INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 10, No. 4, p. 187-200, 2016
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Lithofacies variation of Lower Cretaceous sedimentary succession: An interaction of paleo-high and mixed carbonate-clastic system and its consequence on the distribution of reservoir units in Abadan plain, SW-Iran

Mohammad Hassani-Giv*[1], Bahman Soleimani[2] , Hormoz Ghalavand[3]

[1]*Department of Petroleum Geology, Shahid Chamran University of Ahvaz, Ahvaz, Iran*

[2]*Department of Petroleum Geology, Shahid Chamran University of Ahvaz, Ahvaz, Iran*

[3]*National Iranian Oil Company, Tehran, Iran*

Article published on April 30, 2017

Key words: Fahliyan, Garau, Paleo-high, Lithofacies variation, Abadan plain

Abstract

The Neocomian Fahliyan Formation as a prolific hydrocarbon reservoir in the Abadan Plain, show remarkable lithofacies variation. In the current work, integrating geological, geophysical and petrophysical log data from more than 10 wells belong to six oil fields, the lithofacies variation as a prominent factor affecting the reservoir quality was studied. Also, paleontological investigation were carried out on a number of 253 microscopic thin sections from well A-1,to differentiate the Upper Fahliyan marginal marine fine-grained classic from basinal argillaceous facies of Garau Formation. Moreover, for clay mineral identification as a possible indicator of sedimentary facies, six XRD analysis was conducted. Detailed well log correlation complemented by seismic sections in a regional scale, help us better understand the sedimentary model of the Lower Cretaceous sedimentary succession. Sequence-wised stratigraphic correlation revealed that the facies variation of Lower Cretaceous sedimentary succession influenced from both regional and local parameters. As a conclusion, the lithofacies of the Lower Cretaceous sedimentary succession is the record of the interplay of regional dip of the platform, paleo-high geometry, clastic intrusion from South-West, channeling system pattern and structural lineaments, all affecting the reservoir thickness and quality of the Lower Fahliyan.

***Corresponding Author:** Mohammad Hassani-Giv ✉ m.hassanigiv2010@gmail.com

Introduction

The Neocomian sedimentary succession includes the Garau and Fahliyan formations in the Abadan Plain (Fig. 1). The basinal Garau Formation consists of an alternation of argillaceous limestone and shale, candidate as the main hydrocarbon source rock (Alizadeh *et al.*, 2016) whereas, the shallow marine carbonate, Fahliyan Formation is the most prolific hydrocarbon reservoir in the study area. The Fahliyan Formation in a number of surface and sub-surface sections of different locations has been studied from different point of views such as biostratigraphy, geochemistry, microfacies, sequence stratigraphy, depositional environment, diagenesis and reservoir quality (Khosravi *et al.*, 2009; Habibnia *et al.*, 2010; Adabi *et al.*, 2010; Sabouhi *et al.*, 2010; Jamalian *et al.*, 2011; Abyat *et al.*, 2012; Shakeri and Parham 2013). Most of the above-mentioned studies show that the Fahliyan Formation including four faciesbelt of tidal flat, lagoon, shoal and open marine deposited in a ramp type carbonate platform as two third order sequences. Also, the sequence stratigraphy of the lower Cretaceous sedimentary succession as a part of the AP8 (Arabian Plate tectonostratigraphic megasequence) has been studied in a plate wide scale, the well-known work of Sharland *et al.* (2001), then revised by Davies *et al.* (2002).

The present Study focus on the Lower Cretaceous Fahliyan/Garau rock units in the Abadan Plain, South-West (SW) of Iran. Integrating available sub-surface geological, geophysical data, the purpose of this study is to assess the regional sedimentary pattern of Neocomian strata, the controlling geological factors and the impact on the distribution of reservoir units.

Materials and methods

The present study was carried out based on geological, petrochemical data from more than 10 wells belong to six oil fields (see Fig. 1. for location). Detailed sequence-wised stratigraphic correlation made throughout the Abadan Plain area to track both local and regional lithofacies variations of the Fahliyan Formation.

In addition, the 2D and 3D Seismic sections were used, providing further data control between the wells. Moreover, to differentiate the marginal marine fine-grained clastic from basinal facies, a total number of 253 thin sections prepared from cutting samples from well A-1 were investigated for micropaleontological purpose. Also, the X-Ray Diffraction (XRD) analysis was conducted on a number of six cutting samples for clay mineral identification.

Geological Setting

The study area, Abadan Plain is part of the Mesopotamian foredeep basin, structurally belongs to the stable shelf of the Arabian platform (Saadatinejad and Sarkarinejad 2011). The Mesopotamian foredeep is a narrow belt that extends from northern Iraq to the Persian Gulf (Figs. 1 in Pitman *et al.*, 2004, and in Abeed *et al.*, 2012). The Abadan Plain is located in the SW of Iran (Fig. 1) which is separated from Dezful Embayment based on differences in the structural trends. The border between these two regions is defined by NW-SE trending gentle anticlines which are located along the SW margin of the Dezful Embayment (Abdollahie Fard *et al.*, 2006). In contrast to the NW-SE structural trend in the Dezful embayment, the structural trend in this area is in N-S direction. There is no evidence of geological outcrops for sub-surface structures, therefore, exploration activities have been done based on geophysical seismic data.

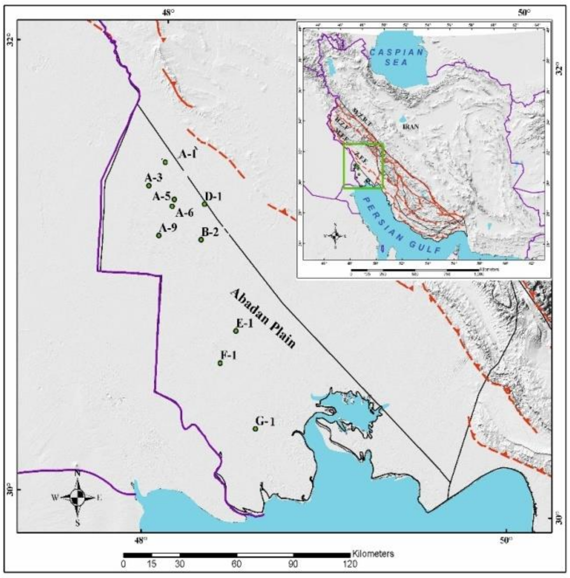


Fig. 1. Location map of the study area.

The most prominent N-S trending huge structure in the study area is the Azadegan paleo-high which is considered the Northward extension of the Khuraise-Burgan high in Kuwait and the Basrah/Zubair high in Iraq (Al-husseini, 2000). The Azadegan paleo-high is a basement-cored complex horst (Abdollahie-Fard *et al.,* 2006) encompasses some of the oil fields in the area. According to Al-husseini (2000), the generation age of the N-S trending structure in Arabian Plate, known as Arabian/Pan African trends, is reported 640-620 My (Precambrian time) as a result of Amar Collision, then reactivated in the Early Cretaceous. The Zagros folding had little effect on the structural architecture of the Abadan Plain. Differential compaction affected by reactivation of structural lineaments are the main factor for generation of the compactional anticlines in the area. The Azadegan paleo-high has a profound effect on the sedimentary succession from lithofacies variation, thickness and reservoir geology point of views. The paleo-high experienced significant tectonic activity in the Early Cretaceous, leading to the deposition of the platform-type facies of Fahliyan Formation on the shallow part and the Garau Formation in the deeper parts at the same time. From Early Cretaceous onward, the activation of this paleo-structure has been reflected in the variation of the thickness and facies of the sedimentary succession as well as distribution of reservoir units. The effective source rock units are the Upper Jurassic-Lower Cretaceous Sulaiy/Garau and to some extent (less important) Yamama carbonate rock units (Al-Ameri and Al-Musawi, 2011; Abeed *et al.*, 2011, 2012). On the other hand, due to high level of maturity and underlain by a disrupted Gotnia evaporate seal, the Sargelu Formation of Middle Jurassic possibly could not contribute in charging the Lower Cretaceous reservoirs (Abeed *et al.*, 2011, 2012).

Oil generation from Upper Jurassic-Lower Cretaceous source rocks commenced in the Late Cretaceous in intrashelf basins, peak expulsion took place in the Late Miocene and Pliocene (Pitman *et al.*, 2004). In the Abadan plain, the main reservoir rock units are Fahliyan, clastic part of Gadvan (Kushk/Zubair Sandstone) and the basal Kazhdumi sandstone (Azadegan/Burgan sandstone), Sarvak and Ilam formations.

Furthermore, the reefal limestone of Tarbur in the middle part of the Gurpi Formation, Campanian Maastrichtian in age (James and Wynd, 1965) as well as Asmari Formation are oil productive in some cases. The main cap rock units for the above-mentioned reservoirs are mainly the argillaceous sections, overlying the reservoirs. The only evaporitic cap rock sealing the Asmari reservoir is the Gachsaran/Lower Fars Formation of Miocene age. Proper juxtaposition of source, reservoir and seal units provide an accumulation of huge volume of oil in the study area. The shallower reservoirs always show lower maturity comparing the deeper ones. Alizadeh *et al.* (2016) suggest that the kerogen type II-S generate heavy Oil at the initial stages of maturation charging above reservoirs. At the later stages of expulsion, lighter oil is migrated to the lower reservoirs superseding heavy oils by pushing them into shallower traps. However the charging process is not clear and has not been discussed in detail, in their work.

Stratigraphy

The penetrated sequence in the Abadan plain encompasses the recent alluvial deposit at the surface down to the Early Jurassic rock units (Fig. 2). The sedimentary succession mainly consists of an alternation of carbonate and clastic units. Also the two evaporatic rock units is present, the first is Miocene Gachsaran /Lower Fars Formation and the latter is Jurassic, Gotnia Formation.

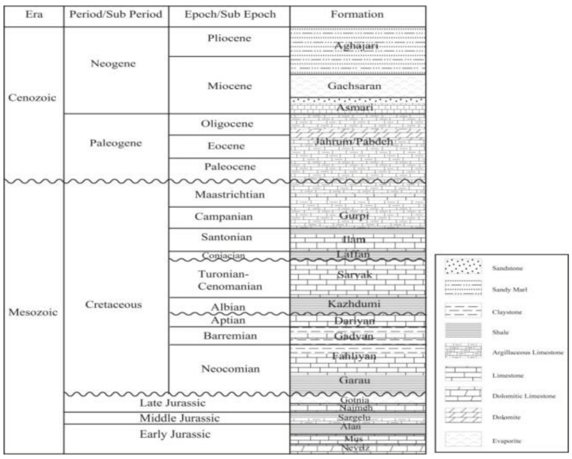


Fig. 2. The general penetrated stratigraphic column in the study area.

This Study focus on the Lower Cretaceous Fahliyan and Garau rock units, hence, the stratigraphy of these two formations explain in detail as the following: Operationally, Fahliyan Formation has been divided into two upper and lower members (Motiei, 1993).

Upper Fahliyan member consists of an alternation of limestone and claystone deposited during the Hauterivian time when abundant clastic influx invade the carbonate ramp (Murris, 1980), whereas, Lower Fahliyan member consists of pure limestone deposited in a ramp-type carbonate platform during Early to Middle Valanginian (Murris, 1980).

Garau Formation consists of an alternation of argillaceous limestone and shale. The Lower boundary with the Gotnia Formation is unconformable and the upper boundary with the Fahliyan Formation is gradational.

The Sulaiy and the Yamama formations in southern Iraq and Mina gish in Kuwait are the time equivalent rock units of the Garau and Fahliyan formations in SW of Iran (Fig. 3). Despite the obvious thickness variation of each of the Fahliyan and Garau formations, the total thickness is about 950m in the area indicating that these two rock units with inter fingering relationship compensate each other to some extent.

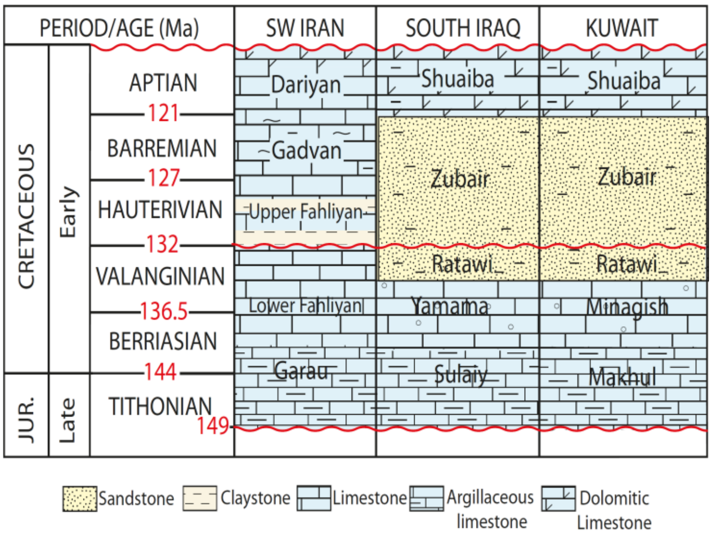


Fig. 3. The Lower Cretaceous rock units terminology in Abadan plain, South Iraq and Kuwait (modified after Christian, 1997).

Result and discussion

Lithofacies variation of Fahliyan/Garau formations

The Berriasian to Hauterivian sedimentary succession is part of the AP8, tectonostratigraphic megasequence (Late Jurassic to Late Cretaceous, 149-92 Ma) of Sharland *et al.* (2001), deposited on a homoclinal carbonate ramp (Davies *et al.*, 2002) and comprises the Garau and Fahliyan formations in the Iranian part. During the Early Cretaceous the climate gradually return to more humid and a ramp-type carbonate platform prevailed (Murris, 1980). At the beginning of the Cretaceous a flooding event caused deposition of organic rich strata of basal Garau on the inherited end-Jurassic paleo-topography.

However, later due to gradual fall of relative sea level, depend on the paleo-topography, the shallow marine condition prevailed and as a consequence platform carbonate of the Fahliyan deposited, whereas, in deeper part, the basinal Garau Formation was deposited in the same time. The thickness of the transitional strata from Garau to Fahliyan depends on the dip angle of the paleo-slope, the more steeper slope, the more narrower transitional interval. To track the lithofacies variation of Fahliyan Formation several stratigraphic correlation charts covering the study area was provided. In the southern part of the

Abadan Plain, the sequence- based well log correlation of Fahliyan Formation through wells F-1, E-1 and G-1 (Fig. 4) imply a sharp lithofacies change in a North and Northeastward trend from both wells F-1 and G-1 toward E-1, (see Fig. 1 for location).

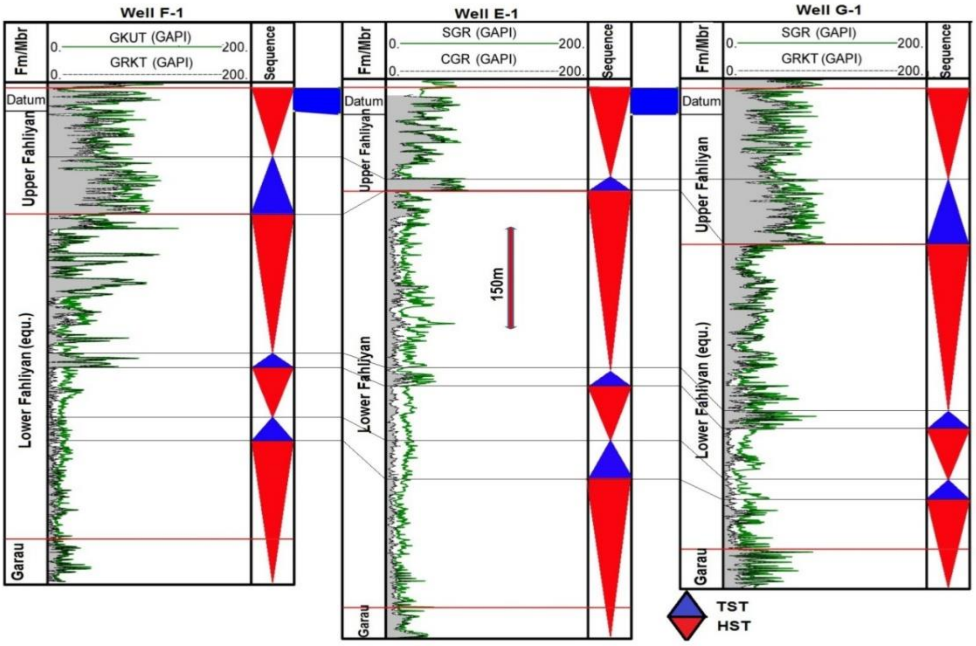


Fig. 4. The sequence-based log correlation of Fahliyan Formation through wells, F-1, E-1 and G-1. The defined sequences are based on internal NIOC report, GR-2382 (Kavoosi *et al.*, 2016). There is an obvious lithofacies variation from both well F-1 and G-1 in a proximal position toward the E-1 in a more distal position. The upper half of the Lower Fahliyan equivalent strata in the wells F-1 and G-1 with an alternation of claystone and subordinate limestone, change facies to a pure limestone in well E-1. Due to lithofacies change, Lower Fahliyan marked as "Lower Fahliyan equivalent" in the wells F-1 and G-1.

The Upper Fahliyan in wells F-1 and G-1 consists of mainly claystone with subordinate interbedded limestone. The carbonate content increases NE ward from wells F-1 and G-1 to well E-1. Also, the Lower Fahliyan show a remarkable lithofacies change from wells F-1 and G-1 toward well E-1. The Lower Fahliyan can be divided in to two parts in well F-1 and G-1. In the upper half, there is a sharp lithofacies change in a North and Northeastward trend from both wells F-1 and G-1 toward well E-1, where the alternation of clay stone and limestone change facies to mainly carbonate part in well E-1.

The lower half of the Lower Fahliyan mainly consists of pure carbonate in all three wells. Considering a regressive cycle for Fahliyan Formation, the lithofacies variation suggest intrusion of near-shore clastic deposit from the SW to the distal part of the basin, during falling sea level (Davies *et al.*, 2002). This phenomenon suppresses the deposition of clay free carbonate as a potential reservoir, decreasing reservoir quality as well as potential reservoir thickness.

In addition, in the northern part of the Abadan plain, distancing from the crestal position of Azadegan paleo-high (Abdollahie-Fard *et al.*, 2006) from well B-2 toward well D-1 in a N-NEward trend, the basal section of shallow water carbonate of Lower Fahliyan reservoir unit, change facies to deep water argillaceous limestone of non-reservoir Garau Formation due to deepening of the depositional environment (Figs. 5,6). This phenomenon clearly affect the thickness of reservoir to non- reservoir interval as well as reservoir quality. Also, a significant lithofacies change can be observed in a short distance between the wells A-6 and A-5. Due to deepening of the depositional environment, the basal part of the Lower Fahliyan Formation in well A-6, change facies to basinal facies of Garau Formation in well A-5 (Fig.7). The mentioned variation obviously affect the reservoir quality. A shelf break, influenced possibly from pre-existing structural lineaments control the mentioned facies change. It is noteworthy that, as a semi-regional phenomenon the most porous interval situated in the lowermost part of the Fahliyan Formation, slightly above the Fahliyan /Garau transition zone. This mud-dominated porous interval has been recognized as a carbonate buildup by Kavoosi *et al.* (2016). The typical sample for this geologic feature can be seen on the inverted seismic section in the position of the well A-6 (Fig. 8).

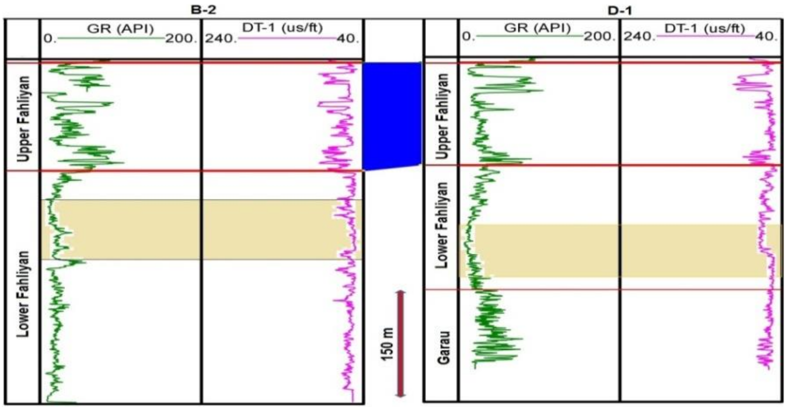


Fig. 5. Log correlation of Fahliyan Formation in a NE ward direction through wells B-2, D-1, a number of reservoir layers in well B-2 cannot be followed in D-1, due to facies change of the Fahliyan to Garau.

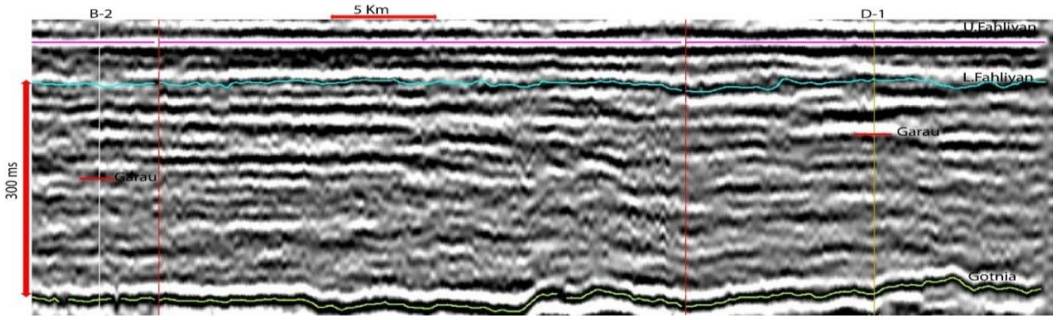


Fig. 6. A NE ward Seismic section through wells B-2 to D-1. Well B-2 located on the paleo-high, whereas well D-1 located down dip on the eastern flank of the paleo-high.

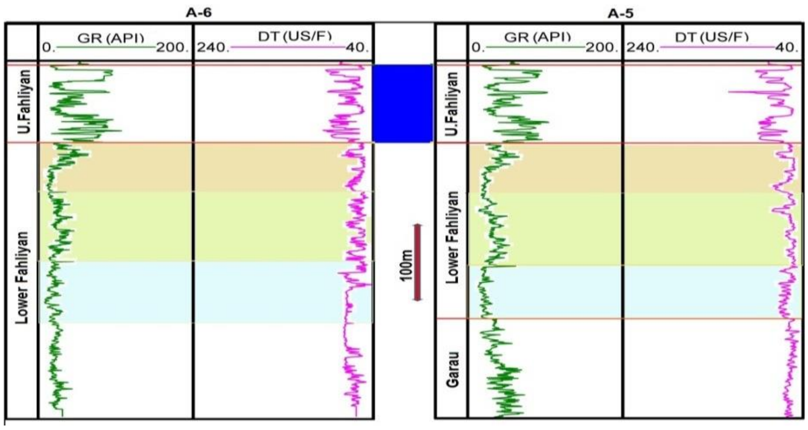


Fig. 7. Log correlation of Fahliyan Formation in a northward direction through wells A-6 and A-5, illustrating a clear facies change in a short distance (3km). Note that the position of porous interval above the Garau Formation, correlatable bathymetrically with the porous interval in well D-1, in both wells, the porous interval situated a little above the Garau/Fahliyan transitional zone. The porous intervals in two wells are not time-equivalent. This phenomenon reflect the role of paleo-bathymetry influenced from paleo-topography on the distribution of reservoir layers.

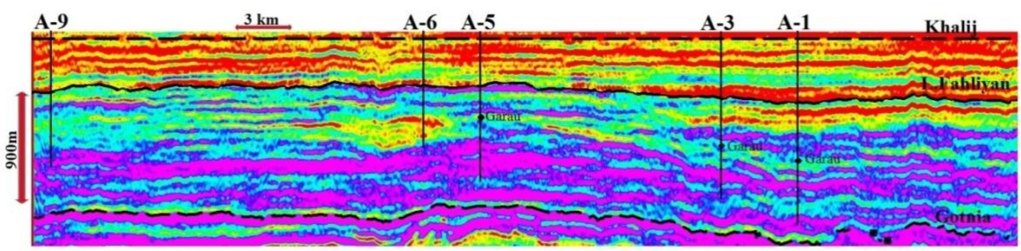


Fig. 8. A Northward trending inverted seismic section through wells A-6, A-5 illustrate a clear shelf break between the wells A-6, A-5, resulted in a lithofacies change which confirm by the well data (Fig. 7).

Moreover, a sequence-wised well log correlation through wells A-9, A-3 and A-1, in a northward trend obviously show a dramatic lithofacies change from A-9 to A-1 (Fig. 9). The thickness of clean carbonate section of the Fahliyan Formation in well-A-9, is nearly twice the thickness of the high argillaceous upper part. Correlating to well A-9, the basal part of the Fahliyan in well A-3 changes facies to the alternation of argillaceous limestone and shale of Garau Formation. Also, at the upper part, the clean carbonate change facies to the alternation of a claystone and limestone, a lithofacies similar to the Upper Fahliyan in the Abadan Plain. The mentioned lithofacies change has been amplified in the well A-1, where the upper land-drived clastic part unexpectedly overlay the Garau basinal facies, without a significant thickness of pure carbonate in between. This phenomenon could be due to the presence of a channeling system intersecting the paleo-high, carrying the clastic sediment to a far distance of shoreline accompany with a much steeper paleo-slope.

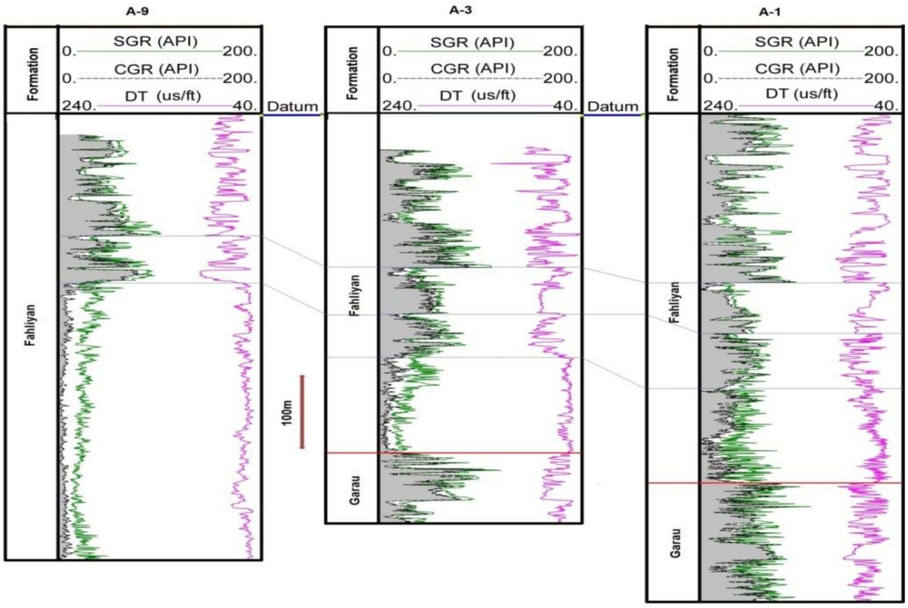


Fig. 9. Log correlation of Fahliyan/Garau formations in a northward direction through wells A-9, A-3 and A-1.The thickness of the pure carbonate interval show a sharp decrease from A-9, to A-1, not only due to lithofacies change of pure carbonate to argillaceous limestone and marl of the Garau from the base but also due to suppression by the intrusion of the land-derived clastic deposit from the top. Due to sharp lithofacies change, it was preferred not to divide the Fahliyan into two lower and upper members.

It is highly recommended that in the Northern part of the Abadan Plain drilling should continue to be sure that the entire section of the Fahliyan has been penetrated. Differentiation of Fahliyan and Garau formations in such cases is not straightforward and should be investigated by paleontological data.

To be sure about the depositional facies of these two upper and lower high argillaceous packages, paleontological investigation carried out on a total number of 253 thin sections prepared from cutting samples from well A-1 (Fig. 10), Indicating the presence of benthic micro fauna (*Pseudocyclamina* sp, *Choffatella decipiens, Nautiloculina* sp, *Lenticulina* sp, *Textularids, Miliolids, Algal* remains, *Echinoid* and *Gastropod* debris) for upper clastic system defined as the Upper Fahliyan and Lower Fahliyan equivalent rock units and plankton icmicrofauna (*Radiolaria* and Planktonic foraminifera) for lower argillaceous section defined as the Garau Formation (Fig. 11).

Also, the NGS log data was applied to differentiate Fahliyan from Garau in well A-1. Th/K ratio does not reflects a meaningful trend from Garau to Fahliyan. Th/U ratio is overaly lower in the Garau compared to the Fahliyan, due to higher concentration of U in Garau Formation. The U content of the Garau Formation is higher than Fahliyan probably due to concomitance of the U and organic matter (Haji-Vassiliou and Kerr, 1972; Nakashima *et al.*, 1984). The U gradually decreases from Garau to Fahliyan. As a result in such cases, where two similar lithofacies with different environmental settings overlay, the NGS data confirmed by pale ontological data could apply for determining the Fahliyan/Garau boundary.

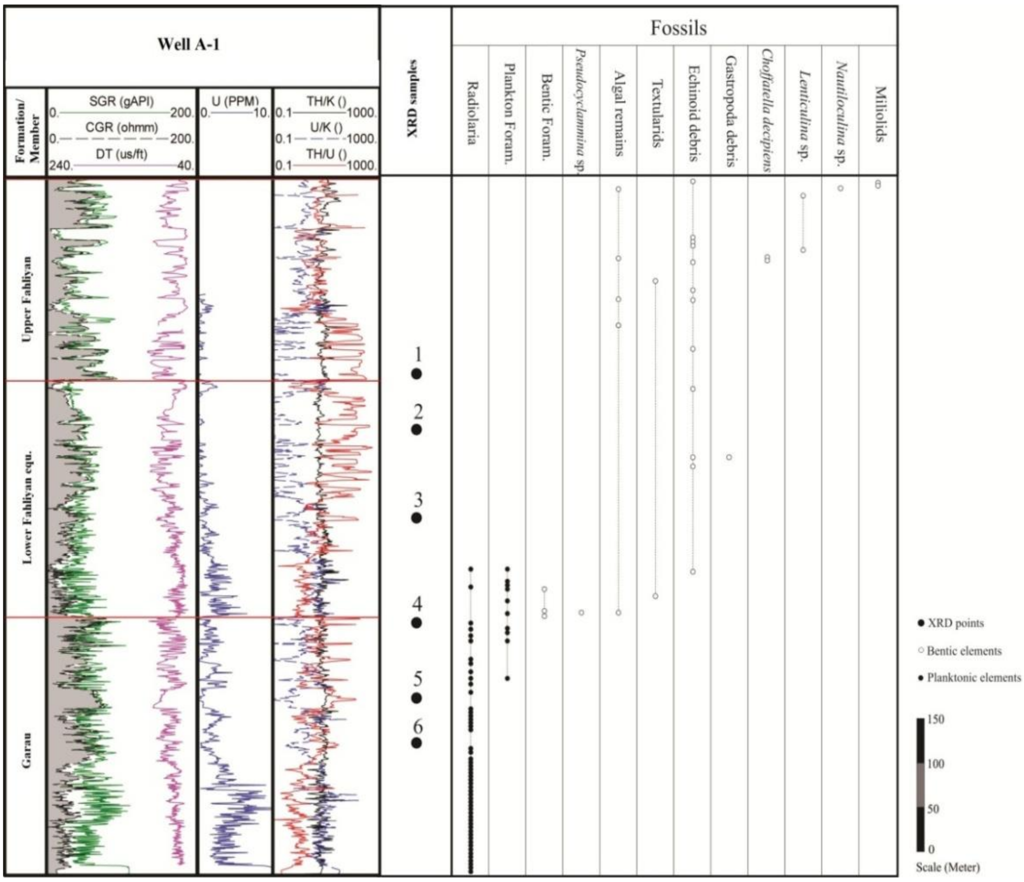


Fig. 10. Plot of NGS log data associated with paleontological data (range chart). The benthic microfauna occur in Fahliyan and the planktonic occur in Garau Formation, confirming shallow marine near shore facies for Fahliyan and a basinal facies for Garau. Both the benthic and planktonic elements assembled in the Garau to Fahliyan transition zone. The U content of the Garau formation is high gradually decreasing toward the upper section. Overally combining the U and Th/U and U/K ratios can differentiate between these two rock units to some extent.

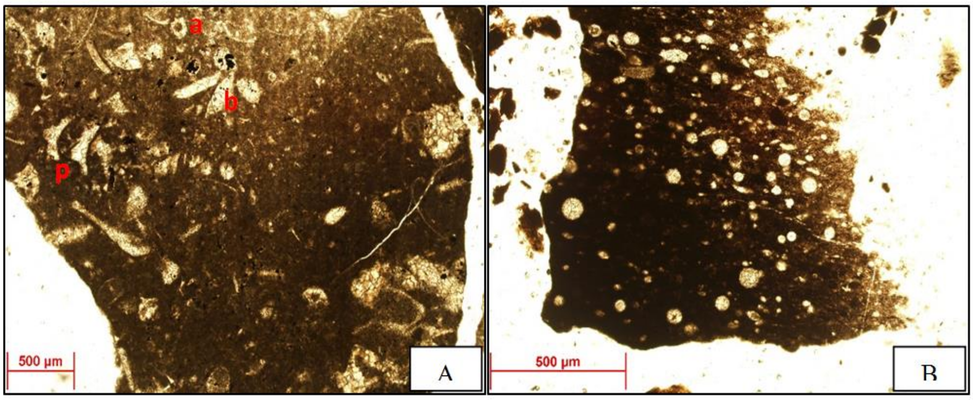


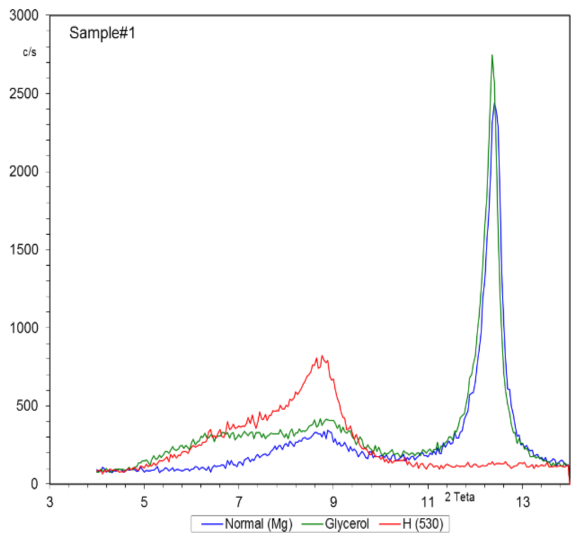
Fig. 11. A: Algal bioclast (a), *Pesudocyclamina* sp (p) and other benthic foraminifers (b) representing lagoonal facies in Fahliyan Formation, B: Radiolaria representing basinal facies in Garau Formation.

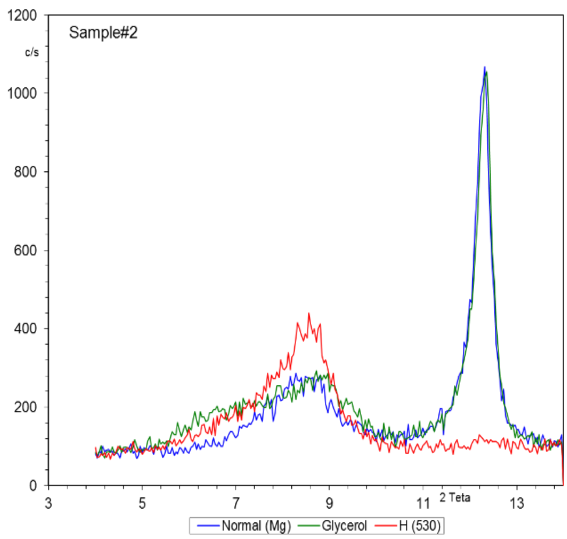
To examine the relationship of the clay mineral and depositional environment, X-ray diffraction (XRD) analysis conducted on a number of six cutting samples, covering the Upper Fahliyan, Lower Fahliyan equivalent and Garau rock units (Fig. 12 and Table 1). As a short introduction, erosion of soils, weathering of rocks and crystallization by reaction between saline solutions and silicate are two main sources of clays in sediments. Clays are transported in two ways of suspensions and fluidized beds. The concentration of clay minerals control by the natural screening, source material and climatic condition in one hand and the chemical condition of depositional environment in the other hand (Meunier, 2005). In addition, the compositional and lattice interchange between the clay minerals during burial diagenesis is very common, complicating the relationship of the clay mineral as the indicator of paleo-depositional environment.

Based on the XRD analysis, (Table 1) the samples one to four covering the Fahliyan and Fahliyan/Garau transition zone are Kaolinite and Illite as the major phase and Chlorite as the minor phase in the samples one and three. Also, the samples five and six from Garau are Kaolinite as the major phase and Illite and Chlorite as the minor phase.

Therefore, in terms of clay mineral, there is no clear differentiation between marginal marine fine grain clastic Fahliyan Formation and argillaceous basinal Garau Formation.

Generally, the amount of Kaolinite should decrease basin ward however, the Illite may be degraded to Kaolinite (Adabi, 2004) owing to Lower Cretaceous humid climate (Murris, 1980).





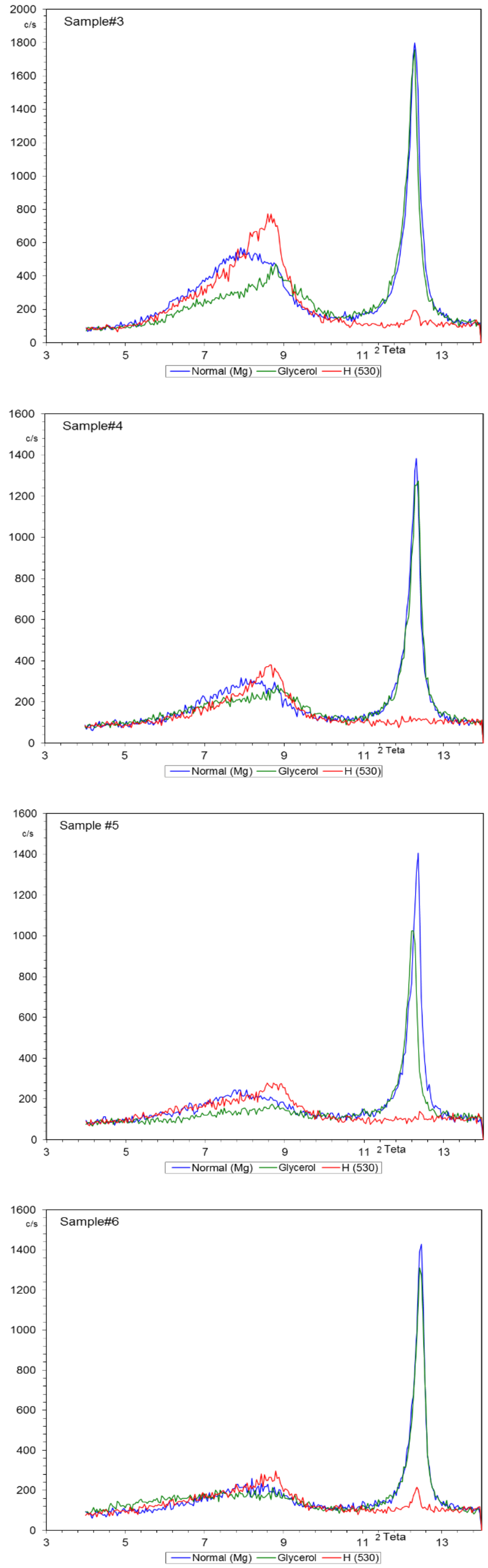


Fig. 12. The XRD graphs of 6 samples selected from Garau and Fahliyan Formation.

Table 1. The XRD analysis results.

Well	Sample	Major Phase	Minor phase
A-1	1	Kaolinite, Illite	Chlorite
"	2	Kaolinite, Illite	-
"	3	Kaolinite, Illite	Chlorite
"	4	Kaolinite, Illite	-
"	5	Kaolinite	Illite
"	6	Kaolinite	Illite, Chlorite

To summarize, the regional stratigraphic correlations lead us to draw two different conceptual depositional models for the Lower Cretaceous sedimentary succession in the southern and northern parts of the Abadan plain, which directly control the thickness and distribution pattern of reservoir zones (Figs. 13 and 14). The conceptual model A has been drawn based on the stratigraphic data of the wells F-1, B-3 and D-1. The well F-1 located in a proximal position where the clastic deposit invade the carbonate platform from the SW, inhibiting the carbonate sedimentation. The well B-3 located on the crestal part of the platform in the midway between the well F-1 and well D-1, where the pure carbonate of the basal part of the Lower Fahliyan substitute the Garau Formation on the eastern flank of the paleo-high due to deepening of the sedimentary environment. The sedimentation pattern in most part of the Abadan plain correlate with the model A (Fig. 13).

The conceptual model B structured based on the stratigraphic data of wells A-9, A-3 and A-1 in an overall South to North-Northeast ward trend. The pure carbonate part (Lower Fahliyan) thickness decreases both due to facies change to Garau from the base and suppressed from the clastic intrusion from the top. In the position of the well A-1 the fine-grained prodelta clastic overlay the argillaceous limestone and shale of the Garau without any pure carbonate in between.

The little thickness of carbonate represent the Fahliyan/Garau transition zone based on paleontological data. The model B is in conflict with assumption of uniform distribution of upper fine-grained clastic part sourced from SW. Therefore, a distributary channeling system accompany with a steep slope should be present near to well A-1.

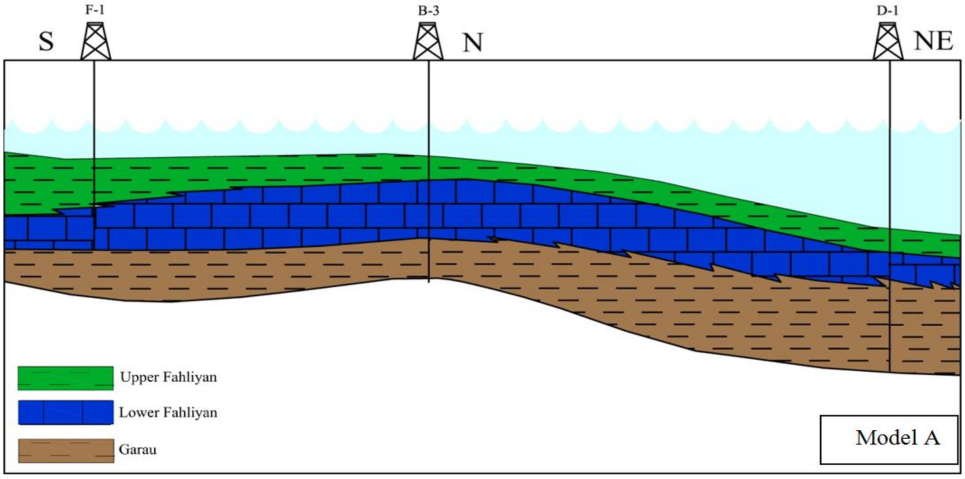


Fig. 13. A conceptual depositional model of Lower Cretaceous Garau, Upper and Lower Fahliyan formations in the most parts of the Abadan plain, based on the stratigraphic column of Wells F-1, B-3 and D-1.

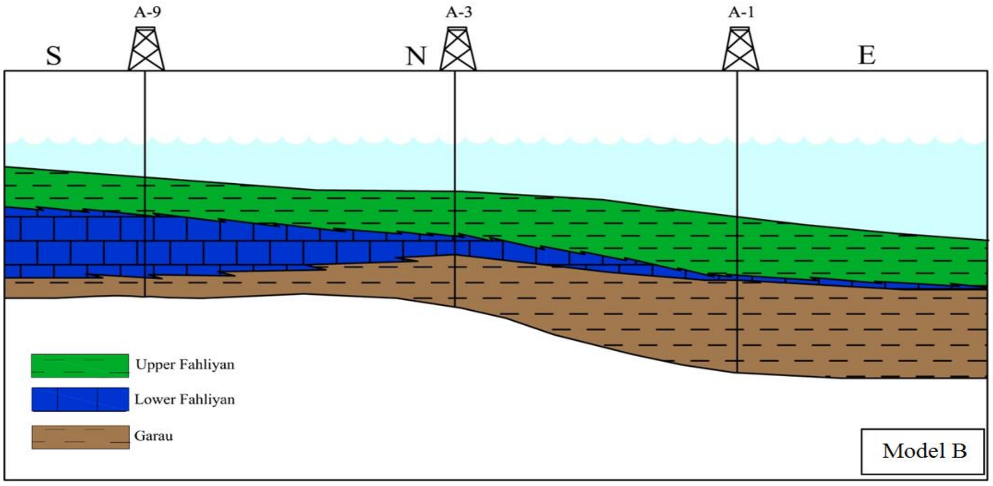


Fig. 14. An alternative conceptual depositional model of Lower Cretaceous Garau, Upper and Lower Fahliyan formations in the northern part of the Abadan plain, based on the stratigraphic column of Wells, A-9, A-3 and A-1.

Based on the presented models, there is a tripartite interplay between the three lithofacies, alternation of marginal marine clastic and subordinate limestone of Upper Fahliyan, pure shallow marine carbonate of Lower Fahliyan and an alternation of basinal argillaceous limestone and shale of Garau Formation suggesting a shallowing upward sequence for the Lower Cretaceous sedimentary succession. The thickness of pure carbonate, Lower Fahliyan rock unit as a reservoir, limited by distal deep water argillaceous limestone of Garau at the base and suppressed from proximal clastic intrusion of Upper Fahliyan at the top. In a regional view, the Lower Cretaceous succession in the study area contains a mixed carbonate-siliciclastic section leading to the deposition of pure limestone of the Lower Fahliyan, and an alternation of claystone and limestone of Upper Fahliyan. The terrigenous clastic material sourced from uplifted areas of the Arabian-Nubian Shield (Murris, 1980; Sharland *et al.*, 2001). The hinterland uplift is due to opening of the South and central Atlantic Ocean (Sharland *et al.*, 2001) and is completely unrelated to eustacy (Al-fares *et al.*, 1998). The clastic sediment grade towards the NE into an alternation of clastic and carbonate and finally pure carbonate deposits (Davies *et al.*, 2002) retreating landward during the TST but then invade the carbonate platform during the subsequent HST (Davies *et al.*, 2002). Therefore, distancing from ancient shoreline there are some parallel lithofacies belts, ranging from clastic to pure carbonate which finally limited to the deep water Garau facies. Therefore, in a regional scale the Lower Fahliyan/Upper Fahliyan boundary is diachronous. Moreover, there is an interplay between the Fahliyan and Garau formations depends on the paleo-topography as well as regional N-NE ward deepening of the depositional environment. The overall thickness of Garau/Fahliyan is about 950 m in the study area. The Garau deep water facies is the time equivalent of the shallow water carbonate Fahliyan platform facies. Therefore, these two rock units have an interfingering relationship. Depend on the depositional situation, the decrease of Fahliyan thickness, compensate with the increase of Garau thickness and vice versa. Therefore, the Fahliyan/Garau boundary is diachronous. In conclusion, the Neocomian sedimentary succession document the complex interplay of both regional and local geological parameters such as distancing from the shore line, dip of the platform, paleo-topography, structural lineaments and the distributary channeling system.

Conclusion

The detailed sequence-wised stratigraphic correlation of Neocomian sedimentary succession in Abadan plain revealed remarkable lithofacies variation. In southern part of the Abadan Plain land derived fine-grained clastic deposit invade the carbonate platform decreasing the quality and also gross reservoir thickness. Distancing from the crest of the Azadegan paleo-high toward the N-NE ward, the pure carbonate reservoir unit of Lower Fahliyan gradually change facies to the non-reservoir argillaceous limestone and shale of Garau rock unit. In northern part of the Abadan plain probably due to a prodelta channeling system associated with the high angle dip of the depositional environment, land derived fine-grained clastic facies directly overlay the Garau basinal facies. The lithofacies variation of Fahliyan/Garau formation suggest a tripartite interplay of land derived fine-grained clastic facies (Upper Fahliyan), a platform pure carbonate (Lower Fahliyan) and argillaceous limestone of Garau intrashelf basin, confirming the ramp-type depositional environment disrupted by some structural lineaments. The distribution of the three lithofacies in time and space has been controlled by relative sea level change, regional dip of the platform, sediment supply, paleo-topography and channeling system in prodelta. Controlling the thickness and regional distribution of three different lithofacies as the source, reservoir and seal units, facies variation of Fahliyan Formation has a major importance at both the reservoir scale and regional play fairway scale, as well as identification of stratigraphic traps.

Acknowledgments

The authors would like to acknowledge the National Iranian Oil Company (NIOC) Exploration Directorate for permission to publish this paper and Research Manager of Shahid Chamran University of Ahvaz for their encouragements. And we also express frankly thanks to anonymous referees for their critical points to improve the quality of the paper.

References

Abdollahie-Fard I, Braathen A, Mokhtari M, Alavi SA. 2006. Interaction of the Zagros Fold-Thrust Belt and the Arabian-type, deep-seated folds in the Abadan Plain and the Dezful Embayment,SW Iran. Petroleum Geoscience **12,** 347-362.

Abeed Q, Alkhafaji A, Littke R. 2011. Source rock potential of the upper Jurassic-lower Cretaceous succession in the Southern Mesopotamian Basin, Southern Iraq. Journal of Petroleum Geology **34(2),**117-134.

Abeed Q, Leythaeuser D, Littke R. 2012. Geochemistry, origin and correlation of crude oils in Lower Cretaceous sedimentary sequences of the southern Mesopotamian Basin, southern Iraq. Organic Geochemistry **46,**113-126.

Abyat A, Baghbani D, Afghah M, Kohansal ghadimvand N, Feghi, A. 2012. Microbiostratigraphy and Lithostratigraphy of Fahliyan and Gadvan Formations in Kuh-e-Surmeh (Zagros Basin, Southwest Iran). Advances in Environmental Biology **6(12),** 3078-3086.

Adabi MH, Salehi MA, Ghabeishavi A. 2010. Depositional environment , sequence stratigraphy and geochemistry of Lower Cretaceous carbonates (Fahliyan Formation) south-west Iran. Journal of Asian Earth Sciences **39(3),**148-160.

Adabi MH. 2004. Sedimentary geochemistry. Arianzamin Publication Iran.

Al-Ameri TK, Al-Musawi FA. 2011. Hydrocarbon generation potential of the uppermost Jurassic—basal Cretaceous Sulaiy formation, South Iraq. Arabian Journal of Geosciences **4(1-2),** 53-58.

Al-fares AA, Bouman M, Jeans P. 1998. A New Look at the Middle to Lower Cretaceous Stratigraphy , Offshore Kuwait. GeoArabia **3(4),** 543-560.

Al-husseini M. 2000. Origin of the Arabian Plate structures : Amar collision and Najd Rift. GeoArabia **5(4),** 527-542.

Alizadeh B, Saadati H, Rashidi M, Kobraei M. 2016. Geochemical investigation of oils from Cretaceous to Eocene sedimentary sequences of the Abadan Plain, Southwest Iran. Marine and Petroleum Geology **73,** 609-619.

Christian L. 1997. Cretaceous Subsurface Geology of the Middle East Region. GeoArabia **2(3),** 239-256.

Davies RB, Casey DM, Horbury AD, Sharland PR, Simmons MD. 2002. Early to mid-Cretaceous mixed carbonate-clastic shelfal systems: Examples, issues, and models from the Arabian Plate. *Geo Arabia*-Manama **7,** 541-598.

Habibnia B, Feghhi A, Amiri Bakhtiar H. 2010. Study of Stratigraphy, Biostratigraphy, Microfacies, Diagenesis, Sequence Stratigraphy and Reservoir Potential of the Fahliyan Formation in the Marun Oil Field, Zagros Basin, Southwest Iran. In: 72nd EAGE Conference and Exhibition incorporating SPE EUROPE.

Haji-Vassiliou A, Kerr PF. 1972. Uranium-organic matter association at La Bajada, New Mexico. Economic Geology **67(1),** 41-54.

Jamalian M, Adabi MH, Moussavi MR, Sadeghi A, Baghbani D. 2011. Facies characteristic and paleoenvironmental reconstruction of the Fahliyan Formation, Lower Cretaceous , in the Kuh-e Siah area, Zagros Basin, southern Iran. Facies **57,** 101-122.

James GA, Wynd JG. 1965. Stratigraphic nomenclature of Iranian oil consortium agreement area. American Association of Petroleum GeologistsBulletin **49(12),** 2182-2245.

Kavoosi MA, Zamannezhad A, Tabarzadi MR, Tavakoli M, Khoshdel H, Moradi M. 2016. Seismic sequence stratigraphy of the Berriasian-Hauterivian deposit (Garau and Fahliyan formations) in Abadan Plain. NIOC Internal Report **GR-2382.** 2016.

Khosravi M, Lasemi Y, Feizi M. 2009. Platform to Basin Facies Transition in the Lower Cretaceous Fahliyan Formation: Evidence for the Formation of Garau Intra. In: Shiraz -1st EAGE International Petroleum Conference and Exhibition.

Meunier A. 2005. Clays. Springer Science & Business Media.

Motiei H. 1993. Stratigraphy of Zagros. Geological Survey of Iran Tehran.

Murris RJ. 1980. Middle East stratigraphic evolution and oil habitat. American Association of Petroleum Geologists *Bulletin* **64,** 597-618.

Nakashima S, Disnar JR, Perruchot A, Trichet J. 1984. Experimental study of mechanisms of fixation and reduction of uranium by sedimentary organic matter under diagenetic or hydrothermal conditions. Geochimica et Cosmochimica Acta **48(11),** 2321-2329.

Pitman JK, Steinshouer D, Lewan MD. 2004. Petroleum generation and migration in the Mesopotamian Basin and Zagros Fold Belt of Iraq: results from a basin-modeling study. Geo Arabia **9(4),** 41-72.

Saadatinejad MR, Sarkarinejad K. 2011. Application of the spectral decomposition technique for characterizing reservoir extensional system in the Abadan Plain, southwestern Iran. Marine and Petroleum Geology **28(6),**1205-1217.

Sabouhi M, Jahani D, Taati F, Aminzadeh A. 2010. Depositional Environment and Sequence Stratigraphy of the Neocomian Fahliyan Formation in North Dezful Embayment, Iran. In: The 1 st International Applied Geological Congress, Department of Geology, Islamic Azad University - Mashad Branch, Iran 26-28 April.

Shakeri A, Parham S. 2013. Reservoir Characterization and Quality Controlling Factors of the Fahliyan Formation Located in Southwest Iran. Journal of Sciences, Islamic Republic of Iran **24(2),** 135-148.

Sharland PR, Archer R, Casey DM, Davies RB, Hall, SH, Heward, AP, Horbury AD, Simmons, MD. 2001. Arabian Plate Sequence Stratigraphy, Geo Arabia special publication **2,** P.1-370.