

## PARURGONINA VALANGINIANA N. SP. FROM THE VALANGINIAN OF SW IRAN (ZAGROS ZONE): THE FIRST CRETACEOUS RECORD OF THE GENUS

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**Abstract.** The new larger benthic foraminifer *Parurgonina valanginiana* is described from the Valanginian deposits of the Fahliyan Formation of southwestern Iran (Zagros Zone). It is separated from the uppermost Oxfordian–lowermost Tithonian genotype *P. caelinensis* (Cuvillier et al.) by a distinct time gap. The Lower Cretaceous specimens exhibit a larger embryonic chamber whereas the internal structural and other biometric data are generally in conformity with the Upper Jurassic morphotypes. Besides the Middle Jurassic *P. primaeva* Kamoun & Peybernès and the Upper Jurassic *P. caelinensis*, *P. valanginiana* sp. nov. represents the third species of the genus described and possibly a Valanginian marker endemic for the Arabian Plate. In the Fahliyan Formation, *P. valanginiana* sp. nov. occurs in wackestones associated with *Pseudocyclammina lituus* (Yokoyama). Additional data for the micropalaeontological assemblages (benthic foraminifera, calcareous algae) of the shallow-water carbonates of the Fahliyan Formation are provided. As it is also the case in the United Arab Emirates (Granier, 2008), it is proposed that the Tithonian/Berriasian boundary does not, as generally indicated in the literature, coincide with the boundary of the Hith Formation and the Fahliyan Formation, but instead occurs within the latter. The new finds provide further evidence that the Tithonian/Berriasian boundary did not represent a major rupture or extinction for larger benthic foraminifera. On the contrary, the Berriasian/Valanginian boundary corresponds to a natural discontinuity (both sedimentological and biological) possibly enhanced by a hiatus of the upper Berriasian strata. The foraminiferal diversity remains quite high during early Valanginian times then falls drastically, which suggests that the Berriasian/Valanginian crisis is a double barrelled crisis (first base Valanginian, second intra-Valanginian).

**Keywords:** Larger Benthic Foraminifera, phylogeny, biostratigraphy, Upper Jurassic, Lower Cretaceous

### INTRODUCTION

In previous times, the boundary between the Jurassic and the Cretaceous Period (~145 Ma) has been considered as one of the eight mass extinction events in earth history (e.g., Raup & Sepkoski, 1982), a view that today has largely been overturned (Tennant et al., 2017). Larger benthic foraminifera (LBF) occurring in shallow-marine carbonates do not provide much data for the separation of Tithonian and Berriasian strata (Bassoulet, 1997; Granier & Bucur, 2011; Granier, 2019). Several genera (and also species) such as *Anchispirocyclina* Jordan & Applin, *Feurtillia* Maync, *Pseudocyclammina* Yabe & Hanzawa, *Torinosuella* Maync, or *Everticyclammina* Redmond extend across the Tithonian/Berriasian boundary (Bassoulet, 1997a, tab. 53). Instead, it is the upper Berriasian that represents a period of high origination rates among LBF, including orbitolinids and other groups (Schlagintweit & Bucur, 2021). Some forms, such as *Pseudocyclammina lituus* (Yokoyama), cross the Tithonian/Berriasian boundary, reaching upwards into the lower Valanginian, while some dasycladaleans that originated in the Upper Jurassic disappeared before the boundary [*Aloisalthella sulcata* (Alth), *Campbelliella striata* Carozzi, *Otterstella lemmensis* (Bernier)] (Granier, 2019). *Parurgonina caelinensis* (Cuvillier et al.)

represents a comparably wide-spread taxon in western and central Neotethys. It is reported correspondingly from the latest Oxfordian–earliest Tithonian interval (Cuvillier et al., 1968; Bassoulet & Fourcade, 1979; Bordea & Bordea, 1987; Bassoulet, 1997a; Pleş et al., 2015). An interesting section of the Fahliyan Formation comprising the uppermost Jurassic–lowermost Cretaceous interval is recorded from southwestern part of Iran (Zagros Zone), witnessing the first occurrence of *Parurgonina* Cuvillier et al., from the Lower Cretaceous strata, including a new species herein described as *P. valanginiana*. In addition, the present contribution provides further data on the biostratigraphy and micropalaeontological inventory (foraminifera, algae) of the Fahliyan Formation, an economically important formation because it is an oil and gas-bearing lithostratigraphic unit in this area.

### GEOLOGICAL SETTING

The Iran plateau consists of different structural units, including the Alborz and Kopet Dagh ranges in the northern part of the country, the Zagros fold and thrust belt and the Sanandaj-Sirjan Zone in the southern part, separated by the Central Iran region in the middle part (Fig. 1A). Following the closure of the Neotethys ocean

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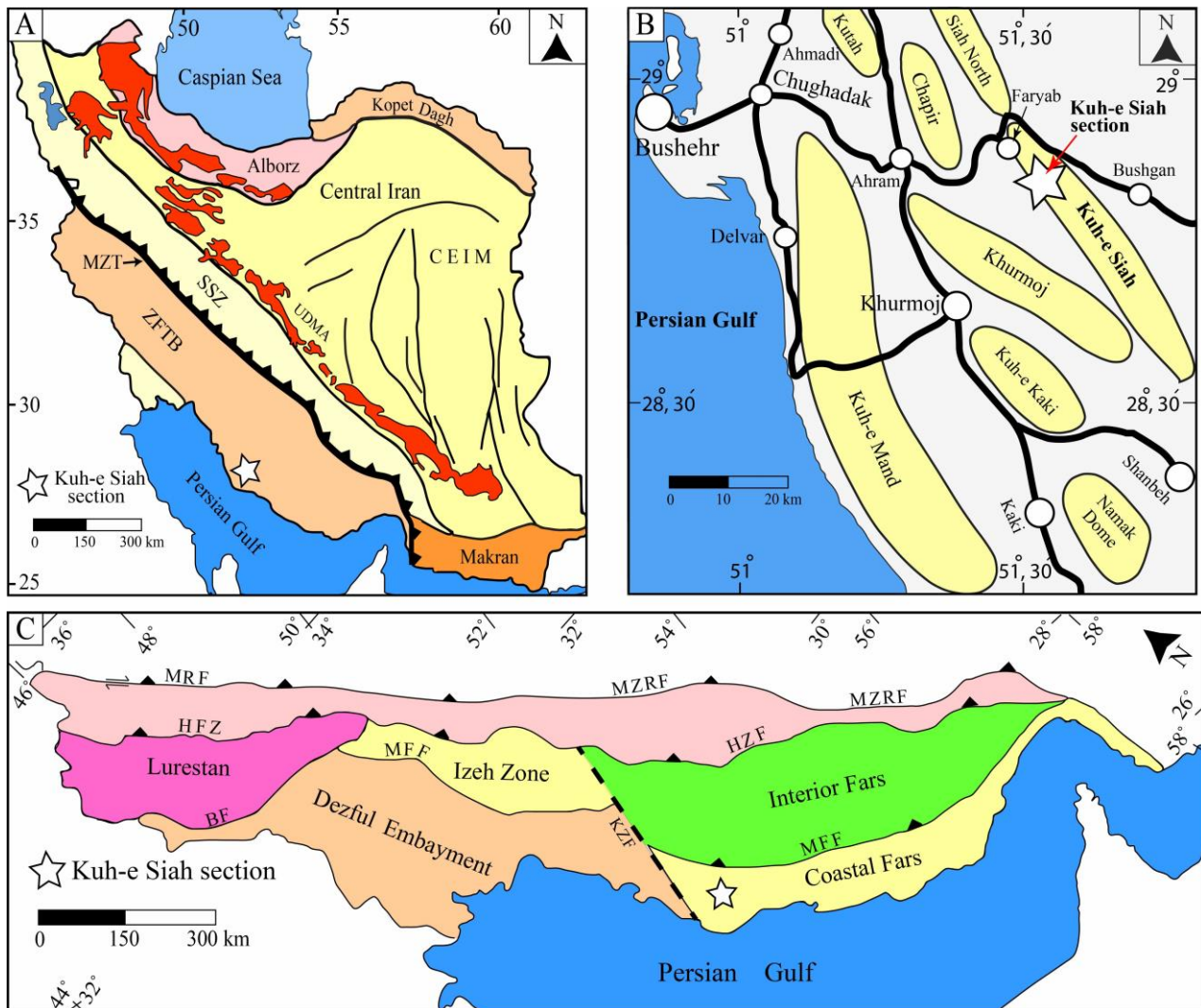
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during the Late Cretaceous, the Zagros fold and thrust belt formed along the Arabian-Eurasian collision zone (e.g., Berberian & King, 1981; Golonka, 2004). The belt, which stretches in a SE-NW direction, is located within the Alpine-Himalayan Orogenic system at the eastern margin of the Arabian Plate. The Zagros belt was affected by major tectonic compressions from the Oligocene to the Holocene, which led to the formation of the present-day Zagros Chain, including large-scale anticlines and fold-and-thrust belt features (Heydari, 2008). Deposition within the belt from the latest Precambrian to the Holocene has resulted in the presence of an extensive sedimentary column which is estimated to be up to 10 km-thick (Motiei, 1993; Sherkati & Letouzey, 2004; Heydari, 2008). Based on its structural style and sedimentary history, the Zagros belt can be subdivided into several tectono-stratigraphic units, including Fars Province (Interior Fars and Coastal Fars), Dezful Embayment, Izeh Zone, High Zagros, Lurestan Province, and Abadan Plain. (e.g., Falcon, 1974; Motiei, 1993,

Sherkati & Letouzey, 2004; Heydari, 2008; Farzipour-Saein et al., 2009) (Fig.1C). A thick succession accumulated in different tectono-sedimentary environments, ranging from shallow carbonate platforms to deep subtidal basins. Some are separated by major unconformities (Berberian & King, 1981; Motiei, 1993; Heydari, 2008). The section described in this study is located in the west of the Coastal Fars Zone (Figs. 1B-C). The Fars area, as part of the Zagros simply folded belt and the Arabian Plate, is characterized by the occurrences of extensive shallow-water carbonate deposits of the Upper Jurassic–Lower Cretaceous Khami group containing rich assemblages of benthic foraminifera and calcareous algae. The material of this study comes from one surface section of the Fahliyan Formation in the Zagros belt, named Kuh-e Siah ( $28^{\circ}47'46''\text{N } 51^{\circ}33'43''\text{E}$ ) (Fig. 1). It is located at the southern flank of the Kuh-e Siah anticline, in the west of the Coastal Fars Zone, approximately 65 kilometer east of Boushehr, and 8 km southeast of Faryab city.



**Fig. 1.** A. Simplified geological map of Iran (modified after Schlagintweit and Yazdi-Moghadam, 2021) showing the main tectonic subdivisions. B. Road map and position of the studied section. C. Tectono-stratigraphic units of the Zagros belt (modified after Yazdi-Moghadam and Schlagintweit, 2021) with position of the Kuh-e Siah section. Abbreviations: BF Balarud Fault, CEIM Central East Iran Microplate, HZF High Zagros Fault, KZF Kazerun Fault, MFF Mountain Front Fault, MZRF Main Zagros Revers Fault, MZT Main Zagros Thrust, SSZ Sanandaj-Sirjan Zone, UDMA Uromia Dokhtar Magmatic Arc, ZFTB Zagros Fold Thrust Belt.

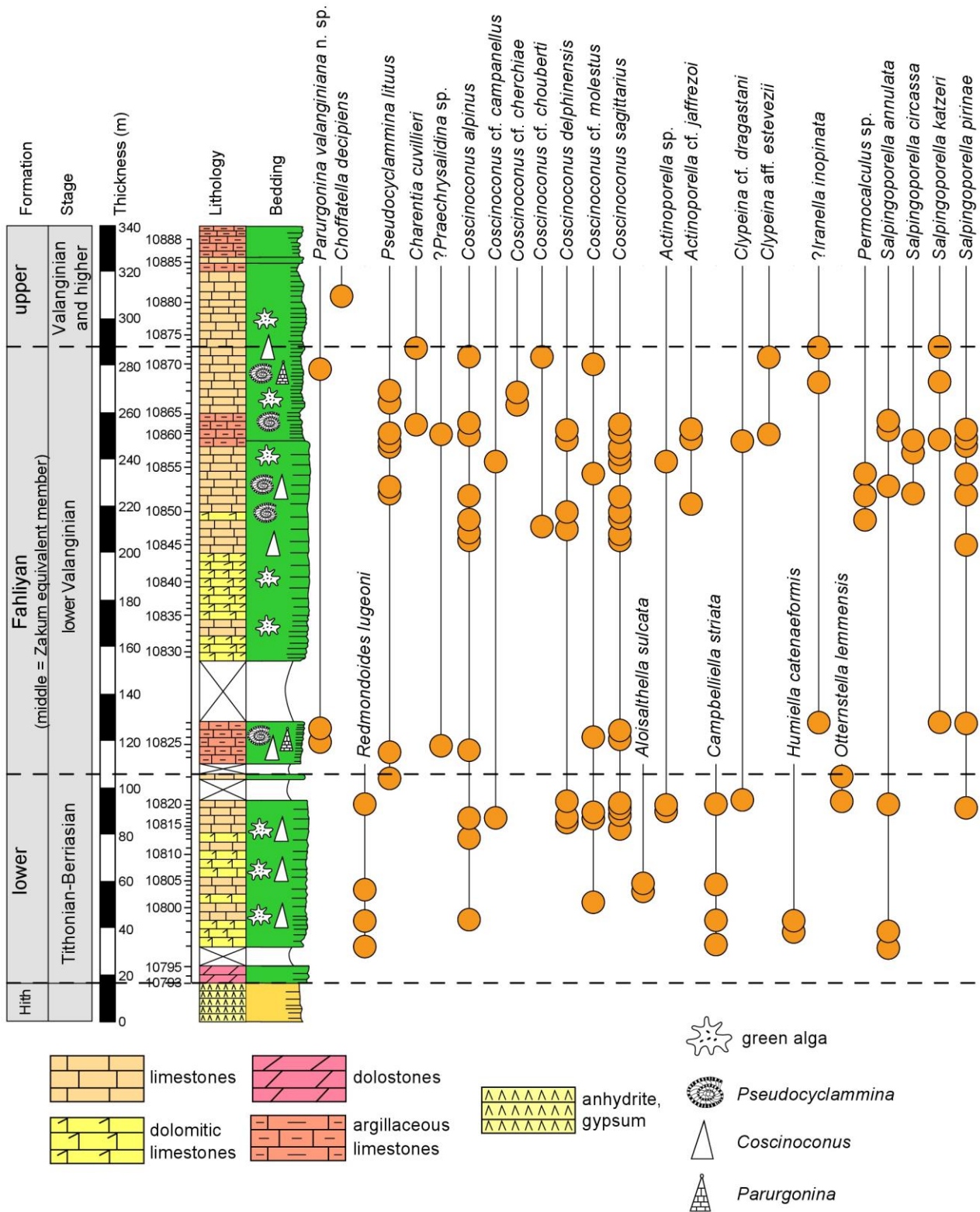


Fig. 2. Lithological log of the Kuh-e Siah section with distribution of larger benthic foraminifera and calcareous green algae.

The section has been studied previously by Jamalian et al. (2011). The 304-m-thick Fahliyan Formation in this area rests conformably on evaporites of the Hith Formation and is unconformably overlain by thin-bedded argillaceous limestones of the Gadvan Formation. The

Fahliyan Formation in this area consists mainly of thick to medium bedded limestones, and argillaceous- and dolomitic limestones containing a rich assemblage of benthic foraminifera and calcareous green algae (Fig. 2). The new taxon *Parurgonina valanginiana* was recorded

in the middle and upper parts of the Fahliyan Formation associated with *Pseudocyclammia lituus* (Yokoyama), *Charentia cuvillieri* Neumann, *Praechrysalidina* ? sp., *Coscinoconus alpinus* Leupold, *C. cf. campanellus* (Arnaud-Vanneau et al.), *C. cf. cherchiae* (Arnaud-Vanneau et al.), *C. cf. chouberti* (Hottinger), *C. cf. molestus* (Gorbachik), *C. delphinensis* (Arnaud-Vanneau et al.), *C. sagittarius* (Arnaud-Vanneau et al.), *Actinoporella* sp., *A. cf. jaffrezoi* Granier, *Clypeina cf. dragastani* Dieni & Radoičić, *C. aff. estevezii* Granier, *?Iranella inopinata* Gollestaneh, *Permocalculus* sp., *Salpingoporella annulata* Carozzi, *S. circassa* Farinacci & Radoičić, *S. katzeri* Conrad & Radoičić, and *Salpingoporella piriniae* Carras & Radoičić (Fig. 3).

Almost all of these taxa have already been recorded from the Fahliyan Formation. (Hosseini & Conrad, 2008; Jamalian et al., 2011; Hosseini et al., 2016; Esrafil-Dizaji et al., 2020). *P. valanginiana* sp. nov. has already been described from the Fahliyan Formation as '*Pseudochrysalidina arabicus* Henson' by Shakib (1994) and from the Kuh-e Siah section as the orbitolinid '*Valdanchella*' by Jamalian et al. (2011) (see synonymy). In Saudi Arabia, an equivalent section with similar faunal and floral assemblages is known as Buwaib Formation (e.g., Deville de Périère, 2023), but published literature on its microfaunal and microfloral content, supporting this equivalency is scarce. Maybe it can be compared with the Zakum Formation (= Thamama IV of Abu Dhabi).

## MATERIAL, METHODS AND REPOSITORY

The material of this study is based on specimens from random cuts of 176 thin sections belonging to 89 cemented carbonate rock samples (wacke- to packstone) of the Fahliyan Formation. *Parurgonina valanginiana* sp. nov. was found in three samples (RAP10825, RAP10827, RAP10869), including six thin sections. The samples and thin sections are housed in the collection of the National Iranian Oil Company Exploration Directorate (NIOCEXP) under the acronym RAP (Kuh-e Siah section).

## SYSTEMATIC PALAEOONTOLOGY

The high-rank classification (Phylum–Class) follows Pawlowski et al. (2013). For the low-rank classification see Kaminski (2014). For Superfamily and Family see Remarks.

Phylum Foraminifera Orbigny, 1826  
 Class Globothalamea Pawlowski et al., 2013  
 Order Loftusiida Kaminski & Mikhalevich in Kaminski, 2004  
 Suborder Orbitolinina Kaminski, 2004  
 ?Superfamily Coskinolinoidea Moullade, 1965  
 ?Family Coskinolinidae Moullade, 1965

**Remarks:** The genus *Parurgonina* has been included in the family Orbitolinidae by Cuvillier et al. (1968). The presence of a pseudo-keriothecal wall structure, however, excludes its belonging to this family (Schroeder in Schroeder et al., 1975). Schroeder confirmed the presence of discoidal (uniserial) chambers in the adult test part, as reported previously by Cuvillier et al. (1968) following a short trochospiral ('helicospiral') early stage. Loeblich and Tappan (1987, p. 185) placed *Parurgonina* in the family Chrysalidinidae (Neagu 1968), that is defined as "triseriate, later biserial", and with canalculated walls, although their diagnosis of *Parurgonina* states that there are "rectilinear discoidal chambers" in the adult stage (Banner et al., 1991 for details). Septfontaine (1988, p. 248) created the Parurgonininae as a subfamily within the family Valvulinidae. Berthelin 1880 thereby claiming a trochospiral coiled test throughout (eight or more chambers in the adult stage) (= Jurassic 'praevalvulinids' in Septfontaine, 2020, tab. 8.4). In fact, the two transverse sections illustrated in Schroeder et al. (1975, pl. 2, figs. 3-4) and re-illustrated herein Fig. 5i, l, might imply the existence of a biserial coiling mode. This impression, however, might also be due to the convexity (in direction to the cone base) of the septa. In the current classification of Kaminski (2014), the Parurgonininae was given family status (Parurgoninidae). In our material of *P. valanginiana* and other illustrated specimens in the literature, a uniserial main part of the test is evident (Fig. 4). Therefore, *Parurgonina* shares characters of both Chrysalidinidae (trochospiral 'helicospiral' early stage) and Coskinolinidae (uniserial adult part). The undivided part of the marginal chamber, the presence of marginal foramina and the pseudo-keriothecal wall are present in both families (e.g., Hottinger & Drobne, 1980; De Castro, 1981; Banner et al., 1991; Septfontaine, 2020). *Parurgonina* is herein placed tentatively within the superfamily Coskinolinoidea Moullade, 1965 and the family Coskinolinidae Moullade, 1965. According to our interpretation, the family Parurgoninidae Septfontaine, 1988 with its only genus *Parurgonina* would then become obsolete (see also Kaminski, 2014). It is worth mentioning in this context that specimens of *Parurgonina caelinensis* from the Upper Jurassic of Greece were named 'Coskinolines' by Bassoullet & Guernet (1970) (Schroeder in Schroeder et al., 1975).

Genus *Parurgonina* Cuvillier et al., 1968

**Type-species:** *Parurgonina caelinensis* (Cuvillier et al., 1968)

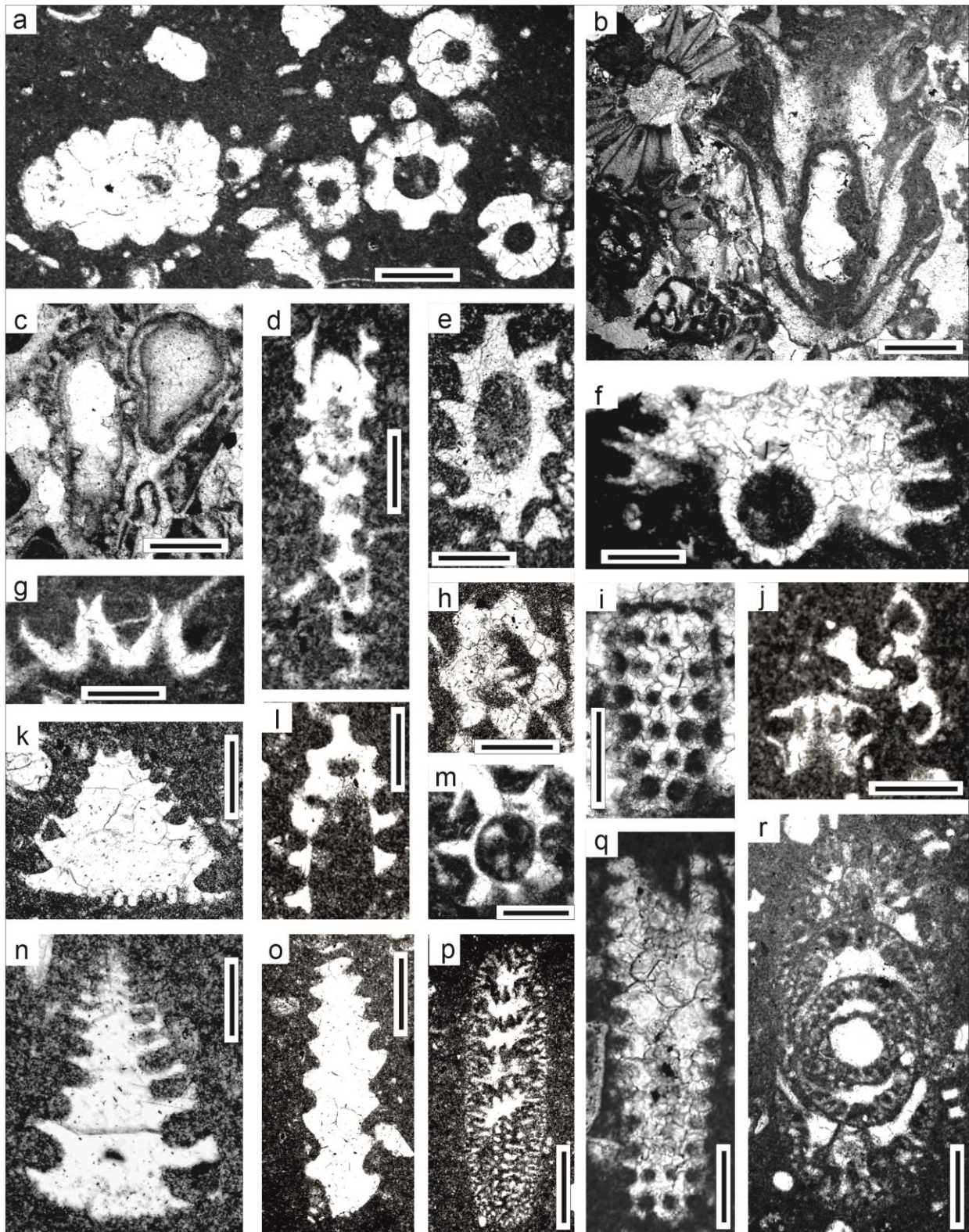
### *Parurgonina valanginiana* sp. nov.

Figs. 4c, 5-6

1994 *Pseudochrysalidina arabicus* Henson – Shakib, pl. 7.3, fig. 10.

2011 *Valdanchella* – Jamalian et al., fig. 7n, fig. 12a-c.

2016 *Falsurgonina pileola* – Hosseini et al., fig. 7d-f.



**Fig. 3.** Selected dasycladalean algae (**a–j, l, m, q**) and benthic foraminifera (**k, n–p, r**) from the Berriasian–Valanginian Fahliyan Formation of SW Iran. **a.** *Salpingoporella annulata* Carozzi, sample RAP 1819. **b.** *Aloisalthella sulcata* (Alth) (right) and *Campbelliella striata* (Carozzi) (middle), sample RAP 10804. **c.** *Humiella* cf. *catenaeformis* (Radoičić), sample RAP 10798. **d, l.** *Salpingoporella granieri* Dieni & Radoičić, samples RAP 10835 (D) and RAP 10825 (L). **e, h, m.** *Clypeina* sp. or *Salpingoporella* sp., or *Iranella inopinata* sensu Hosseini et al. (2013), sample RAP 1028. **f.** *Actinoporella* cf. *podolica* (Alth), sample RAP 10860. **g.** *Clypeina* aff. *dragastani* Dieni & Radoičić, sample RAP 10820. **i, q.** *Salpingoporella piriniae* Carras and Radoičić, sample RAP 10828. **j.** *Actinoporella* ? sp. aff. *jaffrezoi* Granier, sample RAP 10851. **k.** *Coscinoconus alpinus* Leupold, sample RAP 10824. **n.** *Coscinoconus* cf. *sagittarius* (Arnaud-Vanneau et al.), sample RAP 10850. **o.** *Coscinoconus cherchiaie* (Arnaud-Vanneau et al.), sample RAP 10866. **p.** *Choffatella decipiens* Schlumberger, sample RAP 10881. **r.** *Pseudocyclammina lituus* (Yokoyama), sample RAP 10819. Scale bars = 0.20 mm.

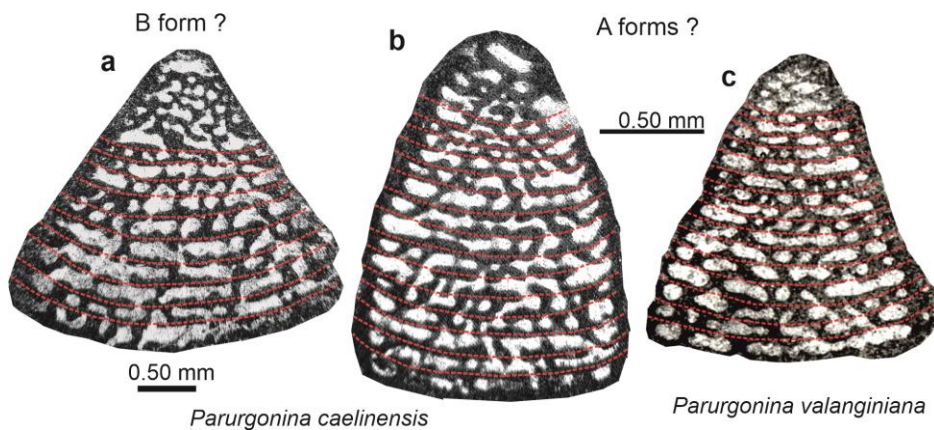
2016 *Falsurgonina pileola* – Hosseini et al., fig. 7d-f.  
 2020 *Pseudochrysalidina arabica* – Eshrafi-Dizaji et al., fig. 6A.

**Origin of the name:** Referring to the Valanginian stage.  
**Horizon and locality:** Valanginian carbonates of the Fahliyan Formation from the Kuh-e Siah section (Figs. 1-2).  
**Holotype:** Slightly oblique axial section shown in fig. 5e; sample RAP 10825.  
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**Description:** Test high-conical with almost plane or convex base, starting with a comparably large embryonic chamber (protoconch) which is situated in a (sub)apical position (Fig. 5a-d). It is followed by a second, also comparatively large, hemispherical to lunular to hemispherical chamber laterally attached to the former (Fig. 5a-e) (= deutoconch in Cuvillier et al., 1968, p. 150). Both chambers are connected by a single pore (Fig. 5a). These in turn are followed by a short trochospiral ('helicospiral') early stage with numerous chambers that apparently lack endoskeletal pillars.

Adult stage is rectilinear with up to 16 chambers and oblique stolon systems (Fig. 6a, c). The marginal chamber part is undivided (e.g. Figs. 5g, 5i). The main central part is occupied by irregular distributed pillars showing a typical semi-lunular shape in transverse sections (Fig. 5i, 5k and 5m above) [= section courbée en forme de crochet (curved section forming a hook) Schroeder in Schroeder et al., 1975, p. 324]. As can be discerned in axial sections, the pillars are not aligned between subsequent chambers; instead they are more or less alternately arranged (e.g., Fig. 5e, 6a, 6c). They broaden (partly also fused) at the base (= pointed towards the cone base). The foramina are represented by multiple large pores irregularly piercing the septa and are linked to the lunular pillars in the central part (Fig. 5i-j, 5l). In axial sections, the foramina are arranged in oblique lines between subsequent chambers (= perforations obliques, Cuvillier et al., 1968) (Fig. 6a, c, adult part). Obliquely arranged marginal foramina are present in the adult rectilinear test part (Fig. 5e, n). The wall is thick with pseudo-keriothecal texture (Gusić, 1969; Schroeder in Schroeder et al., 1975), a feature barely discernible in the Iranian specimens.

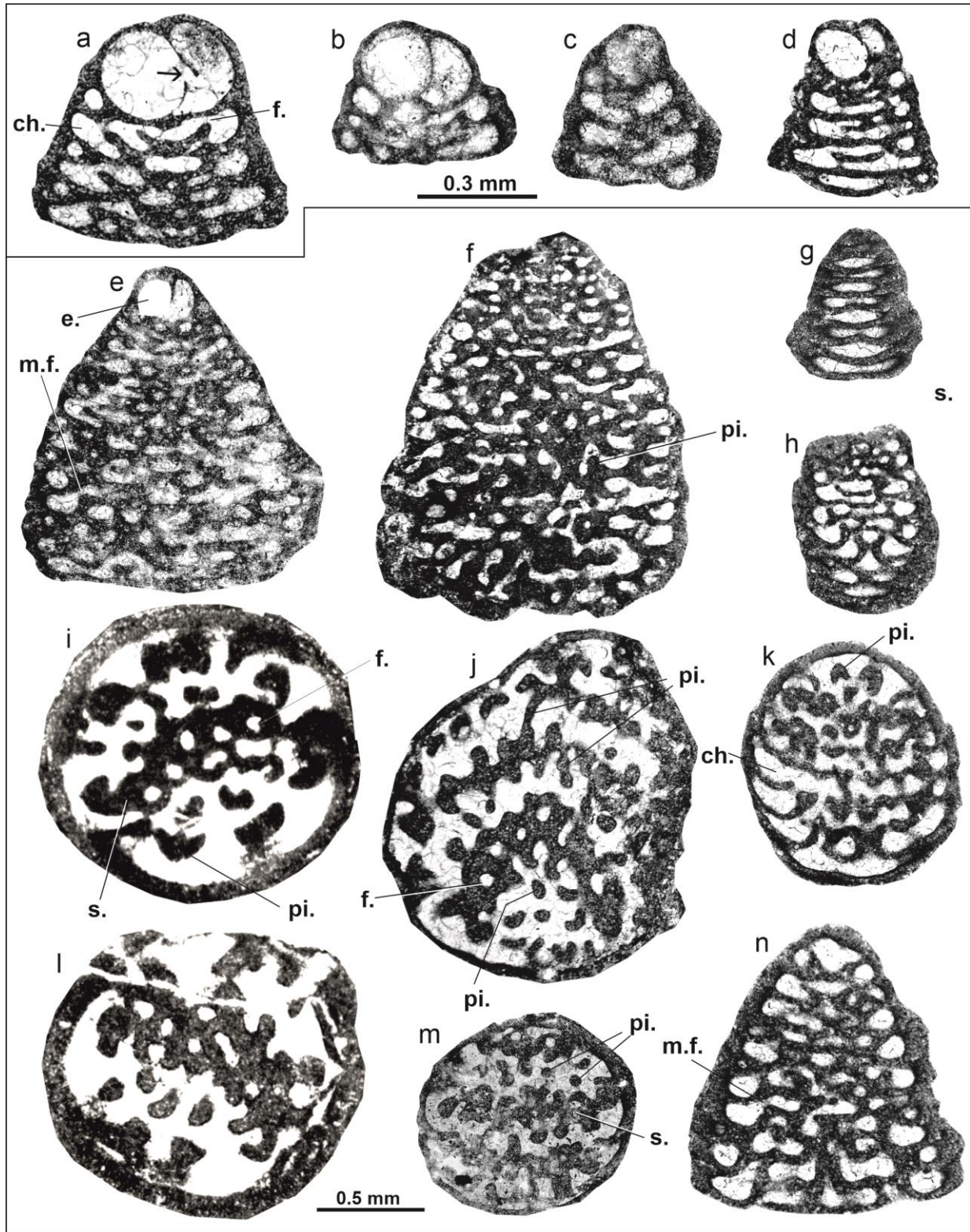
**Dimensions:** See Table 1.



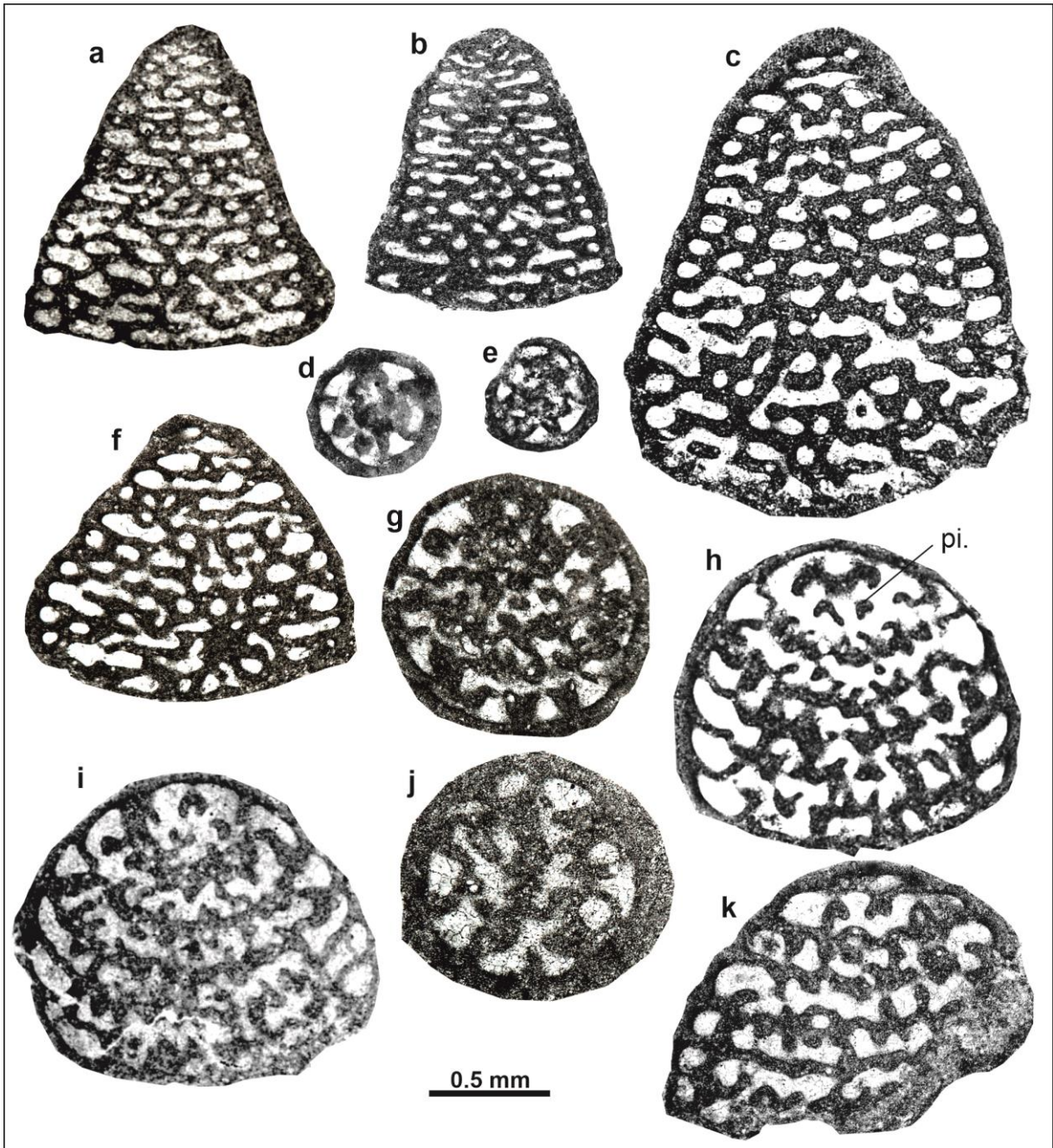
**Fig 4. a-b.** *Parurgonina caelinensis* (Cuvillier et al.), (modified from Velić, 2007, pl. 10, figs. 10-11) from the Upper Jurassic of Croatia and *Parurgonina valanginiana* sp. nov. (c.) from the Lower Cretaceous of Iran. Red dotted lines mark the septa of the rectilinear chambers.

**Table 1.** Biometric data of Upper Jurassic *P. caelinensis* (Cuvillier et al.) and lowermost Cretaceous *P. valanginiana* sp. nov. compared. \* Cuvillier et al. (1968) \*\* Pleš et al. (2015) \*\*\* Gušić (1969 for *Lituonella dinarica*) \*\*\*\* measured from Schroeder et al. (1975, pl. 1, fig. 2).

Biometric data (in mm)	<i>Parurgonina caelinensis</i> (Cuvillier et al.) latest Oxfordian – earliest Tithonian	<i>Parurgonina valanginiana</i> sp. nov. early Valanginian
Test height	* 1.125 mm-2.437 mm ** 1.79 mm-2.18 mm *** 1.00 mm-1.80 mm	up to 1.81 mm
Test diameter	* 1.0 mm-1.375 mm ** 1.17 mm-1.64 mm *** 0.95 mm-1.60 mm	up to 1.47 mm
Chamber height	* 0.0122 mm *** 0.06 mm-0.120 mm	0.08 mm-0.10 mm
Greatest diameter embryonic chamber	* 0.110 mm-0.134 mm **** 0.160 mm	0.145 mm-0.22 mm



**Fig 5.** *Parurgonina valanginiana* sp. nov. from the Valanginian Fahliyan Formation of SW Iran (a–h, j–k, m–n) and the Upper Jurassic of Algeria (i, l; from Schroeder et al., 1975, pl. 2, figs. 3–4). a–d. (Sub)axial sections of juvenile specimens showing embryo and ‘praevalvulinid’ early stage sensu Septfontaine (2020); samples RAP 10825 (a–c), RAP 10869 (d). e. Slightly oblique axial section dissection the apical embryo; holotype specimen, sample RAP 10825. f. Subaxial section showing well developed thickened pillars in the central test part; sample RAP 10825 (= Fig. 12a in Jamalian et al., 2011 illustrated as *Valdanchella*). g. Tangential section showing the undivided marginal chamber area in the part following the ‘praevalvulinid’ stage; sample RAP 10825. h. Tangential oblique section; sample RAP 10825. i. Slightly oblique transverse section showing lunular pillars (from Schroeder et al., 1975, pl. 2, fig. 4, copyright by Swiss Geological Society). j. Oblique section; sample RAP 10825. k. Oblique section showing lunular pillars; sample RAP 10825. l. Slightly oblique transverse section (from Schroeder et al., 1975, pl. 2, fig. 3). m. Oblique transverse section; sample RAP 18025. n. Subaxial section; sample RAP 18025 (= Fig. 7n in Jamalian et al., 2011 illustrated as *Valdanchella*).



**Fig. 6.** *Parurgonina valanginiana* sp. nov. from the Valanginian Fahliyan Formation of SW Iran. **a-c, f** subaxial sections; samples RAP 10825 (a), sample RAP 10869 (b-c, f) (**b, c** = Figs. 12c and 12b in Jamalian et al., 2011 illustrated as *Valdanchella*). **d-e, g, j** transverse sections, partly slightly oblique; samples RAP 10869 (d-e), RAP 10827 (g, j). **h-i, k** Oblique sections; samples RAP 10869 (h), RAP 10825 (i, k). Abbreviation: pi = pillar.

**Remarks:** *Parurgonina* displays a discontinuous fossil record including *Parurgonina primaeva* Kamoun & Peybernès 1993 from the Middle Jurassic (upper Bajocian–lower Bathonian) to the Upper Jurassic *P. caelinensis* (uppermost Oxfordian–lowermost Tithonian, Bassoullet, 1997a; Pleş et al., 2015, 2019). In fact, the only difference between the Upper Jurassic specimens and those from the Iranian Fahliyan Formation that we could observe is the comparably large embryonic chamber(s) at the apex (Tab. 1). According to literature data, the diameter of the megalospheric embryo for *P. primaeva* is 0.200 mm and 0.110–0.160 mm for Upper

Jurassic specimens of *P. caelinensis*. The large-sized embryo of the Lower Cretaceous specimens reaches up to 0.22 mm in size.

As remarked by Cu villier et al. (1968), *Parurgonina* may be confused with the gross homeomorphic *Paravalvulina* (ex. *Dukhanina*) *arabica* (Henson, 1948) described from the ‘Infravalanginian’ limestones and shales containing *Pseudocyclammina lituus* of subsurface Qatar (Dhukan wells), later erroneously assigned to the Hauterivian by Banner et al. (1991) and Whittaker et al. (1998) (see next chapter for biostratigraphic remarks on genuine *Pseudocyclammina lituus*). As indicated by Banner et al.

(1991), *P. arabica* has a quadriserial (juvenile) to triserial growth (adult), lacks a pseudo-keriothecal wall, the pillars are not triangular in axial sections (Banner et al., 1991, figs. 98, 102-104; Schroeder et al., 1975, pl. 2, fig. 1) and do not display the typical semi-lunular shape in transverse sections (e.g., fig. 4i, k). Moreover, the multiple foramina in the adult part of the central zone of *P. arabica* appear predominantly perpendicular to the septa (Banner et al., 1991, figs. 99, 102-104), while cross-wise oblique in *P. valanginiana*. Another difference is that *P. valanginiana* does not show a marginal thickening of the chamber. Therefore, the chamber height remains more or less constant from the marginal to central test area as remarked by Gušić (1969, p. 69).

Like *Barkerina dobrogiaca* (Neagu 2000) or *Valdanchella miliani* (Schroeder 1968) in the middle and western parts of Neotethys, *P. valanginiana* might represent a Valanginian marker taxon endemic to the Arabian Plate.

**BIOSTRATIGRAPHIC REMARKS**

The Fahliyan stratigraphic unit is regarded by most Iranian geologists as a Formation. However, this lithostratigraphic unit spans several stages from the Tithonian to the Barremian. In addition, considering the occurrence of regional unconformities, the Fahliyan should have been considered as a Group and subdivided into subunits, i.e., formations. However, until recently, the Fahliyan Formation was only divided into two informal members: a Lower Fahliyan Member and an Upper Fahliyan Member. As regards biostratigraphy, according to Jamaljan et al. (2011), the Fahliyan Formation of the Kuh-e Siah section spans both the ‘biozone 14’ of Wynd (1965), i.e., *Pseudocyclammina lituus*-*Trocholina* assemblage zone, for the "Neocomian", and his ‘biozone 15’ (Wynd, 1965), i.e., his *Choffatella*-*Cyclammina* assemblage zone, for the Barremian - Aptian. As documented herein, ‘biozone 14’ actually spans the Tithonian – lower Valanginian interval whereas ‘biozone 15’ spans the upper

Valanginian – lower Barremian interval. Besides, it is worth mentioning that the International Commission on Stratigraphy (unpublished report) has urged stratigraphers to abandon the use of the "Neocomian". Initially, the Neocomian was redefined as a superstage divided into two stages, the Valanginian and the Hauterivian, but, later its definition has changed to include the Berriasian and/or the Barremian. This instability justifies its abandonment. No further stage subdivision of the ‘Neocomian’ has been provided by Jamaljan et al. (2011) or in any more recent paper (e.g., Noori et al., 2019; Abedpour et al., 2020; Esrafil-Dizaji et al., 2020). Hosseini (2014; Hosseini et al., 2016, 2021) has introduced a new formation within the Fahliyan, i.e., the Sar Bisheh Formation, and renamed the upper Fahliyan as the Ghari Formation. Although the age ascriptions (i.e., interpretations) differ, it looks like these new units should be treated as unconformity bounded units, similar to their strict equivalent counterparts in the United Arab Emirates (see Table 2).

The studied section starts on top of the Hith Anhydrite at a boundary that is conventionally but erroneously treated as the Jurassic/Cretaceous boundary auct. (i.e., the Tithonian/Berriasian boundary) in the oil and gas industry. Based on its microfossil assemblage, the "lower Fahliyan" (samples RAP 10793-10822) is dated Tithonian – Berriasian. However, it should be noted that *Campbelliella striata* (samples RAP 10796-10819) is found quite high in the interval and, to date, its range is not thought to reach the middle Berriasian (Granier, 2019). Similarly, *Humiella catanaeformis* (samples RAP 10797-10798) is found quite low in the section and, to date, its range is not thought to reach the lower Berriasian. *Aloisalthella sulcata* (samples RAP 10803-10805) and *Otternstella lemmensis* (samples 10820-10821) are known both from the Tithonian and the Berriasian. The former is unknown from the upper Berriasian strata. It is suggested that parts of the Berriasian (middle-upper or upper) could be missing in the Kuh-e Siah section.

The next interval, named here "middle Fahliyan" (samples RAP 10823-10873), is an equivalent of both the

**Table 2.** Relationship of Iranian lithostratigraphic units and their Emirati counterparts.

IRAN	U.A.E.		Stages
Gadvan	Kharaiab		Barremian - lower Aptian
upper Fahliyan	Lekhwair		upper Valanginian - Lower Barremian
"middle" Fahliyan	Zakum		lower Valanginian
lower Fahliyan	Habshan Group	Belbazem	Berriasian
		Bu Haseer	Tithonian - Berriasian
		Habshan	Tithonian
Hith			Tithonian

Zakum Formation of Granier (2008) and the Sar Bisheh Formation of Hosseini (2014). Based on its microfossil assemblage, it is dated early Valanginian. It comprises the last occurrences of many species, e.g., *Pseudocyclamina lituus* and of a number of *Coscinoconus* spp. and *Salpingoporella* spp. (among which *Salpingoporella annulata*). *Parurgonina valanginiana* sp. nov. is restricted to this interval.

The last interval corresponds to the "upper Fahliyan" (samples RAP 10874-10888). It is poorly fossiliferous with rare occurrences of *Choffatella decipiens* (samples 10881), a rather long ranging foraminiferal species. Its last occurrence is Aptian (Furcata ammonite Zone in Abu Dhabi, according to Granier and Busnardo, 2013). According to Maksoud et al. (2014), it probably first appeared "in the Valanginian because it may derive from *Choffatella pyrenaica* Peybernès, 1976". In Oman, it is reported from the Lekhwair Formation, Hauterivian to early Barremian in age (Granier & Lethiers, 2017). Orbitolinids of 'biozone 16' of Wynd (1965), i.e., *Hensonella-Orbitolina-Choffatella* assemblage zone, are not found at the top of the section studied. Accordingly, the upper Fahliyan cannot be accurately dated and is ascribed here a generous range spanning the upper Valanginian to lower Barremian interval.

## CONCLUSION

As documented before elsewhere (Granier, 2019), it is not possible to identify the Tithonian/Berriasian boundary in the shallow-water limestones of the Zagros Mountains (Iran). In contrast, the Berriasian/Valanginian boundary is identified here because it corresponds to the marked lower/middle Fahliyan boundary with a hiatus at least equivalent to the late Berriasian. Pending new finds outside its known stratigraphic range and outside the Arabian Plate, *Parurgonia valanginiana* nov. sp., which is probably an endemic species restricted to the middle Fahliyan, could be used as a regional marker of the lower Valanginian.

The genus *Parurgonia* Cuvillier et al. is reported for the first time from Lower Cretaceous strata giving further evidence that the Jurassic–Cretaceous boundary (Tithonian–Berriasian) did not witness a remarkable extinction event of larger benthic foraminifera within shallow-water carbonate realms. The stratigraphic distribution of the gross homeomorphic *Paravalvulina arabica* against *P. valanginiana* in the Arabian Plate domain need further clarification.

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