

## Barremian-Aptian Dasycladalean algae, new and revisited, from the Tirgan Formation in the Kopet Dagh, NE Iran

**Morteza TAHERPOUR KHALIL ABAD <sup>1</sup>**

**Marc André CONRAD <sup>2</sup>**

**Ali Asghar ARYAEI <sup>3</sup>**

**Ali Reza ASHOURI <sup>4</sup>**

**Abstract:** Abundant, diversified algal assemblages comprising more than 25 species of Dasycladales are described from Barremian-Aptian limestone deposits of the Tirgan Formation in NE Iran. New species are described: one of them possibly belongs to a new endospore genus, tentatively assigned to the Triploporellaceae; two others, *Clypeina* ? sp. 1 and *Rajkaella* ? sp. 1, are left in open nomenclature. The widely distributed, locally abundant *Montiella* ? *elitzae* is revisited, because of the presence of a complete, exceptionally well preserved specimen. Yet to be demonstrated, the species is a junior synonym of *Turkmenaria adducta* MASLOV, also originally described from the Kopet Dagh. Other species found in the Arkan section have already been reported from remote locations, primarily in Europe, in areas corresponding to the Northern and/or Southern Tethyan domains. Some of them are known only from the Hauterivian and/or the Barremian, excluding the Aptian, thus dating the lower part of the Arkan section as Barremian, but not excluding the Late Hauterivian.

**Key Words:** Calcareous algae; Dasycladales; new taxon; Lower Cretaceous; Tirgan Formation; Iran.

**Citation:** TAHERPOUR KHALIL ABAD M., CONRAD M.A., ARYAEI A.A. & ASHOURI A.R. (2010).- Barremian-Aptian Dasycladalean algae, new and revisited from the Tirgan Formation in the Kopet Dagh, NE Iran.- Carnets de Géologie / Notebooks on Geology, Brest, Article 2010/05 (CG2010\_A05)

**Résumé Algues dasycladales du Barrémien-Aptien, nouvelles ou révisées, de la Formation Tirgan dans le Kopet Dagh, NE Iran.**- Des relevés détaillés entrepris près d'Arkan, dans la région de Bojnourd, au Kopet Dagh, montrent la présence de plus de 25 espèces de Dasycladales dans les calcaires de la Formation de Tirgan. En grande partie, ces algues sont déjà connues en Europe, dans l'Hauterivien supérieur, le Barrémien et l'Aptien des domaines Nord- et Sud-Téthysiens. Grâce à elles, la partie inférieure de la coupe d'Arkan peut être datée du Barrémien, sans pour autant exclure l'Hauterivien supérieur. Un nouveau taxon, sans doute endospore, est décrit sur la base d'une seule section. Deux espèces, *Clypeina* ? sp. 1 et *Rajkaella* ? sp. 1, sont décrites de manière informelle. Enfin, une espèce bien connue, *Montiella* ? *elitzae*, est particulièrement abondante. Peut-être s'agit-il d'un synonyme récent de *Turkmenaria adducta* MASLOV, provenant également du Barrémien de la même région. Ici, l'espèce fait l'objet d'une description plus détaillée, fondée en particulier sur un spécimen complet permettant de mettre en question l'interprétation taxonomique proposée jusqu'ici.

**Mots-Clefs :** Algues calcaires ; Dasycladales ; nouveau taxon ; Crétacé inférieur ; Formation de Tirgan ; Iran.

### Introduction and geological setting

Abundant, diversified algal assemblages are described from Barremian-Aptian limestone deposits of the Tirgan Formation in NE Iran. The site is at Arkan, near Bojnourd, in the Kopet Dagh fold belt, at the SW margin of the Turan

Platform.

### Structural Units of Iran

Fundamental differences in the crustal character and age of basement consolidation allow three major structural units to be distinguished, separated by ophiolite-bearing sutures. Other

<sup>1</sup> \* Corresponding author

Department of Geology, Faculty of Sciences, Islamic Azad University-Mashhad branch, Mashhad (I.R. Iran);  
Young Researchers Club  
[mortezataherpour@yahoo.com](mailto:mortezataherpour@yahoo.com)

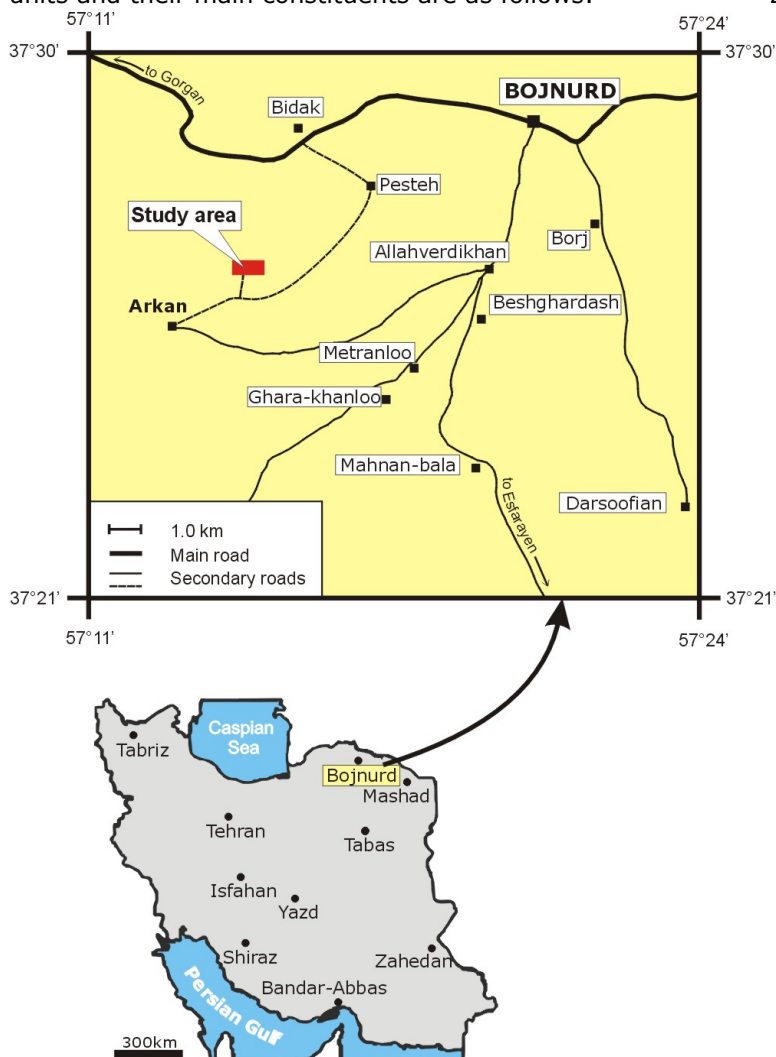
<sup>2</sup> 71 chemin de Planta, 1223 Cologny (Switzerland)

<sup>3</sup> Department of Geology, Faculty of Sciences, Islamic Azad University-Mashhad branch, Mashhad (I.R. Iran)

<sup>4</sup> Center of Excellence for Paleontology, Ferdowsi University of Mashhad, Mashhad (I.R. Iran)

Manuscript online since August 27, 2010

criteria such as structural style, the age and intensity of deformation, the age and nature of magmatism are used to subdivide these major zones into smaller elements. The three major units and their main constituents are as follows:



**Figure 1:** Location of the studied section.

### Kopet Dagh fold belt

The active fold belt of NE Iran, Kopet Dagh, was formed on a Hercynian metamorphosed basement, at the SW margin of the Turan Platform. The belt consists of about 10 km of Mesozoic and Tertiary sediments, mostly carbonates. Like the Zagros, it was rucked into long, linear NW-SE trending folds during the last Plio-Pleistocene phase of Alpine orogenesis. No magmatic rocks crop out in the Kopet Dagh except those in the basement of the Aghdarband Window and some Triassic basic dikes.

- a Southern Unit, with a crystalline basement consolidated in Precambrian time, platform-type Paleozoic sediments and younger deposits. This unit comprises the Zagros fold belt;

- a Central Unit, interpreted as an assemblage of marginal Gondwana fragments, originally united with the mother-continent and separated from the North (Eurasian) continent during the Paleozoic. In Mesozoic times, these fragments were detached from Gondwana and attached to Eurasia. During the Late Cretaceous they rejoined the Gondwanic Afro-Arabia. This unit comprises Central Iran and the Alborz;

- a Northern Unit, markedly separated from the central unit by ophiolites of the North Iran Suture. The continental crust includes remnants of more or less cratonized former (Paleozoic) oceanic crust possibly that of the Paleotethys. The Northern Unit represents a marginal strip of the Hercynian realm of Central Asia, broadly overlapped by the Alpine realm. It was deformed and largely consolidated by strong Early Cimmerian and Late Alpine folding (Stöcklin, 1968). The Northern Unit comprises the South Caspian Depression and the Kopet Dagh Range. These structural units are shown on a schematic map (Fig. 2) published by the Geological Survey of Iran.

### Barremian and Aptian deposits in the Kopet Dagh fold belt

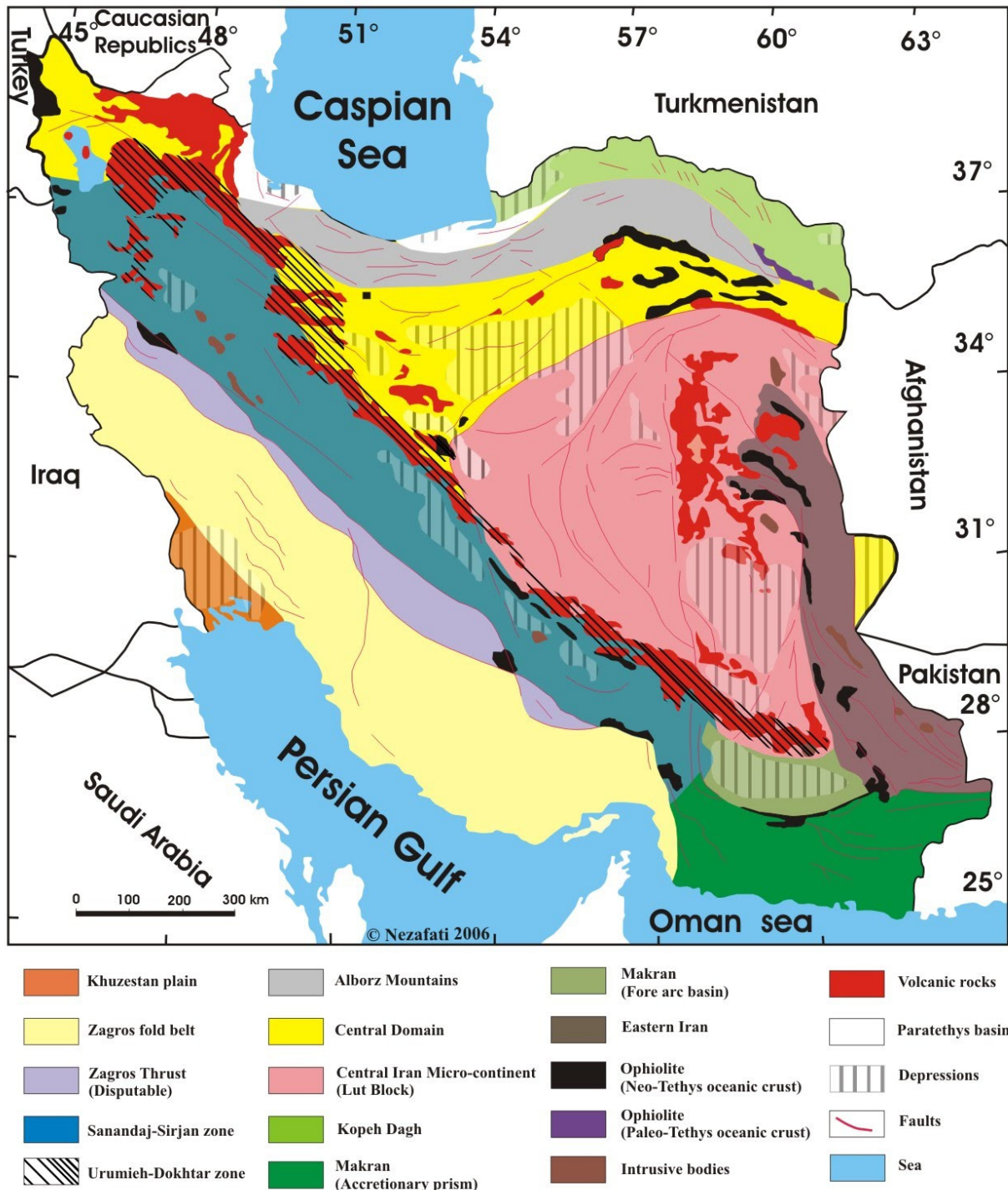
Barremian deposits are up to 300 m thick. They consist of alternating beds of calcareous sand and sandy oolitic limestone. Microfossils include bryozoa, algae and foraminifers with *Gavelinella barremiana*, *Praehedbergella infracretacea*, *Globorotalites intercedens*, *Lenticulina ouachensis*, *Marssonella oxycona*, *Tritaxia tricarinata* and *T. pyramidata*.

Aptian deposits consist of up to 1100 m of mainly massive limestones. Quoting Stöcklin and Setudefnia (1991), foraminifera include *Ammobaculites reophacoides*, *Astacolus* cf. *schloenbachii*, *Brotzenia cretosa*, *B. spinulifera polypoides*, *Citharina aptiensis*, *Dentalina distincta*, *Gaudryina dividens*, *Globorodospira djaffaensis*, *Textularia foedu*, *Verneuillinoidea subfiliformis*, *Orbitolina kurdica*, *O. discoidea*, and *O. conica*.

### Tirgan Formation

This formation is named from its exposure in the Tirgan Valley of Kopet Dagh. It was introduced by geologists of the National Iranian Oil Company for a feature-forming unit of massively bedded, oolitic and organodetrital limestone occurring throughout the Kopet Dagh ranges. The 700 m Tirgan type-section is 39 km southeast of Dargaz and consists mainly of mid-sized to thick beds of grey fossiliferous lime-

stone (AFSHAR-HARB, 1994). For the eastern part of Kopet Dagh, AFSHAR-HARB (1969) indicates the thickness of Tirgan Formation to be only 50 m. It overlies the Shurijeh Formation and underlies the Sarcheshmeh Formation; both contacts are conformable but a transitional interfingering between the Tirgan and the Shurijeh exists in southeastern Kopet Dagh. The Tirgan Formation is essentially Neocomian, locally extending as high as the Aptian.



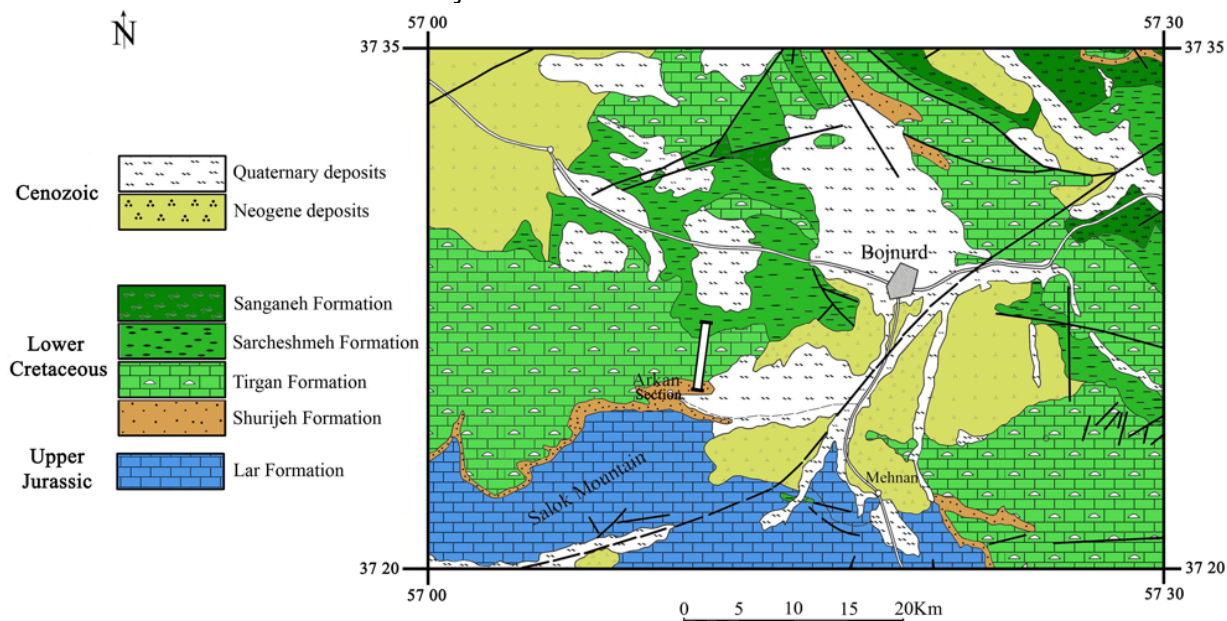
**Figure 2:** Major geological subdivisions of Iran after STÖCKLIN (1968) and NABAVI (1976), modified [copyright N. NEZAFATI (2006), duplicated with permission].



### Phycological content of the Tirgan Formation in the Arkan section

The Bojnourd study area (Fig. 3) of the Kopet Dagh is located in the Northern Khorasan province. In this area, several outcrops of the Cretaceous Shurijeh, Tirgan, Sarcheshmeh, Sanganeh and Abderaz formations are present. The section (Fig. 4) is near Arkan, 10 km southwest of Bojnourd, Khorasan-e-shomali province (Figs. 1 - 2). In this area, the strike is E-W with a dip of 15-35 degrees. The 195 m Tirgan Formation rests on sandstones of the Shurijeh For-

mation. The contact is concordant and transitional. The Tirgan Formation, characterized mainly by the presence of orbitolinids, consists of discrete levels of oolitic limestone, fossiliferous limestone, and some marly limestones, marls and argillaceous limestones. It is overlain by the shales and limestones of the Sarcheshmeh Formation. Lithologies found in the Tirgan type-section are also found in the Arkan section (Fig. 3). In the lower half of this section up to 50% of the biota consists of calcareous algae (Fig. 5), essentially Dasycladales, Halimedaceae and



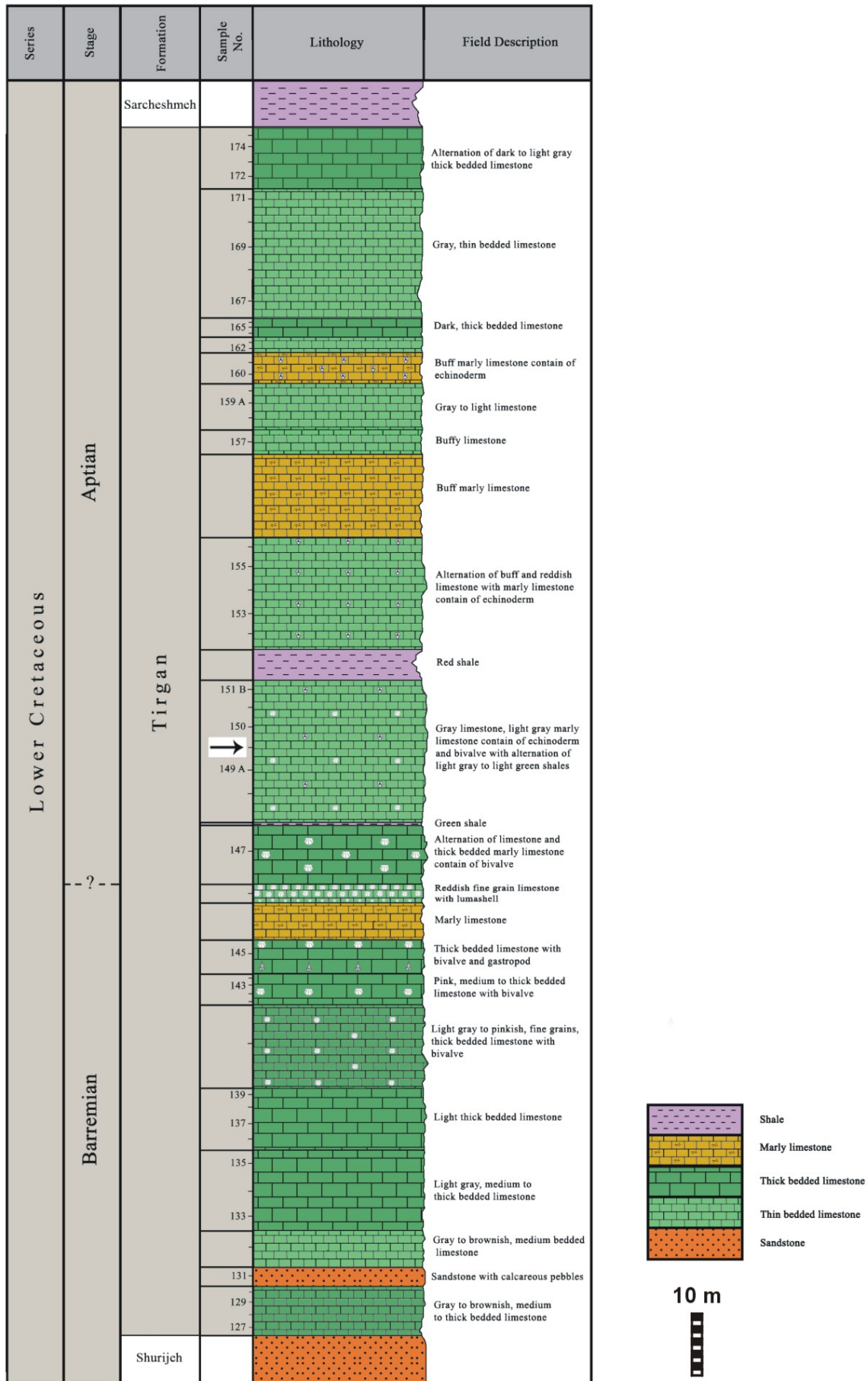
**Figure 3:** Geological map of the Bojnourd area, with the location of the Arkan section.

Bryopsidales. The alphabetically-listed Dasycladales that follow were identified under the microscope, mainly in the thick limestone beds of the Tirgan Formation, but not all of them are illustrated. The generalized range of each is also given.

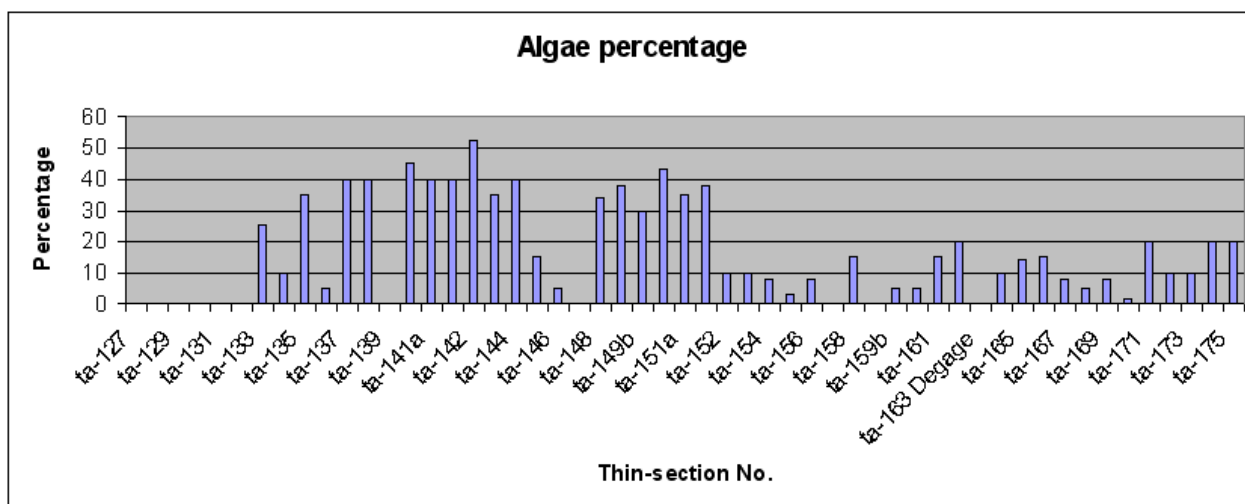
- *Acicularia* sp.
- *Actinoporella podolica* (ALTH); Tithonian – Early Barremian: Fig. 6 (f)
- *Clypeina* cf. *gigantea* SOKAĆ; Barremian: Fig. 6 (b)
- *Clypeina* ? cf. *C. solkani* CONRAD & RADOIĆIĆ; Tithonian-Barremian, ? Aptian: Fig. 6 (g)
- *Clypeina* ? n.sp. 1 (see below): Fig. 6 (i-j)
- *Conradella bakalovae* (CONRAD & PEYBERNÈS); Late Hauterivian – Early Aptian: Fig. 6 (c)
- *Cylindroporella* ? cf. *C. elliptica* BAKALOVA; Late Hauterivian – Early Aptian
- *Holosporella* sp.: Fig. 6 (h), Fig. 7 (k)
- *Montiella* ? *elitzae* (BAKALOVA); Late Hauterivian-Albian: Fig. 8 (a-d)
- *Neomeris* ? cf. *N. cretacea* STEINMANN; Early Hauterivian – Maastrichtian: Fig. 6 (m)
- *Praturlonella dalmatica* (SOKAĆ & VELIĆ); Late Hauterivian – Early Barremian: Fig. 6 (e)
- *Praturlonella nerae* (DRAGASTAN *et alii*); Late

Hauterivian (aff.) – Early Aptian: Fig. 6 (k, l; aff.)

- *Pseudoactinoporella* ? cf. *P. fragilis* CONRAD; Late Hauterivian – Early Aptian
- *Rajkaella* ? sp. 1 (see below): Fig. 9
- *Salpingoporella cemi* RADOIĆIĆ; Late Hauterivian – Early Barremian: Fig. 7 (a-b)
- *Salpingoporella* aff. *S. hasi* CONRAD *et alii*; Late Barremian – Early Aptian. Fig. 7 (j-k)
- *Salpingoporella* cf. *S. hispanica* CONRAD & GRABNER; Kimmeridgian – Early Aptian
- *Salpingoporella* aff. *S. istriana* GUŠIĆ; possibly a new species
- *Salpingoporella muehlbergii* (LORENZ); Late Hauterivian – Early Aptian: Fig. 7 (f-g)
- *Salpingoporella* cf. *S. parapirinia* CONRAD, CARRAS & RADOIĆIĆ; Late Barremian – Early Aptian: Fig. 7 (e)
- *Salpingoporella* cf. *S. pirinia* CARRAS & RADOIĆIĆ; Hauterivian – Barremian: Fig. 7 (c-d)
- *Salpingoporella* aff. *S. milovanovici* RADOIĆIĆ; Cenomanian; possibly a new species: Fig. 7 (h)
- *Steinmanniporella* ? *parsica*, n.sp. (see below): Fig. 10
- *Terquemella* sp.
- *Triploporella* ? sp.: Fig. 6 (a)



**Figure 4:** Geological field section at Arkan, Tirgan Formation. Arrow: stratum typicum of *Steinmanniporella ? par-sica*, n.sp.: sample 149b.



**Figure 5:** Arkan section (Kopet Dagh), Tirgan Formation, Barremian / Aptian: quantitative distribution of the dasy-cladalean and other calcareous green algae. Values are expressed in relative percentages with respect to the total biotic content. Counts were made using the microscope. Sample distribution is shown in Fig. 4.

Other algae and incertae sedis include: abundant Halimedaceae, *Arabicodium* sp., *Boueina* sp., *Cayeuxia* sp., *Coptocampylodon lineolatus* (Fig. 6 (d)), *Ethelia* cf. *alba*, *Palaeosiphonium* sp., *Permocalculus* sp., *Vermiporella* ? sp. (Fig. 6 (d)) and *Juraella bifurcata*. This last species belongs to the Bryopsidales. It is dealt with separately, in TAHERPOUR *et alii* (2009).

Based solely on the known distribution of these Dasycladales at Arkan, the lower part of the Tirgan Formation is Barremian but not excluding the Late Hauterivian. Higher, its age is Barremian-Aptian, as confirmed by the echinoids including *Heteraster* spp. and *Toxaster* spp., in marls and marly limestones. The depositional environment is open marine shallow water throughout.

#### Material, depository

Altogether 85 samples were collected and 108 thin-sections were prepared. Materials (rock samples and thin-sections) are housed in the department of geology, Islamic Azad University, Mashhad branch.

## Systematic paleontology

### Ordo Dasycladales

PASCHER, 1931

Currently, the nomenclature and assignments of fossil Dasycladales with a rank higher than genus necessitates an *ad hoc* revision. The following tentative hierarchy is provisional.

### Familia Dasycladaceae

(KÜTZING, 1843) BERGER & KAEVER, 1992

### Tribus Dasycladeae PIA, 1920

### Genus *Montiella*

(L. & J. MORELLET, 1922) GÉNOT, 1987

The genus *Montiella* was assigned by BAS-SOULLET *et alii* (1979) to the Neomereae (PIA). Here, the genus is placed in the Dasycladaceae, in compliance with BERGER and KAEVER (1992, p. 50). Currently, *Montiella* includes six species, ranging in age from Hauterivian to Paleocene (DELOFFRE & GRANIER, 1993; GRANIER & DELOFFRE, 1994). In the Paleocene type-species *M. munieri*, the presence of two types of secondary laterals, respectively fertile and sterile, terminal to first order laterals is inferred, yet not physically demonstrated. In view of this equivocal situation, the genus *Bakalovaella* BUCUR, 1993 (type-species, *B. elitzae*; see synonymy below) will possibly prove to be a well-founded taxon rather than a junior synonym of *Montiella*.

### *Montiella* ? *elitzae*

(BAKALOVA, 1971) RADOIČIĆ, 1980

Fig. 8 (a-d)

Selected citations:

- ? 1960 *Turkmenaria adducta* gen. et sp. n. MASLOV V.P., 1960, p. 1036, fig. 1b, fig. 2.
- 1971 *Cylindroporella elitzae* sp. n. BAKALOVA D., p. 126, Pl. 3.
- 1978 *Cylindroporella barbui* n.sp. DRAGASTAN O., p. 126, text-fig. 2 (a-e).

**1980** *Montiella? elitzae* (BAKALOVA) nov. komb. RADOIČIĆ R., p. 114, pls. I-IV; figs. 1, 2 [reconstruction].

**1993** *Bakalovaella elitzae* (BAKALOVA) nov. komb. BUCUR I.I., p. 100, pl. 7. [Inclusive of a comprehensive synonymy].

**1995** *Montiella elitzae*. MASSE J.-P. & ARNAUD-VANNEAU A., pl. 1, figs. 4-5.

**2007** *Montiella elitzae*. BUCUR I.I., p. 11.

*Turkmenaria adducta* MASLOV comes from Barremian deposits in the Sviryuzinskoye Gorge, Turkmen Central Kopet Dag. Although formally valid, it unfortunately remains ill-described, so *Montiella? elitzae* might be a junior synonym. The species ranges from the Late Hauterivian to the Albian, usually in open marine deposits. Taxonomically, it is closely related to the Barremian-Aptian *Montiella benizarensis* (JAFFREZO), and the Cenomanian-Turonian *Montiella filipovici* RADOIČIĆ.

The following, simplified description is based on BUCUR (1993, p. 100-102, under *Bakalovaella elitzae*): Thallus cylindrical, non-constricted, bearing numerous, contiguous whorls of short tubular primary laterals, disposed horizontally and form quincunxes. Main axis cylindrical or intusannulated, somewhat larger between the whorls. Two types of secondary laterals are clustered at the tip of the primaries: (1) one (single) large sub-spherical or egg-like fertile appendage (gametophore), oblique to the axis, free or occasionally slightly deformed, on top of a short and narrow proximal attachment; (2) below the gametophore, one (single) secondary lateral, horizontal, commonly slightly twisted, first slender and tubular, then progressively expanding, occasionally compressed by the adjacent gametophores, triangular in section. Gametangia uncalcified. Dimensions, partly modified from BUCUR (1993): L = up to 7 mm, D = 0.51-1.24 mm, d = 0.12- 0.34 mm, d/D = 13-37%, h = 0.17-0.23 with up to 42 whorls, l = 0.09-0.15 mm, p = 0.09-0.11 mm, l' (sterile) = 0.23-0.25 mm, p' (sterile) = 0.09 mm, l' (fertile) = 0.23-0.25 mm, p' (fertile) = 0.19-0.26 mm, w = 6-9.

At Arkan, numerous sections of *Montiella? elitzae* are found in several thick-bedded intervals throughout the Tirgan Formation. Of special interest is the fully 7 mm-long, flexuous specimen depicted in Fig. 8 (a). In the lower, right hand side of the picture, gametophores are missing in the narrow, basal part of the thallus presumably close to the rhizoid. A similar section is depicted in Fig. 8 (d). At top of the Fig. 8 (a), the longitudinal section cuts the acuminate, fertile tip of the lime skeleton. The sterile secondary laterals appear to be missing, causing a striking resemblance with certain sections of *Holosporella* spp. Apparently, the uncalcified, sterile vertex of the alga decayed before the vegetative phase ended, prior to the formation of gametophores.

Here, the traditional interpretation of the taxonomy of *Montiella? elitzae* is retained, although elaborated. However, many of the sections of this alga also suggest the following alternative interpretation: the fertile appendages (gametophores) are lateral in position to the proximal part of the primaries. In other terms, no sterile secondary laterals would exist, a situation found, for example, in the Recent *Bornetella nitida*.

**Familia Triploporellaceae  
(PIA, 1920) BERGER & KAEVER, 1992,  
sensu BARATTOLO et alii, 2008**

Quoting BERGER and KAEVER (1992, table 2.4) "This family is characterized by euspondyl arrangement of laterals and cladospore formation of gametangia". According to BARATTOLO et alii (2008) "Although the kind of reproduction (endosporous or cladospore) is a high taxonomic character, their evidence is lacking in most of fossil taxa (...) the occurrence of thin and delicate laterals, irrespectively of whether trichophorous or phloiophorous, often associated with a bulky central stem, is considered a proof of an endosporous reproduction (for a discussion see DE CASTRO, 1997). (...) Consequently, the diagnosis of Triploporellaceae ought to include both endosporous and cladospore reproduction."

**Tribus Salpingoporelleae  
BASSOULLET et alii, 1979**

**Genus Salpingoporella  
(PIA in TRAUTH, 1918)  
CARRAS et alii, 2006**

At least eight species of *Salpingoporella* (Fig. 7) are present in the Tirgan Formation. Of them only two, *S. cemi* and *S. muehlbergii*, are identified with certainty.

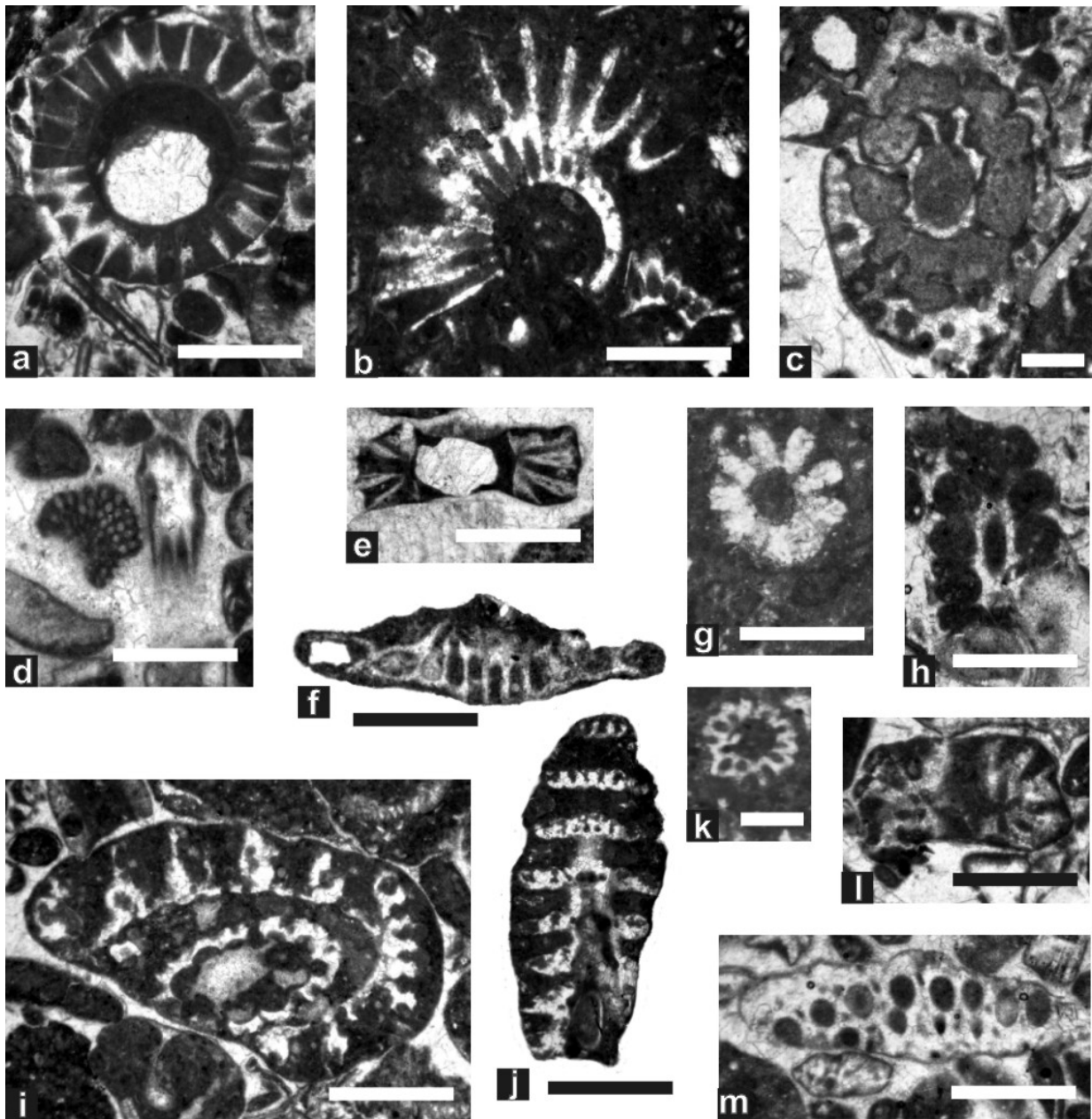
**Genus Clypeina MICHELIN, 1845**

***Clypeina* ? sp. 1**

Fig. 6 (i-j)

The two illustrated specimens, the only ones available, apparently are the same taxon. Provisional description: wide axial main axis, cylindrical and/or intusannulated, weakly calcified, presumably fertile (endosporate), bearing spaced out whorls of numerous, strongly calcified primary laterals, flexuous, almost horizontal, progressively widening out (phloiophorous), open (uncalcified) at tip; irregular presence of slender filaments, coating the axis and/or the laterals. Dimensions: D = ab. 0.9 mm; d = ab. 0.47 mm; d/D = ab. 50%; h = ab. 0.3 mm; w = 28-32; p max. = 0.07 mm.

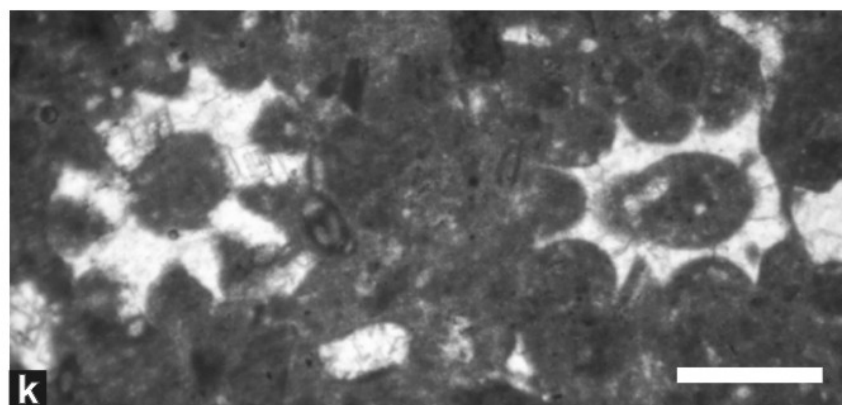
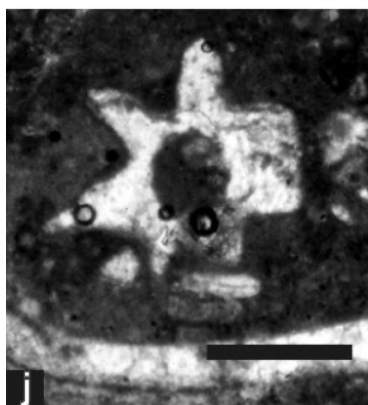
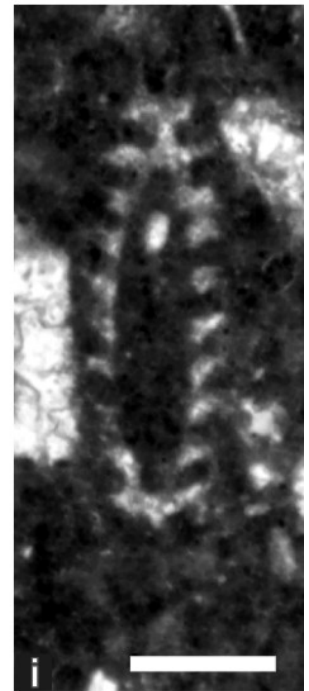
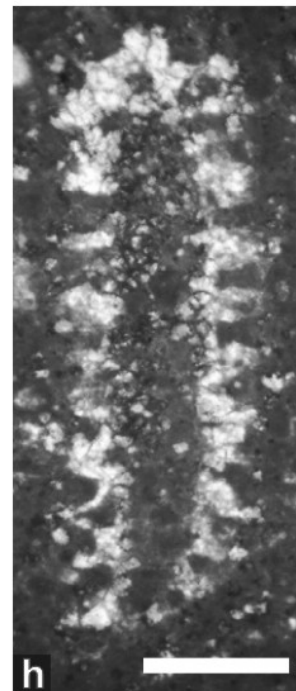
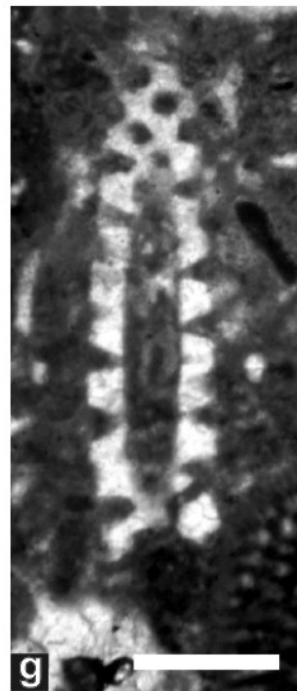
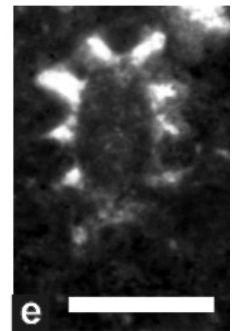
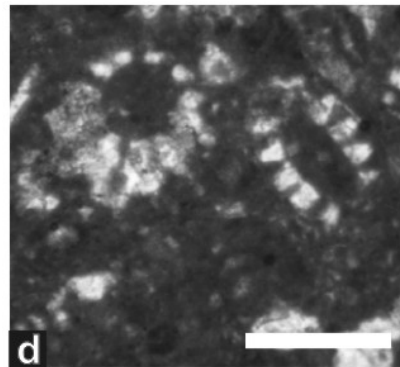
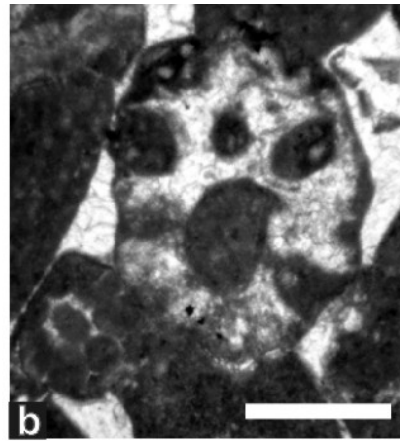
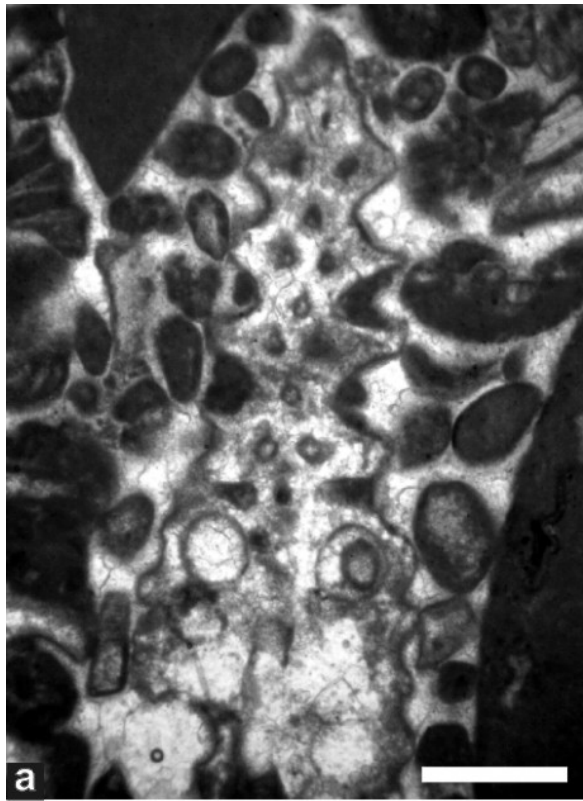


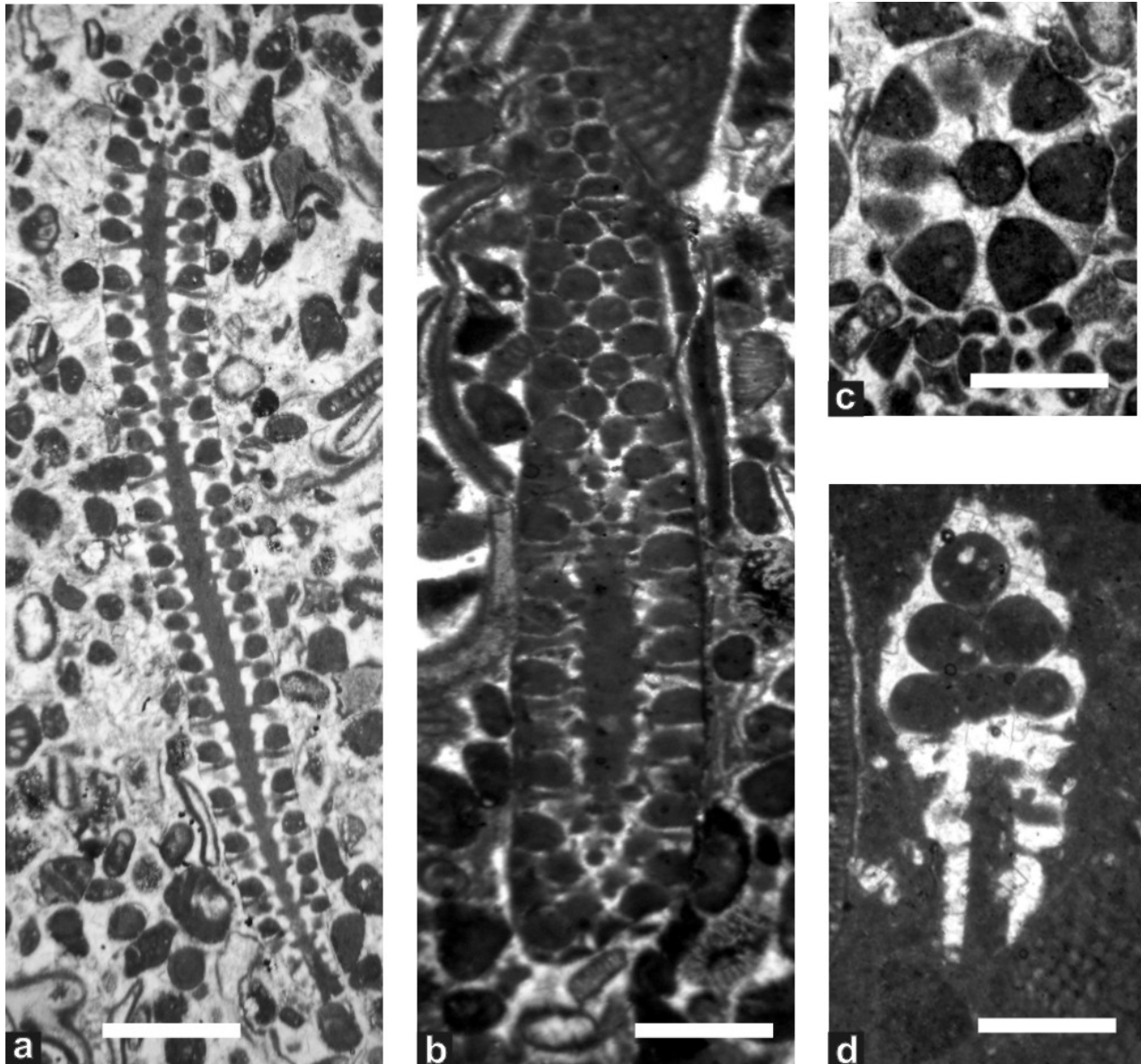


**Figure 6:** Dasycladalean algae from the Tirgan Formation, Kopet Dag; **fig. a:** transversal section of *Triploporella* ? sp. (secondary laterals uncalcified or missing), sample 174, scale bar 0.7 mm; **fig. b:** incomplete, almost transversal section of *Clypeina* cf. *gigantea* (another, smaller specimen is visible above the scale bar), sample 140, scale bar 0.7 mm; **fig. c:** oblique-transversal section of *Conradella bakalovae*, sample 135, scale bar 0.4 mm; **fig. d:** two *incertae sedis*, with *Vermiporella* ? sp. (left) and a tangential section of *Coptocampylodon* cf. *lineolatus* (right), sample 152, scale bar 0.7 mm; **fig. e:** axial section of *Praturlonella* cf. *dalmatica*, sample 133, scale bar 0.6 mm; **fig. f:** tangential section of *Actinoporella podolica*, sample 135, scale bar 0.75 mm; **fig. g:** almost transversal section of *Clypeina* ? cf. *C. solkani*, sample 150, scale bar 0.7 mm; **fig. h:** oblique section of *Holosporella* sp., sample 135, scale bar 0.75 mm; **fig. i:** broken oblique section of *Clypeina* ? n.sp. 1 enclosing a smaller specimen of *Otternstella* ? sp., sample 142, scale bar 0.4 mm; **fig. j:** oblique-tangential section of *Clypeina* ? n.sp. 1, sample 142, scale bar 0.74 mm; **fig. k:** transversal section of *Praturlonella nerae*, sample 150, scale bar 0.6 mm; **fig. l:** axial section of *Praturlonella* aff. *P. nerae*, sample 135, scale bar 0.6 mm; **fig. m:** tangential section of *Neomeris* ? cf. *N. cretacea*; sample 138, scale bar 0.6 mm.

▶ **Figure 7:** Species of genus *Salpingoporella* PtA (Dasycladales) from the Tirgan Formation, Kopet Dag; **fig. a:** oblique-tangential section of *Salpingoporella cemi*, sample 152, scale bar 0.7 mm; **fig. b:** oblique section of *S. cemi*, sample 166, scale bar 0.7 mm; **fig. c:** oblique section of *Salpingoporella* cf. *S. piriniae*, sample 151a, scale bar 0.55 mm; **fig. d:** two sections of *Salpingoporella* cf. *S. piriniae*, sample 150, scale bar 0.7 mm; **fig. e:** oblique section of *Salpingoporella* cf. *S. parapiriniae* sample 140, scale bar 0.6 mm; **fig. f:** oblique section of *Salpingoporella muehlbergii*, sample 140, scale bar 0.6 mm; **fig. g:** oblique section of *S. muehlbergii*, sample 148, scale bar 0.7 mm; **fig. h:** oblique section of *Salpingoporella* sp., sample 151b, scale bar 0.7 mm; **fig. i:** oblique section of *Salpingoporella* sp., sample 145, scale bar 0.75 mm; **fig. j:** almost transversal section of *Salpingoporella* aff. *S. hasi*; sample 145, scale bar 0.8 mm; **fig. k:** to the left, oblique section of *Salpingoporella* aff. *S. hasi*; to the right, oblique section of *Holosporella* ?, sample 150, scale bar 0.7 mm.







**Figure 8:** *Montiella ? elitzae* (Dasycladales), from the Tirgan Formation, Kopet Dagh; **fig. a:** full longitudinal section, sample 149b, scale bar 2.3 mm; **fig. b:** oblique-tangential section, sample 174, scale bar 0.7 mm; **fig. c:** almost transversal section, sample 140, scale bar 0.6 mm; **fig. d:** oblique-tangential section cutting the basal part of the alga, sample 165, scale bar 0.8 mm.

### Tribus Triploporelleae (PIA, 1920)

BASSOULLET *et alii*, 1979

#### Genus *Rajkaella*

DRAGASTAN & BUCUR, 1988

The latest, emended diagnosis was introduced by DRAGASTAN and BUCUR (1993), under the name *Radoiciciella*. Excerpts of the description are as follows: "(...) slightly calcified whorls spaced out along an uncalcified (or extremely poorly calcified) axial cavity. Whorls made up of primary and secondary branches. Primaries, long and cylindrical (tubular), sometimes slightly dilated distally; they are perpendicular or more or less inclined to the axial cavity. Secondaries, shorter and widening distally; they occur as a bush around the distal end of primaries. Sometimes the branches may be coalescent either proximally or on a longer

part of their tract (...). Due to the poor calcification of the axial cavity, the alga is fragile and may be found only as fragments representing branches or part of them." So far, there are six valid species of *Rajkaella*, ranging in age from Tithonian to Aptian.

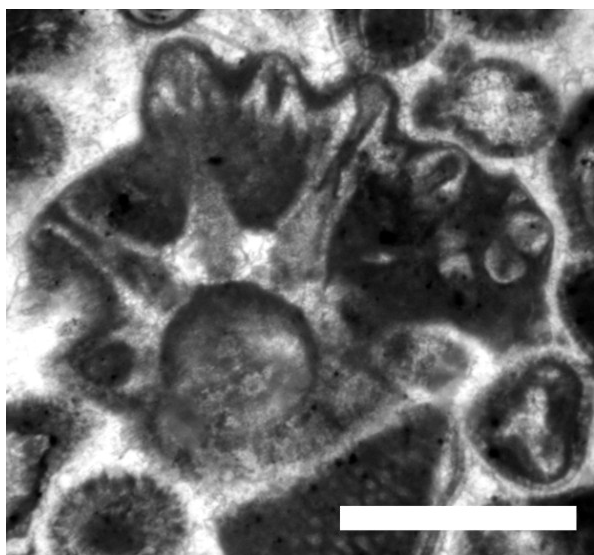
#### *Rajkaella ? sp. 1*

Fig. 9

A provisional description is based on the one specimen (illustrated) available: narrow main axis bearing whorls of weakly calcified primary laterals, dumb-bell shaped, presumably fertile (cladospore), bent at tip, forming imbricate (overlapping) calcified quincunxes. Short, phloiophorous secondary laterals are clustered at tip of the primaries. Dimensions:  $D = 1.7$  mm;  $d = 0.42$  mm;  $d/D = 25\%$ ;  $w = 9$ ;  $w' =$



approx. 9;  $p = 0.15$  mm;  $p' = 0.06$  mm;  $l = 0.65$  mm;  $l' = 0.06$  mm. These values do not widely differ from the known species of *Rajkaella*. However, in *Rajkaella*? sp. 1 the secondary laterals are fewer and shorter.



**Figure 9:** Nearly transversal section of *Rajkaella*? sp. 1 (Dasycladales), Tirgan Formation, Kopet Dagh, sample 153, scale bar 0.7 mm.

### **Genus *Steinmanniporella* BUCUR *et alii*, 2009**

The genus *Steinmanniporella* with its type-species the Late Jurassic *S. kapelensis* (SOKAČ & NIKLER), was recently created to include four species ranging in age from Late Jurassic to Paleocene originally assigned the genus *Linoporella* STEINMANN. Only two orders of laterals are found in these species, instead of the three in *Linoporella*. The diagnosis in BUCUR *et alii* (2009) is as follows: "Cylindrical 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 (endosporate)."

In terms of formal description, these general characters fit well with *Steinmanniporella*? *parsica*, n.sp., but the secondary laterals are horn-shaped, that is phloiophorous throughout their length, instead of being tubular first and phloiophorous at the tip. Such a minor difference is considered significant only at the species level. Conversely, when at the species recently assigned to *Steinmanniporella*, e.g. *S. kapelensis* illustrated in BUCUR *et alii* (2009, fig. 1a), are examined, differences from *Steinmanniporella*? *parsica*, n.sp., are striking: in all of these previously described species the primary laterals are arranged in rather close whorls, are rather short and stout, with quite long, thin secondary laterals that are phloiophorous at tip. In other terms, our new species may also be a new

genus. Here, for convenience, it is provisionally assigned *Steinmanniporella* and thus avoids the creation of a genus based on a single specimen.

### ***Steinmanniporella*? *parsica*, n.sp.**

Fig. 10

Holotype: the sole specimen is a slightly oblique, sub-axial section depicted in Fig. 10. Sample 149b, Arkan section, in the middle of the Tirgan Formation assigned the Aptian.

*Derivatio nominis*: after Persia (= Pars).

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 (endosporate-type).



**Figure 10:** Sub-axial section of *Steinmanniporella*? *parsica*, n.sp. (Dasycladales), Tirgan Formation, Kopet Dagh, sample 149b, scale bar 0.7 mm.

Description: The specimen is about 1 mm wide (D value), with five whorls of about twenty primary laterals. The wide axial cavity is clearly intusannulated, although the width (d value) between the whorls is increased by some process of microbioerosion that possibly destroyed an original proximal attachment of the primary laterals. The approximately 0.17 mm-long primary laterals are only 0.02 to 0.03 mm-wide. They are flexuous, increase very slightly in diameter, or maintain their width throughout their length. Approximately eight horn-shaped (phloiophorous) secondary laterals are clustered at the tip of the primaries, forming a conspicuous, bowl-shaped and gently-tilted downward rosette. Except at the periphery of the rosettes, the mucilage coat of the alga is entirely calcified, and even more heavily around the laterals. The specimen is irregularly worn at its periphery. In the better preserved lower part of the section (the lower part of Fig. 10), the rosettes touch suggestive of a distal, polygonal cortex like that of the Recent genus *Bornetella*. However, this is unlikely, because in the living alga the rosettes are irregularly bent downward by their weight so are probably not connected to each other.

Comparisons: *Steinmanniporella* ? *parsica*, n.sp., is difficult to compare with any other species, except perhaps *Balkhanella hurkai* SRIVASTAVA, 1993. The so far mono-specific genus *Balkhanella* is possibly also endosporate. It was established on the basis of a single nice specimen from Hauterivian bioclastic deposits in the Bolshoi Balkhan, Turkmenia. In *Balkhanella hurkai*, the thallus is clearly articulated, as shown by the orientation of the laterals that form clusters. The wide main axis is slightly intusannulated, heavily calcified, somewhat narrower between the whorls. Possibly it has bulging proximal features, perhaps more like vestibules than slender primary laterals.

## Conclusions

Barremian - Aptian limestones of the Tirgan Formation yield rich assemblages of calcareous algae, including over 25 species of Dasycladales. In the lower part of the Arkan section, three species, namely *Actinoporella podolica*, *Praturlonella dalmatica* and *Clypeina gigantea*, suggest a Barremian age, but do not exclude the Late Hauterivian. In the upper part of the section the presence of *Praturlonella nerae* is indicative of the Aptian. Taxonomy of the particularly abundant *Montiella* ? *elitzae*, is reviewed based on the finding of a complete specimen. Two species, *Clypeina* ? sp. 1 and *Rajkaella* ? sp. 1 are informally described and a new, presumably endosporate taxon, *Steinmanniporella* ? *parsica*, n.sp., is introduced. The one specimen available has a unique combination of characters, possibly requiring the erection of a new genus of Tripoporellaceae. As mentioned by other authors, the family should be emended

to include endosporate taxa.

## Acknowledgements

The authors wish to thank Prof. Ioan BUCUR (University of Cluj-Napoca) for his careful review of the manuscript and helpful suggestions. We thank M.Sc Abbas GHADERI from the Center of Excellence for Paleontology, Ferdowsi University of Mashhad for his contributions in the field. Also, we thank the Department of geology, Islamic Azad University, Mashhad branch for supplying field equipment. Dr. Nicolaos CARRAS (IGME, Athens) advised on the taxonomy of certain species. Reviews of the English by Mr. GHANE (language school head of studies) and Hasmik ASMARYAN (Ecocenter NAS RA) are gratefully acknowledged.

## Bibliographic references

- AFSHAR-HARB A. (1969).- History of oil exploration and brief description of the geology of the Sarakhs area and the anticline of Khangiran.- *Bulletin of the Iranian Petroleum Institute*, Tehran, vol. 37, p. 86-94 (in Persian).
- AFSHAR-HARB A. (1994).- Geology of Kopet-Dagh.- *Geological Survey of Iran publication*, Tehran, 275 p. (in Persian).
- BAKALOVA D. (1971).- Nouvelles espèces de Dasycladaceae (Algae) dans les sédiments urgoniens du Prébalkan central.- *Bulgarian Academy of Sciences - Committee of Geology, Bulletin of the Geological Institute*, Sofia, (Series Paleontology), vol. XX, p. 123-127.
- BARATTOLO F., COZZI A. & ROMANO R. (2008).- New dasycladalean algae from the Middle Norian (Upper Triassic) of northern Italy (Mt. Pramaggiore, Carnic Prealps).- *Facies*, Erlangen, vol. 54, p. 549-580.
- BASSOUILLET J.-P., BERNIER P., DELOFFRE R., GÉNOT P., JAFFREZO M. & VACHARD D. (1979).- Essai de classification des Dasycladales en tribus. In : 2ème Symposium international sur les Algues fossiles (Paris, 23-26 avril 1979).- *Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine*, Pau, vol. 3, n° 2, p. 429-442.
- BERGER S. & KAEVER M.J. (1992).- Dasycladales - An illustrated monograph of a fascinating algal order.- Georg Thieme Verlag, Stuttgart - New York, 247 p.
- BUCUR I.I. (1993).- Some new or poorly known calcareous algae (Dasycladales, Gymnocodiaceae) in the Lower Cretaceous deposits from the Resita-Moldava Noua Zone (Southern Carpathians, Romania).- *Revista Española de Micropaleontología*, Madrid, vol. 25, p. 93-126.
- BUCUR I.I. (2007).- *Salpingoporella* ? *popgrigorei*, a new species of Dasycladales (calcareous algae) from the Lower Aptian deposits of Padurea Craiului (Northern Apuseni Mountains, Romania).- *Facies*, Erlangen, vol. 53, p. 377-388.



- BUCUR I.I., GRANIER B. & SCHLAGINTWEIT F. (2009).- *Steinmanniporella*, a new dasycladale genus name for "*Linoporella*" with two orders of laterals.- *Facies*, Erlangen, vol. 56, n° 2, p. 317-321.
- CARRAS N., CONRAD M.A. & RADOIČIĆ R. (2006).- *Salpingoporella*, a common genus of Mesozoic Dasycladales (calcareous green algae).- *Revue de Paléobiologie*, Genève, vol. 25, n° 2, p. 457-517.
- DE CASTRO P. (1997).- Introduzione allo studio in sezione sottile delle Dasycladali fossili.- *Quaderni dell'Accademia Pontaniana*, Napoli, n° 22, 262 p.
- DELOFFRE R. (1988).- Nouvelle taxonomie des Algues Dasycladales - New taxonomy of Dasycladale Algae.- *Bulletin des Centres de Recherche Exploration-Production Elf-Aquitaine*, Pau, vol. 12, p. 165-217.
- DELOFFRE R. & GRANIER B. (1993).- Inventaire des Algues Dasycladales fossiles. I° partie- Les Algues Dasycladales du Tertiaire.- *Revue de Paléobiologie*, Genève, vol. 11, n° 2 (1992), p. 331-356.
- DRAGASTAN O. (1978).- Microfacies de la serie calcaires, cretacée inférieure d'Aliman (Dobrogea de sud).- *Dari de Seama ale Seditelor*, Bucuresti, t. LXIV (1976-1977), 4. Stratigrafie, p. 107-136, 7 pls.
- DRAGASTAN O. & BUCUR I.I. (1988).- Comments on the genus *Radoiciciella*.- *Analele Universitatii Bucuresti - Geologie*, vol. 37, p. 97-99.
- DRAGASTAN O. & BUCUR I.I. (1993).- The dasyclad genus *Radoiciciella* and its representatives from Romania.- *Revista Española de Micropaleontología*, Madrid, vol. 25, p. 5-23.
- GÉNOT P. (1987).- Les Chlorophycées calcaires du Paléogène d'Europe nord-occidentale (Bassin de Paris, Bretagne, Cotentin, Bassin de Mons).- Thèse de Doctorat d'État, Université de Nantes, 500 p.
- GRANIER B. & DELOFFRE R. (1994).- Inventaire des Algues Dasycladales fossiles. II° partie- Les Algues Dasycladales du Jurassique et du Crétacé.- *Revue de Paléobiologie*, Genève, vol. 12, n° 1 (1993), p. 19-65.
- KUSS J. (1994).- Cretaceous (Albian-Turonian) calcareous algae from Egypt and Jordan - Systematics, stratigraphy and paleogeography.- *Abhandlungen der Geologischen Bundesanstalt*, Wien, Band 50, p. 295-317.
- KÜTZING F.T. (1843).- *Phycologia generalis oder Anatomie, Physiologie und Systemkunde der Tange*.- F.A. Brockhaus, Leipzig, p. 311-313.
- MASLOV V.P. (1960).- Novoye Vodorosli Mela Kopet-Daga (Turkmeniya) [New cretaceous algae of Kopet Dag (Turkmenia)].- *Doklady Akademii Nauk SSSR*, Moscow, Tom 134, n° 4, p. 939-941.
- MASSE J.-P. & ARNAUD-VANNEAU A. (1995).- Early Cretaceous calcareous algae of the Northwest Pacific guyots.- *Proceedings of the Ocean Drilling Program, Scientific Results*, College Station, vol. 144, p. 221-230.
- MICHELIN H. (1840-1847).- Iconographie zoophytologique. Description par localités et terrains des Polypiers fossiles de France et pays environnants.- P. Bertrand, Paris, 348 p., 79 pls.
- MORELLET L. & MORELLET J. (1922).- Nouvelle contribution à l'étude des Dasycladacées tertiaires.- *Mémoires de la Société géologique de France*, Paris, (Paléontologie), t. XXV, fasc. 2, N° 58, 33 p.
- NABAVI M.H. (1976).- An introduction to geology of Iran.- *Geological Survey of Iran publication*, Tehran, Iran, 110 p. (in Persian).
- NEZAFATI N. (2006).- Au-Sn-W-Cu-Mineralization in the Astaneh-Sarband Area, West Central Iran including a comparison of the ores with ancient bronze artifacts from Western Asia.- PhD, Eberhard-Karls-Universität Tübingen, 116 p.
- PASCHER A. (1931).- Systematische Übersicht über die mit Flagellaten in Zusammenhang stehenden Algenreihen und Versuch einer Einreihung dieser Algenstämme in die Stämme des Pflanzenreiches.- *Beihefte zum Botanischen Centralblatt*, Jena, Band XLVIII, Heft 3, p. 17-332.
- PIA J. von (1918).- Dasycladaceae. In: TRAUTH F. (ed.), *Das Eozänvorkommen bei Radstat im Pongau und seine Beziehungen zu den Gleichalterigen Ablagerungen bei Kirchberg am Wechsel und Wimpassing am Leithagebirge*.- *Denkschriften der mathem.-naturw. Klasse*, Wien, vol. 95, p. 171-278.
- PIA J. von (1920).- Die Siphoneae verticillatae vom Karbon bis zur Kreide.- *Abhandlungen der zoologisch-botanischen Gesellschaft in Wien*, Band XI, Heft 2, 259 p., 8 pls. [Les Siphonées verticillées du Carbonifère au Crétacé (1961). Editions Technip, Rueil-Malmaison, 258 p., 8 pls.].
- RADOIČIĆ R. (1980).- Contribution to the reconsideration of a group of cylindroporelliform dasyclads.- *Bulletin de l'Académie Serbe des Sciences et des Arts*, Beograd, (Classe des Sciences mathématiques et naturelles, Sciences naturelles), vol. 20, p. 109-115.
- SRIVASTAVA N.K. (1973).- Neocomian calcareous algae from Bolshoi Balkhan, USSR.- *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte*, Stuttgart, 1973, n° 11, p. 690-708.
- STÖCKLIN J. (1968).- Structural history and tectonics of Iran; a review.- *The American Association of Petroleum Geologists, Bulletin*, Tulsa, vol. 52, n° 7, p. 1229-1258.
- STÖCKLIN J. & SETUDEHNIYA A. (1991).- Stratigraphic Lexicon of Iran, Report No. 18.- *Geological Survey of Iran publication*, Tehran, Iran, 376 p.
- TAHERPOUR KHALIL ABAD M., SCHLAGINTWEIT F., ASHOURI A.R. & ARYAEI A.A. (2009).- *Juraella bifurcata* BERNIER, 1984 (Calcareous alga, Gymnocodiaceae?) from the Lower Cretaceous (Barremian) Tirgan Formation of the Kopet Dag basin, north-east Iran.- *Journal of Alpine Geology*, Leoben, vol. 51, p. 79-86