindrical thallus with verticils (euspondylous setting) of equally spaced out ramifications calcified dividing as far as three times dichotomously: formula of the ramifications = 1 (RI): 2 (RII): 4 (RIII): 8 (RIV). Ramifications slightly spaced out and set in quincunx along the main axis. Primary ramification swollen, shaped like the 'cap of a gendarme', specially developed (corresponding alone to more than the half of the total length of the ramification), communicating with the axial canal through a large and rounded pore. Outer surface of the calcareous sleeve with groups (small plates) of 8 small pores, regularly arranged in rows (4 horizontal, 2 vertical), corresponding to the last order of ramification (RIV)”. Kimmeridgian –? Lower Cenomanian. Type-species *D. quercifoliipora*. Cenomanian *Deloffrella? berthoui* Granier & Berthou, 2002: *Deloffrella?* is original.

Deloffrella quercifoliipora Granier & Michaud, 1987. Source: Bucur et al. (2018), Kopeh-Dagh, lower part of the Tirgan Fm, assigned with doubt to the Upper Barremian.

Description in Bucur et al. (2012): “Thallus relatively small, cylindrical, with four orders of shortly branching laterals. In most of the cases, two or three orders of laterals’ branching are visible. However, this alga is easy to identify, especially in oblique and longitudinal due to the typical “oak-leaf” pattern produced by the branching of the laterals and weak calcification”. Distribution: Kimmeridgian – top of Lower Barremian, Aptian unconfirmed.

Family Triploportellaceae (Pia, 1920) Berger & Kaefer, 1992, emend. Granier et al., 2012

In Granier et al. 2013: “Family Triploportellaceae emend. (basonym *Triploportella*, type species *T.*

fraasi) with endosporate and cladospore forms". Quoting Barattolo *et al.* (2008): Berger & Kaeffer "define the Triploporellaceae by "euspondyl arrangement of laterals and cladospore formation of gametangia". Based on this definition, *Linoporella* and *Elliottoporella* ought to be put apart from this family because they are considered endosporous. Although the kind of reproduction (endosporous or cladospore) is a high taxonomic character, their evidence is lacking in most of fossil taxa; often, the attribution to either of two types reproduction sounds speculative. However, the occurrence of thin and delicate laterals, irrespectively of whether trichophorous or phloiophorous, often associated with a bulky central stem, is considered an evidence of endosporous reproduction (for a discussion see De Castro 1997). According to this idea, several taxa (e.g., *Mizzia*, *Oligoporella*, and *Linoporella*) may be considered endosporous. Consequently, the diagnosis of Triploporellaceae ought to include both endosporous and cladospore reproduction.

Tribus Salpingoporellae Bassoullet & al., 1979
Diagnosis in Deloffre (1989), translated: "Thallus cylindrical, not ramified, only primary ramifications, phloiophorous, trichophorous or pyriform". Remark: not mentioned, typical feature is the presence of first order laterals only, arranged in verticils.

Genus *Morelletpora* Varma, 1950
Original diagnosis: "Thallus club-shaped, upper end rounded with a central depression occasionally open. Axial tube hollow, circular in section, bearing a number of branches of the first order only arranged in verticils forming the cortex. Branches arising as thin, upwardly inclined tubes, enlarging abruptly to form long oval to barrel-shaped sporangia, giving the thinner part a stalk-like nature." Type-species: *M. nammalensis* Varma, 1950, Paleocene, India. In our opinion, the assignment to the Neomereae is debatable. Varma described the new *Morelletpora nammalensis* considering the alga is articulated, with club-shaped segments and only first order laterals. This foundation of *Morelletpora* was questioned for a long time. Attribution of a second species, *Morelletpora dienii*, from the Maastrichtian of southern Italy by Parente, reopened discussion. Eventually, Barattolo (2002) transferred *Salpingoporella turgida* to *Morelletpora*, as *Morelletpora turgida* nov. comb., considering the

latter species to be "structurally similar to *M. dienii*".

Morelletpora turgida (Radoičić, 1975) Barattolo, 2002 (Z158, Z160; Pl. 1, Fig. e, i). Interval D, Aptian, Tirgan Fm.

Basionym: *Pianella turgida* Radoičić, 1965, *nom. nud.*, originally described from a Cenomanian limestone of the external Dinarides. Introducing a lectotype, the species was later (1975) validly transferred to *Salpingoporella* by the same author. Recent, yet to be published studies of Lower Cretaceous deposits from Iran revealed the existence of numerous, well preserved specimens of *Morelletpora turgida* in the upper Barremian-Aptian Taft Formation of the ArdekaneHersisht and Anarak areas of central Iran (Bucur *et al.*, 2016). These specimens allow a thorough morphological re-description of this alga and provide clear evidence for both the segmented character of the thallus and the characteristic shape of the laterals. These new data reinforce the assignment of this alga to *Morelletpora*, adding observation that support emendation of the diagnosis. *Morelletpora turgida* has been identified in limestones of Barremian-Cenomanian age from numerous regions (former Yugoslavia, Italy, Lebanon, Romania, Kopeh-Dagh, Central Iran, Turkey) representing the southern and central part of the Tethyan Domain.

Genus *Holosporella* Pia, 1930, emend.
Bernier, 1984

Emended diagnosis in Bernier, translated: "Cylindrical thallus with branches arranged in whorls. The branches are spherical, subspherical or oblong and connected to the axial cavity by a proximal peduncle. The ramifications are only first-order and are arranged either obliquely or perpendicularly to the axial cavity". Type-species: Aalenian – Oxfordian *Holosporella siamensis* Pia, 1930, emend. Conrad & Peybernès, 1973, in Granier & Hofman, 2002. Synonyms: *Sarfatiella* Conrad & Peybernès, 1993; *Vederosella* Dragastan, 1999.

Holosporella sp. aff. *H. alimani* (Dragastan, 1999), n. comb. (Z81; Pl. 2, Fig. a, e). Interval B, Hauterivian, Tirgan Fm.

Excerpts of the original diagnosis: "Thallus small, cylindrical at both ends, slightly conical, crossed by a very narrow axial siphon. The verticils euspondyle made up only of primary, spherical-globulous

ramifications. The ramifications have in the proximal part, a long tubular, peduncle set at an acute angle to the axial siphon [...]. The distal part is spherical-globulous. The ramifications have an alternating, helicospiral disposition in quadruple manner [...]. In axial-longitudinal sections, the ramifications show clearly the long peduncle (proximal), continued distally with a large spherical-globulous part. Sometimes compressed against each-other, like in a compact structure. The ramifications are more or less covered by a "muff" of microcrystalline or coarsely crystalline calcite. [...]. In the cross sections, the thalli have a round outline, crossed by a very narrow axial siphon, surrounded by a thin, inner calcareous wall [...]. The inner calcareous wall of the siphon has a rhombic [...]."

The so far monospecific genus *Vederosella* Dragastan 1999, type-species the *V. alimani* Dragastan 1999, slightly differs from the type-species of *Sarfatiella* and *Holosporella*. Quoting the original, generic diagnosis of *Vederosella*, the vesiculiferous primary laterals are connected to the central stem by "a long proximal tubular peduncle disposed in a sharp angle against the axis". Conversely, the peduncle is short and perpendicular to the axis in *Sarfatiella*, or almost absent in *Holosporella*. Characters such as the moderate length and inclination of the peduncle are not enough to differentiate two taxa at level of the genus. In this paper, *Vederosella* is therefore dealt with as a junior synonym of *Holosporella*, while ensuing Granier and Hofmann (2002), *Sarfatiella* is considered a junior synonym of *Holosporella*. Distribution of *H. alimani*: Dobrogea, Romania, Spanish Pyrenees (unpublished, Upper Hauterivian?), W. Kopeh-Dagh, Iran.

Genus *Praturlonella* Barattolo, 1978

Tentative assignment to the Salpingoporellaeae. Original diagnosis: "Subcylindrical or pearl necklaced simple thallus. Phloiophorous and no further ramified branches, placed in single and spaced whorls. Adult specimens present branches arranged in several inclinations in each whorl. Cortex is discontinuous and made by subsequent, varyingly wide, cortical bands. One band takes rise from single whorl. Reproductive organs are placed, probably inside branches (cladospore type)". Type-species: *Praturlonella salernitana* Barattolo, 1978, Paleocene. See Barattolo et al. 2019 for a discussion. Junior synonyms, cautiously pending detailed studies: *Draconisella* Granier & Berthou,

1990; *Milanoviciella* Granier & Berthou, 1994.

Praturlonella? cf. *P. pejovicae* (Radoičić, 1975) Sokac, 1996. (Z97; Pl. 2, Fig. h). Interval C, Barremian, Tirgan Fm. Excerpts of the original description: "The central stem of this *Clypeina* bores disc like verticils thickened at the periphery and equally spaced. The verticils consist of two rows of alternately set branches, fused laterally along their entire length. While the branches are arched at the ends, the cross-section shows nice, regular rosette. (...) There is one verticil with a large number of branches distributed in two rows. (...) Branches of the lower row are horizontal, and those of the upper row slightly oblique (...). Distribution: Hauterivian – Barremian, Bosnia – Herzegovina, Croatia, SE France (aff.), Romania (aff.), Kopeh-Dagh, Iran (cf.)."

Genus *Salpingoporella* (Pia in Trauth 1918) emend.

Carras & al. 2006

In Carras et al. 2006: "thallus and stipe simple, cylindrical, occasionally slightly club-shaped. Laterals set in simple, disk-like or conical verticils, phloiophorous, sometimes with a short tubular proximal part, open (uncalcified) at tip, forming a cortex. In certain species, calcified cysts or imprints of cysts are present in the laterals (cladospory). External calcareous skeleton coating the laterals and commonly also the stipe, usually colourless, made of interlocking calcite crystals (originally aragonite). In some species the skeleton consists of yellowish or radial-fibrous calcite crystals, apparently retaining part at least of the original mineralogy." Synonyms, transfers: *Apinella* Granier et al., 1986; *Hensonella* Elliott in Granier & Deloffre, 1993; *Pianella* Radoičić, 1962, *nom. van.*; *Salpingoporella* (subgenus *Hensonella*) Granier, 2000; *Siensiporella* Dragastan, 1999. The fossil genus *Salpingoporella*, although simple from a taxonomic point of view, is nonetheless particularly diversified. Globally, 38 species are known, from the base of the Triassic to the top of the Cretaceous. As for the Hauterivian – Aptian interval, there are no less than 23 species, several of which being known only in a given paleogeographic province. Stratigraphic extensions vary considerably, from a single to several stages. In this paper, several species of uncertain attribution are illustrated.

Salpingoporella sp. cf. *S. cemi* Radoičić, 1975 (Z108; Pl. 1, Fig. g). Interval C, Barremian, Tirgan Fm. See also Taherpour et al. (2010), same area.

Diagnostic characters: Large, with laterals forming quincunxes, 10-15 per verticil, horizontal or slightly tilted, funnel-like (first with a very short proximal narrowing, then gradually widening toward the distal part), circular in section, or very seldom somewhat polygonal in subcortical and cortical section. Massive calcareous skeleton made of colourless sparry calcite. Basionym: *Pianella cemi* Radoičić, 1968, nom. nud. Distribution: Hauterivian – Barremian of Montenegro, Spain and south-east France (cf.). Hauterivian – Barremian, Iranian Kopeh-Dagh, lower part of the Tirgan Fm: yet unpublished by E. Bakshi (2016-2017), presence of an exceptionally well-preserved specimen, showing the subcircular, pentagonal shape of the laterals, as visible in tangential section.

Salpingoporella aff. *S. hasi* Conrad, Radoičić & Rey, 1977 (Z81; Pl. 1, Fig. a). Intervals B, C and D, Hauterivian – Aptian, top Zard and Tirgan formations. See also Taherpour et al. (2010), Kopeh-Dagh.

Spelling should be *S. hasensis*, not *S. hasi*. Contrary to our specimens, the calcareous mantle of the younger, Albian – Cenomanian *S. hasi* sensu stricto is partly interrupted between the laterals, characteristically breaking down in small pieces commonly scattered in the micritic sediment. Similar specimens of *S.* aff. *hasi* are illustrated from the Barremian – Bedoulian of Hungary by Bodrogi et al., (1994), Spain by Conrad and Peybernes (1976) and Croatia by Sokač (1996). Global range of *S.* aff. *hasi* is therefore Hauterivian – Bedoulian.

Salpingoporella muehlbergii (Lorenz, 1902) Pia, 1918 (Z93, Z97; Pl. 1, Fig. b, c, f, j, and k). Intervals B, C and D, Hauterivian – Aptian, top Zard and Tirgan formations. Bucur et al. (2018), Tirgan Fm *pro parte*, Kopeh-Dagh, Upper Barremian – Lower Aptian. See also Taherpour et al. (2010), Kopeh-Dagh.

In Carras et al. 2006: "Laterals set in quincunxes, 5-11 per verticil, horizontal (sometimes slightly leaning up), first with a narrow tubular proximal part, then widening out, circular, rhombic or irregular in section. Distal part of the laterals circular or slightly horizontally elongated. Questionable presence of cysts in the laterals. Calcareous skeleton made of colorless sparry calcite". Type-species of the genus. Synonyms, transfers: *Salpingoporella carpathica* Dragastan 1989, non 1969; *Diplopora muehlbergii* Lorenz,

1902 (the basionym); *Pianella muehlbergii* (Lorenz, 1902) Praturlon & Radoičić, 1973, nom. nud. Distribution: Western and Eastern Europe, Middle East, North Africa, Dinarides, S. Italy, Kopeh-Dagh, Central Iran (cf., Aliabad). Apparently missing in the Zagros.

Genus *Similiclypeina* Bucur, 1993, emend.
Conrad & al., 2009

Provisional assignment, pending a revision of the genus. Emendation in Conrad & al. 2009: "Thallus and stipe cylindrical. Laterals forming contiguous, overlapping whorls, horizontal or slightly tilted, directly connected to the stipe (proximal handle almost missing), first strongly inflated, horizontally flattened and commonly with cyst imprints, then markedly elongated, distally acuminate. Calcification made up of sparry calcite, coating the stipe and each lateral, independently." Type-species: *Similiclypeina conradii*.

Similiclypeina? conradii Bucur, (Z100; Pl. 1, Fig. n). Interval C, Barremian, Tirgan Fm.

Species name herein corrected. Distribution: Barremian of Romania, N.E. Turkey, Kopeh-Dagh, Iran.

Tribus Triploporelleae (Pia, 1920) Bassoulet et al., 1979

Emended diagnosis in Bucur (1993, p. 78): "Thallus cylindrical, claviform, moniliform or spherical; ramifications of the first and second order, possibly the third or fourth."

Genus *Biokoviella* Sokač, 2004, emend. pending Assignment to the Triploporelleae is debatable. The following original diagnosis should be formally emended, based on the presence of clustered secondaries in the type-species *B. robusta* (see below): "Thallus club-shaped, upper end rounded with a central depression occasionally open. Axial tube hollow, circular in section, bearing a number of branches of the first order only arranged in verticils forming the cortex. Branches arising as thin, upwardly inclined tubes, enlarging abruptly to form long oval to barrel-shaped sporangia, giving the thinner part a stalk-like nature." Basionym: *Salpingoporella robusta* Sokac, 1993. *Biokoviella gusici* Sokac, 2004: synonym of *Acroporella radoičićiae* Praturlon, 1964.

Biokoviella cf. *B. robusta* (1993) Sokač, 2004 (Z96,

Z161; Pl. 2, Fig. f, m). Intervals C and D, Barremian and Aptian, Tirgan Fm.

Amended diagnosis in Sokač 2004: "Comparatively large, generally phloiophorous, branches may be variously shaped: more or less strongly swollen, with a short stalk, or more club-shaped, widening gradually from the base toward the distal end. The number of branches in a whorl can also vary [...]. Depending on the shape of the primary branches, the consecutive whorls may be seemingly more or less densely spaced. Primary branches bear short secondaries, crowded together in a tuft, which are visible as funnel-shaped depressions on the outer surface of the skeleton. Some specimens may have irregular secondaries, some of which may even show a tertiary division." Comparisons: in *Salpingoporella muehlbergii*, found in same interval, the laterals are funnel-like instead of bulgy, with no secondaries. *Acroporella radoičićiae*: primary laterals are tubular. Distribution: Barremian – Early Aptian of Croatia, Kopeh-Dagh and Central Iran (cf.).

Genus *Kopetdagaria* Maslov, 1960

Emended diagnosis on Conrad and Radoičić (1979), translated: "Thallus simple, cylindrical and verticillated. Fertile branches close together, short, egg-shaped and entirely calcified. Optional presence of second order sterile hairs".

Kopetdagaria sphaerica Maslov, 1960. Source: Bucur et al. (2018), upper part of the Tirgan Fm, Gelian section, Kopeh-Dagh. Barremian – Aptian. See also Taherpour et al. (2013).

In Bucur 2002, emended diagnosis: "Thallus claviform, with a cylindrical lower part, and an upper ovoidal wider part. Wide axial siphon bearing laterals (branches) in close together verticils. The egg-shaped, subglobular or pyriform laterals alternate in contiguous verticils. They are slightly compressed at the level of their swollen middle part having a hexagonal to rhombic shape in deep tangential sections. They are connected to the siphon by means of a proximal pore. The calcareous envelope is made up of a thin layer of hyaline calcite, covering generally all the surface of the laterals including the distal periphery, but not filling the interstitial spaces; in some specimens, however, the envelope forms a compact calcareous sheath around ramifications. At the distal periphery, the envelope is pierced by narrow pores, presumably corresponding to second order sterile

hairs; some pyriform laterals communicate directly with the exterior through a larger pore". Distribution: Turkmen SSR, Bulgaria, Romania, Central Iran, Kopeh-Dagh.

Genus *Steinmanniporella* Bucur et al. 2009

Thallus with euspondyl tubular primary laterals giving rise to a tuft of secondaries. The tubular secondary laterals enlarge towards the distal end (phloiophorous type), that most probably, formed a cortex at the outer end of the thallus. Reproductive structures were situated very probably inside the central stem (endosporete)." Discussion: see Taherpour et al. (2010).

Steinmanniporella? parsica Taherpour et al. 2010 – Source: Taherpour et al. (2010), middle part of the Tirgan Fm, Kopeh-Dagh, assigned to the Aptian.

Original diagnosis: "Thallus cylindrical, euspondyl. Axial cavity intusannulated. Spaced out whorls of numerous, slender, acrophorous primary laterals, perpendicular to or slightly tilted upward from the main axis. Secondary laterals horn-shaped (phloiophorous), distally uncalcified, approximately eight in number, clustered at the tip of the primaries, forming a rosette. Calcareous skeleton conspicuous, forming a sleeve, originally aragonitic. Gametangia or gametophores uncalcified, assumed to have been located in the main axis (endosporete-type)." Barremian – Aptian. Distribution: Kopeh-Dagh; Albania, Lower Aptian with *Acroporella radoičićiae*, *Mesorbitolina* etc. (F. Schlagintweit in lit. to MC, August 2011).

Tribe Uterieae Morellet, 1922

Diagnosis in Deloffre (1989), translated: "Thallus cylindrical, moniform or not, clear cut separation and alternance of sterile and fertile verticils, position of the fertile organs among the ramifications indeterminate." Systematics fide Berger and Kaever (1992), debatable.

Genus *Conradella* Masse & Bucur, 1992

Original diagnosis: "Dasyclad alga with cylindrical thallus; laterals arranged in distinctive non imbricated and alternating verticils of steriles and fertiles, the number of steriles being equal to the number of fertiles; the sterile and the overlapping fertile laterals communicate in their proximal part; sterile laterals divide distally in secondary divergent laterals."

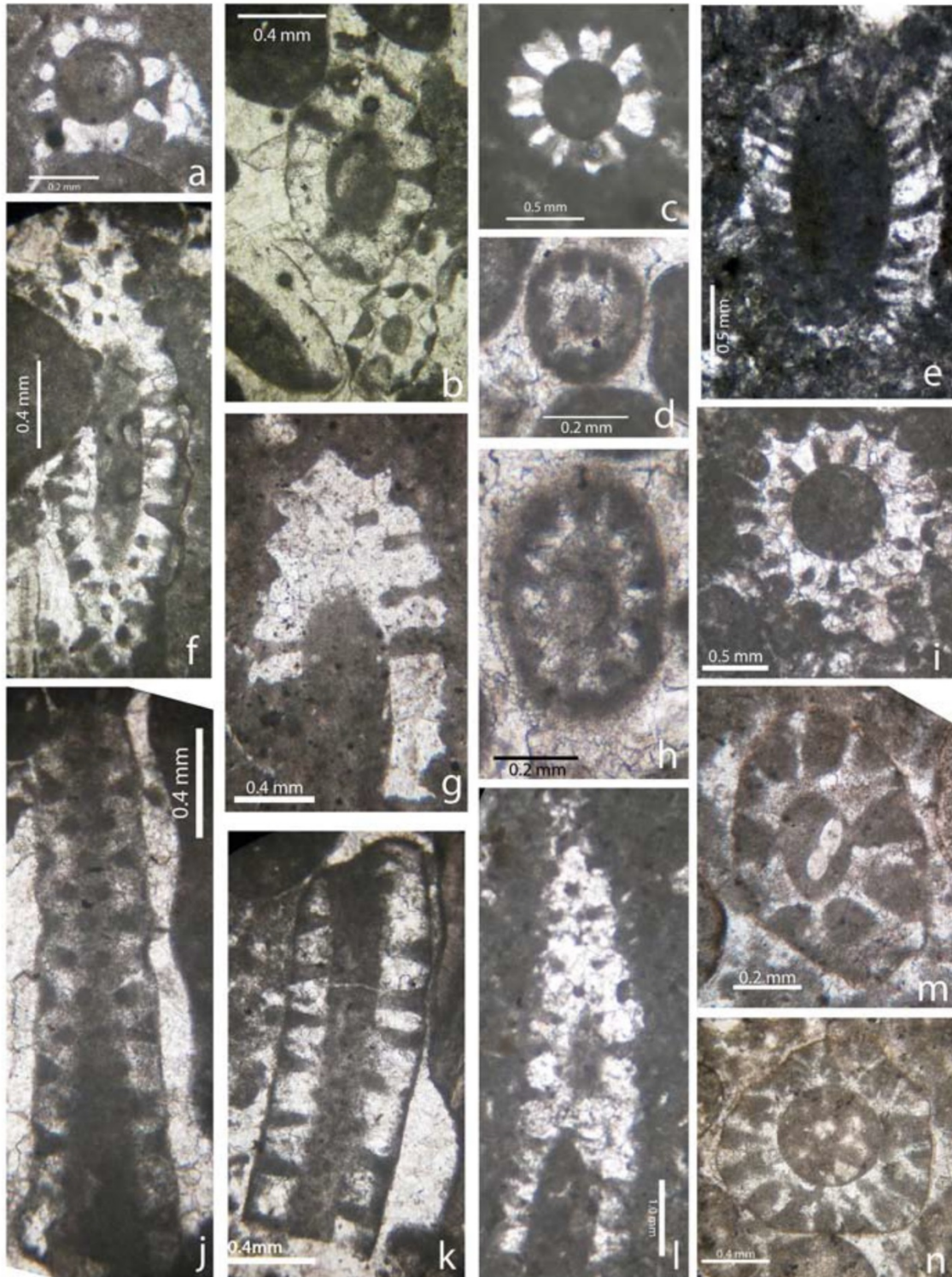


Plate 1. Lower Cretaceous Dasycladales from Zard section. a, *Salpingoporella* aff. *hasi*, Z81; b, *Salpingoporella* *muehlbergii* and *Coptocampylodon* *lineolatus* (below), Z97; c, *Salpingoporella* aff. *Hasi*, Z93; d, *Coptocampylodon* *lineolatus*, Z103; e, *Morelletpora* *turgida*, Z158; f, *Salpingoporella* *muehlbergii*, Z97; g, *Salpingoporella* sp. cf. *S. cemi*, h, *Salpingoporella* sp., Z103; i, *Morelletpora* *turgida*, Z160; j-k, *Salpingoporella* *muehlbergii*, Z97; l, *Salpingoporella* sp., Z93; m, *Pseudoactinoporella* *silvaeregis*, Z100; n, *Similiclypeina* *conradii*, Z100.

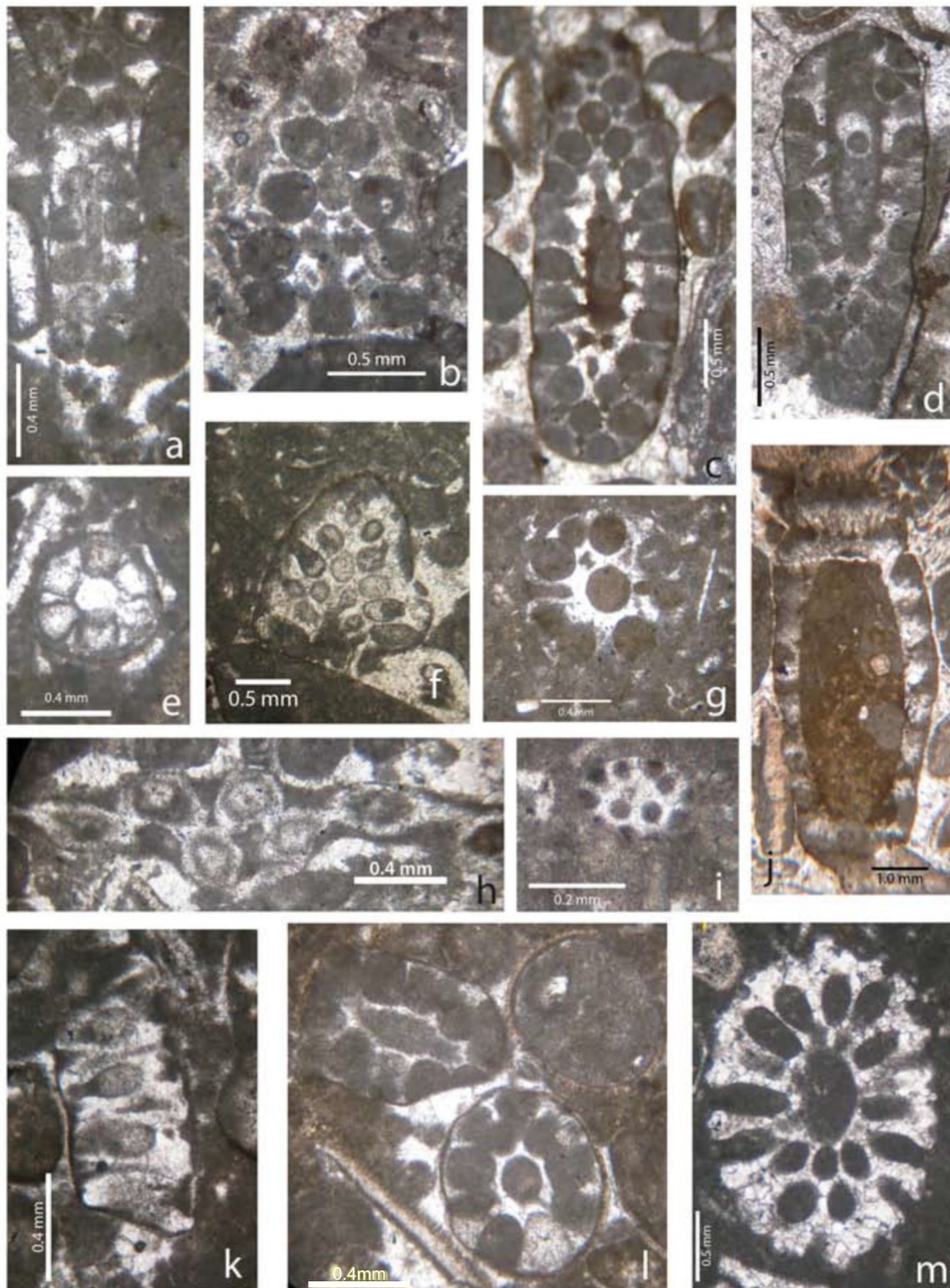


Plate 2. Lower Cretaceous Dasycladales from Zard section. a, e, *Holosporella* aff. *alimani*, n. comb., Z81; b, *Bakalovaella elitzae*, Z98; c-d, *Bakalovaella elitzae*, Z102; f, *Biokoviella* cf. *robusta*, Z96; g, *Bakalovaella elitzae*, Z84; h, *Praturlonella?* cf. *pejovicae*, Z97; i, *Terquemella* sp., Z84; j, *Pseudoactinoporella iranica*, Z102; k, *Neomeris* cf. *cretacea*, Z100; l, *Holosporella* sp., Z100; m, *Biokoviella* cf. *robusta*, Z161.

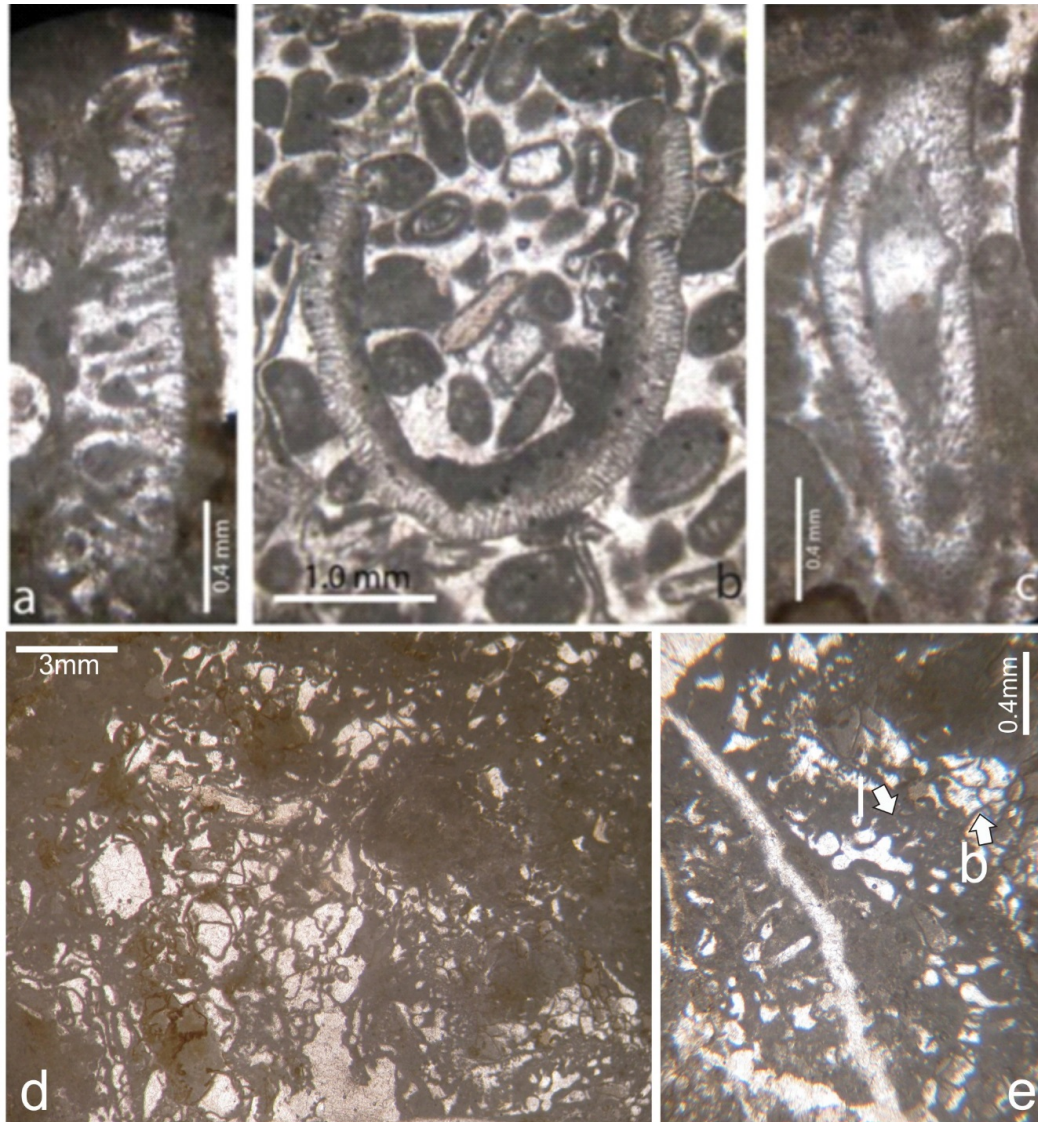


Plate 3. Lower Cretaceous Bryopsidales and Gymnocodiaceae from Zard section. a, *Arabocodium* sp., Z111; b, *Permocalculus* sp., Z103; c, *Permocalculus minutus*, Z100. d, *Bacinella irregularis*, e, *Lithocodium aggregatum*.

Conradella bakalovae (Conrad & Peybernès, 1978) Masse & Bucur, 2002 – Source: Taherpour *et al.* 2010, middle part of the Tirgan Fm, Kopeh-Dagh, assigned to the Aptian.

Type and sole species of the genus. Emended diagnosis, in Masse and Bucur (2002): "Simple, cylindrical thallus, bearing laterals arranged in distinct alternating fertile and sterile verticils. Number of fertile and sterile laterals is equal. The sterile laterals are almost perpendicular to the main axis and widen distally where they give rise to four small, phloiophorous, divergent secondary laterals. The fertile laterals (ampullae) are ovoid, laterally compressed, and there is no visible communication with the axial siphon. They are joined to the

adjacent steriles, so the calcification is missing in the intervening space. Very probably, sterile and adjacent fertile laterals communicate at their proximal part. The calcareous envelope is made up of a fine mosaic of brownish crystals, sometimes replaced diagenetically by a coarser mosaic of hyaline crystals". Distribution: Hauterivian – Lower Aptian, Bulgaria, Romania., Georgia, SE France, Macedonia, Kopeh-Dagh, Central Iran.

Bryopsidales, Gymnocodiaceae, *Arabocodium*, *Permocalculus*, *Bacinella*, *Lithocodium*

These algae (Pl. 3) are found in intervals C and D, Barremian, Aptian of the Zard Formation. Their ecological significance deserves a detailed study,

beyond the scope of this paper.

Morpho-genus *incertae sedis*

Genus *Coptocampylodon* Elliott, 1963
 Original description, Elliott (1963): “Small solid cylindrical calcareous bodies, longer axis gently curved or irregular, circular in cross-section but deeply incised by longitudinal grooves, ends irregularly rounded. Lower Cretaceous; Middle East and Borneo. Type species. *C. lineolatus* sp. nov.” Considered an octocoral by this author. See also emendation in Ljubovic-Obradović and Radoičić (2004). Skeletal elements (sclerites, internodes/branches, holdfasts) of colonial octocorals according to Schlagintweit and Gawlick (2009). Synonym: *Carpathoporella* Dragastan 1967, 1969 (nom. nud.). Quoting Schlagintweit and Gawlick (2009): “The original description of the

incertae sedis Coptocampylodon Elliott was in all likelihood a taxonomic mixing. It was based on either isolated specimens for which a coprolite nature is most likely, or smaller solid specimens in thin sections that could be debris of dasycladalean algae or octocoral sclerites. Therefore, the other later described representatives from thin sections that altogether do not show any feature pointing to a coprolite nature, must belong to a new (morpho) genus (genera?) or should be included in other existing taxa.” An ad hoc revision of this taxon is therefore beyond the scope of the present paper. Without entering in further details, the following species were also assigned to *Coptocampylodon*: *C. elliotti* Radoičić ex Granier & Deloffre, 1993, non 1969, Aptian-Cenomanian; *C. fontis* Patruilius 1966, Cretaceous; *C. pantici* Ljubovic-Obradović & Radoičić, 2004, Turonian; *C.? rhaeticus* Schlagintweit *et al.*, 2002, Rhaetian.

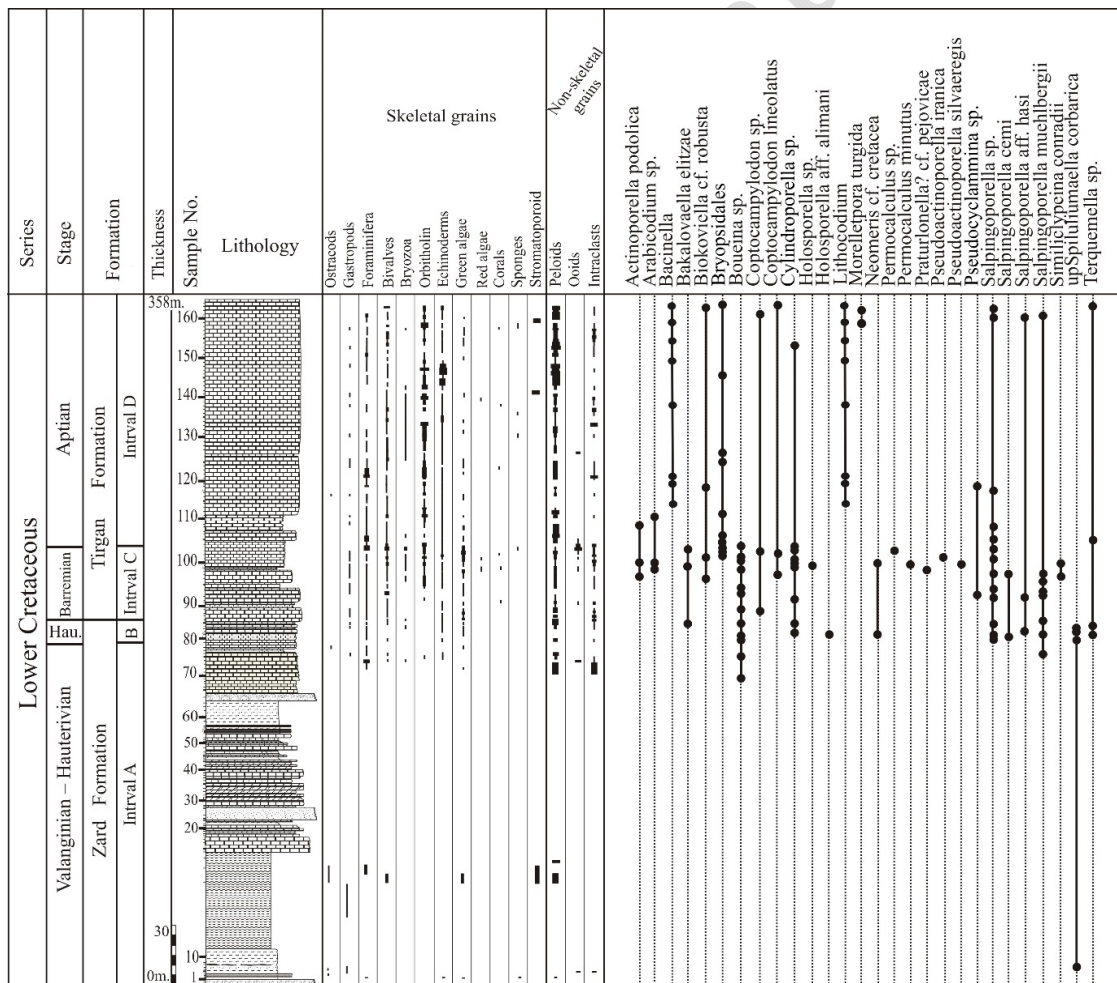


Figure 3. The Lower Cretaceous succession in the West of Kopeh-Dagh basin. Stratigraphical range of the most important calcareous algae and informal stratigraphic intervals identified in the Zard and Tigran formations in the studied section.

Coptocampylodon lineolatus Elliott, 1963 (Pl. 1, Fig. b, d). Interval C, Barremian, Tirgan Formation. Distribution: Iran, Borneo, Italy, S.E. France, Romania, Spain, Venezuela, Greece, Pacific Ocean etc. Tithonian-Turonian.

Age, distribution of the calcareous algae assemblages

The studied succession corresponds to carbonate platform environment with supratidal, shallow subtidal to intertidal deposits frequently containing fenestral structures. Lower part of the section consists of shale, marl and fine crystal dolomite, with a quite poor micropaleontological content. On the other hand, the upper part of the succession (upper part of Zard Formation and Tirgan Formation) is dominated by calcareous green algae. Besides, benthic foraminifera (e.g. orbitolinids), bryozoa, echinoderms were also identified. The analysis of thin sections delivered a relatively diversified assemblage of early Cretaceous calcareous algae, resulting in the identification of several micropaleontological associations and corresponding, informal stratigraphic intervals (presented below as A, B, C, and D).

Interval A

Lower part of the Zard Formation consists of fenestral wackestones, mudstone and dolomudstone of very shallow water origin. Presumably, light penetration was withheld by an excess of suspended matter, thus representing a limiting factor for photosynthetic green algae (Johnson, 1961). Bryopsidales appear at top of the interval, denoting open marine conditions. Tentatively, range is Valanginian – Hauterivian, based on (a) presence, at base of the interval, of specimens possibly belonging to the Valanginian – Barremian of *Suppilulimaella corbarica* (see Jaffrezo 1975 for reference); (b) at top of the interval, herein illustrated good specimens of the Hauterivian – Aptian *Salpingoporella muehlbergii*.

Interval B

The Upper Hauterivian/Lower Barremian upper part of the Zard Formation contains *Salpingoporella* aff. *hasi* (Plate 1a), *Bakalovaella elitzae* (Plate 2g), *Terquemella* sp. (Plate 2i) and of special interest the quite rare *Holosporella* aff. *alimani* (Plate 2a, e).

Interval C

Our results in the lower part of Tirgan Formation

point Barremian deposits. These Barremian shallow-water carbonate deposits (also known commonly as Urgonian limestones) contain *Salpingoporella muehlbergii* (Plate 1b, c, f, j, and k), *Salpingoporella* sp. (Plate 1l), *Pseudoactinoporella silvaeregis* (Plate 1m), *Similiclypeina conradii* (Plate 1n), *Coptocampylodon lineolatus* (Plate 1b), *Praturlonella?* cf. *pejovicae* (Plate 2h), *Pseudoactinoporella iranica* (Plate 2j), *Neomeris* cf. *cretacea* (Plate 2k), *Holosporella* sp. (Plate 2l), and *Permocalculus minutus* (Plate 3c).

Interval D

As shown by the range chart in Figure 3, Aptian assemblages include *Coptocampylodon lineolatus* (Plate 1d), *Morelletpora turgida* (Plate 1e, and i), *Salpingoporella* cf. *cemi* (Plate 1g), *Biokoviella* cf. *robusta* (Plate 2m), *Arabicodium* sp. (Plate 3a), and *Permocalculus* sp. (Plate 3b), while *Morelletpora turgida* is found in the upper part of the section. Micro-encrusters such as *Bacinella irregularis* (Plate 3d) and *Lithocodium aggregatum* (Plate 3e) are also present in this interval.

Ecological significance of Calcareous algae

Dasycladaleans lived in shallow marine warm / temperate waters, mainly at depths up to 10–12 m, i.e., in the upper photic zone, commonly protected from strong storm and ground waves (Valet, 1979). Dasycladales tolerance to variation of seawater salinity is high (euryhaline). More generally, calcareous algae live under shallow, clear, warm-water marine conditions (Johnson, 1961; Kundal *et al.*, 2007). In the Urgonian facies (Tirgan Formation) the observed orbitolinids also indicate marginal platform conditions. Most species found in the upper part of the section are believed to be in situ.

Biogeography – Comparison tryout

Adequately compare assemblages found in the study area with other provinces requires material far more abundant than currently available, as well as a better biostratigraphic control based, as far as possible, on other organisms such as orbitolinidae and dinoflagellates. Yet, examples of the presence or, contrarywise, typical nonappearance of certain species in the study area yields interesting results which are provisionally summarized as follows.

Excluding synonyms and taxa of uncertain affinity, all over, the Berriasian - Aptian stratigraphic interval contains no less than 64

genera and 186 species of Dasycladales, including organ-genera such as *Terquemella*. For the same period, published papers and available reports mention the presence of some 33 species only in the Kopeh-Dagh, realizing that such a small fraction reflects observations made to date. According to Stampfli and Borel (2004), the Kopeh-Dagh was at that time located at the eastern end of the Izanca, the Neotethys northernmost branch, therefore in a relatively isolated paleotectonic setting. In this paper, the biogeographic distribution of some only of these above-mentioned 33 species is reported in Fig. 4, using the paleotectonic context and terminology of Barrier and Vrielynck (2008). Maps published by these authors for the Middle East contain tectonic elements, fields, formations and environments, making it feasible to position the species.

Distribution of the 11 species referred to in Fig. 4, allows to make, provisionally, three interesting findings. Firstly, distribution of certain species looks linked, or partly linked, to certain regions in relation to systematics, under any reserve at level of the genus. *Conradella bakalovae* and *Kopetdagaria sphaerica*, for example, are missing south of the Tethys and Mesogean Ocean. Secondly, the species

life habitat is only partially related to their distribution. Certain open sea species such as *Deloffrella quercifoliipora* and *Montiella elitzae*, which are usually associated with filter-feeders such as Bryopsidales and bryozoans, look cosmopolitan. However, other open sea species such as *Kopetdagaria sphaerica* and *Salpingoporella genevensis*, both missing in the Gondwana but present in the Carpathian-Danubian foreland, respectively only extend east and west of the latter area. Thirdly, distribution of certain well-known, often very abundant species originating from protected marine environments, is particularly appealing. For example, stratigraphic distribution of the cosmopolitan *Salpingoporella annulata* differs from one region to another, seemingly, because of the OAE1 oceanographic event, dated Valanginian. Yet, the well-known *Salpingoporella dinarica*, which is particularly abundant in the Dinarides, Hellenides and in Arabia, lacks completely in regions as distant from each other such as southeast of France and the Kopeh-Dagh, although a taxonomically close but different taxon is present in Central Iran.

Paleotectonic domains: Barrier & Vrielynck (2008)	IBERIA		NE Ligurian Ocean	LAURASIA				Sistan Ocean	TETHYS	WEST GONDWANA	Mesogean Ocean	WEST GONDWANA		
Present time geological setting	Sardo-Balearic Mesozoic Basins	W. Alps, Provençal Basin		Apulia, S. France, Dinarides, Carpathian-Danubian Foreland	Pontides	Iran Plate		Kopet Dagh (this paper)		Hellenides Taurides		Zagros	Arabia	Maghrebides
<i>Biokoviella robusta</i> (Sokac) - Barremian -?Aptian - Protected marine - W. Kopet Dagh: in this paper interval D, Barremian-Aptian- See text								cf.						
<i>Conradella bakalovae</i> (Conrad & Peyrès) - Hauterivian-Aptian - Open & protected marine - W. Kopet Dagh: Aptian - See text								cf.						
<i>Deloffrella quercifoliipora</i> Granier & Michaud - Kimmeridgian-Aptian - Open marine - W. Kopet Dagh: cf. Upper Barremian - See text														
<i>Iranella inopinata</i> Bucur & al. - Berriasian - Aptian,protected marine - Ref. Hosseini et al. (2012) -W. Kopet Dagh: questionable presence, Tirgan Fm								?					cf.	
<i>Kopetdagaria sphaerica</i> Maslov - Barremian-Aptian- Open marine - Kopet Dagh: see text														
<i>Montiella elitzae</i> (Bakalova) - Hauterivian-Albian- Open marine - W. Kopet Dagh: in this paper intervals B, C, Hauterivian-Barremian - See text														
<i>Moreletpora turgida</i> (Radoicic) - Barremian - Cenomanian - Protected marine - W. Kopet Dagh: in this paper interval D, Aptian - See text														
<i>Pseudoactinoporella ? iranica</i> Bucur & al. - Barremian-Aptian- Open marine - W. Kopet Dagh: Upper Barremian - Lower Aptian - See text														
<i>Salpingoporella annulata</i> Carozzi - Bathonian-Hauterivian,?Barremian,missing or locally missing above the intra-Valanginian Weissert Event- Protected marine, occasionally brackish - ref. Carras et al. (2006) - W. Kopet Dagh: Berriasian, ref. Bucur et al. (2013)														
<i>Salpingoporella dinarica</i> Radoicic - Berriasian-Albian- Protected marine to polyhaline, yet unconfirmed also open marine								aff.						
<i>Salpingoporella genevensis</i> (Conrad & al.) - Hauterivian-Barremian - Open marine														
<i>Salpingoporella muehlbergii</i> (Lorenz) - Hauterivian- Aptian - Open & protected marine - W. Kopet Dagh: in this paper intervals B, C, D, Hauterivian-Aptian - see text								cf.						
<i>Suppilulimaella corbarica</i> Jaffrezo - Valanginian - basal Barremian- Open marine - W. Kopet Dagh: in this paper intervals A and B, Valanginian - Hauterivian														

Figure 4. Over all distribution and habitats of eleven, particularly significant species of Dasycladales, identified or apparently absent in the Neocomian – Aptian, Western Kopeh-Dagh, Iran. Paleotectonic setting and terminology: Barrier and Vrielynck (2008).

Conclusions

This research centers on the nomenclature and distribution of dasycladalean algae encountered in the west of the Kopeh-Dagh. West of Bojnurd, the relatively algal-poor Zard Fm, is divided into two parts. First the A-interval, about 180 m-thick, is assigned to the Valanginien and the Hauterivian, owed to the presence, from the bottom to the top of the interval, of *Suppiluliumaella corbarica*. The B-interval, about 15 m-thick, encompasses the top of the formation. It is assigned to the Upper Hauterivian or base of Barremian, due to the presence of the quite rare *Holosporella* aff. *alimani*. The following Tirgan Fm is also subdivided into two parts: the algal-rich C-interval, which is about 35 m-thick, is assigned to the Barremian, based on an assemblage comprising at least seven species of Dasycladales, one of which, *Pseudoactinoporella? iranica*, is also present in Central Iran, in a different paleotectonic setting; higher-up, the also algal-rich D-interval, about 120 m-thick, is assigned to the Aptian, based on an assemblage comprising a number of Dasycladales, including *Morelletpora turgida*, a species commonly encountered in central and southern Tethyan areas.

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The systematics and nomenclature of 18 species of algae, all of them present in the Kopeh-Dagh, is examined. The genera *Bakalovaella* and *Barattoloporellospis* are tentatively put into synonymy with the genus *Montiella*. Also, the species originally named *Vederosella alimani* is transferred to the genus *Holosporella*.

The distribution of 11 species is compared with other regions, extending from Iberia to the northern margin of West Gondwana. Under all reservations, the biogeographic distribution of *Kopetdagaria sphaerica*, present in the Kopeh-Dagh, and the far-off *Salpingoporella genevensis*, totally missing in the region, is linked to systematics. Importance of the algal habitat remains problematic: *Deloffrella quercifoliipora* and *Montiella elitzae*, for example, both linked to open marine environments and present in the Kopeh-Dagh, only partially overlap in terms of biogeographic distribution. As for the well-known *Salpingoporella dinarica*, which is totally lacking in the study area, it is commonly encountered in other, comparable carbonate platform deposits developed on the southern margin of the Tethys.

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