GEOSCIENCES

journal homepage: www.gsjournal.ir

# Microfacies analysis and depositional environment of the Fahliyan Formation (Lower Cretaceus), Abadan plain, West South of Iran (Arvand-field)

**Abbas Dehkar[1], Vali Ahmad Sajjadian[2*], Mohammad Reza Noora[3] and Kazem Shabani Goorji[3]**

[1]*Ph.D. Student, Department of Geology, Faculty Of Sciences, Islamic Azad University, Zahedan Branch, Zahedan , Iran*

[2]*Assistant Professor, Department of Geology, Faculty Of Sciences, Islamic Azad University, Khark Branch, Khark; Arvandan Oil and Gas Company, Tehran, Iran*

[3]*Assistant Professor, Department of Geology, Faculty Of Sciences, Islamic Azad University, Zahedan Branch, Zahedan , Iran*

ARTICLE INFO

*Received: 2017 October 09*

*Accepted: 2017 December 31*

*Available online: 2018 March 17*

*Keywords:*
*Fahliyan formation*
*Depositional environment*
*Carbonate ramp*
*Microfacies*
*Cretaceuse*

**Corresponding author:*
*V. A. Sajjadian*
*E-mail:vas1382@yahoo.com*

ABSTRACT

The Fahliyan Formation of Khami Group is hosting important hydrocarbon reserves in Iran and also is a main reservoir rock in the Abadan Plain oil fields which is Neocomian in age. In the studied wells its thickness is about 406 meters. In the Abadan Plain, the Fahliyan Formation transitionally overlies of the Garau Formation and its upper boundary changes into the Gadvan Formation. According to thin sections examinations prepared from cores analysis 11 microfacies is recognized by various facies including dolostone and dolomudstone of tidal flat, skeletal wackestone to packstone of the open and restricted lagoon, bioclastic intraclastic grainstones, peloid grainstone and coralinrudist-algae grainstone (boundstone) of the barrier setting and fine grained echinoderm rudist bearing deposits of the slope. high frequency of core facies belong to restricted and open marine lagoon deposits composed of benthic foraminifera, shell fragments and peliods. They are often observed in wackestone to packstone fabrics. The remained rock facies is composed of the bioclastic skeletal lime grainstones characterizing by large rudists and echinoderm debries which are interpreted to constitute the platform margin in this well. Tidal flat dolomudstone with a few bioclast contribute, which they often show moderate reservoir quality.

## 1- Introduction

The main objective of this study is to develop a methodological approach to improve the reservoir description of the Fahliyan carbonate succession with special emphasis on the reservoir facies development in the studied Field. Recognition of facies is very important in stratigraphy layers. Facieses is studied in microscopic scales. In this study, microfacies are named based on the microfacies of Flugel's standard (Flugel, 2010), and according to available lithological and paleontological features, we tried each of microfacieses compare the facies belts of Flugel's model as much as possible. In general, lithological and paleontological characteristics of a sedimentary facies have to be specified, so that facies are easily separated from each other.

This report hence provides the ultimate results of the reservoir geological description and sedimentological studies of one well in Arvand oil field (Fig. 1).

Fahliyan formation has been studied in many other field (Sherkati and Letouzey, 2004; Adabi et al., 2010; Maleki and Lasemi, 2011; Kamali and Abolghasemi, 2013; Ramezani Akbari et al., 2016; Soleimani et al., 2017) and so in this field, Fahliyan formation is on the Garu formation (Fig. 2), was first recognized and described in 2006. Arvand is a geophysical structure without any outcrop that located in Abadan Plain. Darquain, Khoramshahr, Yadavaran are the adjacent fields of Arvand oil field.

Based on the structural analysis, Arvand structure in Fahliyan horizons is a domical asymmetric anticline, which this North-South trend is parallel to Arabian structures with folding and sinusoidal axis.

This study has several objectives that The main objective is to determine the possible depositional system and depositional environment based on the study of carbonate rocks and microfacies analysis.

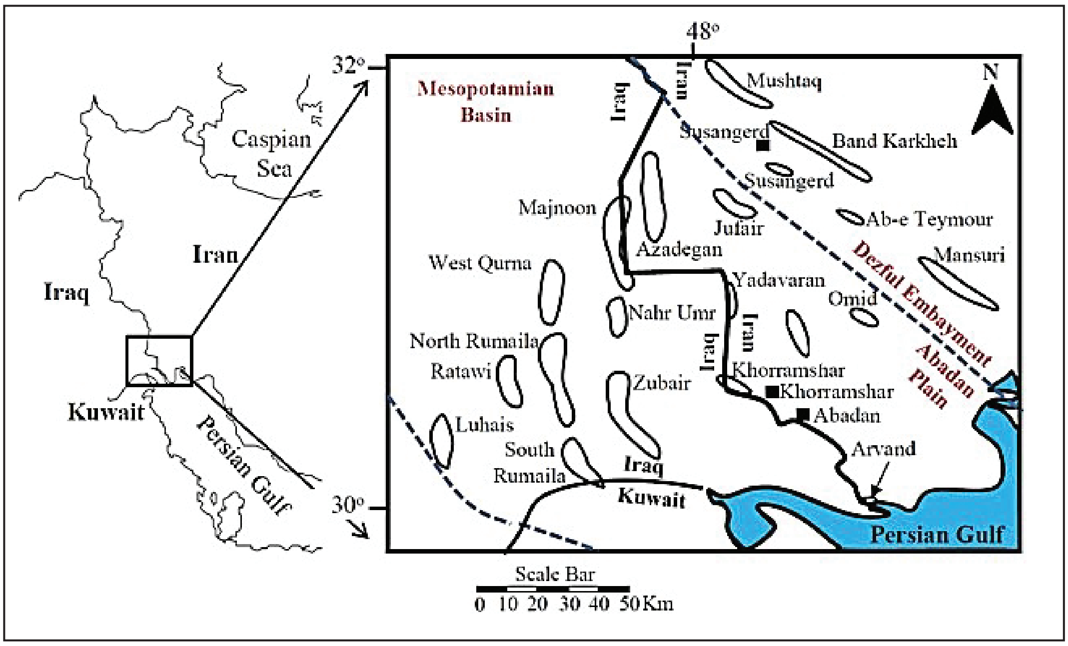


Fig. 1- Location map of the Arvand oil field (Sajjadian et al., 2015).

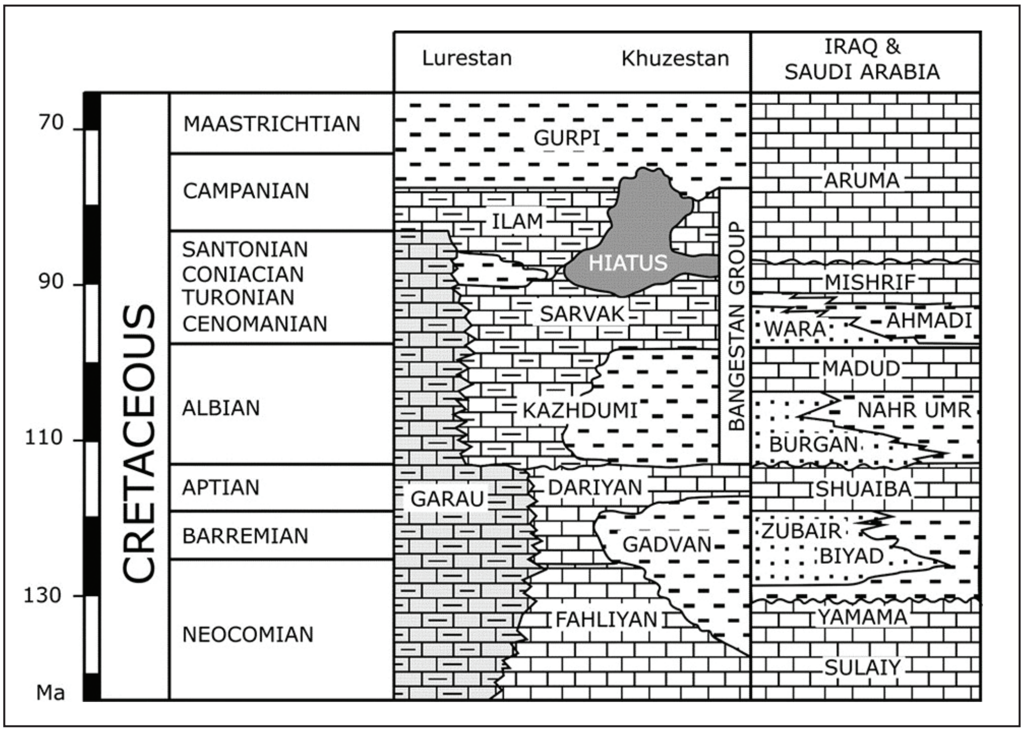


Fig. 2- The general penetrated stratigraphic column in the study area (Hajikazemi et al., 2010).

## 2- Location

The studied cross section is located in Khuzestan province, southwest of Iran, far from Zagros Mountains, southwest margin of Abadan Plain, 130 km southwest of Ahwaz, near Iran/Iraq boundary.

This structural trend is the result of old Precambrian, which has been made in younger periods. At least, a half of this structure located in Iraq country. Arvand structure is an inclined structure with 0 to 2 degree of dip, compatible with common structures in Abadan Plain. The field is located in boundary of Iran and Iraq and part of available closed contours are notclear in map.

Approximately, the last closed contour is in 4050 m ss. This field apparent area 43*4 Km$^2$ with 128 m closed to the top of Fahliyan.The AVD-02 core intervals (121.55 m) have been studied in terms of sedimentological subjects on the early Cretaceous units of Fahliyan Formation. Fig. 1 shows the location map of the Arvand field.

## 3- Methods And Materials

About 121.55m available cores related to one wall has been described. Different parameters such as lithology, texture, allochems and their frequency and sedimentary environment are recorded. The cross matching of visual observations have been done by thin sections that were prepared to confirm all the observations carried out in the core laboratory to minimize the errors on observations. The whole cores as well as slab photography are preceded simultaneously which are the support of all the observations carried out in core lab. About 290 thin sections of one well have been studied. The microfacies and sedimentary environments were studied and interpreted in detail using the classification of Dunham (1962) and Carozzi (1989) Depositional environment was determined using Wilson (1975) and Flugel (2010). Greggand Sibley (1984), Sibley and Gregg (1987) and Mazzullo (1992) used for classification of dolomites. They send to Using the sedimentological data a 3D depositional model will be prepared showing the regional history of deposition of the Fahliyan formation in the area.

## 4- Microfacies

Sedimentological studies have been resulted in identification of eleven microfacies (MF) described below.

### 4- 1. MF1-Dolostone

Dolomite microfacies is dominated in the Fahliyan formation from 4317.91 m to 4319.63m core intervals. This facies is composed of fine to medium dolomite (dolomicrite to plannar). High patchy dolomotization and pressure solution frature are observed as digenetic event. This facies is supposed to be deposited in a tidal flat setting.

The two above facies are supposed to be deposited in a tidal flat setting regarding the fact that tidal flats are characterized by daily exposure of the sediments during low tide, and produce a harsh environment which was not conducive to the development of an active benthos and thus are also characterized by a low diversity of fauna developed (Flugel, 2010). The lithofacies of the tidal flat setting are dominated bygenerally low energy mudstones and packstone with locally very distinct features (Fig. 3- A).

### 4- 2. MF2: Mudstone with fine skeletal debris

Mudstone facies with low diversity and low frequency of skeletal debris such as echinoid, echinoid spine, and ostracoda is dominated in the lower part of Fahliyan formation (from 4320 to 4321.34 m) containing core No. 8. Fracture porosity is notable; however, some of fractures are filled by calcite.This facies has been deposited within a shallow depth and poor circulation in restricted lagoon environment (Flugel, 2010). The latter is evidenced by low diversity of faunas. Reservoir core photograph of CF2 have been shown in the Fig. 3- B.

### 4- 3. MF3: Algae Wackestone to Packstone

This facies is characterized by the presence of large algae debris such as Permocalcalus cf. inopinatus, Salpingoporella cf. pygmaea and Lithocodiumaggregatum associated with benthic foraminiferta such as Pseudocyclammina lituus, Trocholina cf. lenticularis, Trocholina alpine, Trocholina cf. delphensis and echinoid.

Subordinate components include shell fragments such as rudist, gastropod, bivalve and ostracod. CF3 is dominated in Fahliyan core intervals and it is mainly composed of limestone with light gray color on hand specimen and core samples. Presence of large bioclasts particularly algae which are very common, indicate that this facies has been deposited in an open marine condition with no limitation in water circulation. Therefore, based on the faunal components, textural features, CF3 has been formed under moderate to low energy condition.

This wackestone to packstone facies with high amount of algae associated with benthic foraminifera, bivalves and algal material is interpreted as shallow subtidal environment with a low energy and is supposed to be deposited in restricted lagoon setting (Flugel, 2010). core photograph of CF3 have been shown in the Fig. 3- C and D).

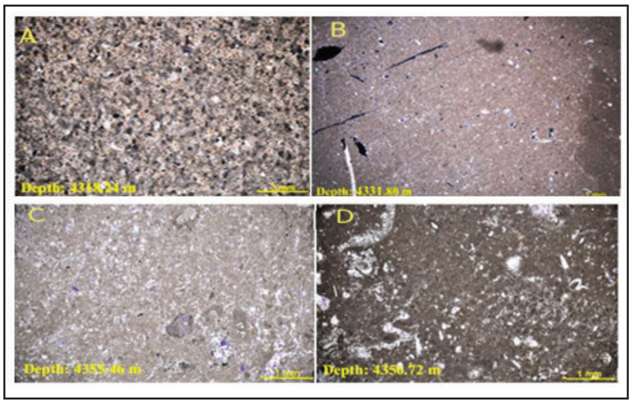


Fig. 3- Photomicrograph XPL. Microfacies types of Fahliyan Formation in A- MF1-Dolostone , B- MF2: Mudstone with fine skeletal debris , C & D- MF3: Algae Wackestone to Packstone.

### 4- 4. FM4: Skeletal Peloid Wackestone to Packstone

This facies is mainly characterized by a wackestone to packestone fabric, peloid isthe main component associated with fine to medium grained bioclasts. The bioclastsare mainly benthic foraminifera (Trocholina alpina, Pseudocyclammina lituus, Cylindroporella sp. and Miliolidae) and gastropoda, which are accompanied withgreen algae such as Permocalcalus cf. inopinatus, bivalve and ostracods.

Bioturbation has rarely seen in this facies. The main lithology is limestone, with lightgray color, however, dolostone have been obsereved in some core intervals of Fahliyan Formation. Dissolution is mostly appeared in the forms of vuggy and intraparticle porosity affected the facies by increasing the porosity. Dolomites includea variety of forms from planar to very fine early dolomicrite. Micro-fractures are visible on the core intervals of this facies, which are often filled by secondary calcite.

Ichnofacies (small condrites isp.) are also obsereved in this facies. This skeletal wackestone to packstone with high amounts of pelloid associated with benthic foraminifera, bivalves and algal material is interpreted as shallow subtidal (Flugel, 2010). core photograph of CF4 have been shown in the Fig. 4- A.

**4- 5. MF5: Skeletal Wackestone to Packstone**

This facies dominated in Fahliyan formation and characterized by high amount ofechinoid, benthic foraminifera such as Bouenia sp., Cyclammina sp., Trocholinaalpine, Pseudocyclammina lituus, Trocholina cf. lenticularis and Miliolidae, bivalve,crinoids and green algae such as Permocalcalus cf. inopinatus and Lithocodiumaggregatum representing more connection with the open marine environment.

Ostracod, gastropod, echinoid spine associated with peloids are subordinates component. Presence of benthic foraminifera in a muddy texture indicates a shallow and low energy depositional environment.

Presence of benthic foraminifera in a muddy texture indicates that CF5 has been deposited in a shallow and low energy environment. Occurrences of large bioclasts particularly those belong to normal marine condition suggest an open marine lagoonpaleo-environment for this facies (Flugel, 2010). core photograph of CF5 have been shown in the Fig. 4-B.

**4- 6. MF6: Fine to Medium Grained Pelloid Skeletal Packstone toGrainstone**

This core facies generally consists of fine-grained peloids. They often have significant amounts of shell material (bivalves and gastropods), echinoid, echinoidspine, algae debris (Lithocodium aggregatum and Permocalcalus cf. inopinatus) and benthic foraminifera such as Trocholina alpine, Lenticulina sp., Pseudocyclamminalituus., and Textularids. The facies represent moderate to high-energy condition thatis deposited in the ramp carbonate platform. CF6 found in limestone lithology withlight gray color in hand specimen cores. In terms of reservoir quality, this facies has not notable reservoir characteristics, due to lacking of any effective porosity.Occurrence ofplatform margin bioclasts and lagoonal biota suggests deposition at the lagoonal end to back barrier environments for this facies (Flugel, 2010). Leeward shoal is suggested for this facies with regard to large foraminifer's content core photograph of CF6 have been shown in the Fig. 4- C.

**4- 7. MF7: Boundstone**

This facies dominated in the lower part of Fahliyan Formation. It is mainly composed of large algae debris such as Lithocodium aggregatum, and rudist fragment accompanied with benthic foraminifera such as (Pseudocyclammina lituus, Trocholina alpine, Miliolidae and Textularids), echinoid, bivalve and peloid. It has a gray color on the hand specimen samples Due to the dominance of large algae and rudist fragments, this facies is interpreted to be deposited in a high-energy environment above the fair-weather wave base (Flugel, 2010). Core photograph of CF7 have been shown in the Fig. 4- D.

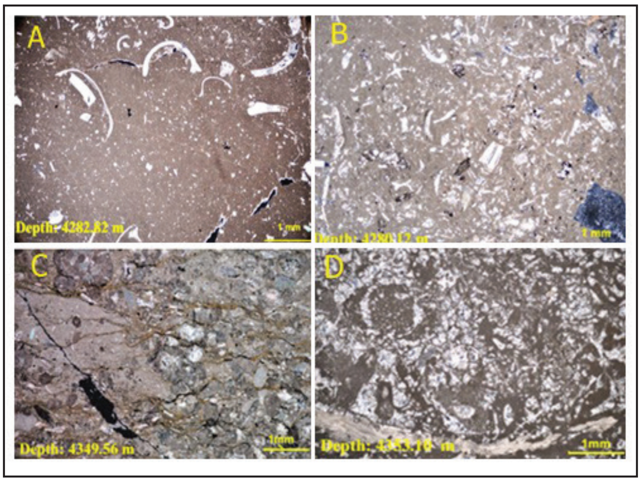


Fig. 4- Photomicrograph XPL: Microfacies types of Fahliyan FormationA- CF4: Skeletal Peloid Wackestone to Packstone, B- CF5: Skeletal Wackestone to Packstone, C- CF6: Fine to Medium Grained Pelloid Skeletal Packstone toGrainstone D- CF7: Boundstone.

**4- 8. MF8: Peloid Grainstone**

This facies dominated in Fahliyan formation from 4307.00 to 4309.00 m of coreintervals. It is mainly composed of peloid as the main component, whichis associated with low abundant of echinoid, benthic foraminifera and intraclast in agrain-supported texture. Vuggy porosity is the most porosity type in this facies. In terms of reservoir quality this facies has poor reservoir characteristics, due to lacking of any effective. Generally, no mud is present in the matrix due to high energy of water, representing good water circulation. From the reservoir point of view, these types ofhigh-energy shallow environmental condition facies13 ,72 (Flugel, 2010). core photograph of CF8 have been shown in the Fig. 5- A.

**4- 9. MF9: Coarse Grained Skeletal Interclastic Grainstone**

Coarse Grained bioclast intraclast grainstone is characterized by large skeletal debris such as algae, ostracod, echinoid, sparse peloid, benthic foraminifera such as Pseudo-cyclammina lituus, Aeolisaccus inconstans, Trocholina cf. lenticularis,Trocholina alpine and Textularids associated with high abundant of interclast. Themain lithology is limestone with gray color on core samples.

This facies is interpreted as a high-energy lower intertidal to seaward shoal settingwith significant sediment supply13, 72 and very well water circulation (Flugel, 2010). The latter issupported by presence of large allochems and dominance of cement in the matrix. corephotograph of CF9 have been shown in the Fig. 5- B.

**4- 10. MF10: Coarse Grained Echinoid-Algae Wackestone to Packstone**

This facies observed in lower part of Fahliyan studied core intervals.It is mainly composed of limestone with cream color and characterized by largeechinoids and shell fragments such as rudist and algae debris. Subordinate components include ostracod and benthic foraminifera such as Pseudocyclamminalituus and Lenticulina sp.

Presence of large bioclasts particularly echinoderm which are very common, indicate that this facies has been deposited in an open marine condition with nolimitation in water circulation 11, 67. Here fore based on the faunal components, textural features, CF10 has been formed in an upper midramp environment under moderateto low energy condition (Flugel, 2010). Core photograph of CF10 have been shown in the Fig. 5- C.

**4- 11. CF11: Fine to Medium Grained Rudist or Echinoid Wackestone to Packstone**

This facies consists of wackstone to packestone facies and the size of allochems have decreased significantly representing a change in depositional environment. This microfacies include fine to medium grains of rudist and echinoid, echinoid spine,crinoid, and small benthic foraminifera such as Cyclammina sp. and Lenticulina sp.

The depositional environment is interpreted as the lower part of a carbonate ramp.The latter is supported by the faunal components, wackestone to packstone fabrics and the size of skeletal grains, which are fine to medium 61. In general, the facies supposed to be deposited in a medium to low energy environments (Flugel, 2010). photography CF11 have also been shown in the Fig. 5- D.

## 5- Paleo-Environment Reconstruction

With regards to sedimentological characteristics of the studied successions and based on macroscopic features observed on the core intervals a carbonate rampsystem is suggested for the study area and It has been illustrated in Fig. 6.

Carbonate deposits, which are dominant in the Fahliyan Formations have been deposited high standsystem tracts in the mentioned ramp type platform. The carbonate being deposited in a shallow marine, very gentle ramp is evidenced by lack of bioherms and carbonate build ups able to form a continuous break insedimentary basin which may completely isolate the mid ramp facies from the inner ramp (shallower lagoonal and sub tidal parts) of the carbonate platform. It should benoticed that some carbonate mounds and barrier settings such as coralline rudistgrain stone and peloid grain stone deposits are found in the studied basin but they arenot high enough and laterally extended to create a major break in carbonate platform and develop a shelf margin that can separate open marine sediments from theshallow sub-tidal facies belts.

The lower cretaceous Fahliyan formation is also believed to be deposited in ashallow carbonate ramp consisting from various facies associations. This has been shown in Fig. 6. This formation represents a shallow tidal flat deposit, restricted lagoon to highenergy carbonate shoal depositional setting in the AVD-02 well among which theupper part core No. 11 shows more high energy upper to lower slope condition. Therest of the formation mainly represents a very shallow restricted to open marine lagoon setting.

To summarize the above discussions we can say that the core facies have been interpreted in terms of depositional environment and are categorized as seven paleoenvironments including:

1-Tidal flat deposit. 2- Sub-tidal lagoon (restricted lagoon to open marine lagoon). 3- Leeward shoals (lagoonal margin to lower intertidal settings). 4-Bioclastic shoal belts (sub-tidal to lower intertidal settings). 5- Seaward shoal margin (coarse bioclastic /intraclastic grainstone). 6- Mid-Ramp setting (upper part of carbonate slope and lower part of it). A plot representing the frequency of each described core facies is illustrated in the Fig. 7.

## 6- Conclusions

results of activities and achievements on the geological core analyses, sedimentological characteristics studies of the Fahliyan formations in the Arvand oil field have received some comments from facies classification, depositional environment recognition have been carried out on the received core intervals. The studied succession is composed of three distinct lithostratigraphical units aged early to late cretaceous. This includes Neocomian-Barremian, Fahliyan formation Lithology is composed of limestone bearing successions which has been partially dolomitized.

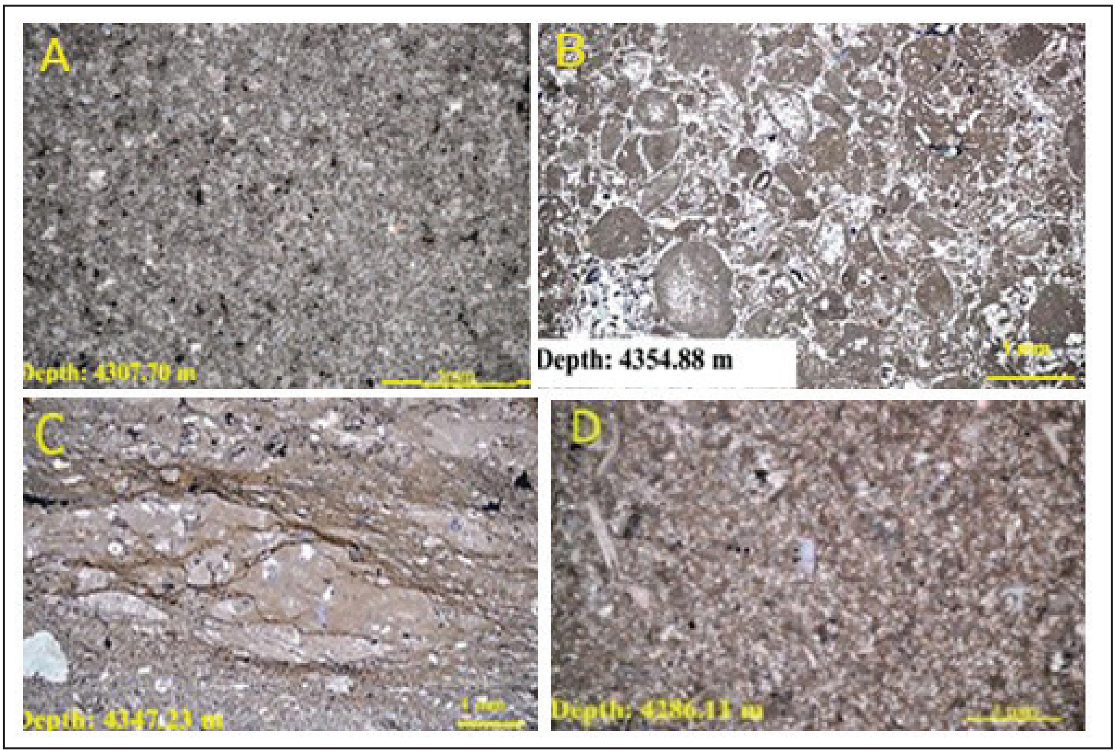


Fig. 5- Photomicrograph XPL: Microfacies types of Fahliyan FormationA- CF8: Peloid Grainstone, B- CF9: Coarse Grained Skeletal Interclastic Grainstone, C- CF10: Coarse Grained Echinoid-Algae Wackestone to Packstone D- CF11: Fine to Medium Grained Rudist or Echinoid Wackestone to Packstone.

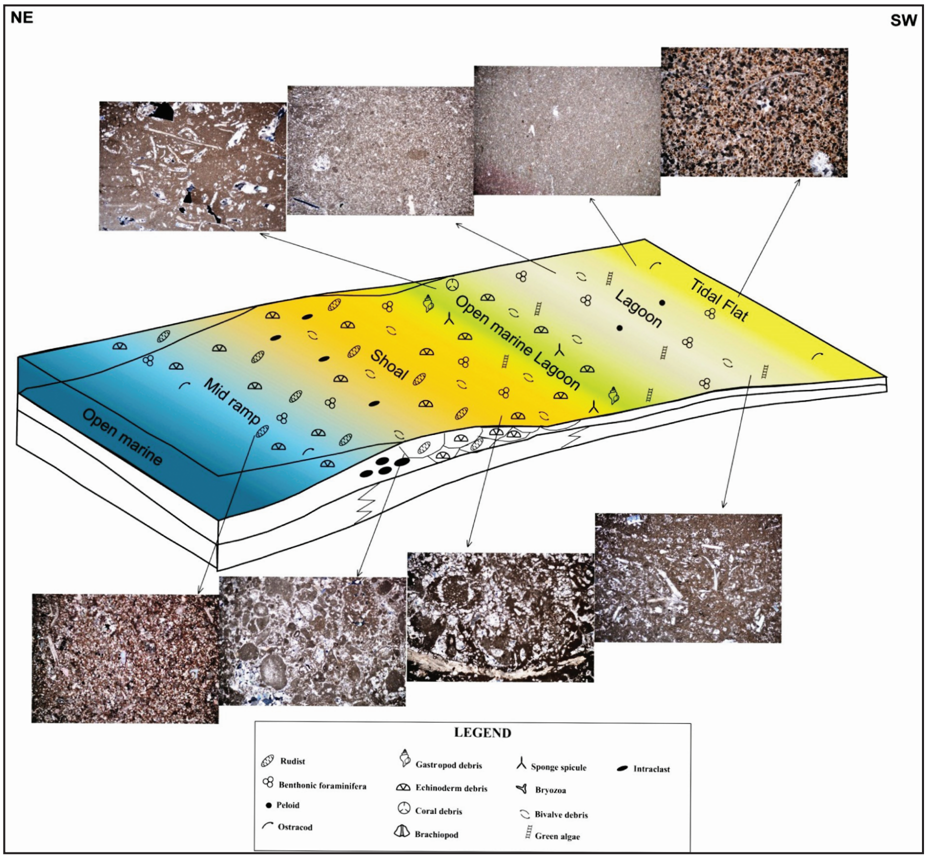


Fig. 6- Conceptual depositional model (Ramp system) for Fahliyan formation in well No. AVD-02.

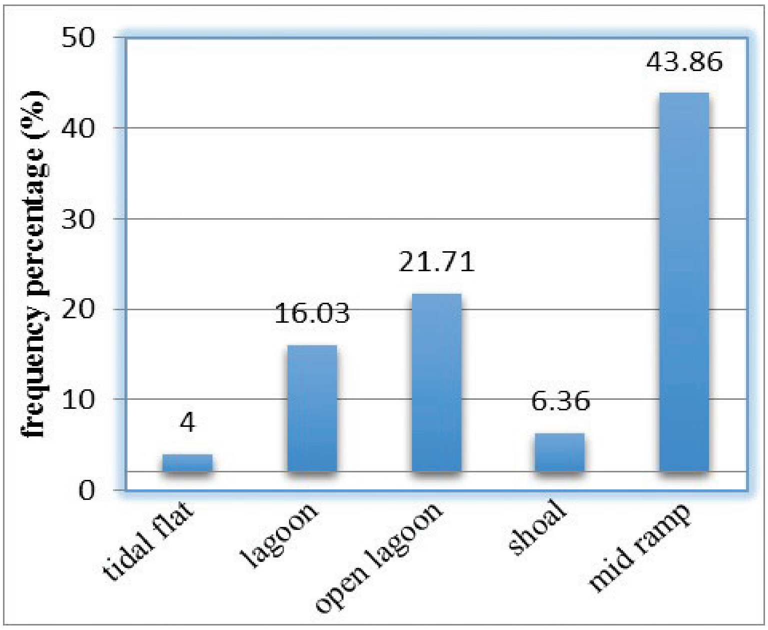


Fig. 7- Frequency percentage of the types of depositional environment for Fahliyan formation in Arvand Field, well No. AVD-02.

Based on the sedimentological studies, 11 principal Core Facies (CF1 to CF11) have been identified on the cores which are: CF1: Dolostone, CF2: Dolomudstone with Bioclast, CF3: Algae Wackestone to Packstone, CF4: Skeletal Peloid Wackestone to Packstone, CF5: Skeletal Wackestone to Packstone, CF6: Fine to Medium Grained Peloid Skeletal Packstone to Grainstone, CF7: Coralin-Rudist- Algae Grainstone (Boundstone), CF8: Peloid Grainstone, CF9: Coarse Grained Skeletal Interclastic Grainstone, CF10: Coarse Grained Echinoid-Algae Wackestone to Packstone, CF11: Fine to Medium Grained Rudist or Echnoid Wackestone to Packstone.

These core facies have been interpreted in terms of depositional environment and are categorized in seven paleo-environments including:Tidal flat deposits, Sub-tidal lagoon (restricted lagoon to open marine lagoon), Leeward shoals (lagoonal margin to lower intertidal settings), Seaward shoal margin (coarse bioclastic/intraclastic grainstone). Mid-ramp setting (upper part of carbonate slope and lower part of it).

It should be mentioned that the outer ramp is divided into distal open marine and proximal open marine environments.

Fahliyan Formation in the AVD-02 well is characterized by various facies including dolostone and dolomudstone of tidal flat, skeletal wackestone to packstone of the open and restricted lagoon, bioclastic intraclastic grainstones, peloid grainstone and coralinrudist-algae grainstone (boundstone) of the barrier setting and fine grained echinoderm rudist bearing deposits of the slope. From the reservoir quality point of view, the Fahliyan Formation is categorized as a high permeable but medium to low in general the whole carbonate dominated studied core interval of the well AVD-02, indicate an overall shallow water platform type depositional environment.

In this well, high frequency of core facies belong to restricted and open marine lagoon deposits composed of benthic foraminifera, shell fragments and peliods. They are often observed in wackestone to packstone fabrics.

The remained rock facies is composed of the bioclastic skeletal lime grainstones characterizing by large rudists and echinoderm debries which are interpreted to constitute the platform margin in this well. Tidal flat dolomudstone with a few bioclast contribute in the core intervals of the studied well, which they often show moderate Macroscopic observations indicate that studied formations are not highly fracturized in the well AVD-02 and that micro-fractures are not supposed to contribute very much in hydrocarbon production or in the case of presence they have a very limited share to reservoir quality of the Formation. This is due to thin aperture of the fractures and being included by calcite in most of the cases Micropaleontology and biostratigraphical studies Neocomian for Fahliyan Formation

**Acknowledgments**

Our deepest thanks to the Department of Geology at University ofAzadand Geological Department at Arvandan Oil and Gas Company for their generous support including equipment and facilities that contributed to this work.

**References**

Adabi, M. H, Salehi, M. A. and Ghabeishavi, A., 2010- Depositional Environment, Sequence Stratigraphy and Geochemistry of Lower Cretaceous Carbonates (Fahliyan Formation), South-West Iranjournal of Asian Earth Sciences 39 148–160 P

Adabi, M. H., Salehi, M. A. and Ghobeishavi, A., 2010- Depositional Environment, Sequence Stratigraphy and Geochemistry of Lowercretaceous Carbonates (Fahliyan Foemation), South–West Iran: Journal of Asian Earthsciences, V. 39, P. 148–160.

Carozzi, A.V., 1989- Carbonate Rocks Depositional Model, A Microfacies Approach. Prentice, Hall, New Jersey, Usa.

Dunhum, R. J., 1962- Classification of Carbonate Rocks According to Depositional Texture. In: Ham, W.E. (Ed.), Classification of Carbonate Rocks. American Association of Petroleum Geologists, Memoir 1: 108-121.

Flugel, E., 2010- Microfacies of Carbonate Rocks. Analysis, Interpretation of Application: Springer, Berlin Heidelberg, New York, 144p.

Gregg, J. M. and Sibley, D. F., 1984- Epigenetic Dolomitization of the Origin of Xenotopic Dolomite Texture Reply: Jour Sed Petrology 56: 735-763.

Hajikazemi, E. Al-Aasm I. S. and Coniglio M., 2010- Subaerial Exposure of Meteoric Diagenesis of the Cenomanian-Turonian Upper Sarvak Formation, Southwestern Iran Special Publications, London, Geological Society; V. 330, P. 253-272

Kamali, M. R. and Abolghasemi, A., 2013- Correlation of The Fahliyan of Surmeh Reservoirs In The Garangan of Chilingar Oilfields, The Dezful Embayment (Sw Iran) , Journal of Petroleum Exploration of Production Technology,June, Volume 3, Issue 2, Pp 85–92

Maleki, S. and Lasemi, Y., 2011- Sedimentary Environment Sequence Stratigraphy of the Fahliyan Formation in Assaluyeh (Bidkhon) of Khartang Sections, Southwest Iran. Journal of Basic of Applied Scientific research., 1(12)2641-2647

Mazzullo, S. J., 1992- Geochemical of Neomorphic Alteration of Dolomite: A Review. Carbonate of Evaporates 7: 21-37. Folk, R.L., 1959, Practical Petrographic Classification of Limestone: Aapg Bull., V. 43, No. 1, P. 1-38.

Ramezani Akbari, A., Rahimpor-Bonab, H., Kamali, M. R., Moussavi-Harami, R. and Kadkhodaie, A., 2016- Depositional environment, electrofacies and sequence stratigraphy of the Fahliyan Formation (lower Cretaceous), Abadan plain, Scientific Quarterly Journal, GEOSCIENCES, Vol. 26, No.102, 351p.

Sajjadian, V. A., Zeinalzadeh, A., Moussavi-Harami, R. and Mahboubi, A., 2015- Basin of Petroleum System Modeling of The Cretaceous of Jurassic Source Rocks of The Gas of Oil Reservoirs In Darquain Field, South West Iran, Journal of Natural Gas Science of Engineering, Volume 26, Pages 419-426

Sherkati, S. and Letouzey, J., 2004- Variation of structural Style of Basin Evolution in The Central Zagros (Izeh Zone of DezfulEmbayment), Iran. Marin of Petroleum Geology 21, 535–554.

Sibley, D. F. and Gregg, J. M., 1987- Classification of Dolomite Rock Texture, Journal of Sedimentary Petrology 57: 967-975.

Soleimani, B., Hassani, M. and Abdollahi, I., 2017- Formation Pore Pressure Variation of The Neocomian Sedimentary Succession (The Fahliyan Formation) In The Abadan Plain Basin, SW of Iran, Geofluids. Volume 2017, Article ID 6265341, 13 Pages

Wilson, J. L., 1975- Carbonate Facies in Geological History. Springer, Berlin– Heidelberg, New York. P. 471