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# Benthic foraminiferal and calcareous algal biostratigraphy of the Fahliyan Formation in oil well X1, Dorood Oilfield, Persian Gulf

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**Abstract**

The Dorood oilfield is located offshore in the northern part of the Persian Gulf. It partly underlies the Kharg Island. The Neocomian Fahliyan Formation represents the high-quality reservoir in the oilfield. It includes five carbonate members: The Manifa, Middle and Upper Yamama, Khami and Lower Ratawi. The Fahliyan Formation in the studied well attains a thickness of 378.1 m and mainly consists of thin-bedded limestones. It unconformably overlies the evaporate Hith Formation and conformably underlies the Gadvan Formation. An integrated biostratigraphic (benthic foraminifera and algae) and lithostratigraphic study is presented. Paleontological studies led to the identification of 19 genera and 29 species of benthic foraminifera and 10 genera and 9 species of calcareous algae. Two biozones of Berriasian through Valanginian age have been recognized. These are *Lithocodium aggregatum-Salpingoporella muehlbergii* assemblage zone (Valanginian) and *Pseudocyclammina lituus- Coscinoconus* assemblage zone (Berriasian-Valanginian).

**Keywords***: Fahliyan Formation, Foraminifera, Calcareous Algae, Berriasian-Valanginian, Dorood Oilfield.*

## Introduction and geological setting

The Mesozoic carbonate systems of the Arabian Plate form one of the richest hydrocarbon provinces of the world. This is mostly due to the combination of their large scale and the presence of source rock, reservoir, and seal facies within the same depositional system (Murris, 1980). The Zagros Mountain is southern part of an Alpine orogenic belt (Stöcklin, 1968). It extends from southeastern Turkey through northern Syria, Iraq to western and southern Iran (Alavi, 2004; Falcon, 1994). By the end of Mesozoic time, the principle paleogeographic features of southwestern Iran are represented by the main trough of the Neotethys to the north and a smaller minor trough which runs from eastern Iraq (Motiei, 1993).

The Fahliyan Formation is named after a village in the Fars province. The type-section is located in the southern flank of Kuh-e-Dal near the Fahliyan village. It attains a thickness of about 360 m. The Fahliyan formation is dominated by thick-bedded to massive, oolithic and pelletic limestones. At the type locality, the Fahlyian Formation conformably overlies dark brown dolostone of the Surmeh Formation. It is conformably overlain by a continuous succession of marls and limestones of the Gadvan Formation (Stöcklin & Setudehnia, 1991).

The Fahliyan Formation represents an oil and gas-bearing rock unit within the Khami Group (James & Wynd, 1965) (Figure 1). It is best developed in Fars province, but also recorded in northeastern Khuzestan and Lurestan. The transition from the Fahliyan Formation to dark shales and limestones of the Garau Formation is visible in the southwestern Lurestan and Khuzestan (Stöcklin & Setudehnia, 1991).

In this study, the biostratigraphy of the Berriasian-Valanginian successions from oil well X1 in the Dorood oil field, Persian Gulf is presented (Figure 2).

Dorood oil field is the largest Iranian offshore oil field discovered in 1961. It is 25 km long and 5 km wide, located offshore in the northern part of the Persian Gulf. The Dorood structure is an elongated anticline plunging toward north and northeast approximately 25 km long and 5 km wide (Figure 3). The Fahliyan Formation in the studied well is recovered at depths of 3210.1 m to 3588.2 m.

Although many articles have been published on the facies, depositional environment, sequence stratigraphy, geochemistry and paleoenvironmental reconstruction Gollesstaneh including (1965), James & Wynd (1965), Kalantari (1975, 1976),

Shakib (1994), Mohammad-Khani (2003), Afghah (2006), Lasemi & Feyzi (2007), Hosseini & Conrad (2008), Rastegar Lari (2009), Mosadegh & Parvaneh Nejad Shirazi (2009), Adabi *et al.* (2010), Feghhi (2010) and Jamalian *et al.* (2011), the stratigraphic setting of the Fahlyian Formation has received very little attention. The aim of this paper is to present Lower Cretaceous lithostratigraphic and biostratigraphic data for the Fahliyan Formation and to propose a zonal scheme on the basis of benthic foraminifera and calcareous algae.

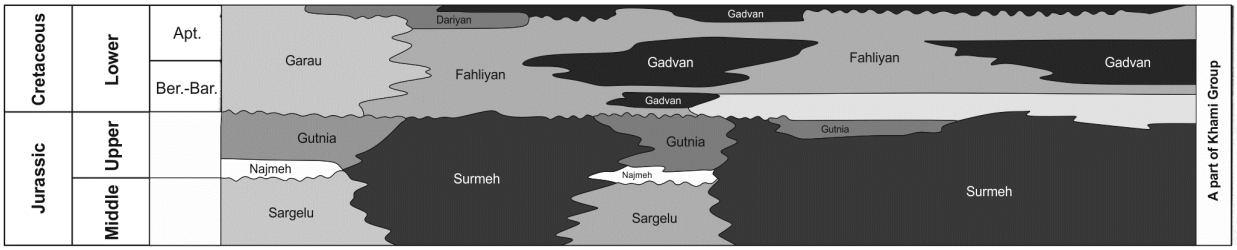


Figure 1. Lithostratigraphic chart of the Cretaceous of the Arabian Plate (James & Wynd (1965) with minor changes.


Figure 2. The location map of the studied area.

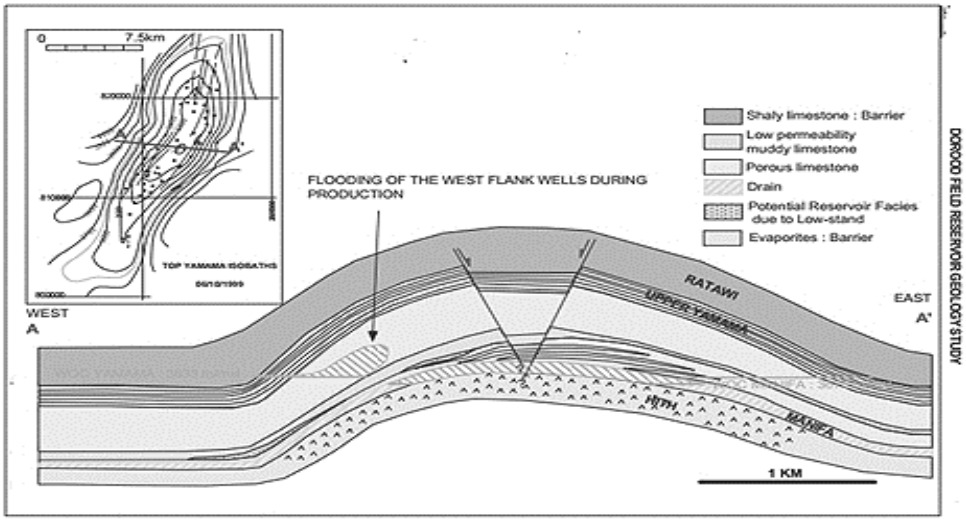


Figure 3. Conceptual geological model of the Fahliyan Formation (Yamama, Manifa and Ratawi members) reservoirs with dynamic parameters (IOOC, 2000).

## Material and methods

Detailed paleontological investigations have been carried out on one oil well in Dorood oilfield supported by the analysis of 250 thin-sections which are made of provided cores by the Iranian Offshore Oil Company (IOOC). Vertical distribution of determined taxa allowed identification of biozones. Taxonomic interpretations include generic attributions of the benthic foraminiferal taxa based on Loeblich and Tappan's (1987) and the latest classification of agglutinated foraminifera by Kaminski (2014) and Rigaud *et al*. (2013) (new achievement on Involutinina) also supplemented by the algae publications e.g. Gollesstaneh (1965), James & Wynd (1965), Dieni & Radoičić (1999), Husinec & Sokač (2006), and Hosseini & Conrad (2008).

## Results and discussion

*Lithostratigraphy*

The Fahliyan Formation is 378.1 m thick in the studied oil well. It is represented by limestone, dolostone and argillaceous limestone and marl. This lithostratigraphic unit can be divided into five members as follow (from base to top) (Figure 4):

*Manifa member (50.3 m)*:

This member consists of gypsiferous marl, chalky oolitic limestone with scattered anhydrite-crystals, limestone and chalky bituminous marl.

*Middel Yamama member (166 m)*:

This member consists of alternating suboolitic, oolitic limestone, calcarenite/detrital limestone, recrystallized chalky limestone and dolostone.

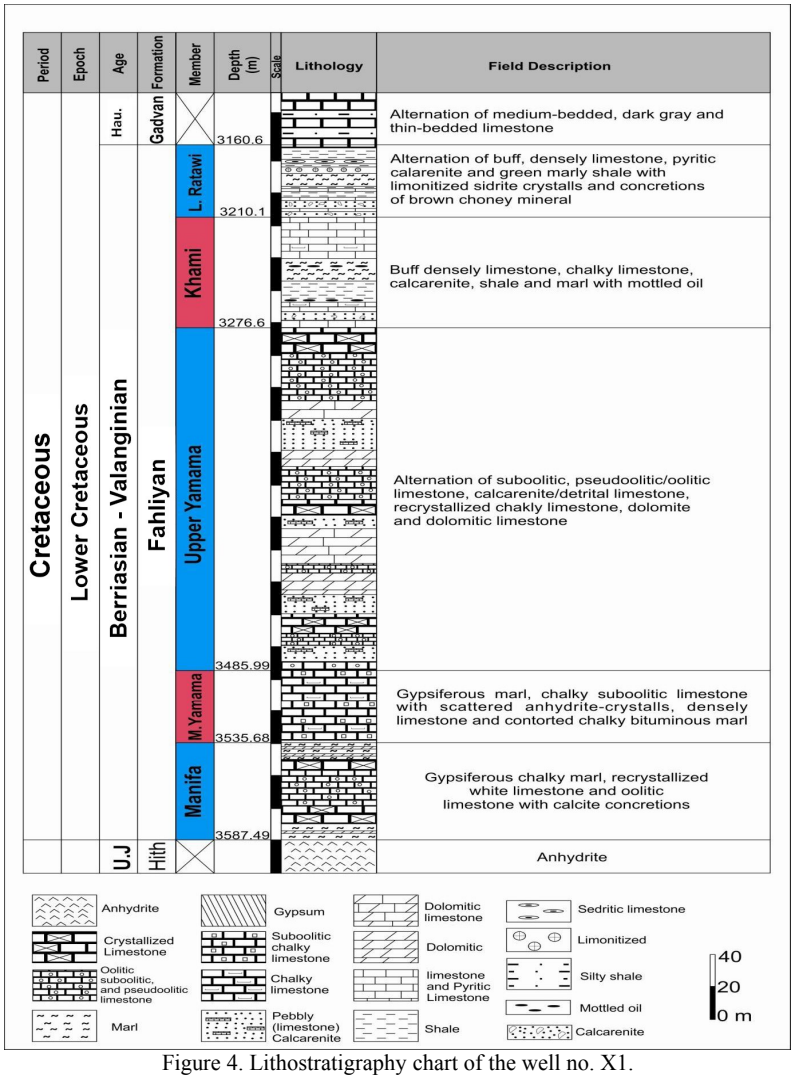


Figure 4. Lithostratigraphy chart of the well no. X1.

*Upper Yamama member (95 m)*:
The Upper Yamama member is the first reservoir member. It consists of buff dense limestone, chalky and calcarenite limestone, shale and marl with mottled oil.
*Khami member (66.8 m):*
It consists of alternating buff, densely limestone, pyritic calarenite and green marly shale with limonitized sidrite crystals.
*Lower Ratawi (49.5 m)*:
It consists of alternating buff, densely limestone, pyritic and glauconitic (in some parts), calarenite and brown to green marly shale with limonitized sidrite crystalls and concretions of brown choney mineral.

**Biostratigraphy**

There are many references on the biostratigraphy of Berriasian/Valanginian shallow-water benthic foraminifera and algal assemblages (e.g. Gollestaneh, 1965; Conrad, 1977, Jaffrezo & Renard, 1979; Jaffrezo *et al*., 1980; Bucur *et al.*, 1995; Bucur *et al.*, 2004; Ivanova & Kolodziej, 2004; Dragastan & Schlagintweit, 2005; Bucur & Săsăran, 2005; Husinec & Sokacˇ, 2006; Kobayashi & Vuks, 2006; Krajewski & Olszewska, 2007; Bruni *et al*., 2008; Hosseini & Conrad, 2008; Parvaneh Nejad Shirazi, 2008; Mosadegh & Parvaneh Nejad Shirazi, 2009; Ivanova & Kolodziej, 2010; Jamalian *et al.,* 2011). Foraminifera are represented by *Belorusiella* sp. (Pl. 1, Fig. r), ?*Belorusiella* sp. (Pl. 1, Fig. s), *Charentia* sp. cf. *Ch. cuvillieri* Neumann (Pl. 2, Fig. i), *Charentia* sp. (Pl. 1, Fig. q), Chrysalidinid (Pl. 1, figs. t-w), *Comittosphaera sublapidosa* (Vogler) (Pl. 1, Fig. n), *Debarina hahounerensis* Fourcade, *Coscinoconus alpinus* Leupold, *Coscinoconus altispira* (Henson), *Coscinoconus chouberti* (Hottinger), *Coscinoconus campanella* (Arnaud-Vanneau, Boisseau & Darsac), *Coscinoconus delphinensis* (Arnaud-Vanneau, Boisseau & Darsac) (Pl. 1, figs. c-d), *Coscinoconus elongatus* Leupold (Pl. 1, Fig. e; Pl. 2, figs. a-b, g), ?*Coscinoconus elongata* (Pl. 1, figs. d-e), *Coscinoconus sagittaria* (Arnaud-Vanneau, Boisseau & Darsac) (Pl.2, Fig.c), *Coscinoconus* sp., Cyclaminid (Pl. 2, Fig. o), *Eomarssonella paraconica* Levina, *Frentzenella* sp. (Pl. 1, figs. a-b; Pl. 2, Fig. f), *Haplophragmoides joukowski* Charollais, Brönnimann and Zaninetti, *Haplophragmoides* sp., *Istriloculina elliptica* (Iovcheva), *Lenticulina* sp. (Pl. 1, figs. l-m), Lituolid (Pl. 1, fig. o), *Mayncina bulgarica* Laug, Peybernès & Rey (Pl. 1, Fig. h), Miliolidae, *Nautiloculina broennimanni* Arnaud-Vanneau & Peybernès (Pl. 1, figs. j, k, p), *Nautiloculina cretacea* Arnaud-Vanneau & Peybernès, *Nautiloculina* sp. (Pl. 1, Fig. f), *Neotrocholina aptiensis* (Iovcheva), *Novalesia distorta* Arnaud-Vanneau, *Peudocyclammina lituus* (Yokoyama) (Pl. 1, Fig. i; Pl. 2, Fig. n), *Pseudocyclammina* sp., *Praechrysalidina* sp. (Pl. 1, Fig. g), *Paravalvulina arabica* Henson (Pl. 2, figs. h, s), *Paravalvulina conica* Henson (Pl. 2, Fig. r), *Paravalvulina* sp., *Pseudotextularia* sp., *Quinqueloculina semisphaeroidalis* Danitsch, *Redmondoides* sp., *Redmondoides lugeoni* (Septfontaine) (Pl. 2, Fig. p), *Redmondoides* sp. (Pl. 2, Fig. q), *Reophax*? *rhaxelloides* Schlagintweit, Auer & Gawlick (Pl. 2, Fig. m), *Textularia depravatiformis* Bielecka & Kuznetsova and *Textularia* sp. Algae are represented by *Actinoporella* ? *podolica* (Alth)*, Bacinella irregularis* Radoičić (Pl. 3, figs. a-b), *Boueina hochstetteri* Toula*, Cayeuxia* sp.*, Iranella inopinata* Gollestaneh*, Lithocodium aggregatum* Elliott*, Neomizza* sp.*, Permocalculus inopinatus* Elliott, *Permocalculus* sp.*,* Rivulariacean-type cyanobacteria*, Otternstella lemmensis* (Bernier) (Pl. 3, Fig. g)*, Salpingoporella muehlbergii* (Lorenz) (Pl. 3, Fig. c)*, Salpingoporella* sp. (Pl. 3, Fig. i)*,* ?*Salpingoporella* sp. (Pl. 3, figs. f, k), *Salpingoporella* sp. cf. *S. pygmaea* (Gümbel) (Pl. 3, Fig. d), *Rajkanella* sp. (Pl. 3, Fig. h) and *Terquemella* sp. The micropalaeontological associations in oil well number X1 include both foraminifera and algae composed mostly of taxa with stratigraphic ranges through the Berriasian-Valanginian.

Among identified benthic foraminiferal taxa from the Fahliyan Formation, *Reophax*? *rhaxelloides* is one of the most important taxa previously introduced from the Kimmeridgian and Tithonian reefal limestones of the Alpine Plassen carbonate platform in Northern Calcareous Alps of Austria (as well as Germany and Romania) by Schlagintweit *et al*. (2007). This is the first report of this taxon from the Berriasian strata in Iran. Schlagintweit *et al.* (2007) have indicated that *Reophax*? *rhaxelloides* can be found in younger strata than Tithonian. This fact is proven for the first time from the Fahliyan Formation in Zagros sedimentary basin with a Berriasian-Valanginian age (Figure 5).

**Identified biozones of the Fahliyan Formation in the studied well**

According to the studied thin-sections and identified taxa, two local biozones are established

as follow (Table 1 and Figure 6):

*Lithocodium aggregatum-Salpingoporella muehlbergii* assemblage zone:

Biostratigraphic interval represented by the abundance of *Lithocodium aggregatum* and *Salpingoporella muehlbergii*. The thickness of this interval is about 147 m. (depth of 3367 to 3514 m.). It represents the lower part of the oil well and Valanginian age.

Table 1: Biozonation of the Early Cretaceous in the Zagros basin, in southwest of Iran based on previous studies and present study (Abbreviations in the table: Pc. *Pseudocyclammina conica* (Critical note: this benthic fauna is not yet reported from any other paper except Afghah (2006). So the authors suggest it must be redetermine by him again), Pg. *Pseudocyclammina greigi*, Ca. *Calpionella alpina*).

| Age | Sissingh (1977) | | Gollestaneh (1965) | | Wynd (1965) | | Shakib (1994) | Hashemi *et al.* (2006) | Afghah (2006) | This Study | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Foraminifera | Algae |
| **Hauterivian** | B3 | C | | *Pseudocyclammina lituus-Dokhania arabica* Algal zone II | | *Pseudocyclammina lituus-Trocholina* Assemblage zone 14 | *Pseudocyclammina lituus* | | *Pseudocyclammina lituus* | | |
| | | B | | | | | | *Pseudocyclammina lituus* | | | |
| | | A | | | | | | | | | |
| **Valanginan** | B2 | | Tintinid zone III | | *Calpionella*-Spicules Assemblage zone11 -11a | | *Pseudochrysalidina arabica* | *Pseudochrysalidina arabica* | | | *Lithocodium aggregatum-Salpingoporella muehlbergii* assemblage zone |
| **Berriasian** | B1 | | | | | | | | Pc | *Pseudocyclammina lituus - coscinoconus* assemblage zone | |
| | | | | | | | | | Pg | | |
| | | | | | | | | | Ca | | |

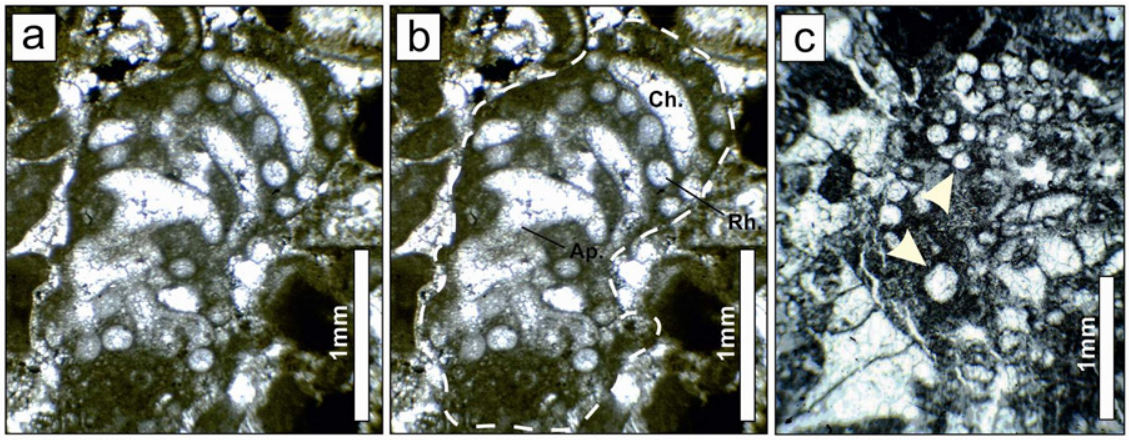


Figure 5. a-b. *Reophax*? *rhaxelloides* (benthic foraminifer) from depth 3423 m and 3465 m, c. Bioclastic microfacies with debris of *Bacinella irregularis* and abundant rhaxellid sponge microscleres which are shown by white arrows. (Abbreviations: Ch.: Chamber, Ap.: Aperture, Rh.: rhaxes).

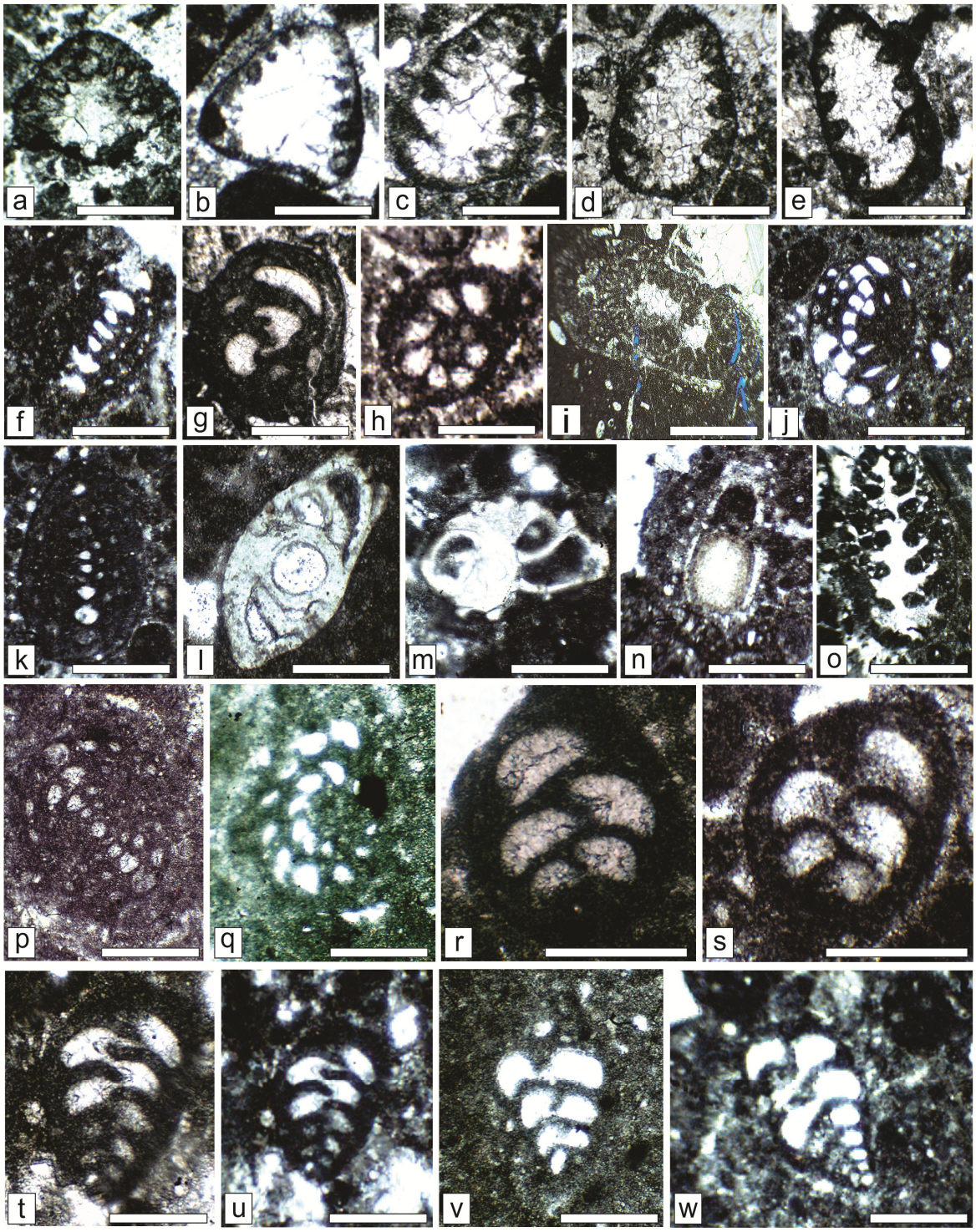


Plate 1. (a-b) *Frentzenella* sp. (Sample no. 3466, 3467.70), (c-d) *Coscinoconus delphinensis* (Sample no. 3466, 3465.58), (e) *Coscinoconus elongata* (Sample no. 3471.98), (f) *Nautiloculina* sp. (Sample no. 3504, 3503, 3507), (j, k, p) *Nautiloculina broennimanni* (Sample no. 3504, 3503, 3507), (g) *Pseudochrysalidina* sp. (Sample no. 3465.58), (h) *Mayncina bulgarica* (Sample no. 3474), (i) *Pseudocyclammina lituus*, l-m. *Lenticulina* sp. (l: Sample no. 3503.68, m: Sample no. 3504.90), (n) *Comittosphaera sublapidosa* (Sample no. 3506.73), (o) Lituolid (Sample no. 3506.73), (q) *Charentia* sp. (Sample no. 3507), (r) *Belorussiella* sp. (Sample no. 3505), (s) ?*Belorussiella* sp. (Sample no. 3510.38), (t-w) Chrysalidinid foraminifer (Sample no. 3507, 3503.98, 3505) (Scale bars: 150 µm).

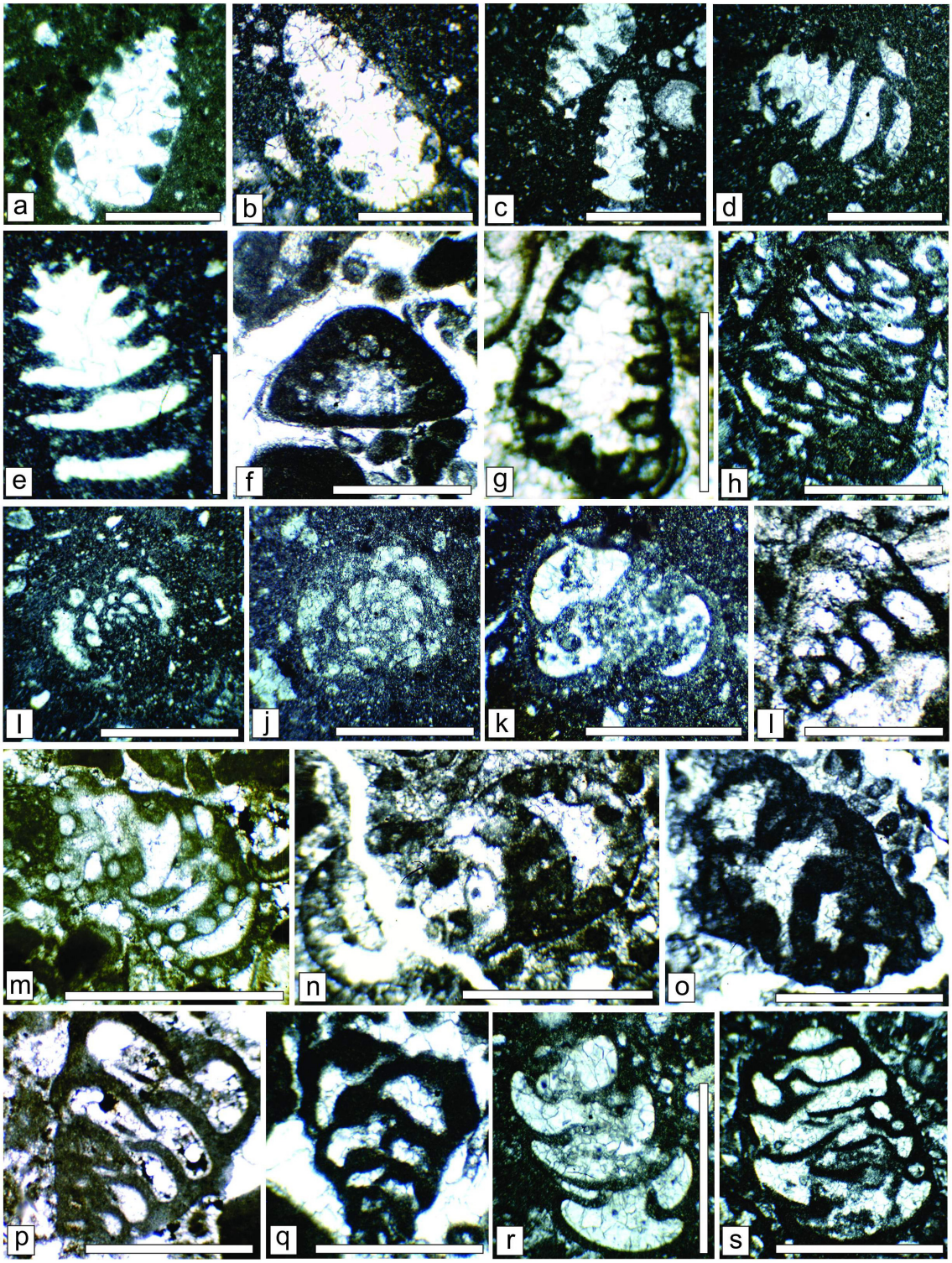


Plate 2. (a-b, g) *Coscinoconus elongata* (Sample no. 3363.77, 3446.37, 3388.46), (c) *Coscinoconus sagittaria* (Sample no. 3367.43), (d-e) ?*Coscinoconus elongatus* (Sample no. 3363.47, 3367.74), (f) *Frentzenella* sp. (Sample no. 3387.55), (h, s) *Paravalvulina arabica* (Sample no. 3365.91), (i) *Charentia* sp. cf. *Ch. cuvillieri* (Sample no. 3367.43), (j-k) indet agglutinated benthic foraminifera (Sample no. 3368), (l) indet biserial benthic foraminifera (Sample no. 3402.48), (m) *Reophax*? *rhaxelloides* (Sample no. 3423.21), (n) *Pseudocyclammina lituus* (Sample no. 3392.42), (o) Cyclaminid indet (Sample no. 3392.73), (p) *Redmondoides lugeoni* (Sample no. 3423.21), (q) *Redmondoides* sp. (Sample no. 3387.55), (r) *Paravalvulina conica* (Sample no. 3365.91) (Scale bars: 150 µm).

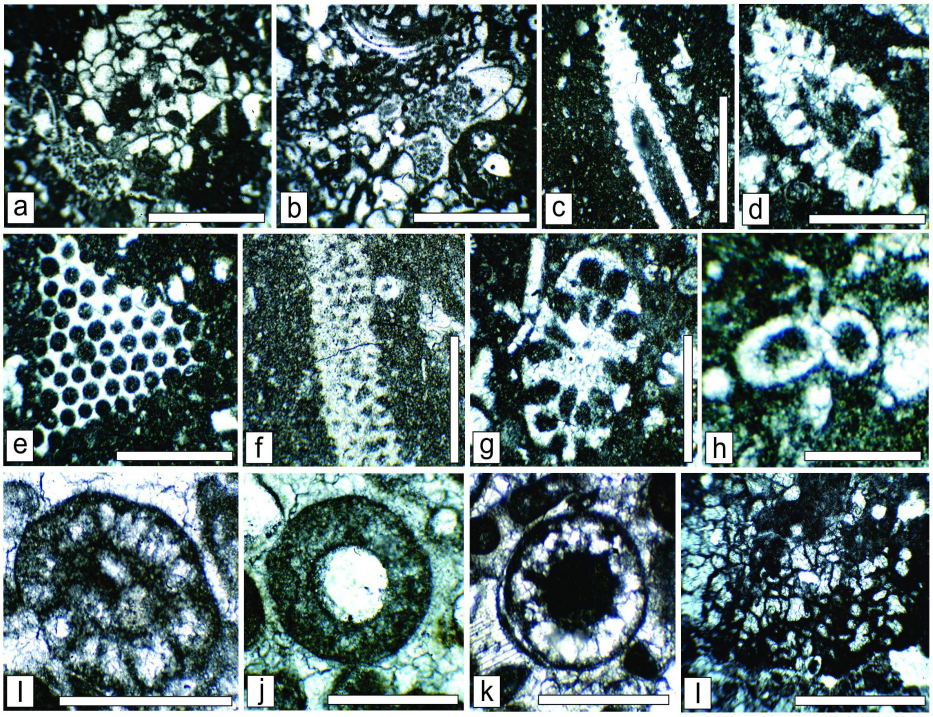


Plate 3. (a-b) Bacinellid fabrics (Sample no. 3507, 3502), (c) *Salpingoporella muehlbergii* (Sample no. 3367.43), (d) *Salpingoporella* sp. cf. *S. pygmaea* (Sample no. 3363.47), (e) Tangential section of an indet. dasyclad alga (Sample no. 3367.43), (f) ?*Salpingoporella* sp. (Sample no. 3363.47), (g) *Otternstella lemmensis* (Sample no. 3363.47), (h) a part of *Rajkanella* sp. (Sample no. 3363.47), (i) *Salpingoporella* sp. (Sample no. 3390.29), (j) indet dasycladalean algae (Sample no. 390.29), (k) ?*Salpingoporella* sp. (Sample no. 3386.94) (Scale bars: 150 µm).

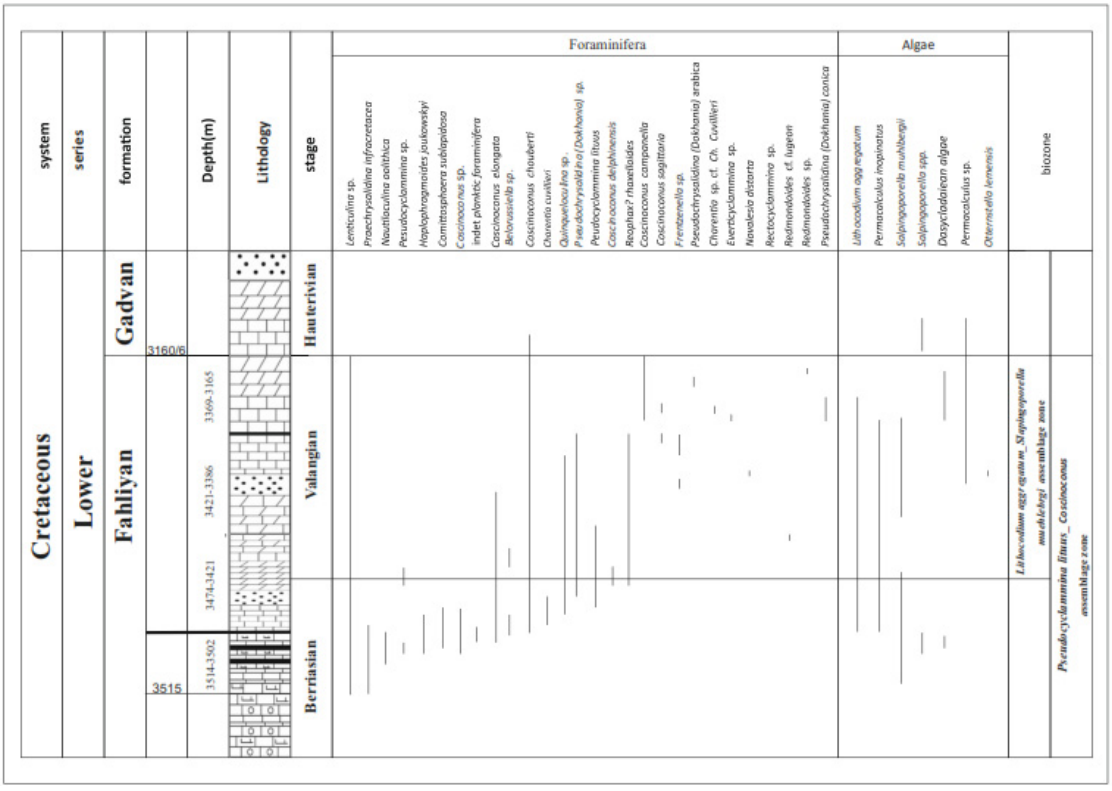


Figure 6. Biostratigraphic distribution of the most important benthic foraminifera and calcareous algae from the studied well no. X1.

*Pseudocyclammina lituus- Coscinoconus* assemblage zone

Biostratigraphic interval represented by the abundance of *Pseudocyclammina lituus* and *Coscinoconus*. The thickness of this interval is about 88 m. (depth of 3368 to 3456 m.) This biozone represents the upper part of the oil well and suggests a Berriasian-Valanginian age. This is marked by the last appearance of *Paravalvulina arabica* and the first occurrence of *Pseudocyclammina lituus*. This interval is equivalent with the *Pseudocyclammina lituus–Trocholina* Assemblage Zone no. 14 by Wynd (1965), also with upper part of the *Pseudocyclammina lituus-Paravalvulina arabica* zone no. 1 (Gollestaneh, 1965), *Pseudocyclammina lituus* Zone in Kuh-e-Surmeh in Zagros basin (Abyat *et al.*, 2012a,b; 2014) and *Pseudocyclammina lituus-Trocholina* Assemblage Zone at Kuh-e-Siah (Abedpour *et al*., 2016) (for more data see Table1). This biozone is introduced as a local biozone in this study.

## Conclusions

In the oil well no. X1, Dorood oilfield in the Khark Island, the Fahliyan Formation unconformably overlies the evaporate Hith Formation and conformably underlies the Gadvan Formation. It is represented mainly by thin-bedded limestones. Microbiostratigraphical studies led to identification of 19 genera and 29 species of benthic foraminifera and 10 genera and 9 species of calcareous algae. According to determined microfossil assemblages, two local biozones are introduced: *Lithocodium aggregatum-Salpingoporella muehlbergii* assemblage zone (Valanginian) and *Pseudocyclammina lituus-Coscinoconus* assemblage zone (Berriasian-Valanginian). The Lower Cretaceous (Berriasian-Valanginian) age is suggested for the Fahliyan Formation in the studied oil well. Benthic foraminifer *Reophax*? *rhaxelloides* previously introduced from the Late Jurassic of Austria, Germany and Romania has been recorded for the first time in Berriasian-Valanginian strata in the Zagros sedimentary basin.

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