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FIRST RECORD OF CALCAREOUS GREEN ALGAE (DASYCLADALES, HALIMEDACEAE) FROM THE PALEOCENE CHEHEL KAMAN FORMATION OF NORTH-EASTERN IRAN (KOPET-DAGH BASIN)

Felix Schlagintweit[1] Koorosh Rashidi[2*] & Abdolmajid Mosavinia[3]

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Abstract The micropalaeontological inventory of the shallow-water carbonates of the Paleocene Chehel-Kaman Formation cropping out in the Kopet-Dagh Basin of north-eastern Iran is poorly known. New sampling has evidenced for the first time the occurrence of layers with abundant calcareous green algae including Dasycladales and Halimedaceae. The following dasycladalean taxa have been observed: *Jodotella veslensis* Morellet & Morellet, *Cymopolia cf. mayaense* Johnson & Kaska, *Neomeris plagnensis* Deloffre, *Thyrsoporella-Trinocladus*, *Uteria* aff. *merienda* (Elliott) and *Acicularia* div. sp. The studied section is devoid of larger benthic foraminifera and can be referred to the middle-upper Paleocene (SBZ 2-4) due to the presence of *Rahaghia khorassanica* (Rahaghi). Some of the dasycladalean taxa are herein reported for the first time not only from Iran but also the Central Neotethyan realm.

Keywords: Green algae, Paleogene, taxonomy, biostratigraphy, Kopet-Dagh Basin, Iran

INTRODUCTION

Paleocene shallow-water carbonates are known from different parts (or tectonic zones) of Iran: the Kopet-Dagh Basin, NE Iran (e.g., Rahaghi, 1983; Rivandi and Moosavizadeh, 2015; Salahi et al., 2018), the Sistan Suture Zone, E Iran (e.g., Rahaghi, 1983; Tirrul et al., 1983), Central Iran (e.g., Deloffre et al., 1977; Khosrow-Tehrani, 1987), or Zagros Zone, SW Iran (e.g., James and Wynd, 1965; Kalantari, 1976). While the larger benthic foraminifera occurring in these deposits experienced much attention (e.g., Rahaghi, 1978, 1980, 1983), data on calcareous green algae are scarce (e.g., Deloffre et al., 1977; Barani et al., 2017; Schlagintweit et al., 2019a, b) or, referring to the Kopet-Dagh Basin, are almost completely lacking. In the present contribution an assemblage of Dasycladales and Halimedaceae is reported for the first time from the Chehel-Kaman Formation of the Kopet-Dagh Basin.

GEOLOGICAL SETTING

The Kopet Dagh (or Koppeh Dagh) mountain range represents a NE-trending about 650 km long and about 200 km wide active fold belt at the frontier between Iran and Turkmenistan, east of the Caspian Sea (Fig. 1a). It was formed on Hercynian metamorphosed basement at the SW margin of the Turan Platform and is composed of about 10 km of mostly conformably Mesozoic and Tertiary sediments (e.g., Berberian and King, 1981; Afshar-Harb, 1994; Golonka, 2004). These sediments were deposited in a marginal sea of the northern Tethys ocean, one of the so-called Peri-Tethyan Basins (Brunet and Cloething 2003, for overview), that became closed with the suturing of northeast Iran to the Eurasian Turan platform resulting from the convergence between the Arabian and Eurasian plates (e.g., Stöcklin, 1968, 1974; Berberian and King, 1981).

The Paleocene Chehel Kaman Formation mainly consists of dolomites, marls, marly limestones and limestones conformably overlying the reddish siliciclastic Pesteh Ligh Formation (Afshar-Harb, 1979, 1994) (Fig. 1c). The type-locality is the Chehel Kaman gorge, south of the eponymous village. As the accessibility to the gorge is difficult, Afshar Harb (1979, p. 163) designated the road-cut of the Mashhad-Sarakhs main road, about 125 km from the town of Mashhad, passing the Chehel Kaman Formation as paratype section (Fig. 1b). There are a few papers dealing with the carbonates of the Chehel Kaman Formation published in the last decade, but the presence of calcareous algae has not been mentioned therein (Rivandi et al., 2013; Rivandi and Moosavizadeh, 2015; Erfani et al., 2016; Carrasco et al., 2019). The only indication of algae that we found is from Rahaghi (1976), noting the presence of *Trinocladus* aff. *perplexus* and *Acicularia* sp.

Some samples from the carbonates of the Chehel Kaman Formation have been taken along the road-cut Mashhad-Sarakhs, a locality also named Tang-e-Neyzar in Rahaghi (1978, p. 7) (Fig. 1d). The intention was to get a first overview of the micropalaeontological content. A profile log has not been measured. The samples revealed a few biostratigraphic data related to benthic foraminifera and algae. From this locality, the calcareous larger benthic *Laffiteina khorassanica* has been described by Rahaghi (1976), later taxonomically revised by Hottinger (2014) becoming *Rahaghia khorassanica* (Rahaghi) (Fig. 2). The stratigraphic range of this species is not well known

[1]Lerchenauerstr. 167, 80935 Munich, Germany, felix.schlagintweit@gmx.de
[2]Department of Geology, Yazd University, 89195-741 Yazd, Iran, kooroshrashidi@yazd.ac.ir
[3] Department of Geology, Payame Noor University, Tehran, Iran, Po Box 19395-3697
* Corresponding author

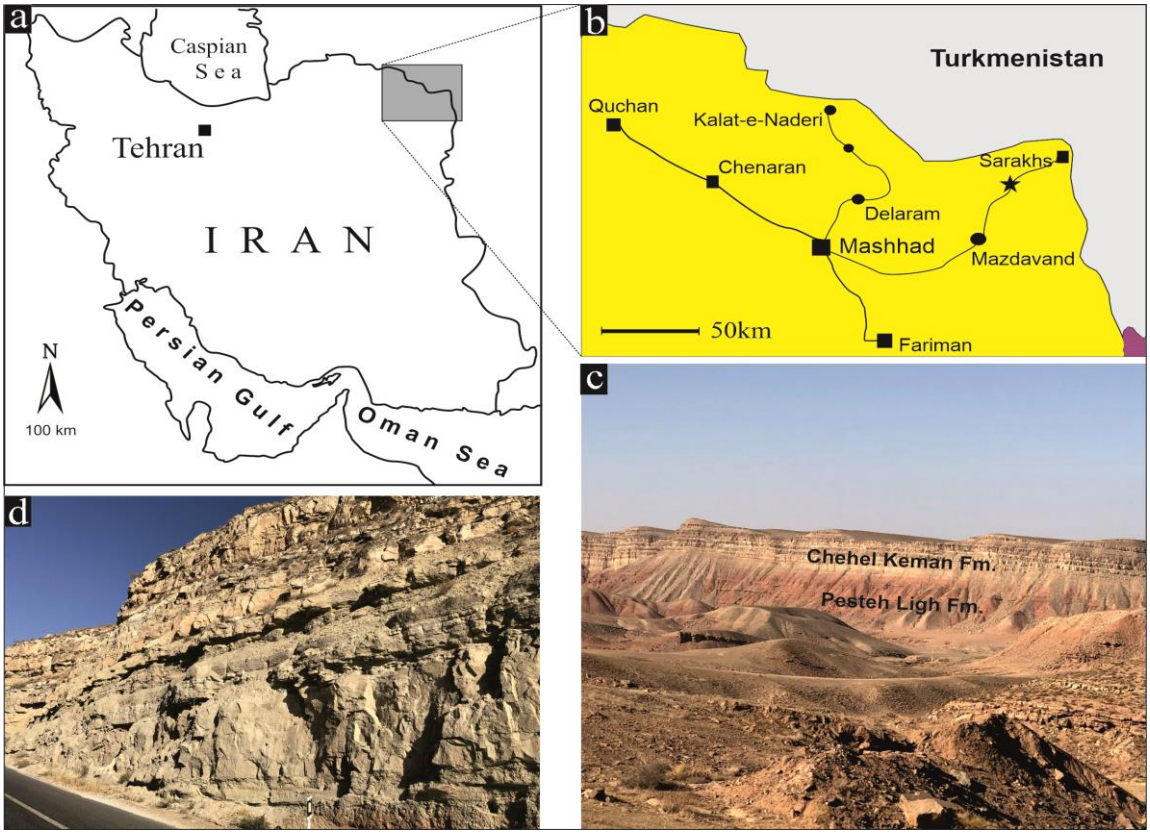

Fig. 1 a–b Location of the sampled locality in northeastern Iran along the road from Mashhad to Sarakhs. **c** field view to the north-west on the Pesteh Ligh and Chehel Kaman formations close to the sample location. **d** Road-cut of the Chehel Kaman Formation.

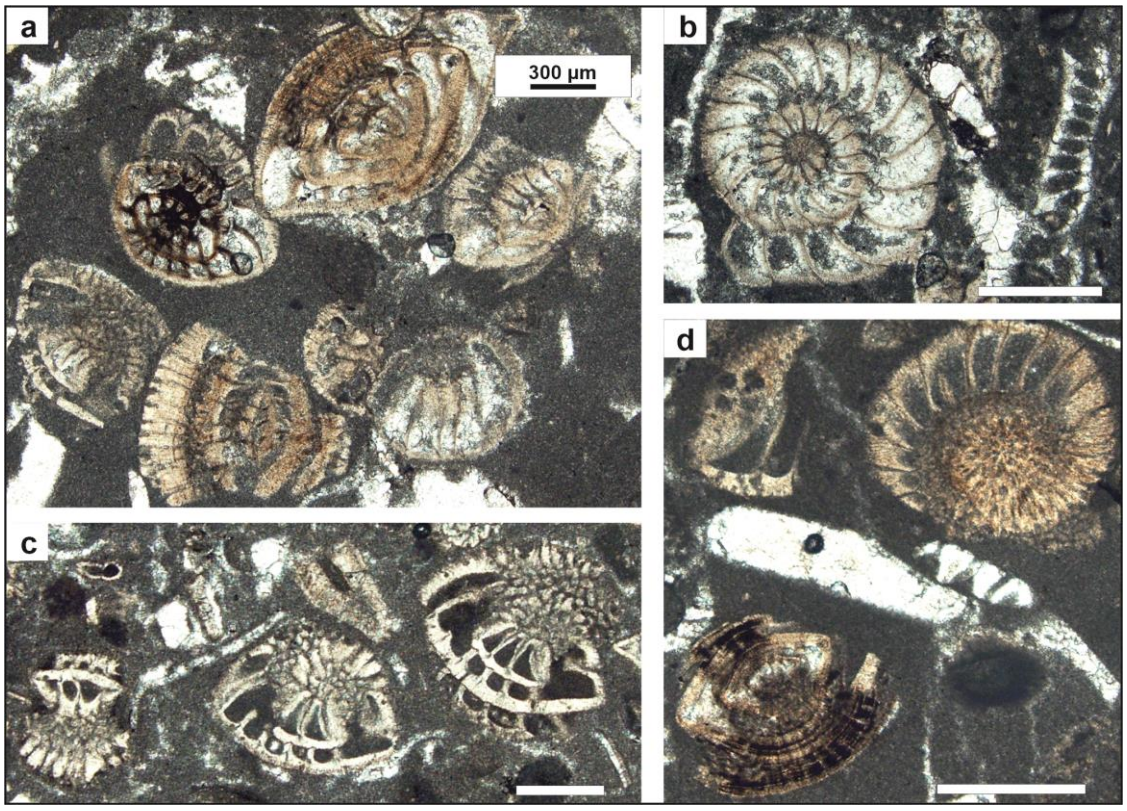

Fig. 2 Wackestone with numerous specimens of the calcareous benthic foraminifera *Rahaghia khorassanica* (Rahaghi) from the Chehel Kaman Formation, outcrops along the road Mashhad-Sarakhs. Note the verticil of *Uteria* aff. *merienda* (Elliott) in **b** and fragment of *Neomeris* in **d** with two partially preserved pedunculated fertile ampullae and one secondary lateral. Scale bars 0.5 mm in **b–d**. Thin-sections Nf 8 (**a, d**), Nf 5 (**b**), Nf 13 (**c**).

indicated as possibly upper part of Shallow Benthic Zone (SBZ) 1 to lower part of SBZ 4 (Hottinger, 2014, fig. 1.3). Among the observed calcareous algae, *Jodotella veslensis* Morellet & Morellet is known from the Selandian-Thanetian and *Neomeris plagnensis* Deloffre from the Thanetian (Barattolo, 2002). The microfacies containing the algae is represented by wackestone, (bioclastic) packstone and grainstones in parts with benthic foraminifera (rotaliids, miliolids), gastropods, and more rarely bryozoans, serpulids and remains of crustacean cuticles (Fig. 3). The most frequent taxa occurring also together in some samples are *Acicularia* div. sp., *Neomeris plagnensis* Deloffre, *Jodetella veslensis* Morellet & Morellet and *Halimeda*? sp.

MATERIAL AND DEPOSITORY

The analyses of the Paleocene limestones refer exclusively to thin-sections. Altogether 14 samples were taken labelled Nf1 to Nf14. They are currently stored at the Yazd University, Iran, in the Rashidi collection. It is planned to store the material at the Geosciences Museum of Mashad (in the Geological Survey of North-Iran East territory).

SYSTEMATIC MICROPALAEONTOLOGY

Phylum Chlorophyta
Class Dasycladophyceae Hoek et al., 1995
Order Dasycladales Pascher, 1931
Family Acetabulariaceae (Endlicher, 1847) Deloffre, 1987
Genus *Acicularia* d'Archiac, 1843
Acicularia sp. 1
Fig. 4a-i, l-o

Remarks: The longitudinal sections of the relative large-sized spicules (length up to 2.0 mm) are straight-rectangular (thickness ~0.3 mm), sometimes with a small central hollow and with close-set elongated cysts (width 0.08-0.15) of palisade-like appearance. This morphotype is the most common observed in the studied samples. It is typically associated with *Jodotella veslensis* Morellet & Morellet, *Neomeris plagnensis* Deloffre and *Halimeda?* sp.

Acicularia sp. 2
Fig. 4j-k

Remarks: In the studied thin-sections, this morphotype is less frequent than *Acicularia* sp. 1. It is more slender and exhibits spherical cysts (diameter 0.06-0.10 mm). Similar sections have been illustrated from the Thanetian Bekrit-Timahdit Formation of Morocco (Kuss and Herbig, 1993, pl. 6, fig. 17).

Genus *Uteria* Michelin, 1845
Uteria aff. *merienda* (Elliott, 1968)
Fig. 2b, 5b

*1968 *Clypeina merienda* n. sp. – Elliott, p. 35, pl. 4, figs. 2-3, 7-8.
1982 *Clypeina merienda* Elliott – Deloffre and Génot, p. 51, pl. 3, figs. 6-7.
1990 *Uteria merienda* (Elliott) – Radoičić, pl. 10, fig. 5.

Remarks: As the sections illustrated by Elliott (1968) from the Paleocene Sinjar Formation of Iraq were assigned to the genus *Clypeina* Michelin, they were interpreted as belonging to fertile laterals. "Reminiscent of *Clypeina*", they were referred to the sterile laterals of the genus *Uteria* Michelin showing two types of laterals, sterile and fertile (Radoičić, 1990; Dieni et al., 1985, p. 26). This type of thallus structure is well discernible in the longitudinal section illustrated in Figure 11a, a specimen from Eastern Iran (Sistan Suture Zone). There may be one or two fertile whorls between the disc-like whorls of sterile laterals. The specimens from the Chehel Kaman Formation refer exclusively to fragments of sterile laterals. A comparative table of the different *Uteria* species, excluding *U. merienda*, has been provided by Deloffre et al. (1989, tab. 1). In fact, the new species described by Deloffre et al. (1989) as *Uteria mexicana* from the upper Paleocene can in our opinion not be differentiated distinctly from the Iraqi species and might be a possible junior synonym of the latter.

Families Thyrsoporellaceae Granier and Bucur, 2013 or Triploporellaceae (Pia, 1920)
Thyrsoporella Gümbel, 1871 – *Trinocladus* Raineri, 1922
Fig. 5a

Remarks: The available tangential section does not allow the recognition of the lateral morphology and number of orders. We can just mention similarities to sections of *Trinocladus perplexus* Elliott (Elliott, 1955; Deloffre and Fourcade, 1994) and *Thyrsoporella longa* Radoičić, both described from Paleocene strata of Iraq. Granier and Braik (2002) already put up for discussion the possibility that some of the forms described as *Trinocladus perplexus* are identical to the thyrsoporellids reported by Radoičić (1990). If verified, it would then result in the new combination *Thyrsoporella perplexa* (Elliott) due to priority reason. On the other side, the existence of three orders of laterals (> *Trinocladus*) has been demonstrated by Deloffre and Fourcade (1994, transverse section in pl. 1, fig. 16) in material from Mexico excluding the belonging to *Thyrsoporella* (> 3 orders).

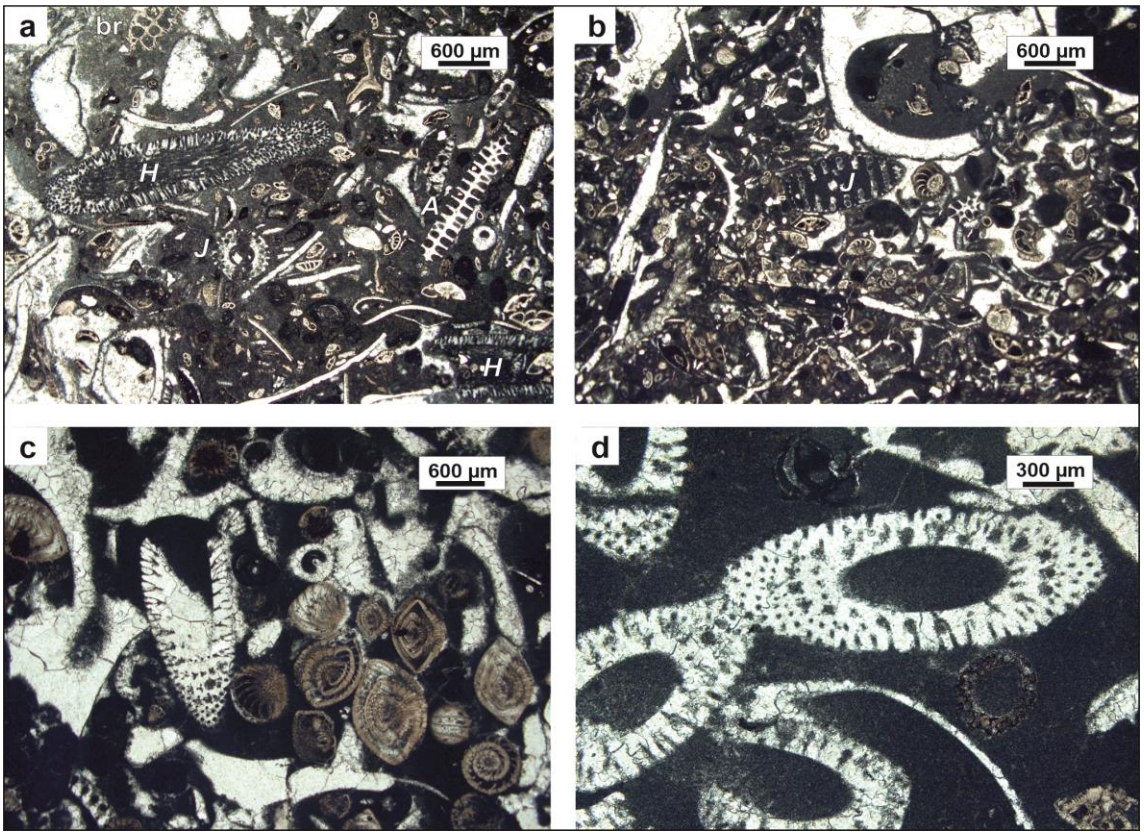

Fig. 3 Algal-bearing bioclastic packstone-wackestone from the Paleocene Chehel Kaman Formation of northeastern Iran with *Halimeda*? sp. (*H* in **a**), *Jodotella veslensis* Morellet & Morellet (*J* in **a-b**), *Cymopolia cf. mayaense* Johnson & Kaska (**c-d**), *Acicularia* sp. 1 (*A* in **a**), bryozoans (br in **a**), and common *Rahaghia khorassanica* (Rahaghi) (**c**). Locality see Figure 2. Thin-sections Nf 12-2 (**a**), Nf 14 (**b**), Nf 6-2 (**c-d**).

Genus *Jodotella* Morellet & Morellet, 1913
Jodotella veslensis Morellet & Morellet, 1913
Fig. 6

*1913 *Jodotella veslensis* n. gen., n. sp. – Morellet & Morellet, p. 29-30, text-fig. 17 (schematic drawing), pl. 3, fig. 12 (isolated specimen).
1980 *Jodotella veslensis* Morellet & Morellet – Génot, p. 18, text-fig. 8, pl. 21, figs. 1-12.
1982 *Jodotella veslensis* Morellet & Morellet – Deloffre and Génot, p. 104-105, pl. 9, figs. 2-5.
1985 *Jodotella veslensis* Morellet & Morellet – Dieni et al., p. 11-14, text-figs. 5-6, pl. 7, figs. 1-10, pl. 8, figs. 1-8.
2011 *Jodotella veslensis* Morellet & Morellet – Génot and Granier, p. 22, pl. 8.
?2019 *Jodotella* sp. – Vicedo et al., fig. 15B.

Remarks: *Jodotella veslensis* represents the type-species of the genus described from the Thanetian of the Paris Basin, Central France based on a single isolated specimen by Morellet and Morellet (1913). Further isolated material from the Paris Basin has been presented by Génot (1980) and Génot and Granier (2011). Compilations of different *Jodotella* species with their biometrical data have been provided by Parente (1997, tab. 2) and Dieni et al. (1985, tab. 2). With respect to the biometric data from the Paris Basin (Génot, 1980) and Sardinia (Dieni et al., 1985), the Iranian specimens display smaller outer dimensions (D), and a reduced vertical spacing (h), while other parameters fall in the ranges reported from the species (e.g., d/D, p, ds). The occurrence in the Chehel Kaman Formation is the first record of the species from Iran and also in the Central Neotethysian area.

Dimensions (in mm); data from Génot (1980; * measured from pl. 21, fig. 12) in brackets:

External diameter (D):	0.6-0.8; mean: 0.7, n = 9	(0.88-1.29)
Diameter axial cavity (d):	0.21-0.3; mean: 0.25, n = 6	(0.24-0.43)
d/D:	0.31-0.41; mean: 0.36, n = 6	(0.23-0.32)
width of laterals (R1) (p):	0.06-0.12; mean: 0.09, n = 9	(0.06-0.085)
vertical height (h):	0.15-0.2; mean: 0.17, n = 5	(0.27*)
diameter fertile ampulla (ds):	0.05-0.075; mean: 0.06; n = 12	(0.068-0.098)
Maximum length (L):	2.8	

Table 1 Preliminary compilation of Paleocene Dasycladales from different tectonic units of Iran based on literature (Deloffre et al., 1977; Barani et al., 2017; Schlagintweit et al., 2019a, b; this work) and unpublished own data.

Taxa	**Central Iran (CIM)**	**Eastern Iran (Sistan Suture Zone)**	**NE Iran (Kopet Dagh Basin)**	**SW Iran (Zagros Zone)**
Acroporella anceps Segonzac	X	X		X
Broeckinella maroccana Tragelehn		X		
Clypeina elliotti Beckman & Beckman	X	?		
Clypeina socaensis Deloffre & Radoičić		X		
Cymopolia div. sp.	X	X	X	X
Dissocladella gracilis Radoičić				X
Dissocladella? *chahtorshiana* Schlagintweit & Rashidi	X	X		
Dissocladella savitriae Pia		X		
Hamulusella sedalenensis Elliott	X	X		X
Jodotella sloveniaensis Deloffre & Radoičić		X		
Jodotella veslensis Morellet & Morellet	?	X	X	
Neomeris plagnensis Deloffre	X	X	X	
Neomeris sp.				X
Orioporella malaviae Pia		X		X
Orioporella sinensis (Wang)	X	X		X
Orioporella vilattae Segonzac	X	X		
Rostroporella oviformis Segonzac	X	X		X
Sandalia multipora Dieni et al.	X	X		
Thyrsoporella gr. *longa-turgidipora* Radoičić			?	X
Thyrsoporella sp.				X
Trinocladus atacis Segonzac	X	X		
Triploporella apenninica Baretti		X		
Uteria merienda (Elliott)	X	X	aff.	X
Uteria sarda Dieni et al.		X		X
Zittelina cf. *maksimovici* Radoičić		X		
Zittelina sp.	X			

Genus Neomeris Lamouroux, 1816
Subgenus *Neomeris* (Lamouroux, 1816) Pia in Hirmer, 1927
Neomeris plagnensis Deloffre, 1970
Fig. 7

*1970 *Neomeris plagnensis* n. sp. – Deloffre, p. 356-357, pls. 2-3.
1977 *Neomeris plagnensis* Deloffre – Deloffre et al., p. 41, pl. 5, figs. 3-7.
1982 *Neomeris plagnensis* Deloffre – Deloffre and Génot, p. 144-145, pl. 14, figs. 2-5.
1993 *Neomeris plagnensis* Deloffre – Kuss and Herbig, p. 275, pl. 4, figs. 7-8, pl. 8, figs. 1-3.

Remarks: This species, characterized by ovoid fertile ampullae combined with a comparably large main axis, was originally described from the Thanetian of France (Deloffre, 1970). From Central Iran *N. plagnensis* was reported by Deloffre et al. (1977, pl. 5, fig. 7) from bioclastic packstones with *Halimeda* sp., bryozoans, gastropods, and small rotaliids, a microfacies comparable to our samples from the Chehel Kaman Formation. Deloffre et al. (1977, p. 41, translated) reported specimens "slightly larger, probably corresponding to better developed individuals thriving in an ecologically more favourable environment", an observation obtained also from our material.

Dimensions (in mm); data from Deloffre (1970) in brackets:

External diameter (D):	1.0-1.4	(0.625-1.175)
Diameter axial cavity (d):	0.50-0.65	(0.35-0.8)
d/D:	0.43-0.64	(0.63-068)
wall thickness (e):	0.17-0.39	(0.1-0.3)
vertical spacing (h):	0.15-0.16	(0.125-0.175)
diameter fertile ampullae (ds):	0.08-0.14	(0.1-0.125)
Maximum length (L):	4.6	(3.6)

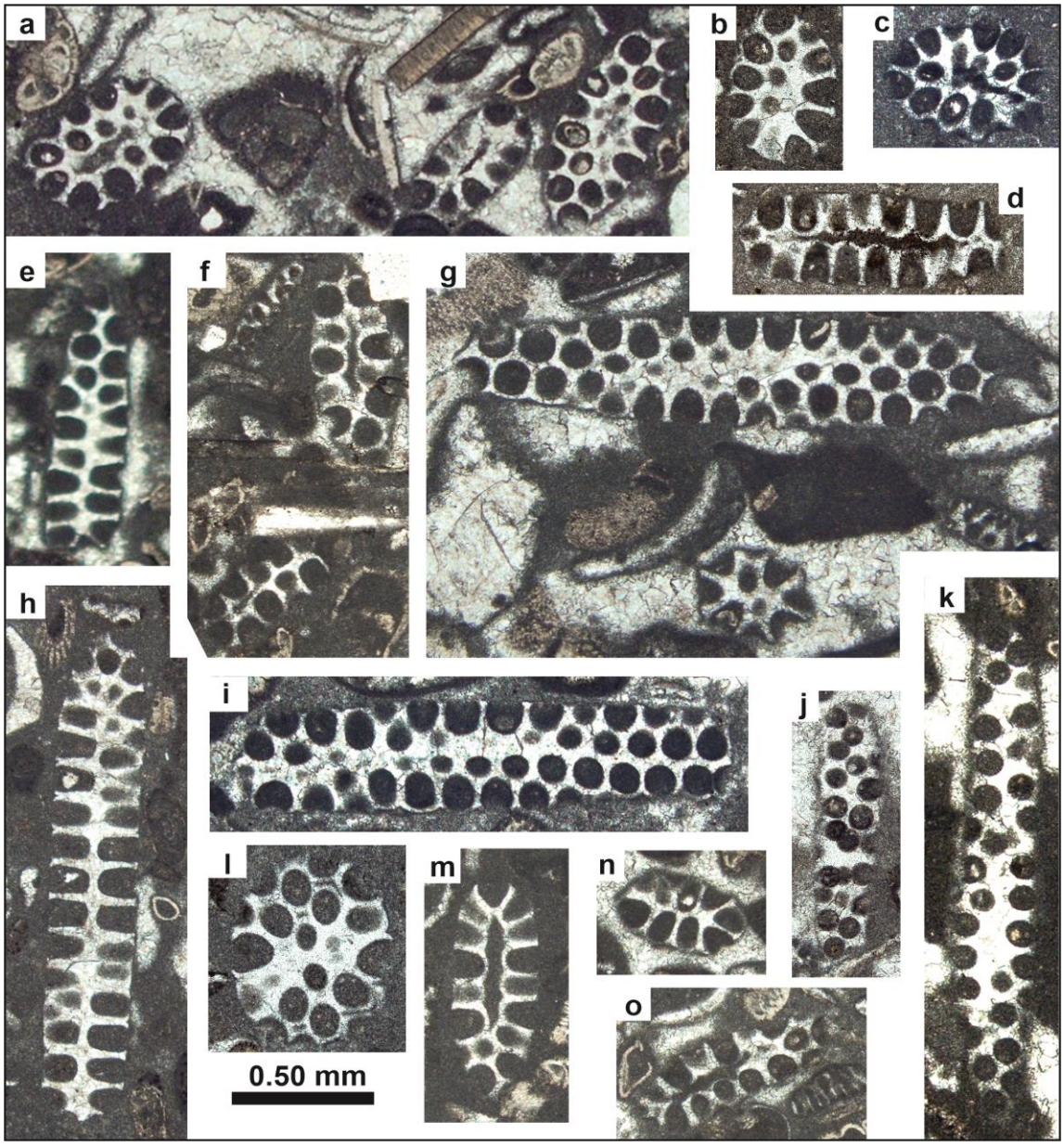

Fig. 4 *Acicularia* sp. 1 (**a-i, l-o**), diverse oriented sections. Note the regular palisade-like arrangement of elongated cysts in h and the presence of a central hollow in some specimens (e.g., **d, m**). *Acicularia* sp. 2 (**j-k**) displaying spherical cysts. Thin-sections: Nf 12-1 (**a, k**), Nf 12-2 (**b, d-e, g-j**), Nf 12-3 (**c, l**), Nf 12 (**f, m-o**).

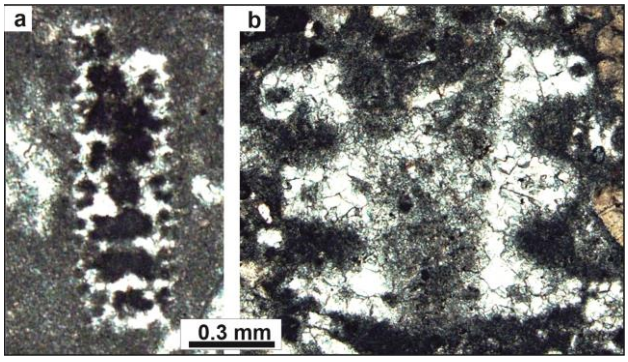

Fig. 5 *Thyrsoporella/Trinocladus*, tangential section (**c**), *Uteria* aff. *merienda* (Elliott) (**b**), oblique longitudinal section from Paleocene carbonates of the Chehel Kaman Formation, northeastern Iran. Thin-sections: Nf 13 (**a**), NF 4 (**b**).

Genus *Cymopolia* Lamouroux, 1816
Cymopolia cf. *mayaense* Johnson & Kaska, 1965
Cymopolia mayaense Johnson & Kaska, 1965
Figs. 3c-d, 8a-e, g-h

*1965 *Cymopolia mayaense* n. sp. – Johnson and Kaska, p. 83-85, pl. 18, figs. 1-4.
2013 *Cymopolia mayaense* Johnson and Kaska – Granier in Granier et al., p. 283, Fig. 3.1-4, pl. 4, figs. d-f, pl. 5, figs. a-i, pl. 6, figs. a-c, pl. 7, figs a-f, pl. 8, fig. e (with synonymy).

Remarks: *C. mayaense* represents a species showing a rather wide variability of article morphology and range of biometric data. The type-material of the Johnson collection has been recently revised by Granier in Granier et al.

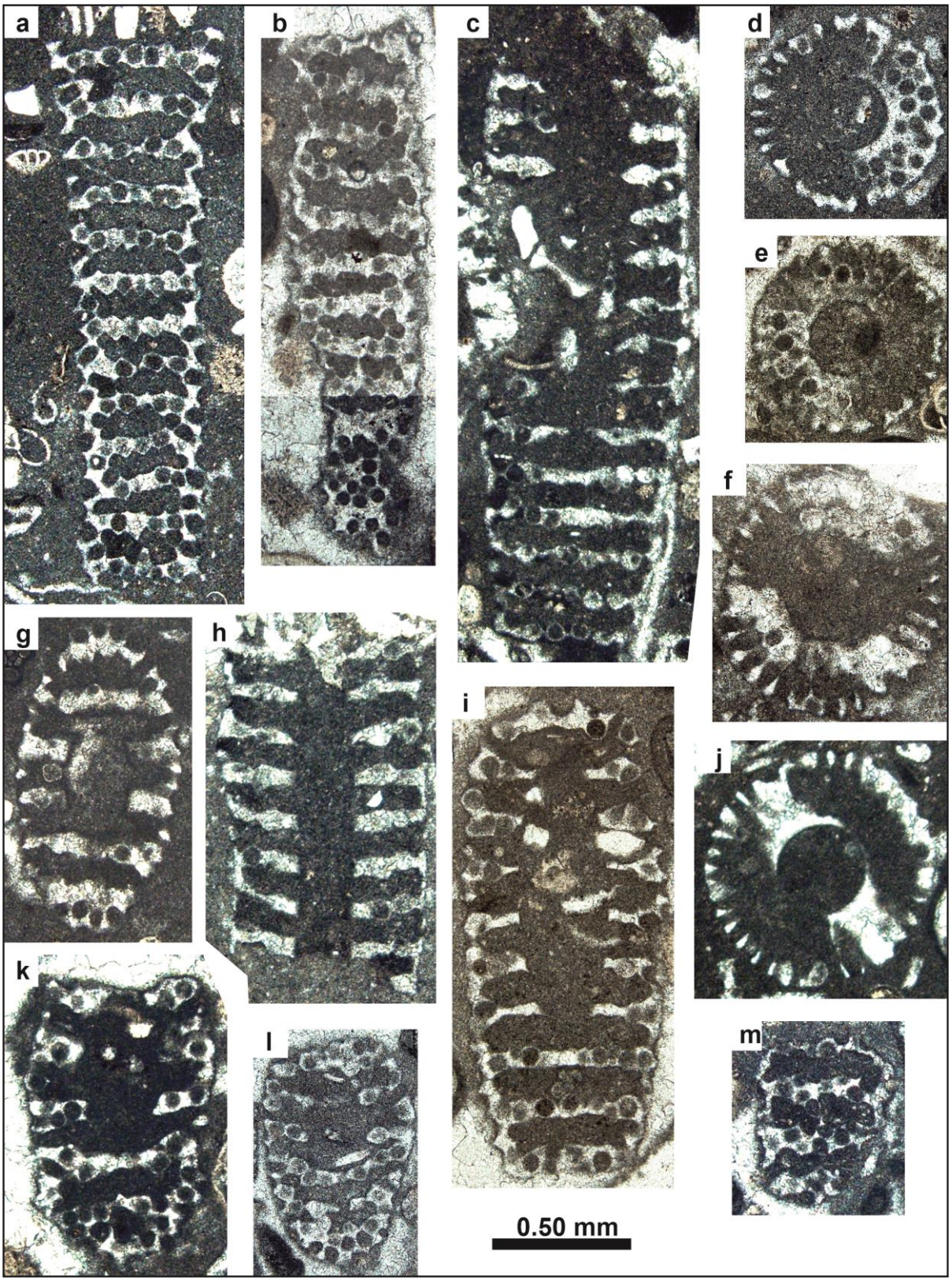

Fig. 6 *Jodotella veslensis* Morellet & Morellet from Paleocene carbonates of the Chehel Kaman Formation, northeastern Iran. **a-b, m**, tangential sections. **c**, longitudinal oblique section. **d-f, j**, transverse sections. **g, i, k-l,** oblique sections. **h,** longitudinal section. Thin-sections: Nf 12-4 (**a, l, m**), Nf 12-2 (**b**), Nf 13 (**c, h, j**), Nf 12-3 (**d**), Nf 12-1 (**e-f, i**), Nf 12 (**g, k**).

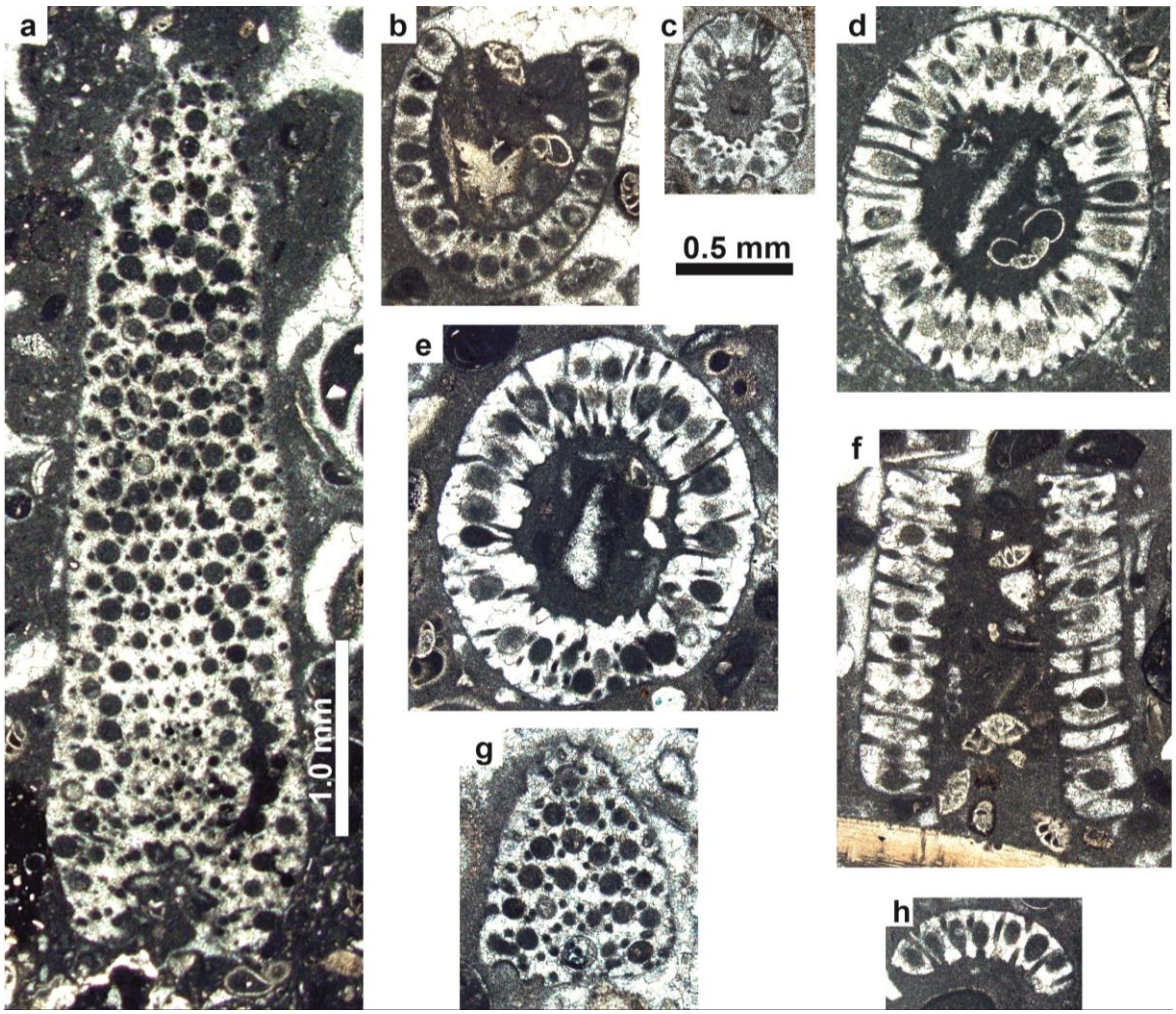

Fig. 7 *Neomeris plagnensis* Deloffre from Paleocene carbonates of the Chehel Kaman Formation, northeastern Iran. **a**, tangential section. **b-e**, oblique transverse sections. **f**, fragmentary longitudinal section. **g**, tangential section. **h**, fragment of a transverse section. Thin-sections: Nf 10 (**a**), Nf 12-1 (**b, f, h**), Nf 12-3 (**c, e, g**), Nf 13 (**d**).

(2013). Characteristics of the Iranian specimens are a smooth inner surface, comparably small ovoid sporangia surrounded by 4 to 5 secondary laterals (Fig. 8c-e, h). Most specimens are represented by cylindrical segments (length up to 4.0 mm; diameter up to 0.9 mm). The primary laterals bearing numerous fertile ampullae at the distal end are shorther than the secondaries. In some samples, *C*. cf. *mayaense* shows an assemblage with the calcareous benthic foraminifera *Rahaghia khorassanica* (Rahaghi) (Fig. 3c, 8g).

Cymopolia sp.
Fig. 8f

Remarks: This very rare morphotype is characterized by subspherical fertile ampullae different from *C*. cf. *mayaense*. Due to adequate sections, nothing is known about the segment morphology.

Class Ulvophyceae Stewart & Mattox
Order Bryopsidales Schaffner
Family Halimedaceae Link, 1832
Halimeda Lamouroux, 1812

Halimeda? sp.
Fig. 9

Remarks: In our thin sections we observed one specimen showing a lateral protuberance (swelling) indicating a possible branching (Fig. 9f). Accepting the reconstruction of *Boueina* as provided by De Castro et al. (2008, fig. 1a; see also Bucur et al., 2018, pl. 6b), the Paleocene form ascribed to *Halimeda nana* Pia in Pia et al., 1932 by Segonzac et al. (1986, pl. 1, fig. 7) showing solid (= calcified, without uncalcified internodes) branching should be ascribed to *Boueina* Toula (see additional remarks by Granier and Bucur, 2017, p. 255 and Dragastan and Herbig, 2007). Being aware of the segment (node) variability (morphology and size) within a single species, we hesitate to ascribe the Iranian forms displaying three (four?) utricle layers in the cortical zone to any of the numerous established species (e.g., Dragastan and Herbig, 2007). Instead it is treated in open nomenclature expressing also doubts on the generic identity.
Dimensions: greatest observed length of cylindrical segments = 3.5 mm, diameter of segments = 0.48-0.85 mm,

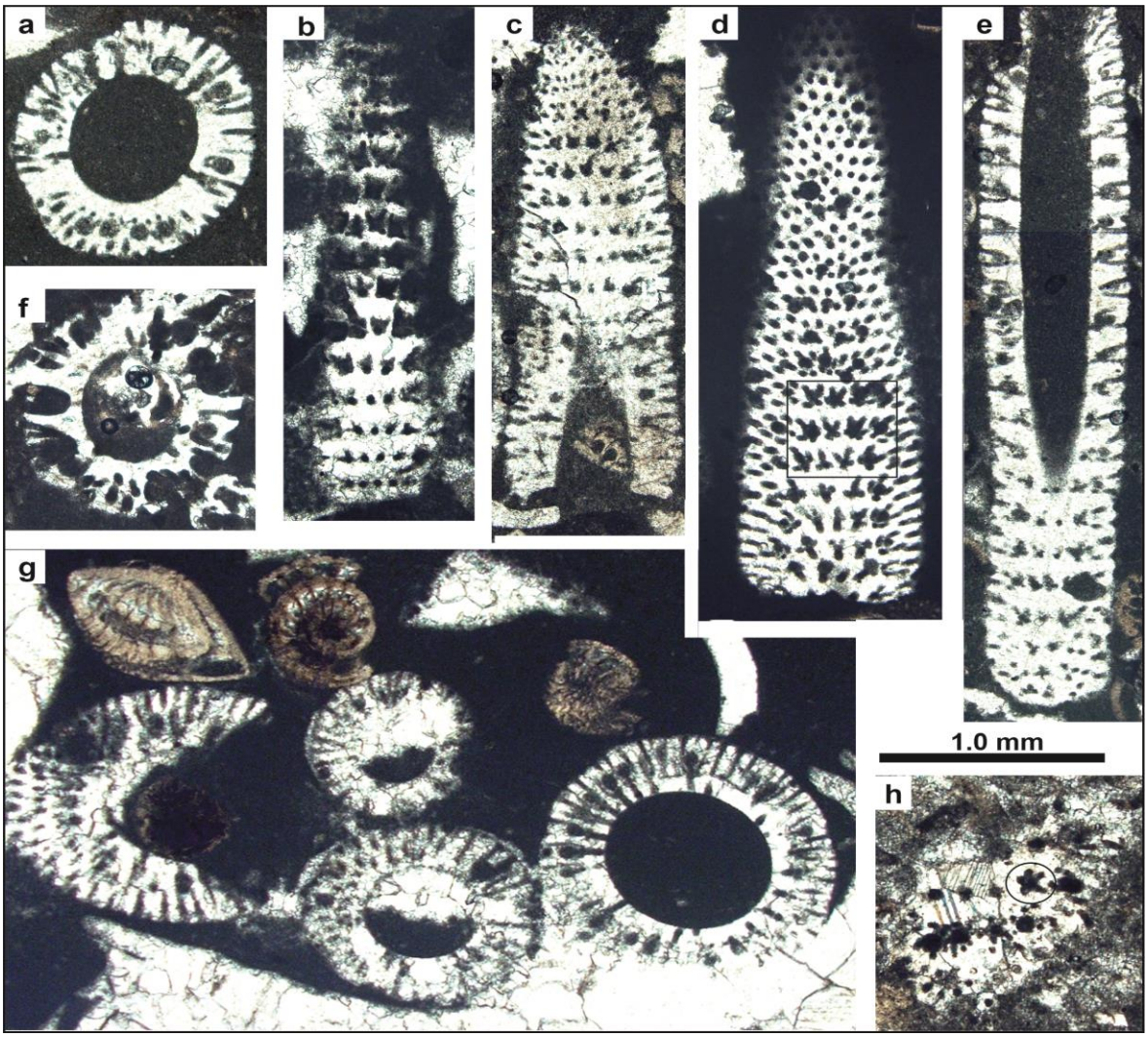

Fig. 8 *Cymopolia* cf. *mayaense* Johnson & Kaska (**a-e, g-h**) and *Cymopolia* sp. (**f**). **a**, Oblique transverse section. **b**, tangential section. **c**, tangential-oblique section. **d**, tangential section showing five secondaries (rectangle). **e**, longitudinal (above)-oblique (below) section. **f**, oblique transverse section. **g**, variously oriented sections together with *Rahaghia khorassanica* (Rahaghi) (left ablove). **h**, fragmentary tangential section showing five secondaries. Thin-sections: Nf 9 (**a**), Nf 6-2 (**b, d, g**), Nf 9 (**c**), Nf 8 (**e**), Nf 6-1 (**f**), Nf 4 (**h**).

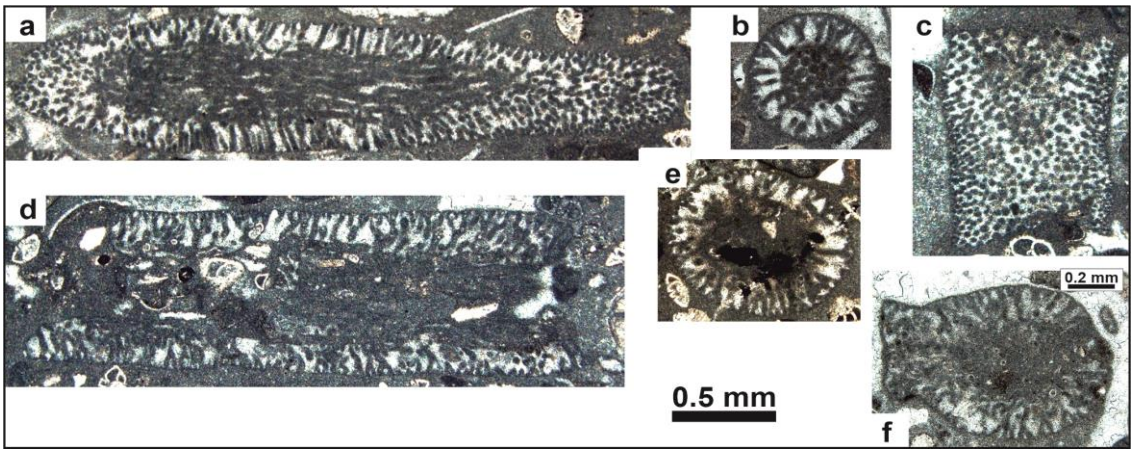

Fig. 9 *Halimeda*? sp. from Paleocene carbonates of the Chehel Kaman Formation, northeastern Iran. **a**, longitudinal oblique section. **b**, transverse section with medullar zone occupying about the half of the total diameter. **c**, tangential section showing cortical filaments. **d**, longitudinal section. **e**, oblique transverse section. **f**, specimen exhibiting a protuberance/swelling/ or branching. Thin-sections: NF 12-2 (**a**), NF 12-3 (**b-c**), Nf 12-4 (**d, f**), Nf 12-1 (**e**).

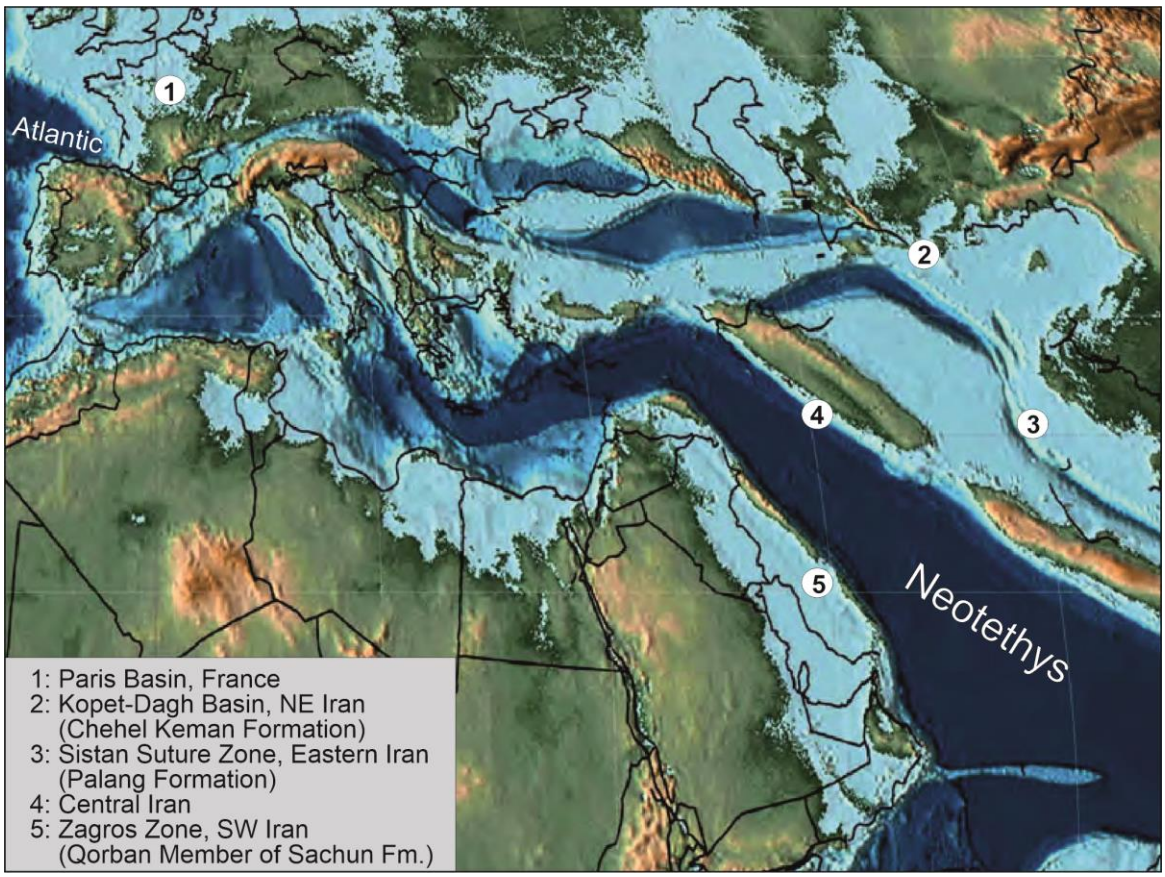

Fig. 10 Paleocene paleomap of the Western-Central Neotethysian realm showing the occurrences of dasycladalean-bearing localities in Iran, and the location of the Paris Basin, France (extracted from Scotese, 2016).

diameter of medullary filaments = 0.045-0.063 mm, diameter of cortical filaments = 0.025-0.042 mm.

PALEOCENE CALCAREOUS ALGAE FROM IRAN: STATE OF THE ART AND PROSPECTIVES

Iranian Paleocene shallow-water carbonate deposits from the Zagros Zone (Arabian Plate), the Yazd area (Central Iranian Microcontinent), the Kopet Dagh Basin (Turan Plate) and eastern Iran (Afghan Block) yield structurally preserved and highly diverse fossil assemblages comprising dasycladalean green algae and larger benthic foraminifera (LBF) (Figs. 10-11). In contrast to larger benthic foraminifera (e.g., Rahaghi, 1978, 80, 83), dasycladaleans experienced much less attention. Monographic works are completely missing, and the poor knowledge available refers to just a few papers (see Introduction). One main prospective is therefore gaining base data, assessing the micropalaeontological inventories of the different areas along with information about the stratigraphic position. The biostratigraphic framework of the algal-bearing carbonates largely depends on the presence of larger benthic foraminifera (e.g., Shallow Benthic Zones; Serra-Kiel et al., 1998). Afterwards, these assemblages can be compared between different parts of Iran, and also with other occurrences in the Central (e.g., Middle East area, Tibet, India) and Western Neotethysian realms (e.g., Spain, Italy, Slovenia, Morocco), intracratonic basins connected to the Atlantic Ocean (e.g., Paris and Aquitaine basins of France), or the Caribbean realm (e.g., Mexico, Guatemala). The Paleocene microflora of the neighbouring territory of Iraq (e.g., Sinjar Formation) is much better known than the one from Iran and can be used for comparison in general and especially for the assemblages of the Zagros Zone as part of the Arabian Plate (Elliott, 1955, 1956, 1968, 1978; Radoičić, 1990; Daod, 2009; Salih and Abdullah, 2009; Al-Dulaimi and Al-Dulaimi, 2017).

In table 1 some preliminary data are compiled showing some differences between the individual occurrences belonging to different paleotectonic units (work in progress). Among these, the assemblage from the Kopet Dagh Basin is the most poorly diversified, but this might also be due to sampling bias. Differences might also be due to facies preferences of some taxa, e.g., platform margin/reefal deposits: *S. multipora*, *T. apenninica*, *Zittelina*) (e.g., Barattolo, 1982; Radoičić, 1999; Vitale, 2008). Another future prospective will be the compilation of distributional pattern of selected taxa plotted on paleomaps and the application of statistical analyses (e.g., Jaccard Similarity Index; Rasser and Fenninger, 2002).

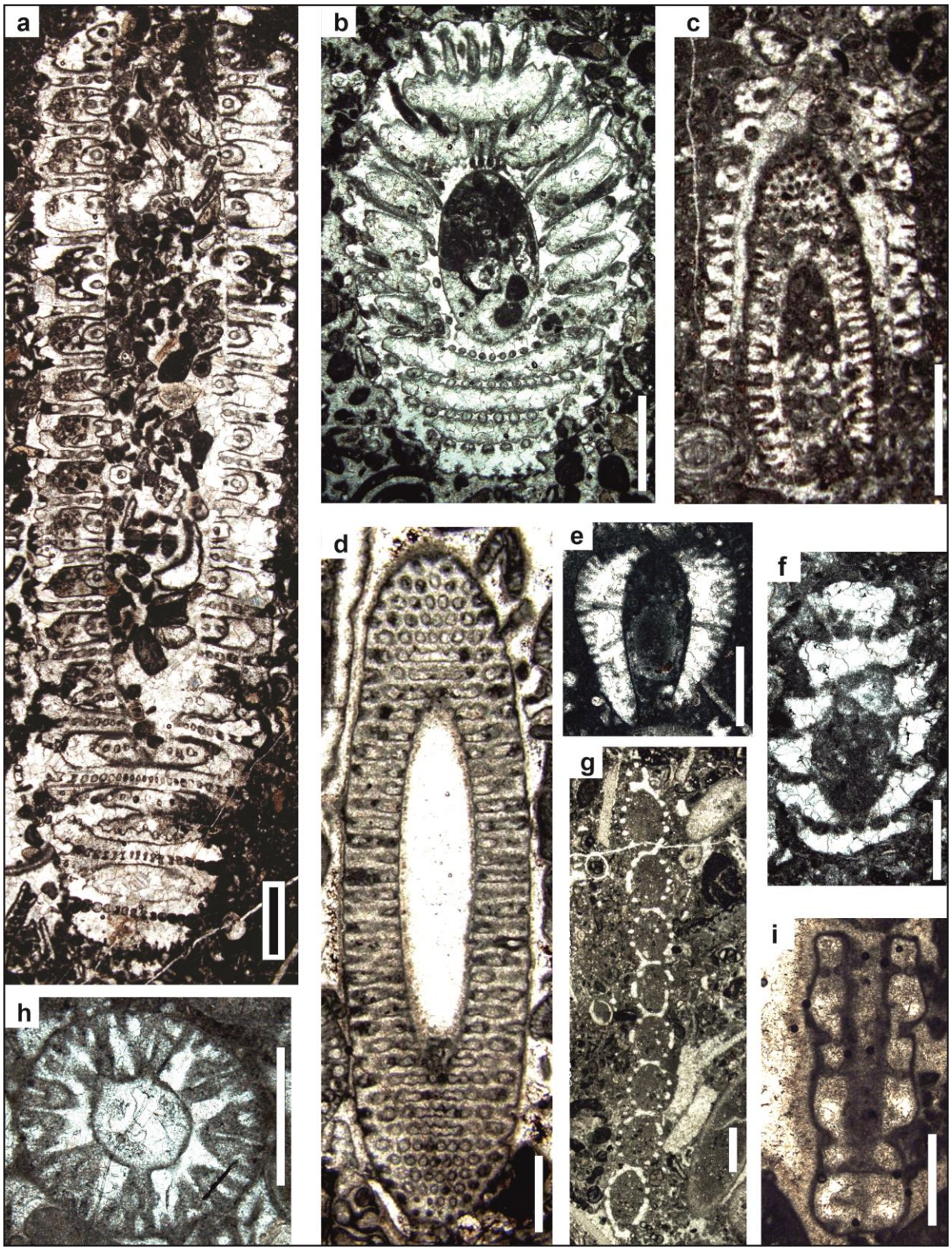

Fig. 11 Selection of Paleocene Dasycladales from different parts of Iran: Eastern Iran-Sistan Suture Zone (**a, c-f, i**), Central Iran (**g**), and Southwestern Iran-Zagros Zone (**b, h**). **a**, *Uteria merienda* (Elliott), longitudinal section, thin-section BN 59. **b**, *Rostroporella oviformis* Segonzac, oblique section, thin-section Qs 59. **c**, *Dissocladella savitriae* Pia (above), longitudinal section, and *Cymopolia* aff. *morelletorum* Beckman (below), oblique section, thin-section 2pb 76. **d**, *Triploporella apenninica* Baretti, longitudinal-oblique section, thin-section 2pb 39. **e**, *Cymopolia* sp., longitudinal section of an article, thin-section 2pb 3. **f**, *Clypeina socaensis* Deloffre & Radoičić, oblique section, thin-section 2pb 27. **g**, *Orioporella sinensis* (Wang), thin-section Ah 161. **h**, *Thyrsoporella* sp., thin-section Qs 7. **i**, *Jodotella sloveniaensis* Deloffre & Radoičić, oblique longitudinal section, thin-section 2pb 40. Scale bars 1 mm (**a-d, g**) and 0.5 mm (**e-f, h-i**).

CONCLUSIVE REMARKS

The taxonomic inventory of Paleocene calcareous green algae from Iran is poorly known. This so far neglected group however appears in well diversified and partly excellently preserved assemblages often together with larger benthic foraminifera allowing stratigraphic dating. Moreover, the occurrences belong to different paleotectonic units/settings (e.g., Southern versus Northern Neotethysian margin) and therefore allow palaeobiogeographic analyses. So far only some preliminary data can be presented together with the here described assemblage from the shallow-water carbonates of the Chehel Kaman Formation of the Kopet Dagh Basin in northeastern Iran. Some of the taxa are recorded for the first time from Iran. Interestingly, these have their type-locality in the Thanetian of the Paris Basin of France. In addition, they are seemingly absent in time-eqivalent assemblages of the Zagros Zone, southwestern Iran. Highly diverse assemblages of Paleocene Dasycladales that have been observed in different parts (= paleotectonic units) of Iran will be the topic of ongoing studies.

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REFERENCES

Al-Dulaimi, E.K. & Al-Dulaimi, S.I., 2017. A study of biostratigraphy of Sinjar Formation in selected sections from northern Iraq. Iraqi J. Sci., 58 (2B): 891-916.

Afshar-Harb, A., 1979. The stratigraphy, tectonics and petroleum geology of the Kopet Dagh Region, Northern Iran. Phd Thesis University of London, 1-316. Available online from https://spiral.imperial.ac.uk

Afshar-Harb, A., 1994. Geology of Kopet Dagh. Geological Survey of Iran publication, 275 p. (in Persian).

Berberian, M., King, G.C.P., 1981. Towards a palaeogeography and tectonic evolution of Iran. Canadian Journal of Earth Sciences, 18: 210-265.

Barattolo, F., 1982. Osservazioni su *Triploporella apenninica* Baretti 1922 (Alghe verdi, Dasicladali del Paleocene dell'Abruzzo Aquilano. Geologica Romana, 21: 29-59.

Barattolo, F., 1998. Dasycladacean green algae and microproblematica of the uppermost Cretaceous-Paleocene in the Karst area (NE Italy and Slovenia). In: Hottinger, L, Drobne, K., Eds., Paleogene shallow benthos of the Tethys. Dela-Opera SAZU 4 razr., 34: 65-127.

Barattolo, F., 2002. Late Cretaceous-Paleogene Dasycladaleans and the K/T boundary problem. In: Bucur, I.I., Filipescu, S. (eds.), Research advances in calcareous algae and microbial carbonates, Proceedings of the 4th IFAA Regional Meeting, Cluj Napoca, Romania, 29 August-5 September 2001, pp. 17-40.

Barani, F., Rashidi, K., Raisolssadat, S.N., Khazaee, M., 2017. Green Algae (Dasycladales) from Paleocene deposits in Western Birnjand (Grong section). Sedimentary Facies, 10 (1): 1-22 (in Persian with English abstract).

Brunet, M.F., Cloething, S., 2003. Integrated Peri-Tethyan Basin studies (Peri-Tethys Programme). Sedimentary Geology, 156: 1-10.

Bucur, I.I., Sudar, M.N., Săsăran, E., Jovanović, D., Pleş, G., Polavder, S., 2018. Rediscovery of the type locality of the Udoteacean alga *Boueina hochstetteri* Toula, 1884, in the Lower Cretaceous of Serbia. Carnets de Géologie, 18 (4): 123-137.

Carrasco, J.F., Taherpour-Khalil-Abad, M., Taheri, J., Ahmadi-Kooshki, M., Majidifard, M.R., 2019. First record of *Gitolampas subrotundus* (Cotteau, 1856) (Echinoidea) from the Late Paleocene of Iran. Geološki Anali Balkanskoga Poluostrva, 80 (2): 1-11.

Daod, H., 2009. Carbonate microfacies analysis of Sinjar Formation from Qara Dagh Mountains, south-west of Sulaimani City, Kurdistan region, Iraq. World Acad. Sci., Eng. Techn., 58: 752-762.

De Castro, P., Cimmino, M.G., Barattolo, F., 2008. On some infrageneric rank-changes within the Mesozoic *Boueina* (Chlorophyta, Caulerpales). Atti Accademia Pontaniana, N.S., LVII: 175-182.

Deloffre, R., 1970. Niveau à Algues dans le Sparnacien de la région de Plagne (Petites-Pyrénées-Haute – Garonne) et observations sur le genre *Neomeris* Lamouroux, 1816. Bulletin du Centre de Recherches Pau-SNPA, 4 (2): 353-379.

Deloffre, R., Fourcade, E., 1994. Algues chlorophycées calcifiées du Paléocène du Guatemala. Geobios, 27 (5): 525-541.

Deloffre, R., Fleury, J.-J., Fourcade, E., Michaud, F., 1989. Dasycladales (Algues Vertes) du Paléocène-Éocène inférieur du Mexique. Revue de Micropaléontologie, 32 (1): 3-15.

Deloffre, R., Poignant, A.F., Teherani, K., 1977. Algues calcaires de l' Albo-Aptien au Paléocène de l' Iran central. Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine, 1: 29-57.

Deloffre, R., Génot, P., 1982. Les Algues Dasycladales du Cénozoïque. Bulletin des Centres de Recherches Exploration-Production Elf-Aqutitaine, Mém. 4:1-247.

Dieni, I., Massari, F., Radoičić, R., 1985. Palaeocene Dasycladalean algae from Orosei (Eastern Sardinia). Memorie di Scienze Geologiche, Padova, 38: 1-77.

Dragastan, O., Herbig, H.G., 2007. *Halimeda* (green siphonous algae) from the Paleogene south of the central High Atlas (Morocco)-Taxonomy, phylogeny and paleoenvironment. Micropaleontology, 53 (1-2), 1-72.

Dieni, I., Massari, F., Radoičić, R., 1985. Palaeocene Dasycladalean algae from Orosei vicinity (Sardinia). Memorie di Scienze Geologiche, 38: 1-77.

Elliott, G.F., 1955. Fossil calcareous algae from the Middle East. Micropaleontology, 1 (2): 125-131.

Elliott, G.F., 1956. Further records of fossil calcareous algae from the Middle East. Micropaleont., 2: 327-334.

Elliott, G.F., 1968. Permian to Paleocene calcareous algae (Dasycladaceae) of the Middle-East. Bulletin of the British Museum, Natural History, Geology, supplement, 4: 1-111.

Elliott, G.F., 1978. A new dasycladacean alga from the Palaeocene of Kurdistan. Palaeontol., 21: 687-691.

Erfani, S., Javanbakht, M., Poursoltani, M.R., 2016. The study of the diagenetic processes in the Chehel Kaman Formation in the eastern of Kopet-Dagh region, North-East of Iran. Iranian Journal of Earth Sciences, 8: 125-134.

Génot, P., 1980. Les Dasycladacées du Paléocène supérieur et de l'Eocène du bassin de Paris. Mémoires de la Société géologique de France (Nouvelle Série) LIX (138): 1-40.

Génot, P., 2009. Cenozoic Dasycladales. A photo-atlas of Lutetian species from French Cenozoic Basins. Carnets de Géologie – Notebooks on Geology, Special Paper 2009/01 (CG2009_SP01): 180 p.

Génot, P., Granier, B, 2011. Cenozoic Dasycladales. A photo-atlas of Thanetian, Ypresian and Bartonian species from the Paris Basin. Carnets de Géologie, Book 2011/01: 44 p.

Granier, B., Braik, F., 2002. *Thyrsoporella pseudoperplexa* n. sp., une Dasycladacée (algue verte calcaire) du Jurassique Supérieur Téthysien. In: Bucur, I.I., Filipescu, I. (eds): Research advances in calcareous algae and microbial carbonates, Cluj University Press: 127-133.

Granier, B., Bucur, I.I., 2017. Révision de la collection Juliette Pfender. 3e partie. À propos des quelques algues vertes fossiles. Carnets Géologie, 17: 251-269.

Granier, B., Radoičić, R., Drobne, K., 2013. Revision of the Jesse Harlan Johnson Collection. Part 1. Some fossil Dasycladales from Guatemala. Carnets de Géologie [Notebooks on Geology]: Article 2013/07 (CG2013_A07).

Golonka, J., 2004. Plate tectonic evolution of the southern margin of Eurasia in the Mesozoic and Cenozoic. Tectonophysics, 381: 235-273.

Hottinger, L., 2014. Paleogene larger rotaliid foraminifera from the western and central Neotethys. Springer, Heidelberg: 196 pp.

James, G.A., Wynd, J.G., 1965. Stratigraphic Nomenclature of Iranian Oil Consortium Agreement Area. AAPG Bulletin, 49 (12): 2218-2232.

Johnson, J.H., Kaska, H.V., 1965. Fossil Algae from Guatemala. Professional Contributions of the Colorado School of Mines, 1: 1-152.

Kalantari, A., 1976. Microbiostratigraphy of the Sarvestan area, southwestern Iran. National Iranian Oil Company, 5: 130 p.

Khosrow-Tehrani, Kh., 1987. Late Maestrichtien and Paleocene deposits in south – southeast of Yazd area – central Iran. Journal of Science (University of Tehran), 16: 41-48.

Kuss, J., Herbig, H.-G., 1993. Biogeography, facies and taxonomy of Early Tertiary green algae from Egypt and Morocco. Bolletino della Società Paleontologica Italiana, Spec. vol. 1: 249-280.

Morellet, L., Morellet, J., 1913. Les Dasycladacées du Tertiaire parisien. Mémoires de la Société géologique de France, 47: 1-43.

Morellet, L., Morellet, J., 1922. Nouvelle contribution à l'étude des Dasycladacées tertiaires. Mémoires de la Société géologique de France. Paléontologie, 25 (2), 1-33.

Parente, M., 1997, Dasycladales from the Upper Maastrichtian of Salento Peninsula (Puglia, southern Italy). Facies, 36: 91-122.

Pia, J., Pfender, J., Termier, H., 1932. Etudes géologiques sur les calcaires de Bekrit et Timhadit (Moyen-Atlas). Notes et Mémoires Service des Mines et de la Carte Géologique du Maroc, 49: 57-71.

Radoičić, R., 1990. Paleogene dasycladalean algae from the subsurface of the western Iraqi Desert. Bulletin de l'Académie Serbe des Sciences et des Arts (Sciences mathématiques et naturelles, Sciences naturelles), t. CII, 32: 91-103.

Radoičić, R., 1999. Two new Zittelinae (Dasycladales) from Paleocene of Slovenia. Bulletin de l'Académie Serbe des Sciences et des Arts (Sciences mathématiques et naturelles, Sciences naturelles), 39: 55-60.

Rahaghi, A., 1976. Contribution à l'étude de quelques grands foraminifères de l'Iran. Part 2 Étude de quelques grands foraminifères du Maestrichtien et du Paléocéne d'Iran. National Iranian Oil Company Geological Laboratories, 6: 32-44.

Rahaghi, A., 1978. Paleogene biostratigraphy of some parts of Iran. Publications of the National Iranian Oil Company Geological Laboratories, 17: 1-161.

Rahaghi, A., 1980. Tertiary faunal assemblage of Qum-Kashan, Sabzewar and Jahrum areas. National Iranian Oil Company, Geological Laboratories, 8: 64 p.

Rahaghi, A., 1983. Stratigraphy and faunal assemblage of Paleocene-Lower Eocene in Iran. National Iranian Oil Company, Geological Laboratories, 10: 73 p.

Rasser, M., Fenninger, A., 2002. Jurassic/Cretaceous dasycladalean algal stratigraphy in the Northern Calcareous Alps: A critical review and a palaeobiogeographic approach using similarity indices. In: Bucur, I.I., Filipescu, S. (eds.): Research advances in calcareous algae and microbial carbonates. Proc 4th Int IFAA Reg. Meet. Cluj-Napoca, 167-190, Cluj University Press.

Rivandi, B., Moosavizadeh, S.M.A., 2015. Larger Benthic Foraminifera from the Paleocene sediments in the

Chehel-Kaman Formation, North-East Iran. Open Journal of Geology, 5: 224-229.

Rivandi, B., Vahidinia, M., Nadjafi, M., Mahboubi, A., Sadeghi, A., 2013. Biostratigraphy and sequence stratigraphy of Paleogene deposits in Central Kopet-Dagh Basin (NE of Iran). Journal of Geological Research, volume 2013, article ID 892198, 12 p.

Salih, H.D., Abdullah, Y.K., 2009. Microfossils and carbonate microfacies of Sinjar Formation, west of Sulaimaniyah City, Kurdistan region, NE Iraq. Iraqi Bulletin of Geology and Mining, 5: 13-28.

Schlagintweit, F., Rashidi, K., Yarahmadzahi, H., Habibimood, S., Amirshahkarmi, M., Ahmadi, A., Khokan, H., 2019a. *Dissocladella*? *chahtorshiana* Rashidi & Schlagintweit n. sp., a new Dasycladale (Green algae) from the Paleocene of Iran. Acta Palaeontologica Romaniae, 15 (2): 3-13.

Schlagintweit, F., Rashidi, K., Yarahmadzahi, H., Habibimood, S., Amirshahkarmi, M., Ahmadi, H., Mirjalili, M., 2019b. New data on some type-species of Maastrichtian-Paleocene Dasycladales (Green algae) from Iran. Part II. *Hamulusella* Elliott in Deloffre & Granier, 1992. Micropaleontology, 65 (5): 407-423.

Salahi, A., El Hedeny, M., Vinn O., Rashwan, M., 2018. Sclerobionts on organic substrates from the Late Paleocene Chehel-Kaman Formation, Kopet-Dagh Basin, NE Iran. Annales Societatis Geologorum Poloniae, 88: 291-301.

Scotese, C.R., 2016. PALEOMAP PaleoAtlas for GPlates and the PaleoData Plotter Program, PALEOMAP Project. http://www.scotese.com

Segonzac, G., Peybernès, B., Rahhali, I., 1986. Les Algues du « Calcaire rosé de Timahdite » (Eocène inférieur) dans le Moyen-Atlas (Maroc): description d`*Halimeda nana* Pia, 1932, dans sa localité-type et son paléoenvironment. Journal of African Earth Sciences, 5 (5): 501-507.

Serra-Kiel, J., Hottinger, L., Caus, E., Drobne, K., Ferràndez, C., Jauhri, A.K., Less, G., Pavlovec, R., Pignatti, J., Samsó, J.M., Schaub, H., Sirel, E., Strougo, A., Tambareau, Y., Tosquella, J., Zakrevskaya, E., 1998. Larger foraminiferal biostratigraphy of the Tethyan Paleocene and Eocene. Bulletin de la Société Géologique de France, 169: 281-299.

Stöcklin, J., 1968. Structural history and tectonics of Iran: A review. AAPG Bulletin, 52: 1229-1258.

Stöcklin, J., 1974. Possible Ancient Continental Margin in Iran. In: Burke, C.A., Drake, C.L., Eds., The Geology of Continental Margins, Springer, New York, 873-887.

Takin, M., 1972. Iranian geology and continental drift in the Middle East. Nature, 23: 147-150.

Tirrul, R., Bell I.R., Griffis, R.J., Camp, V.E., 1983. The Sistan Suture Zone of eastern Iran. Geological Society of America Bulletin, 94: 134-150.

Vicedo, V., Robles-Salcedo, R., Serra-Kiel, J., Hidalgo, C., Razin, P., Grélaud, C., 2019. Biostratigraphy and evolution of larger rotaliid foraminifera in the Cretaceous–Palaeogene transition of the southern Oman Mountains. Papers in Paleontology, 2019: 1-26.

Vitale, V., 2008. Analisi paleoecologica e sistematica delle Alghe Verdi Dasicladali del Paleocene die Pirenei occidentali. Phd Thesis University of Naples, 1-322. Available online www.fedoa.unina.it/3550/