

EARLY CRETACEOUS CALCAREOUS BENTHIC MICROFOSSILS FROM THE EASTERN ALBORZ AND WESTERN KOPET DAGH (NORTHERN IRAN) AND THEIR STRATIGRAPHIC SIGNIFICANCE

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Abstract We have studied the micropaleontological association in two carbonate successions within the Lar and Mozduran Formations cropping out in the eastern Alborz and western Kopet Dagh area of northern Iran. Our study resulted in the identification of several species of foraminifera and calcareous algae that indicate a Berriasian-?Early Valanginian age for most of the deposits investigated. These results contradict most of the previous age assignments for these formations, i.e., to the Oxfordian–Kimmeridgian, or Kimmeridgian–Tithonian intervals.

Keywords: microfossils, calcareous algae, foraminifera, Alborz, Kopet Dagh, Iran

INTRODUCTION

The Middle and Upper Jurassic sedimentary successions in northern and northeastern Iran comprise each two formations. In the Alborz Mountains (northern Iran) they are named the Dalichai Formation and Lar Formation. The time equivalent series in Kopet Dagh (northeastern Iran) are named the Chaman Bid Formation and Mozduran Formation.

According to Assereto (1966) the age of the Lar Formation in the Alborz Mountains is Oxfordian to Kimmeridgian. At the type locality (Lar Valley in the central Alborz) the Lar Formation reaches up to 350 m thickness and consists in its lower part mainly of thin-bedded white to brown limestones, but in its upper part massive limestones are dominating (Assereto, 1966; Fantini Sentini & Assereto, 1970).

The Mozduran Formation in Kopet Dagh reaches at the type locality (in the Mozduran pass in eastern Kopet Dagh) a thickness of almost 500 m (Afshar-Harb, 1979) and consists of light-coloured thick-bedded limestones and massive, porous dolomitic limestones and dolomites. Kavooosi et al. (2009) and Kavooosi (2010) dated the Mozduran Formation from the Kopet Dagh area as Oxfordian–Kimmeridgian, and Oxfordian–Tithonian respectively based on a micropaleontological assemblage with *Saccocoma*, *Tubiphytes*, *Cayeuxia*, *Lithocodium* and *Nautiloculina oolitica*. The same age is considered by Aghaei et al. (2012). Majidifard (2003) sustains for the first time the diachronous character of the Upper Jurassic deposits of the eastern Alborz-western Kopet Dagh area, showing that their thickness increases from west to east. The same author (Majidifard, 2008) considers the two formations (Lar and Mozduran) as having lithostratigraphic similarities which would justify their lithostratigraphic synonymy under the name Lar Formation, and also supposes the presence of the Neocomian within the upper part of the succession in the Kopet Dagh area.

The calcareous Upper Jurassic deposits are overlain by the terrigenous Shurijeh Formation, which in turn is overlain by the calcareous Tirgan Formation.

GEOLOGICAL SETTING

A section of the Lar Formation in the eastern Alborz, near the town of Jajarm (Jorbat section) and another one from the Mozduran Formation in the western Kopet Dagh (Taktehbashgheh section) were measured and sampled. The samples of the Jorbat section are marked with “MJ”, those of the Taktehbashgheh with “MS”.

Jorbat section

This section is located 51 km NE of the town of Jajarm (Fig. 1). The locality can be reached by taking the unpaved road of Jajarm-Sankhast. The section lies 9 km after the small village of Jorbat, at the right side of the road (Greenwich co-ordinates: N 37°09'00'', E 56°43'59''). At the Jorbat section, the Lar Formation conformably overlies the Middle Jurassic Dalichai Formation and underlies gradually the Shurijeh Formation (?Lower Cretaceous). The Lar Formation is represented by thick-bedded, cliff-forming, grey dolomitic limestones and limestones that, when they are weathered, are cream-coloured to yellowish. The formation reaches a thickness of 414 m, ranging from the Middle to Upper Jurassic (reaching probably the Neocomian in the upper part). We collected 70 samples from the Lar Formation, 16 of which were analysed for their micropaleontological content.

Taktehbashgheh section

This section is located 1 km NE of Taktehbashgheh farm (Haji Ali Kalat), 80 km SW of the town of Bojnourd and 91 km NW of the town of Esferayen (Fig. 1). The locality can be reached by taking the road from Bojnourd to Esferayen. After driving 27 km from Esferayen, and turning left onto an unpaved road, after 53 km, the Taktehbashgheh farm is reached (co-ordinates: N 37°19'42'', E 56°04'13'').

The Mozduran Formation at this locality is represented by thick-bedded, cliff-forming, grey limestones (mudstone to grainstone) and buff dolomitic limestones

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◀ **Fig. 2** Succession of the carbonate deposits of the Mozduran Formation in the Takhtebashgeh locality. m-Mudstone; w-Wackestone; p-Packstone; f-Floatstone; g-Grainstone; B-Platform margin; BD-Distal basin; BP-Proximal basin; D-Delta; L-Shelf lagoon; S-Platform slope; T-Tidal flat; 1-Shale; 2-Siltstone-sandstone; 3-Marly-limestone and marl; 4-Dolomite; 5-Limestone; 6-*Crescentiella*; 7-Echinoderms; 8-Ostracodes; 9-Brachiopods; 10-Foraminifera; 11-Gastropods; 12-Sponges; 13-Corals; 14-Bivalves; 15-Bryozoans; 16-Algae; 17-Peloids; 18-Ooids; 19-Oncoids; 20-Intraclasts; 21-Bioturbation; 22-Microbial crusts; 23-Birds-eyes structures.

Upwards they pass into internal platform subtidal deposits followed by platform margin bioclastic oolites, denoting a general transgressive trend. In this section, the upper part of the investigated succession is rich in calcareous algae and benthic foraminifera indicating a Berriasian age.

Micropaleontological content

The lithology, general facies characteristics and environment interpretation of the Mozduran Formation at the Takhtebashgeh locality is illustrated in Fig. 2. The analysis of thin sections delivered a relatively rich micropaleontological assemblage of foraminifera and calcareous algae (Table 1; Figs. 3-6). Figure 7 illustrates the distribution of this micropaleontological assemblage within the Berriasian succession of the Mozduran Formation *pro parte* at Takhtebashgeh.

Within the Lar Formation the micropaleontological assemblage is quite poor. Among the foraminifera, we identified *Everticyclammina* sp. (Fig. 4m, v), *Charentia* sp., *Andersenolina* sp., and rare undetermined foraminifera with alveolar wall structure (Fig. 4n, w). The calcareous algae are represented by *Salpingoporella pygmaea* (Gümbel) (Fig. 6j, k), *Terquemella* sp. (Fig. 5p), *Nipponophycus* sp., and very frequent rivulariacean-type cyanobacteria (Fig. 8m). The microencruster *Crescentiella morronensis* (Crescenti) is also present. Some supplementary samples were collected from the calcareous Tirgan Formation. They contain a relatively rich assemblage of foraminifera [*Comaliamma* sp. (Fig. 4r), *Debarina* sp. (Fig. 4l), *Palorbitolina lenticularis* (Blumenbach) (Fig. 4q, s, t?), *Praeorbitolina cormyi* Schroeder (Fig. 4o, p) and ?*Praeorbitolina* sp. (Fig. 4u)], and calcareous algae [*Cylindroporella? elliptica* Bakalova (Fig. 6i), *Cylindroporella? sp. cf. Cylindroporella lyrata* Masse and Luperto Sinni (Fig. 8g), ?*Holosporella* sp. (Fig. 6l), *Kopetdagaria sphaerica* Maslov (Fig. 8b-d), *Montiella? elitzae* (Bakalova) (Figs. 6m; 8a, e, f), *Neomeris cretacea* Steinmann (Fig. 8h), *Salpingoporella* sp. (Fig. 6h), *Similiclypeina conradi* Bucur (Fig. 8i), *Boueina* sp. (Fig. 8j, k), *Pycnoporidium* sp. (Fig. 8n), and the problematicum *Carpathoporella occidentalis* Dragastan (Fig. 6n)].

DISCUSSION

Stratigraphic significance of the microfossil assemblages.

The benthic foraminifera and calcareous algae associations identified in the Mozduran Formation

consist of species characteristic for the Tithonian–Valanginian interval. Based on their typical stratigraphic occurrences, two types of species could be discriminated:

Species known from the Upper Jurassic that are also common in Berriasian–Valanginian deposits:

- *Anchispirocyclina lusitanica* (Egger, 1902) was described as *Dicyclina lusitanica* (Egger, 1902). Subsequently, this species was transferred to the genus *Anchispirocyclina* Jordan and Applin, 1952 (Jordan and Applin, 1952; Maync, 1959; Loeblich & Tappan, 1964). It is very common in Tithonian–Berriasian deposits (Ramalho, 1969; Peybernès, 1976; Darga & Schlagintweit, 1991; Dya, 1992; Bassoulet, 1997; Gawlick et al., 2005; Schlagintweit et al., 2005). Jaffrezo (1980) and Sotak (1989) documented this species in the Berriasian, and respectively Berriasian–Valanginian deposits. Frequently, *Anchispirocyclina lusitanica* was identified at the Tithonian–Berriasian boundary.

- *Andersenolina alpina* (Leupold, in Leupold & Bigler, 1935). In most of the references, this species is mentioned as *Trocholina alpina*. The species was transferred to the new genus *Andersenolina* by Neagu (1994). *A. alpina* was identified in deposits with ages ranging from Oxfordian(?)–Kimmeridgian to Valanginian (Azema et al., 1977; Azema et al., 1979; Chiocchini et al., 1988; Luperto Sinni & Masse, 1994; Arnaud-Vanneau et al., 1988; Bucur, 1988; Fourcade & Granier, 1989; Altiner, 1991; Bucur et al., 1996; Mancinelli & Coccia, 1999; Ivanova, 2000; Schlagintweit et al., 2005; Bucur et al., 2011). Together with *Andersenolina elongata* (Leupold), this species was very often cited from Berriasian–Valanginian deposits (Masse, 1976; Peybernes, 1976; Jaffrezo, 1980; Darsac, 1983; Boisseau, 1987; Granier, 1987; Bucur, 1988; Chiocchini et al., 1994; Neagu, 1994; Bucur et al., 1995; Clark and Boudagher-Fadel, 2001).

- *Andersenolina molesta* (Gorbachik, 1971), originally described from basal Cretaceous deposits in the Crimea, and was afterwards identified also in Upper Tithonian–Berriasian deposits (Ebli and Schlagintweit, 1998), Valanginian (Bucur et al., 1995) or Hauterivian deposits (Claps et al., 1996).

- *Mohlerina basiliensis* (Mohler, 1938). Mohler (1938) described this foraminifer from Jurassic deposits in northern Switzerland (as *Conicospirillina basiliensis*). Afterwards the species has been often cited in the open generic nomenclature (followed by “?”) in order to emphasize the inconsistency of its affiliation to the genus *Conicospirillina*. Bucur et al. (1996) transferred it to the new genus *Mohlerina*, their paper including also an almost complete list of synonyms. The species has been cited from deposits ranging between the Callovian and the Hauterivian. *Mohlerina basiliensis* has also been commonly recorded in Berriasian–Valanginian limestones (Darsac, 1983; Salvini-Bonnard et al., 1984; Boisseau, 1987; Granier, 1987; Bucur, 1988; Chiocchini et al., 1988; Altiner, 1991; Chiocchini et al., 1994; Bucur & Săsăran, 2011).

- *Pseudocyclammina lituus* (Yokoyama, 1890) was originally described from Upper Jurassic deposits (Yokoyama, 1890). It was frequently cited either from

Table 1. Micropaleontological assemblage of Mozduran Formation at Takhtebashgeh

Taxa	Illustration	General stratigraphic range
Foraminifera		
<i>Ammobaculites</i> sp.	Fig. 4j	-
? <i>Ammobaculites</i> sp.	Fig. 4k	-
<i>Anchispirocyclina lusitanica</i> (Egger)	Fig. 3c-i	Tithonian-Berriasian
<i>Andersenolina</i> cf. <i>alpina</i> (Leupold)	Fig. 3 l, q	-
<i>Andersenolina cherchiai</i> (Arnaud-Vanneau, Boisseau & Darsac)	Fig. 3m-o	Berriasian-Lower Valanginian
<i>Andersenolina</i> cf. <i>cherchiai</i> (Arnaud-Vanneau, Boisseau & Darsac)	Fig. 3r	-
<i>Andersenolina elongata</i> (Leupold)	Fig. 3p	Tithonian-Lower Valanginian
<i>Andersenolina</i> cf. <i>molesta</i> (Gorbachick)	Fig. 3j, k	Tithonian-Berriasian
<i>Everticyclammina</i> sp.	-	-
<i>Freixialina</i> sp.	Fig. 4a, b	-
<i>Lenticulina</i> sp.	-	-
? <i>Mayncina</i> sp.	-	-
<i>Mohlerina basiliensis</i> (Mohler)	Fig. 4c, h, i	Callovian-Hauterivian
? <i>Nautiloculina</i> sp.	-	-
<i>Neotrocholina</i> sp.	-	-
<i>Protopeneloplis banatica</i> Bucur	Fig. 4d-g	Berriasian-Aptian
<i>Pseudocyclammina lituus</i> (Yokoyama)	Fig. 3a, b	Kimmeridgian-Valanginian
<i>Pseudocyclammina</i> sp.	-	-
Calcareous algae		
<i>Clypeina parasolkani</i> Farinacci & Radoićić	Fig. 5i	Upper Tithonian-Valanginian
<i>Clypeina</i> cf. <i>parasolkani</i> Farinacci & Radoićić	-	-
<i>Clypeina solkani</i> Conrad & Radoićić	Fig. 5l	?Upper Tithonian-Berriasian-Lower Aptian
? <i>Clypeina</i> sp.	-	-
<i>Dissocladella</i> cf. <i>intercedens</i> Bakalova	Fig. 6a-d	?Upper Tithonian-Berriasian-Hauterivian
<i>Otternstella lemmensis</i> (Bernier)	Fig. 5h	Kimmeridgian-Berriasian
<i>Rajkaella bartheli</i> (Bernier)	Fig. 6q-y	Kimmeridgian-Berriasian
<i>Russoella radoicicae</i>	Fig. 5m, n	
<i>Salpingoporella annulata</i> Carozzi	Fig. 5a-c	Bathonian-Hauterivian
<i>Salpingoporella</i> cf. <i>annulata</i> Carozzi	-	-
? <i>Salpingoporella</i> sp.	Fig. 5g	-
<i>Salpingoporella granieri</i> Dieni & Radoićić	Fig. 5d, e	Berriasian-?Lower Valanginian
<i>Salpingoporella pygmaea</i> (Gümbel)	Fig. 5f	Oxfordian-Aptian
<i>Terquemella</i> sp.	Fig. 5k, o	-
<i>Zergabriella embergeri</i> (Bouroullec & Deloffre)	Fig. 6e-g	Upper Tithonian-Valanginian
? <i>Arabicodium</i> ?/ <i>Permocalculus</i> sp.	Fig. 8l	-
<i>Marinella lugeoni</i> Pfender	-	Upper Jurassic-Cretaceous

Upper Jurassic deposits (e.g., Vila, 1980; Luperto Sinni & Masse, 1994; Schlagintweit & Ebli, 1999; Schlagintweit et al., 2005; Gawlick et al., 2010), or Upper Jurassic-Valanginian (e.g., Azema et al., 1979; Chiocchini et al., 1988; Altiner, 1991; Gorbachik & Mohamad, 1997; Ivanova, 2000) or, most commonly, from Berriasian-Valanginian deposits (Masse, 1976; Peybernes, 1976; Jaffrezo, 1980; Darsac, 1983; Salvini Bonnard et al., 1984; Boisseau, 1987; Granier, 1987; Bucur, 1988; Chiocchini et al., 1994; Bucur et al., 1995; Bulot et al., 1997).

- *Clypeina parasolkani* Farinacci and Radoićić (1991) was originally described from Berriasian deposits of

Turkey (Farinacci and Radoićić, 1991). The most frequent citations are from Berriasian-Valanginian deposits (Yilmaz, 1999; Dieni & Radoićić, 2000; Bucur & Săsăran, 2005; Dragastan et al., 2005; Bruni et al., 2007), but this dasycladalean alga was also identified in Upper Tithonian – Berriasian limestones (e.g., Ebli and Schlagintweit, 1998, Schlagintweit, 2011).

- *Otternstella lemmensis* (Bernier, 1971), and *Rajkaella bartheli* (Bernier, 1971) are two dasycladalean algae first described from Upper Jurassic deposits (Bernier, 1971). Subsequently, they have been found in Berriasian limestones (Wyssling, 1986; Dieni & Radoicic, 2000; Bucur & Cociuba, 2001; Bucur & Săsăran, 2005).

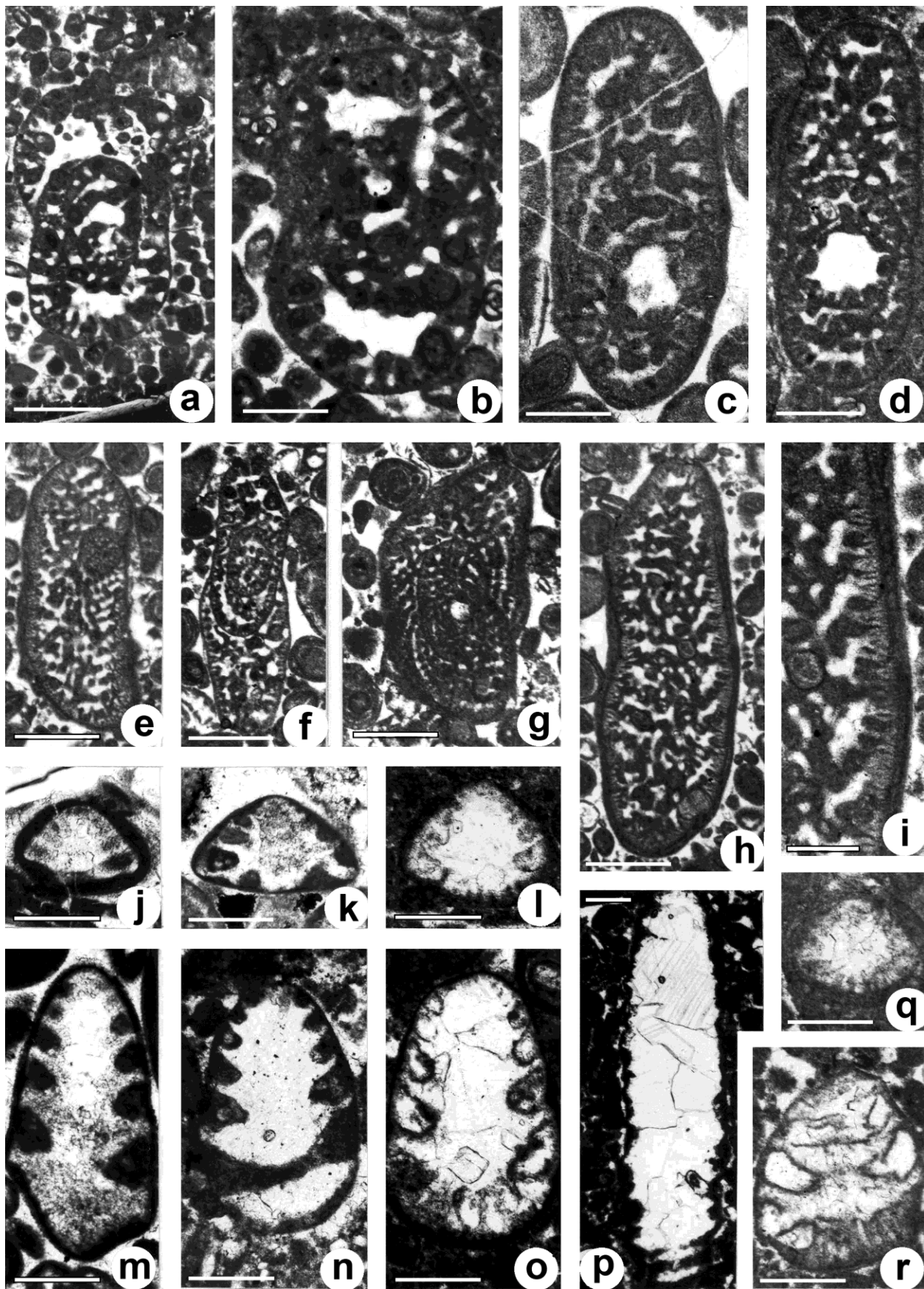


Fig. 3 Foraminifera from the Mozduran Formation. **a, b** *Pseudocyclammmina lituus* (Yokoyama), sample MS 75; **c-i** *Anchispirocyclina lusitanica* (Egger), sample MS 62. **j, k** *Andersenolina* cf. *molesta* (Gorbachik); **j**, sample MS 62; **k**, sample SM 76. **l, q** *Andersenolina* cf. *alpina* (Leupold), sample MS 62. **m, n, o** *Andersenolina cherchiaie* (Arnaud-Vanneau, Boissau and Darsac); **m**, sample MS 73; **n, o**, sample MS 73. **p** *Andersenolina elongata* (Leupold), sample MS 76. **r** *Andersenolina* cf. *cherchiaie* (Arnaud-Vanneau, Boisseau and Darsac), sample MS 62. Scale bar is 0.5 mm (a, e-g); 0.25 mm (b, c, d, h-s); 0.125 mm (i).

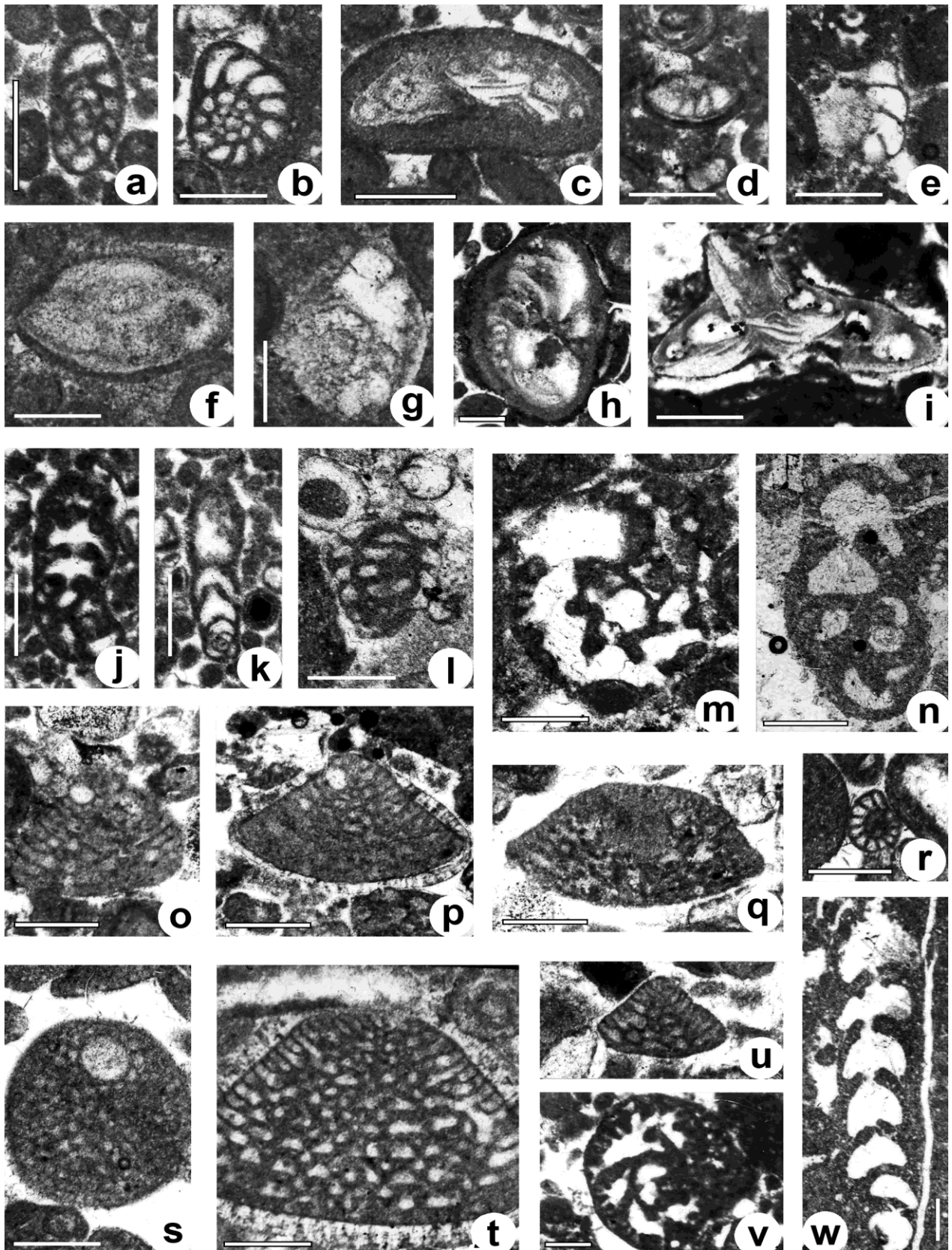


Fig. 4 Foraminifera from the Mozduran (a-l), Lar (m, n, v, w) and Tirgan (o-u) formations. **a, b** *Freixialina* sp., sample MS 75. **c, h, i** *Mohlerina basiliensis* (Mohler); **c**, sample MS 76; **h**, sample MS 78; **i**, sample MS 77. **d-g** *Protopeneroplis banatica* Bucur; **d**, sample MS 73; **e-g**, sample MS 71. **j** *Ammobaculites* sp., sample MS 74. **k** *Ammobaculites* sp., sample MS 74. **l** *Debarina* sp., sample MS 249. **m, v** *Everticyclammina* sp., **m**, sample MJ 81; **v**, sample MJ 81. **n, w** Unidentified foraminifer with fine pseudoalveolar structure of the wall, sample MJ 68. **o** *Praeorbitolina wienandsi* Schroeder, sample MS 245. **p** *Praeorbitolina cornyi* Schroeder, sample MS 245. **q, s** *Palorbitolina lenticularis* (Blumenbach); **q**, sample MS 245; **s**, sample MS 246. **r** *Comaliamma* sp., sample MS 246. **t** *Palorbitolina lenticularis* (Blumenbach), sample MS 246. **u** *Praeorbitolina* sp., sample MS 245. Scale bar is 0.5 mm (n), 0.25 mm (a-e, h-m, o, q, s, t-w), 0.125 mm (f, g).

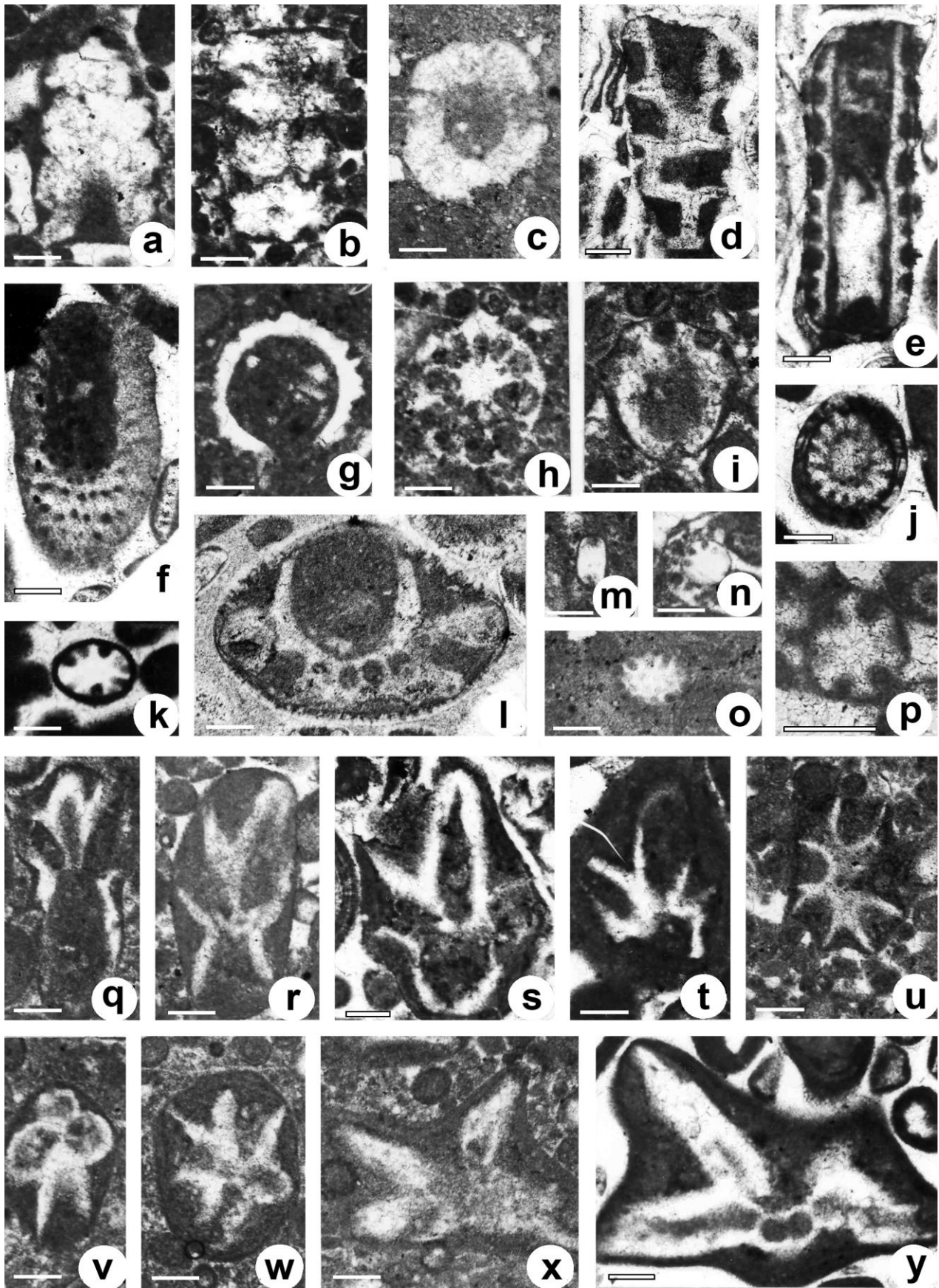


Fig. 5 Calcareous algae from the Mozduran Formation. **a-c** *Salpingoporella annulata* Carozzi, sample MS 75. **d, e** *Salpingoporella granieri* Dieni & Radoičić; **d**, sample MS 96; **e**, sample MS 102. **f** *Salpingoporella pygmaea* (Gümbel), sample MS 102. **g** ?*Salpingoporella* sp., sample MS 75. **h** *Otternstella lemmensis* (Bernier), sample MS 75. **i** *Clypeina parasolkani* Farinacci & Radoičić, sample MS 76. **j** *Salpingoporella* sp., sample MS 102. **k, o, p** *Terquemella* sp.; **k**, sample MS 78; **o**, sample MJ 0; **p**, sample MS-73. **l** *Clypeina solkani* Conrad & Radoičić, sample MS 96. **m, n** *Russoella radoicicae* Barattolo, sample MS 76. **q-y** *Rajkaella bartheli* (Bernier); **q, r, v, x**, sample MS 71; **s, y**, sample MS 78; **t**, sample MS 77; **u**, sample MS 74. Scale bar is 0.125 mm.

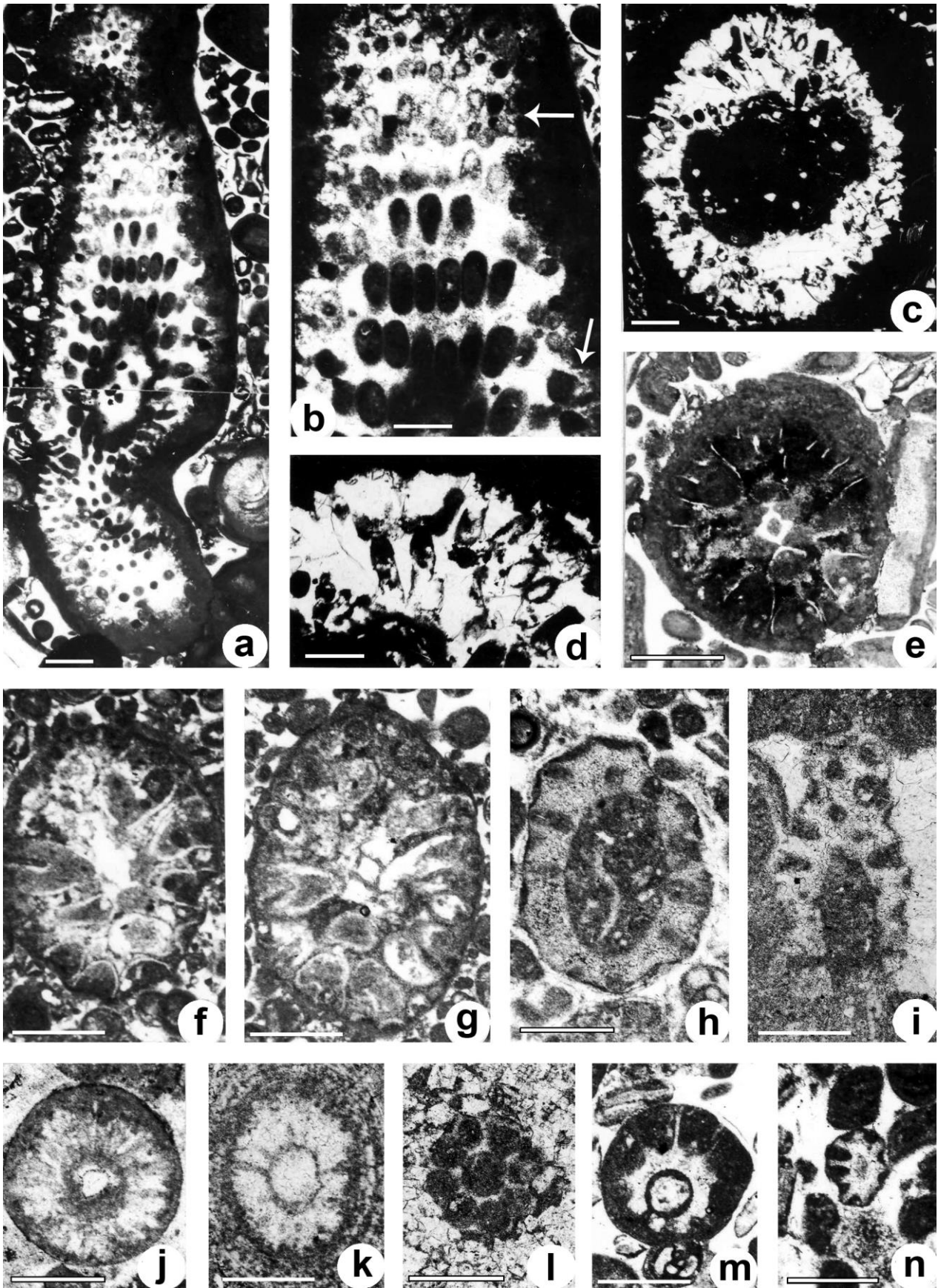


Fig. 6 Calcareous algae from the Mozduran (a-i), Lar (j, k) and Tirgan (l-n) Formations. **a-d** *Dissocladella* cf. *intercedens* Bakalova; a, b, sample MS 78; c, d, sample MS 77. **e-g** *Zergabriella embergeri* (Bouroullec & Deloffre); e, sample MS 78; f, g, sample MS 62. **h, i** *Salpingoporella* sp., sample MS 245. **j, k** *Salpingoporella pygmaea* (Gümbel), sample Mj 43. **l** ?*Holosporella* sp., sample MS 235. **m** *Montiella?* *elitzae* (Bakalova), sample MS 246. **n** *Carpathoporella occidentalis* Dragastan, sample MS 245. Scale bar is 0.5 mm (a, c, e, g), 0.25 mm (b, d, f, h-n).

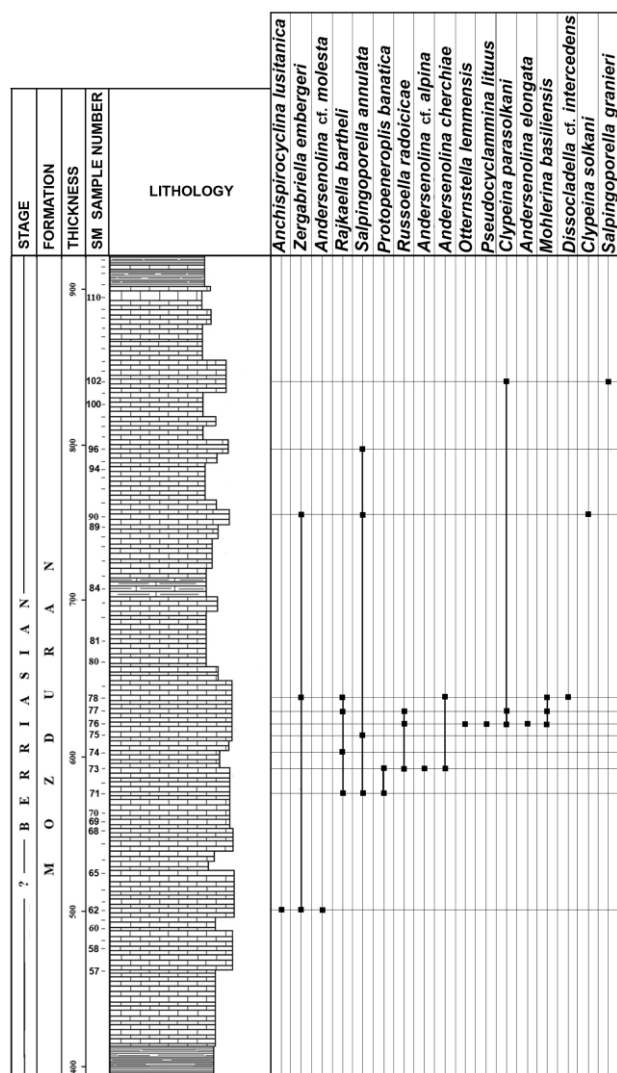


Fig. 7 Stratigraphical range of the most important microfossils identified in the Mozduran Formation from Takhtehbashgheh

- *Salpingoporella annulata* Carozzi, 1953 is another dasycladalean alga widely distributed in Middle Jurassic–Lower Cretaceous deposits (Carras et al., 2006); its most frequent age affiliation belonging to the Tithonian–Valanginian interval (Darga and Schlagintweit, 1991; Luperto Sinni and Masse, 1993; Schlagintweit, 1993; Dieni & Radoičić, 2000; Bucur & Sasāran, 2005; Bucur et al., 2005; Dragastan et al., 2005; Gawlick et al., 2010).
- *Zergabriella embergeri* (Bouroullec & Deloffre, 1968) Granier, 1989 has been frequently identified in Berriasian–Valanginian deposits (Bouroullec & Deloffre, 1968; Darga & Schlagintweit, 1991; Masse, 1993; Schlagintweit, 1993; Dragastan, 1999); nevertheless, it is also present in Upper Jurassic deposits (e.g., Jaffrezo, 1980; Bernier, 1984).

Species characteristic for the Berriasian–Valanginian interval:

- *Andersenolina cherchiaie* (Arnaud-Vanneau et al., 1988) was cited exclusively from Berriasian–Valanginian deposits (Boisseau, 1987; Arnaud-Vanneau et al., 1988; Altiner, 1991; Chiocchini et al., 1994; Bucur et al., 1995;

Mancinelli & Coccia, 1999; Moshammer & Schlagintweit, 1999), most authors assigning it to the genus *Trocholina*. Neagu (1994) transferred it to the new genus *Andersenolina*.

- *Protopeneloplis banatica* Bucur, 1993a. This foraminifer has been first mentioned (as *Protopeneloplis* aff. *trochangulata*) from Hauterivian deposits (Bucur, 1988) that were subsequently revised and reassigned to the Upper Valanginian–Lower Hauterivian (Bucur, 1991). Bucur (1993a) provided a detailed description of the species. The distribution of this foraminifer is relatively unknown, in spite of another record in SE France (Blanc et al., 1992). The species has also been identified in the Southern Carpathians in Lower Valanginian deposits (Pop & Bucur, 2001), in Serbia in Valanginian deposits (Bucur et al., 1995), and in Slovenia in both Valanginian and Aptian deposits (Bucur, 1997).

- *Clypeina solkani* Conrad and Radoičić, 1971, originally described from Valanginian–Lower Aptian limestones was then commonly recorded in the Berriasian–Hauterivian interval (Sokač & Velić, 1978; Mancinelli, 1992; Bodrogi et al., 1993; Luperto Sinni & Masse, 1993; Masse, 1993; Schlagintweit, 1993; Dozet & Šribar, 1998; Dragastan et al., 2005; Bruni et al., 2007). Seldom the species has also been identified in the Upper Tithonian–Valanginian (Darga & Schlagintweit, 1991; Gawlick et al., 2005) or Berriasian–Barremian (Carras & Fazzuoli, 1991; Bodrogi et al., 1994; Schindler & Conrad, 1994).

- *Salpingoporella granieri* Dieni & Radoičić, 2000 is an alga known from the Berriasian, possibly also the Early Valanginian (Dieni & Radoičić, 2000; Schlagintweit et al., 2009).

- *Dissociadella intercedens* Bakalova, 1978 seems to be a dasycladalean alga poorly known out of its type-locality (Pre-Balkan area, Bakalova, 1978, Late Tithonian–Early Berriasian). Doubtlessly, it was identified in limestones attributed to the Berriasian–Hauterivian interval (Bucur, 1993b; Schindler & Conrad, 1994; Schlagintweit & Ebli, 1999).

Based on this analysis we consider that the micropaleontological assemblage identified in the Mozduran Formation most probably documents a Berriasian age. This conclusion is underpinned by the presence of some species currently identified solely from Lower Cretaceous deposits. For comparison, see the overview on the stratigraphic distribution of Tithonian–Berriasian foraminifers and calcareous algae published by Granier & Bucur (2011).

Taking into account that the Berriasian association in the Mozduran Formation was identified in the middle part of Takhtehbashgheh section (Fig. 7), we can assume that the base of this section could be assigned to the Tithonian, and the top to the Valanginian.

As far as the Tirgan Formation is concerned, the simultaneous presence of the orbitolinids *Palorbitolina lenticularis* and *Praeorbitolina cormyi* certainly indicate a Lower Aptian age (Cherchi & Schroeder, 1998; Schroeder et al., 2010). The associated calcareous algae have also been frequently cited from Lower Aptian deposits (Granier & Deloffre, 1993; Bucur, 1999). Recently, Taherpour Khalil Abad et al. (2009, 2010, 2013) described calcareous algae from the Tirgan

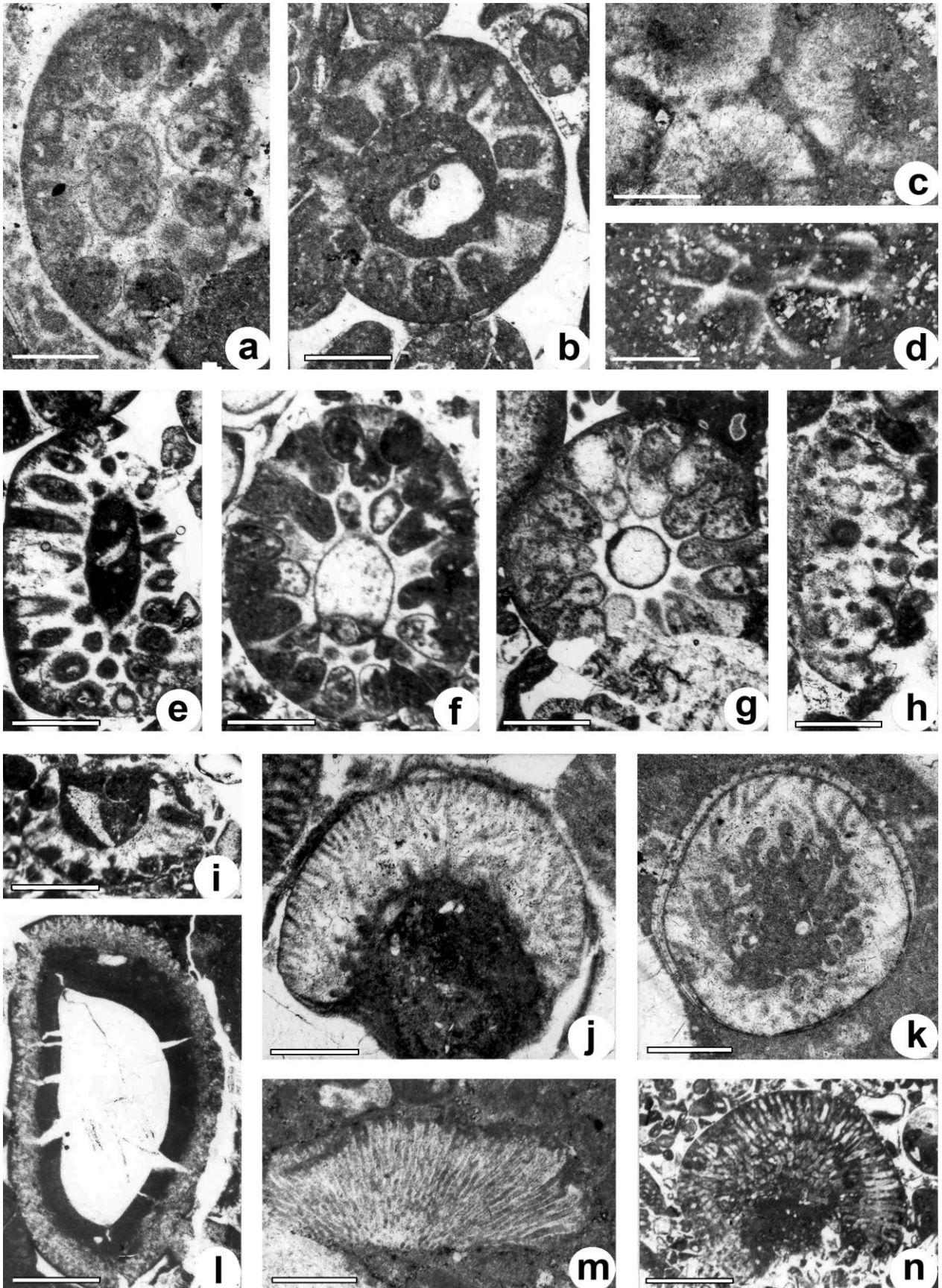


Fig. 8 Calcareous algae from the Mozduran (l), Lar (m) and Tigran (a-k, n) formations. **a, e, f** *Montiella? elitzae* (Bakalova); a sample MS 231; e sample MS 246; f sample MS 245. **b, c, d** *Kopetdagaria sphaerica* (Maslov); b sample MS 231; c, d sample MS 235. **g** *Cylindroporella?* sp. cf. *Cylindroporella lyrata* Masse and Luperto Sinni, sample MS 246. **h** *Neomeris cretacea* Steinmann, sample MS 245. **i** *Similiclypeina conradi* Bucur, sample MS 245. **j, k** *Boueina* sp.; j sample MS 245; k sample MS 235. **l** *?Arabicodium/?Permocalculus* sp., sample MS 96. **m** Rivulariacean-type cyanobacteria, sample Mj 0. **n** *Pycnoporidium* sp., sample MS 246. Scale bar is 1 mm (N), 0.5 mm (b, d-g, i, l), 0.25 mm (a, c, h, j, k, m).

Formation, and assigned the carbonate deposits of this formation to the Barremian–Aptian.

Column A in Fig. 9 illustrates the generalized succession of the Lower Cretaceous deposits in the East Alborz - West Kopet Dagh area, based on the results of the present study.

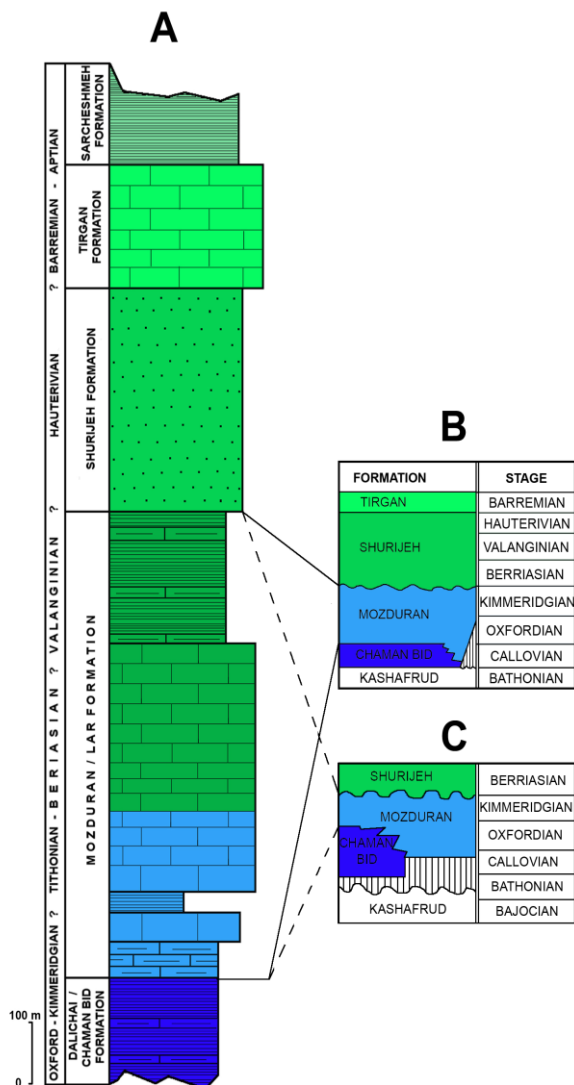


Fig. 9 The generalized succession of the Lower Cretaceous deposits in the East Alborz - West Kopet Dagh area. The interval corresponding to the Lar/Mozduran Formation in the studied sections (A) is compared with the stratigraphic succession of the Mozduran Formation according to Kavooosi et al. (2009) (B) and Lasemi (1995) (C).

Columns B and C represent the stratigraphic succession of the Mozduran Formation according to previous references, i.e., Kavooosi et al. (2009) and respectively Lasemi (1995). This comparison clearly emphasizes significant differences related to the ages assigned to the Mozduran Formation. This can be the result of either insufficient paleontological documentation, or of the west-to-east diachronous character of this formation as already postulated by Majidifard (2003). The diachronous character of the Lower Cretaceous formations in the

Kopet Dagh is also well documented by ammonites (Immel et al., 1997).

Comparisons with other areas of Iran

Little is known about the microfossil assemblages of the basal Cretaceous carbonate deposits in Iran. The few papers dealing with the calcareous algae focused on Zagros area, which belongs to the Arabian plate, or from a paleogeographical point of view, the southern Tethys. Gollestaneh (1965, 1979) in his study of the Fahlyan Formation in the Zagros area mentions for the first time Berriasian–Valanginian algae such as *Salpingoporella annulata*, *Iranella inopinata*, *Cylindroporella iranica* and *Fenestrella dunningtoni* (the two latter species being in fact *nomina nuda*, and their illustrations corresponding to *Otternstella lemmensis* Bernier). *Iranella inopinata* was recently typified and revised by Hosseini et al. (2013). *Salpingoporella annulata* was also identified in deposits from the Zagros area by Parvaneh Nejad Shirazi (2008, 2009) and Jamalians et al. (2011).

Hosseini and Conrad (2008) have described the richest Berriasian–Valanginian microfossil assemblage from the Fahliyan Formation: 18 species of algae and 24 species of foraminifera. Seven of these algal species (*Clypeina parasolkani*, *Clypeina* gr. *solkani*, *Otternstella lemmensis*, *Salpingoporella annulata*, *Salpingoporella granieri*, *Salpingoporella pygmaea* and *Zergabriella embergeri*) and three foraminifera [*Trocholina* (= *Andersenolina*) *alpina*, *Trocholina* (= *Andersenolina*) *cherchiaie* and *Pseudocyclammina lituus*] have also been identified by us in the deposits of the Mozduran Formation in northern Iran.

At a first glance, there are only minor differences between the microfossil associations from Alborz-Kopet Dagh area and the one from the Zagros area, to be considered as paleogeographical benchmarks. In principle, the few discriminating species, i.e., the algae *Rajkaella bartheli* and *Dissocladella* cf. *intercedens* (in the Kopet Dagh area) and *Clypeina* cf. *onogosti*, *Salpingoporella* aff. *pirinia* (in the Zagros area), and the foraminifera *Anchispirocyclina lusitanica* and *Protopenneroplis banatica* (in Kopet Dagh) could be used for delimiting the southern vs. the central-northern border of the Tethys during the Berriasian–Valanginian interval.

CONCLUSIONS

We have studied two limestone successions located in the eastern Alborz and western Kopet Dagh area - covering the stratigraphic interval of the Lar and Mozduran Formations, as well as samples collected from the Tirgan Formation in Kopet Dagh. The micropaleontological associations identified in the Lar Formation (Jorbat section) is relatively monotonous and of low biostratigraphic relevance. Nevertheless, the microfossil association identified in the Mozduran Formation (Taktehbashgeh section) documents for the first time an Early Cretaceous (Berriasian–?Early Valanginian) age for most of these deposits. This conclusion contradicts the previous assignments of the Lar/Mozduran Formations to the Oxfordian–Kimmeridgian, respectively the Kimmeridgian–Tithonian intervals (e.g., Assereto, 1966;

Lasemi, 1995; Kavooosi et al., 2009; Kavooosi, 2010; Aghaei et al., 2012). At the same time, our results support the assumption of Majidifard (2008) that the upper part of this formation includes Berriasian deposits. One partial explanation for the different age assignments could be the diachronous nature of the Lar/Mozduran Formations, as asserted by Majidifard (2003, 2008) and Aghaei et al. (2012). Another possibility could be the previously insufficient documentation of the micropaleontological content of these limestones.

The samples collected from the Tirgan Formation indicate a Lower Aptian age, overlapping the Barremian–Aptian interval recently attributed to this formation by Taherpour Khalil Abad et al. (2009, 2010, 2013). We consider that further detailed biostratigraphic investigation of this formation, mainly based on the deposits in the type-section, and correlations with similar deposits in central and south-west Iran would be necessary.

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