

Biostratigraphic and Lithostratigraphic Study of Fahliyan Formation in Kuh-E-Siah (Arsenjan Area, North-East of Fars Province)

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Abstract

Fahliyan Formation is importance in terms of Zagros stratigraphy since it is one of the oil reservoir rocks at the Jurassic-Cretaceous boundary. This rock unit consists of two types of deep and shallow facies in Zagros area. Recognition of bio-zones as well as discontinuity or continuity between the studied formation and the encompassed strata is taken into consideration. In order to study biostratigraphy on Fahliyan Formation, the stratigraphic section of Kuh-e-siah in the north-east of Fars Province was selected. In this section, Fahliyan Formation is measured 345 m consisting of thin to medium-bedded of limestone with the interbeds of sandy and dolomitic limestones. Fahliyan Formation conformably overlies Surmeh formation and underlies the marls of Gadvan formation. Vertical distribution of the identified foraminifers and calcareous algae confirms presence of 3 biozones in the sediments of Fahliyan Formation, as follows: 1) *Calpionella alpina zone*, 2) *Pseudochrysalidina conica zone*, 3) *Pseudocyclamina lituus-Trocholina sp. assemblage zone*. Based on Established biozones, the age of Fahliyan Formation in Kuh-e-Siah section was determined from Berriasian to Late Hauterivian.

Keywords

Biostratigraphy, Lithostratigraphy, Fahliyan, Zagros, Iran

1. Introduction

Neocomian and Barremian sediments in Persian Gulf and Zagros area have been introduced with Fahliyan, Gadvan and Garau Formations. These sediments in Zagros area have changed in terms of bio and lithofacies, laterally during the Neocomian age,

confirming the tectonic and paleogeographical settings of the Zagros basin. Thus, the mentioned sediments with shale neritic, carbonate, hemipelagic and pelagic facies in Fars, south of Dezful and southeast of Persian Gulf and with Fahliyan and Gadvan Formations in the north of Dezful embayment, Lorestan and north-west of Persian Gulf have been introduced as Garau, Fahliyan and Gadvan Formations, respectively.

Studying the Biostratigraphy of the Jurassic-Cretaceous sequence reveals regression between the mentioned strata in different parts of Zagros as well as its better comparison with other regions in the Arabian Plate Aghanabati A. (1998) [1].

Facies analysis of the Jurassic-Cretaceous succession, determining the relationship between the sequences formed by the sea-level fluctuation, tectonic setting, rate of sediment supply and age determination of the mentioned strata based on the bio and lithofacies would make it possible to present the sedimentary model and establish a conformity between the currently set sequences and other parts of the Iranian and Arabian Plates.

Since studies on Fahliyan Formation have been focused on the oil-rich regions of southern Iran and there are few studies at this level on biostratigraphy, microfacies and sedimentary environment of Fahliyan Formation in the interior and coastal Fars, e.g. Abyat *et al.* (2016), Abyat *et al.* (2014), Abyat *et al.* (2013) [2] [3] and Afghah (2006) [4].

2. Methods and Materials

In order to study biostratigraphy, Kuh-e Siah was selected which was one of stratigraphic section of Fahliyan Formation. Lower and Upper lithostratigraphic limits were determined by detail field work, 240 samples were collected from selected section; then, thin sections were prepared from each sample for microscopic investigation. According to Abyat *et al.* (2016) [2] [3], Lopez-Martinez *et al.* (2015) [5], Krische *et al.* (2013) [6], Abyat *et al.* (2012) [2], Petrova *et al.* (2012) [7], Granier *et al.* (2011) [8], Turi *et al.* (2011) [9], Ivanova and Koldzziej (2010) [10], Hossieni and Conrad (2008) [11], Jozsa and Aubrecht (2008) [12], Afghah (2006) [4], Canudo (2002) [13], Danelian *et al.* (1997) [14], Deloffre (1988) [15] and Dragestan (1982) [16], the foraminifers and calcareous algae were determined. Investigation of foraminifer and calcareous algae stratigraphic distribution led us to established biozones and age determination of Fahliyan in Kuh-e-Siah.

3. Geographical and Geological Setting

The studied section is located at southwest of Arsanjan (Figure 1). The geographical coordinates (latitude and longitude) of this section are 29° 47' 52" N and 53° 12' 04" E, respectively (Figure 2).

Based on Alavi (2004) [17], Zagros is divided into three major structural zones which are Simply-Folde, Imbricated and Metamorphic zones. Kuh-e-Siah stratigraphic section is located in Simply-Folded zone of the Zagros. Actually, structure of the Kuh-e-Siah is referred to an anticline with SW-NE trend similar other structures of the Zagros area

[18]. It consists of well exposed of Jurassic though Cenomanian sequence (Surmeh, Fahliyan, Gadvan, Dariyan, Kazhdumi and Sarvak formations). Studied section is assigned to Interior Fars area by James and Wynd (1965) [19]. In this section, Fahliyan Formation is encompassed by Surmeh (mid to late Jurassic) and Gadvan (Barremian) continuously (Figure 3).

4. Lithostratigraphic Units

Fahliyan Formation in Kuh-e-Siah section with the thickness of 345 m conformably overlies Surmeh formation and is lithologically inseparable; further, it is underlied by the marls of Gadvan formation and covers limestone of Surmeh formation. Lithologically, this rock unit divided into five lithostratigraphic units as follows (Figure 4).

- 1) The initial 63 m of this Formation is composed of cream thin-bedded to massive-colored dolomitic limestone with an interbed sandy limestone. This unit continuously lies over the dolomitic limestone of Surmeh Formation (Unit 1).

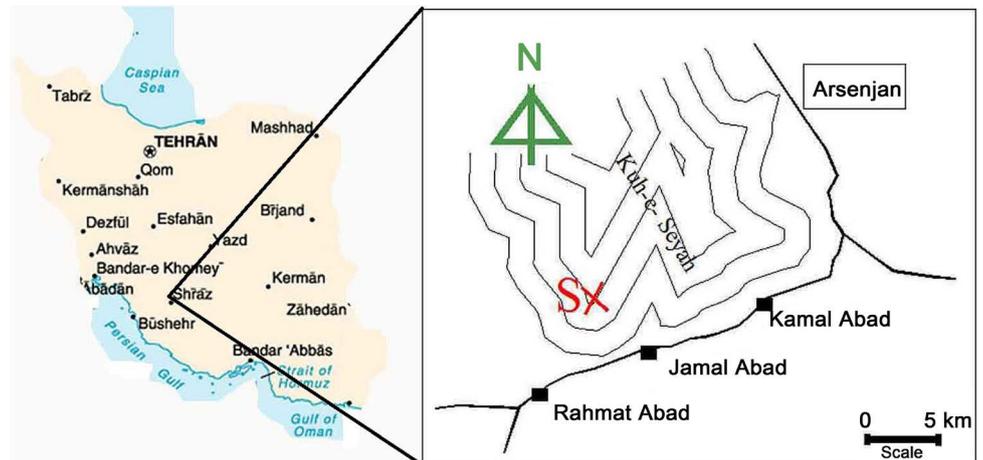


Figure 1. Geographical location of Fahliyan Formation in Kuh-e-Siah section.

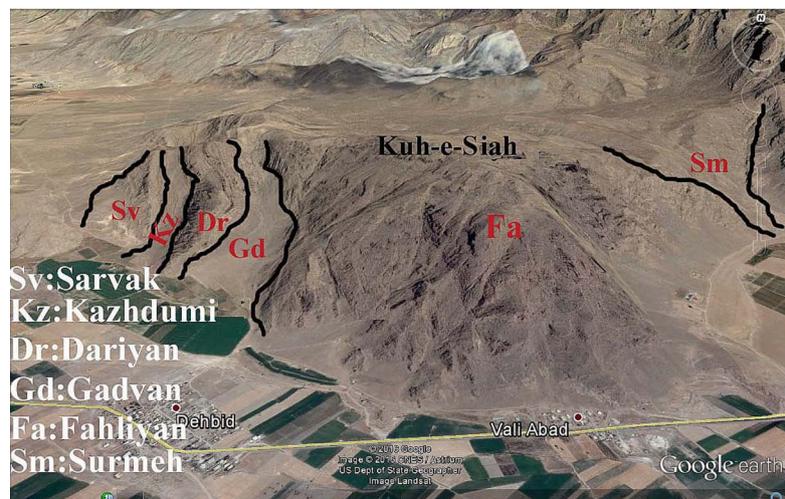


Figure 2. Satellite image of Formations in the region.

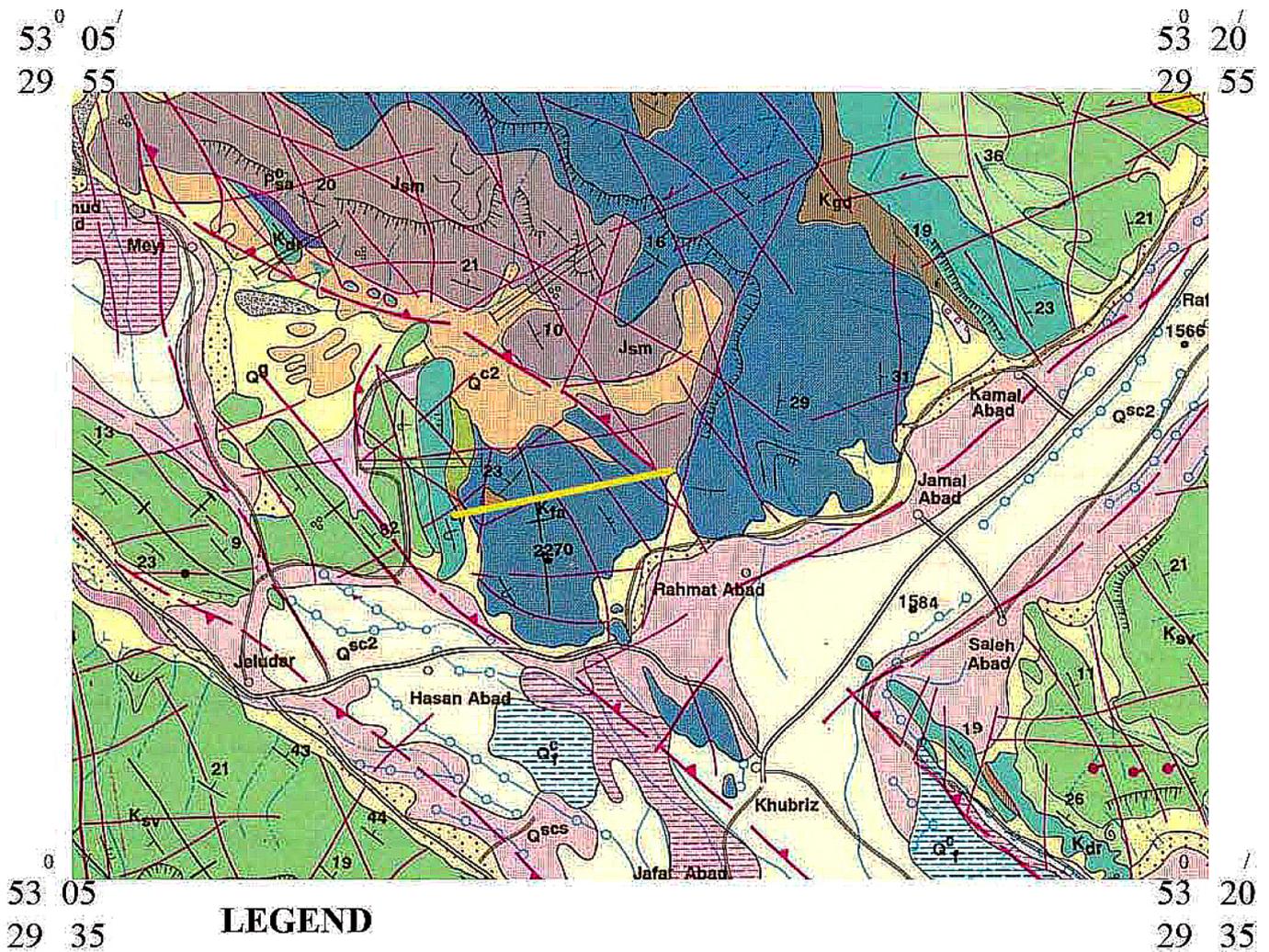


Figure 3. Geological map of Fahlyan Formation outcrop in stratigraphic section of Kuh-e-Siah (adopted from Arsanjan 1/100,000 map, Geological Survey and Mineral Exploration of Iran).

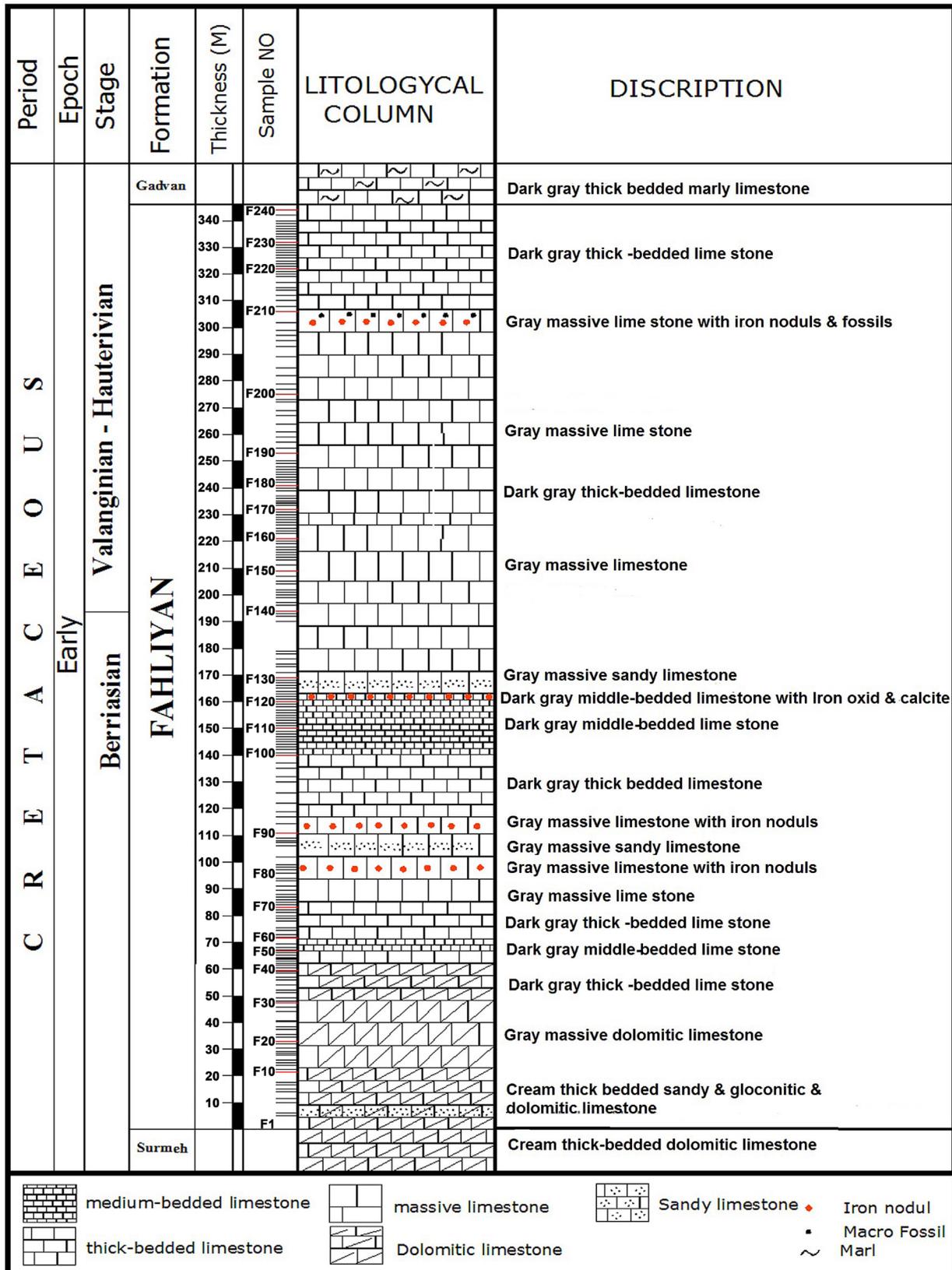


Figure 4. Stratigraphy column of Fahliyan Formation in Kuh-e-Siah section, Arsanjan.

- 2) The second unit is described by 77 m of dark gray thick-bedded to massive limestone with interbeds of sandy limestone and iron nodules.
- 3) The third unit is covered by 30 m of dark gray medium-bedded limestone and, in the upper part, sandy limestone along with a small amount of iron nodules (Unit 3). It is better to add Unit 2 and 3 in this form: Alternation of dark gray medium to thick bedded with massive limestone and an interbed sandy limestone which is extended approximately 107 m. This unit overlies the Unit 1.
- 4) The Unit 4 is determined by of gray thick to massive Limestone which is measured approximately 128 m.
- 5) 47 m of massive gray-colored limestone with iron nodules and it terminates to dark gray thick-bedded to massive limestone (Unit 5) which lies under the marly limestone of Gadvan Formation.

5. Biostratigraphy and Biozonation

Stratigraphic distribution of identified foraminifers supports three biozones in the Fahliyan section of Kuh-e-Siah. According to the studies, the last presence of *Pfenderina salernitana* (Sartonia and Crescenti) is coeval with the first appearance of *Calpionella alpina* Lorenz which indicates of the Lower biostratigraphic limit of Fahliyan Formation. The upper limit of Fahliyan Formation with Gadvan Formation is identified with to the first occurrence of the *Choffatella decipiens* Schlumberger that continuously overlies the Fahliyan Formation. Moreover, three biozones have been identified for Fahliyan Formation's sediments in Kuh-e-Siah section, including:

Bizone 1: *Calpionella alpina* zone

This zone comprises the lower part of Fahliyan Formation in Kuh-e-Siah section in Arsanjan and immediately overlies the dolomitic limestone sediments of Surmeh Formation. As mentioned before, the first presence of *Calpionella alpina* Lorenz marks the lower biostratigraphic limit of the Fahliyan Formation which is synchronous with disappearance of *Pfenderina salernitana* (Sartonia and Crescenti). This zone has is measured approximately 185 m and is composed of dolomitic limestone and massive limestone with sandy limestone interlayers. The faunal assemblage of this zone consists of:

Calpionella sp., *Calpionella oblonga* Cadisch, *Paleotextolaria* sp., *Marsonella trochus* (D'Orbigny), *Marsonella* sp., *Lenticulina* sp., *Pseudolithunella* sp., *Fenestrella dunnington*, Elliot, *Miliolid*, *Trocholina* sp., *Trochulina elongata* (Leupold), *Trocholina arabica* Schlumberger, *Praeochrysalidina infracretacea* Luperto Sinni, *Pseudochrysalidina* sp., *Nautiloculina oolitica* Mohler, *Novalesia distorta* Arnaud-Vanneau and diagnosed calcareous algae are consisted of *Lithocodium aggregatum* Elliot, *Acicularis* sp., *Permocalculus inopinatus* Elliot.

The age of this zone is determined as Berriasian.

Biozone 2: *Pseudochrysalidina conica* zone

This zone is described by disappeared of *Calpionella alpina* Lorenz which is coeval with of the presence of *Pseudochrysalidina conica* Henson. This zone has the thickness of 40 m and comprises of gray massive limestone. It is associated with the following

species of foraminifera:

Calpionella sp., *Calpionella oblonga* Cadisch, *Crassicollaria colomi* Doben, *Pseudochrysalidina arabica* Henson, *Lenticulina* sp., *Pseudolithunella* sp., *Miliolid*, *Trocholina* sp., *Trocholina elongata* (Leupold), *Praechrysalidina infracretacea* Luperto Sinni, *Pseudochrysalidina conica* Henson, and calcareous algae *Lithocodium aggregatum*, *Permocalculus inopinatus* Elliott.

The foraminiferal assemblage and calcareous algae of this biozone indicates early Valangian age.

Biozone 3: *Pseudocyclammina lituus*, *Trocholina* Assemblage zone

This zone is marked by the first presence of *Pseudocyclammina lituus* Yokoyama and various taxa of *Trocholina*. *Pseudocyclammina lituus*, *Trocholina* Assemblage zone is bounded by the first occurrence *Chofatella decipensis* Schlumberger. This zone is 120 m thick and contains gray thick bedded limestone with interbeds containing abundant iron nodules and fossils. This zone is associated with the following species of foraminifera:

Crassicollaria colomi Doben, *Calpionella* sp., *Marsonella trochus* (D'Orbigny), *Lenticulina* sp., *Pseudolithunella* sp., *Fenestrella* sp., *Paleogoudyrina* sp., *Glomospira* sp., *Miliolid*, *Trocholina* sp., *Trocholina elongata* (Leupold), *Trocholina arabica* Schlumberger, *Trocholina alpina* (Leupold), *Trocholina altispira* Henson, *Praechrysalidina infracretacea* Luperto Sinni, *Pseudochrysalidina* sp., *Marsonella* sp., *Navalesia disorta* Arnaud-Vanneau, *Hedbergella sigali* Moullade, *Nautiloculina oolitica* Mohler, *Gorbachikella* sp., and rarely calcareous algae *Permocalculus inopinatus* Elliot.

According to diagnosed foraminifers and non-foraminifers microfossils the age determination of this biozone is assigned to early Hauterivian age (Figure 5).

6. Biostratigraphy Consistency of Fahliyan Formation's Biozones in Kuh-E-Siah in Arsanjan with Previous Studies

Table 1 shows the lower Cretaceous zones based on the studies by Gollesstaneh (1965) [20], Sissigh (1977) [21], Wynd (1965) [22], Afghah (2006) [4] and Abyat (2012) [2]. Accordingly:

- **Zone (1)** of Fahliyan Formation in Kuh-e-Siah section in Arsanjan called *Calpionella alpina* zone with the Berriasian age is equivalent to *Tintinnid*, B1, and *Calpionella-Sponge Spicules* assemblage zones in Gollesstaneh (1965) [20], Sissigh (1977) [21] and Wynd's (1965) [22] studies.
- **Zone (2)** of Fahliyan Formation in Kuh-e-Siah section in Arsanjan called *Pseudochrysalidina conica* with the age of Valangian is equivalent to *Tintinnid*, B2, and *Calpionella-Sponge Spicules* assemblage zones in Gollesstaneh (1965) [20], Sissigh (1977) [21] and Wynd's (1965) [22] studies, respectively.
- **Zone (3)** of Fahliyan Formation in Kuh-e-Siah section in Arsanjan called *Pseudocyclammina lituus*, *Trocholina* assemblage zone with the Hauterivian age is equivalent to *Pseudocyclammina lituus*, *Dokhania arabica*, *Algal Assemblage*, B3, and *Pseudocyclammina lituus*, *Trocholina* assemblage zones in Gollesstaneh (1965) [20], Sissigh(1977) [21] and Wynd's (1965) [22] studies.

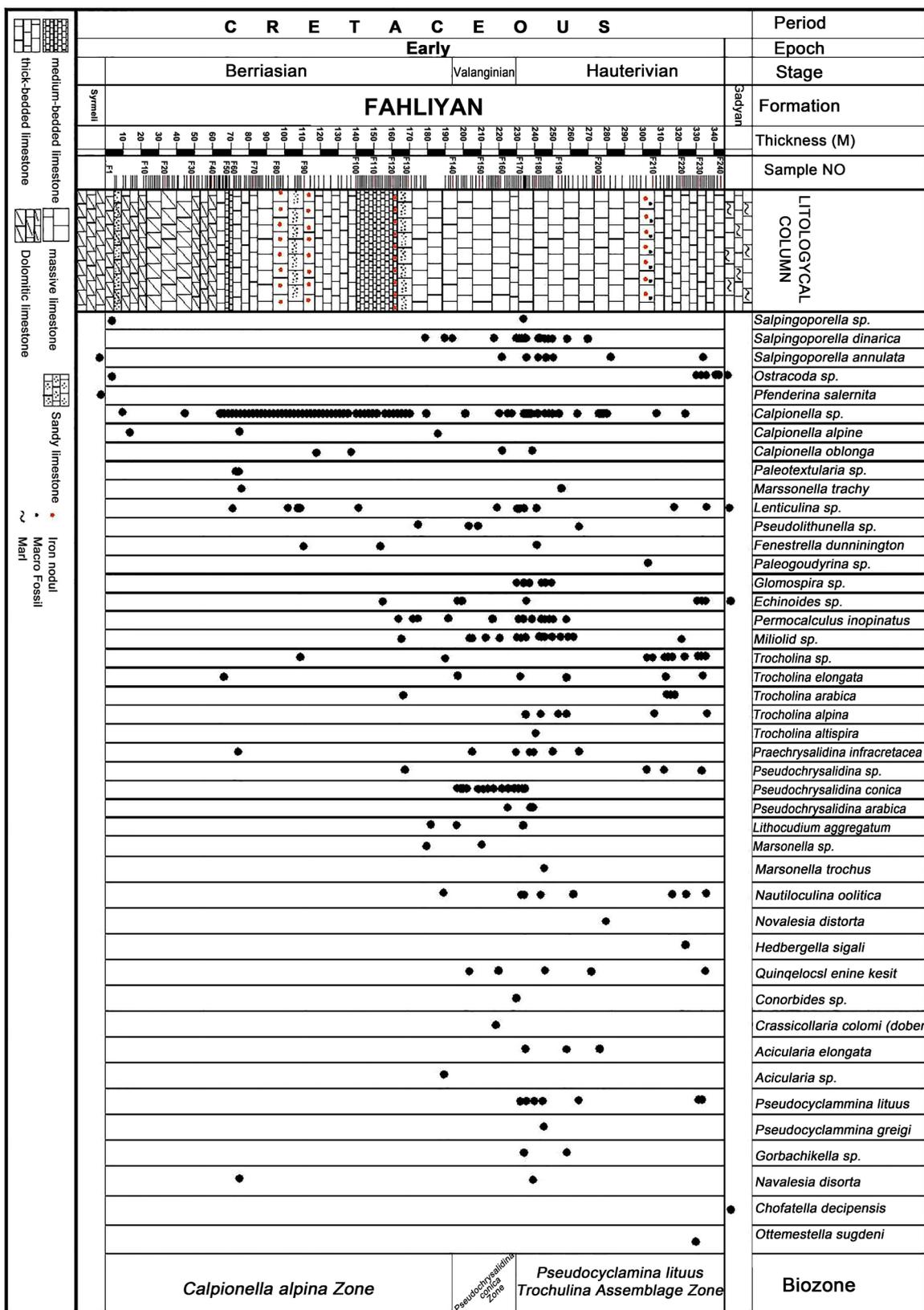


Figure 5. Vertical distribution of foraminifers, calpionelids and calcareous algae of Fahliyan Formation in Kuh-e-Siah section of Arsanjan.

Table 1. Comparison of Fahliyan Formation's biozones in Kuh-e-Siah section with the studies by Gollesstaneh (1965) [20], Sissigh (1977) [21], Wynd (1965) [22], Afghah (2006) [4] and Abyat et al. (2012) [2].

Age	This study	Afghah (2006)	Abyat et al. (2012)	Sissigh (1977)	Gollesstaneh (1965)	James & Wynd (1965)
Hauterivian	<i>Pseudocyclammina lituus</i> , <i>Trocholina</i> Assemblage zone	<i>Pseudocyclammina lituus</i> zone <i>Pseudochrysalidina conica</i> zone	<i>Pseudocyclammina lituus</i> zone	B3	<i>Pseudocyclammina lituus</i> , <i>Dokhanian arabica</i> , Algal zone III	<i>Pseudocyclammina lituus</i> , <i>Trocholina</i> Assemblage zone
Valanginian	<i>Pseudochrysalidina conica</i> zone			B2		
Berriasian	<i>Calpionella alpina</i> zone	<i>Pseudocyclammina greigi</i> zone & (<i>Trocholina alpina</i> sub zone) <i>Calpionella alpina</i> zone	<i>Dokhanian</i> zone <i>Tintinnid</i> zone	B1	<i>Tintinnid</i> zone III	<i>Calpionella</i> , <i>Spiculus</i> assemblage zone

Generally, comparing of established biozone of Fahliyan Formation in Kuh-e-Siah with previous work is summarized in **Table 1**. Biostratigraphic studies confirm shallow water paleoenvironment during Valanginian-Hauterivian age whereas the established biozones of Berriasian support open marine to shallow water depositional system. However, the biostratigraphic study on lower contact of the Fahliyan Formation indicates continuous sedimentation during Jurassic/Cretaceous boundary. Moreover the *Calpionelids* were recorded in many previous works (e.g. Abyat et al. (2012) [2], Afghah (2006) [4], Gollesstaneh (1965) [20] and Wynd (1965) [22]). Therefore, open marine paleoenvironment are recognized in Berriasian age. Since many of studied section of Fahliyan Formation are located in Coastal and Interior Fars regions, the *Calpionelids* are well distributed along the mentioned areas. Stratigraphic distribution of faunal assemblage of the Fahliyan sections supports a regression during Neocomian time. Generally the mentioned regression is recorded by the beginning of Valanginian time Abyat et al. (2012) [2] which is concordance with the present study. Afghah (2006) [4] and Kalantari (1976) [23] reported the regression in late Berriasian by the presence of *Pseudocyclammina greigi* (Henson) whereas Gollesstaneh (1965) [20] and Wynd (1965) [22] suggested the regression record to Hauterivian age. In addition sea-level fluctuation of lower Cretaceous confirms heterochronous event in various stratigraphic sections of the Zagros area. All documents show the presence of *Pseudocyclammina lituus* Yokoyama in upper biostratigraphic limit of Fahliyan Formation as described zone. Many studies revealed the disappearance of this taxon is synchronous with the first presence of *Choffatella decipiens*. Schlumberger previous biostratigraphic data reflected that the presence of the mentioned taxon is distinguished in the lowermost lithostratigraphic limit of Gadvan Formation. But new biostratigraphic record Afghah et al. (2016) [24] supports the stratigraphic distribution of *Pseudocyclammina lituus* Yokoyama is extended to some part of lower lithostratigraphic of Gadvan Formation in **Table 1** and **Figure 6**.

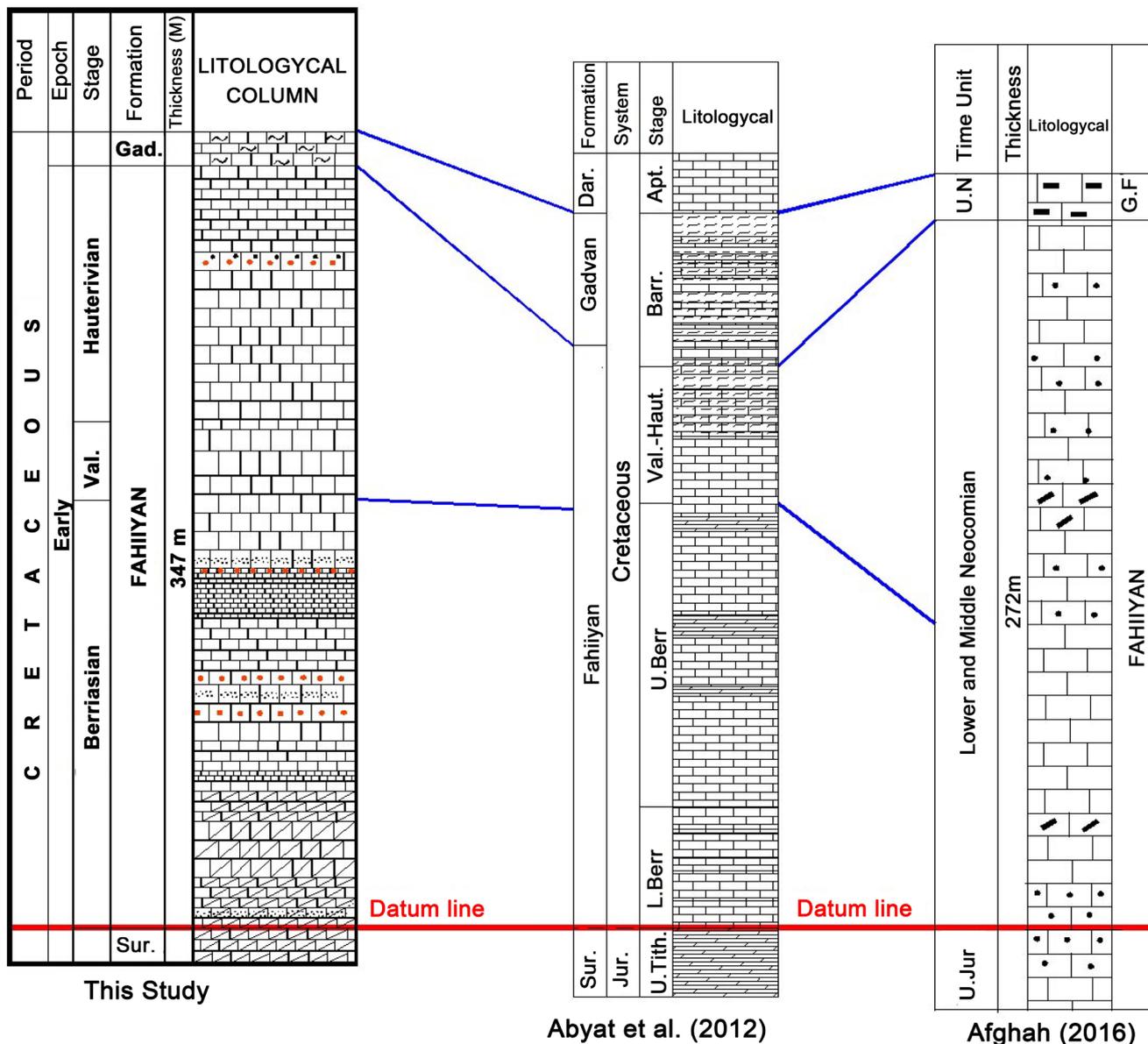


Figure 6. Comparing Fahliyan Formation in Kuh-e-Siah section with the studies by Afghah (2006) [4] and Abyat (2012) [2].

7. Conclusions

Biozonation of the Zagros lower Cretaceous strata is mainly established by foraminifers and Calpionelids. By the present study, disconformity is not recognized between Jurassic/Cretaceous boundaries. Vertical distribution of *Pseudocyclammina lituus* Yokoyama is similar with other previous records of Zagros Neocomian succession.

Regression of Neocomian time can be assigned to global tectonic movement of Upper Jurassic which is distinguishable in many geologic zones of Iran Aghanabati (1988) [1]. Actually the mentioned tectonic setting causes of break in sedimentation and angular unconformity in other zones of Iran. Deep water depositional system of Zagros is a proof which does not show hiatus between Jurassic/Cretaceous boundaries.

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Appendix Plates

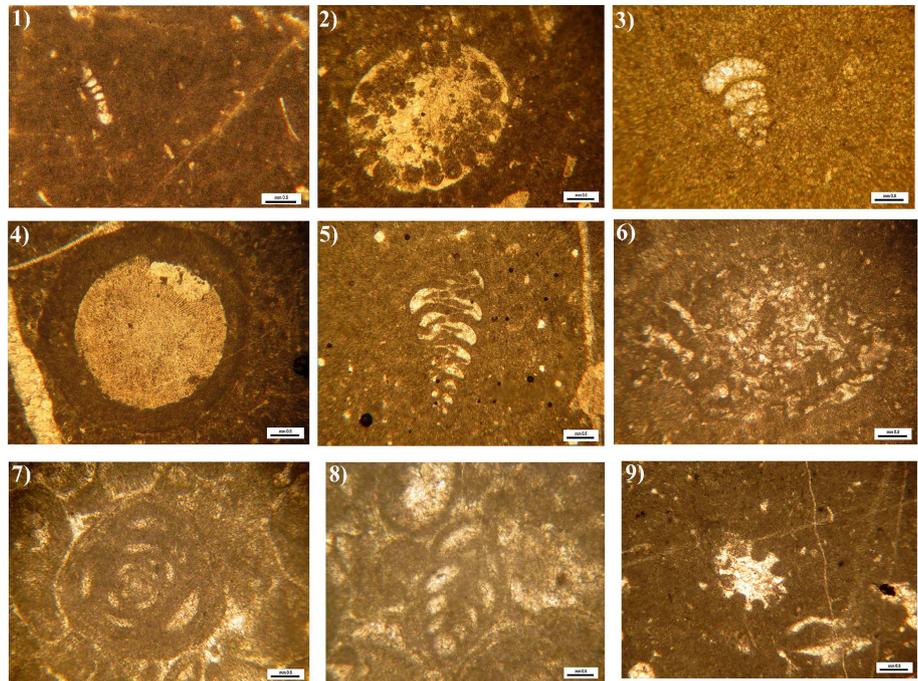


Plate 1. (1) *Pfenderina salernitana*; (2) *Clypeina solkani*; (3) *Praechrysalidina infracretacea*; (4) *Permocalculus innopinatus*; (5) *Pseudochrysalidina conica*; (6) *Pseudocyclamina lituus*; (7) *Quinqueloculina*; (8) *Siphoalveolina sp.*; (9) *Terqumella sp.*

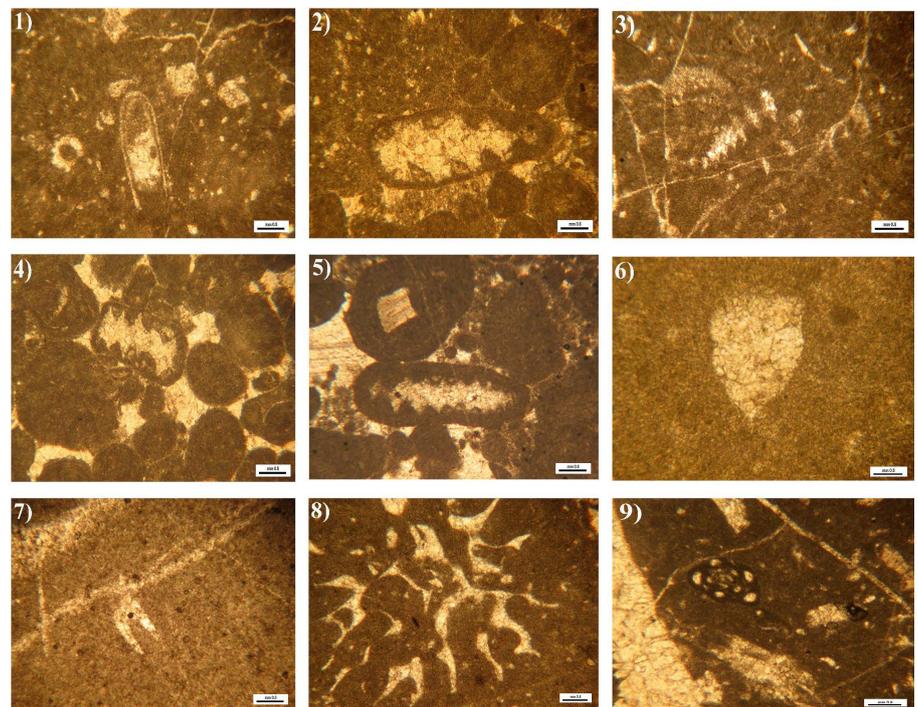


Plate 2. (1) *Tintinolina campanella*; (2) *Trocholina alpine*; (3) *Trocholina Arabica*; (4) *Trochololina campanella*; (5) *Trocholina elongate*; (6) *Calpionella alpine*; (7) *Calpionella oblonga*; (8) *Clypeina jurassica*; (9) *Glomospina neocomian*.

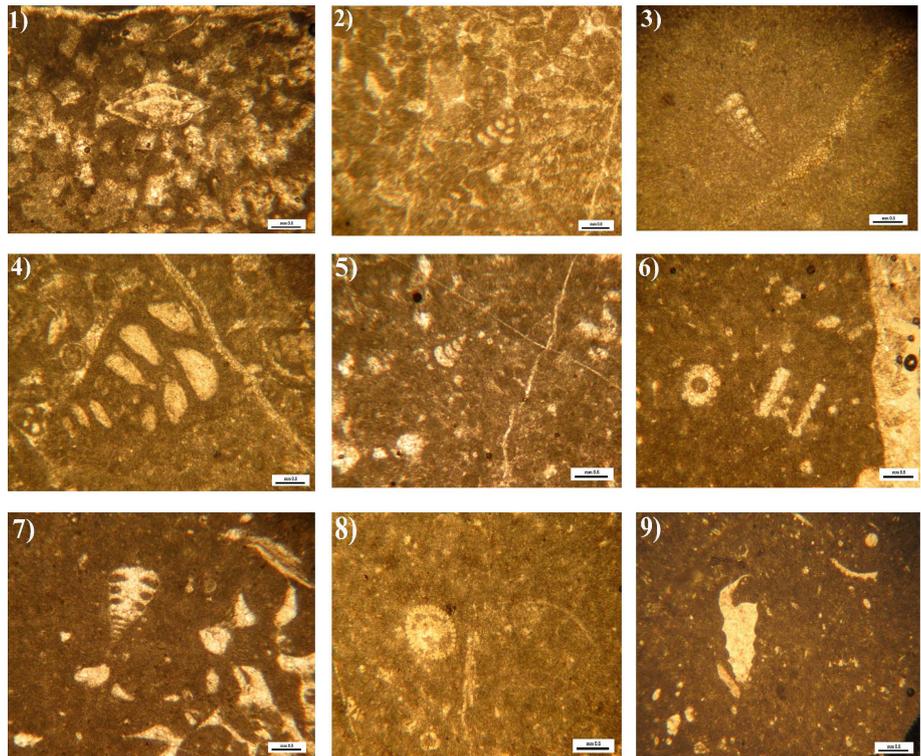


Plate 3. (1) *Lenticulina sp.*; (2) *Marsonella trochus*; (3) *Paleotextolaria sp.*; (4) *Praechrysalidina infracretacea*; (5) *Pseudolithunella sp.*; (6) *Salpingoporella annulata*; (7) *Salpingoporella dinarica*; (8) *Trocholina companella*; (9) *Trocholina elongate*.



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