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Integrated rock typing in carbonate reservoir using MRGC method, a case from SW of Iran

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Abstract

According to thin sections examination prepared from cuttings plus core samples, and using petrophysical data (Electrofacies), 10 microfacies and two lithfacies are recognized in Fahliyan Formation in the Abadan plain. This formation consists of two carbonate ramp and mixed carbonate–siliciclastic (mixed zone) members. Rock type and electrofacies were modelled with using MRGC method. Gamma, acoustic, density, neutron, and resistivity are considered as main logs (model logs) and volume logs that have been evaluated in multimin method like shale, limestone, dolomite, sandstone, and effective porosity which are considered associated logs both have been subjected to training in MRGC method. The best result in MRGC method is 12 cluster model. These results suggest that electrofacies model is in agreement with heterogenetic rock type such as mixed carbonate–siliciclastic environment observed in petrography. Also, in heterogeneous rock type such as carbonate ramp environment electherofacies can't completely determine geological facies. The result of this study shows that in sedimentary environments where there is a sharp difference between rock types electrofacies can play an important role in interpretation of sedimentary environment.

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Introduction

Electrofacies identification is vital for geological and reservoir engineering studies especially when there is no core data. Studies have shown that cluster analysis is the best method for Electrofacies determination (Shin-Ju and Rabiller, 2000). Multi Resolution Graphic based Clustering (MRGC) solves problems that other methods such as Ascendant Hierarchical Clustering (AHC), Dynamic Clustering (DC) and Self Organizing Map (SOM) are not able to answer them (Tavakoli and Amini, 2006; Kadkhodaie-Ilkhchi, *et al.*, 2013). For instance, the main problem in the cluster analysis is the number of clusters that MRGC was able to recognize without any presumption (Shin-Ju and Rabiller, 2005).

The reservoir rock type and relationship between them is an essential step to understanding of hydrocarbon reservoirs (Bastani and Bidhendi, 2015). Generally, a geological rock type is defined on the base of their depositional features (physical, chemical, biological and diagenetic imprints) using outcrop Interpretations, cutting and core descriptions that it called as “litho-Facies”. A petrophysicist characterizes a rock type on the base of similar responses of log measurements in a whole well profile and calls it as “electrofacies”.

The rock types resulted from these different approaches are not considered in the same way, and generally are not correlated thoroughly (Askari and Behrouz, 2011). The cause of this poor relationship can be traced in a dimensional dependency problem. This means that geological facies and petrophysics log space cannot be similar and there is not linear relationship of mathematical calculations between them.

The goals of this study are: to interpret the depositional environment, to establish the relationship between geological rock type (Lithofacies) and petrophysical rock type (Electrofacies) for the Fahliyan Formation in an oilfield in southwest of Iran.

Material and methods

Study area

The studied oilfields are located in the Abadan Plain as a part of the Dezful Embayment of Zagros area in southwest of Iran (fig. 1A). Also the structures were explored by geophysical operations in the Abadan plain (fig. 1B). The Mesozoic carbonate systems of the Abadan plain host important hydrocarbon reservoirs which one of this carbonate reservoirs succession is Fahliyan Formation. Khami Group consist of Nayriz, Surmeh, Fahliyan, Gadvan and Dariyan Formations (Fig. 2). Figure two show lithostratigraphical Column of Fahliyan Formation.

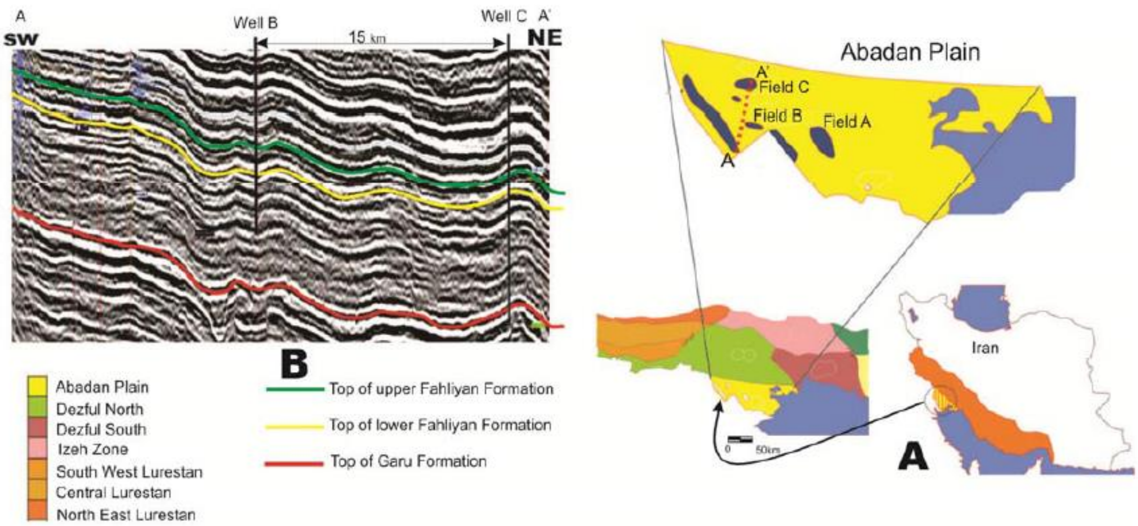


Fig. 1. A. area study, Abadan plain that is a part of Zagros Fold–Thrust Belt, A-A’ seismic cross section and locations of A, B and C oil fields. B- 2D seismic cross section from B and C fields, well B is located in highest and well C in lowest part of Bourghan-Azadeghan paleohigh.

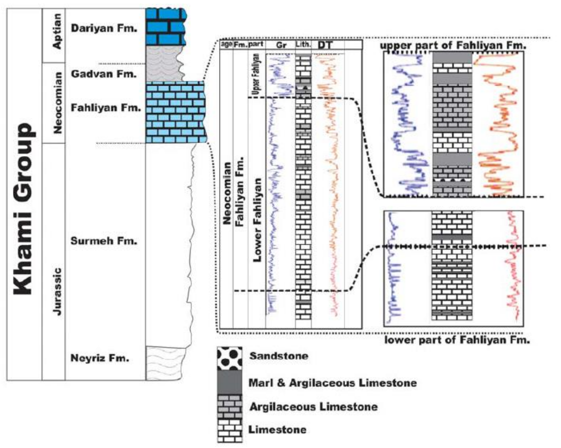


Fig. 2. Khami Group and Fahliyan Formation stratigraphical column.

Wells, core and cutting

Three cored wells that penetrated the Fahliyan Formation were chosen from three oilfields and the upper and lower boundaries of Fahliyan Formation were determined. Using thin sections prepared from cutting and core samples (for cutting, one sample in each 1-2 meters (total number of thin section is 950) and for core, one sample in each 30 centimetre (total number of thin section is 320)) led to depositional sub-environment results.

Geological classification

For carbonate and terrigenous samples classifications of Embry and Klovan (1971), Dunham (1962) and Folk (1974) is considered, and recognition of facies belts and sedimentary profile is based on Flugel (2010). To identify lateral facies changes in Fahliyan Formation, the boundary of upper part have been flatted in a border.

Petrophysical data

Lithofacies and porosity have been determined from gamma ray (GR), sonic (BHC=DT), density (RHOB), neutrons (NPHI) and resistivity Loges (MSFL, LLD, LLS). Effective porosity and volumes of shale (V sh), Dolomite (V dol), Limestone (V calc), and sandstone (V qtz) have been evaluated by the Multimin method of the Geolog software. These logs have been used as associated logs in MRGC method.

Geological setting

The Abadan Plain is including structures that are situated within Mesopotamian fore deep basin in southwestern of the Zagros foreland and fore deep basin area and contain many super giant oil and gas fields (Berberian, 1995). Arabian, N–S-trending, basement-involved horst systems have been named differently, according to their geographical location, such as Burgan High. In SW Iran, the N–S trend can be identified in the Abadan Plain that related whit Burgan-Azadeghan Paleohigh (Abdollahie-Fard *et al*., 2006). The lower cretaceous Fahliyan Formation, as part of the Khami Group, transitionally overlying the argillaceous limestone of the Garu Formation (in study area) and its upper boundary gradually changes into marl and argillaceous limestone of the Gadvan Formation. In studied area Fahliyan Formation consist of upper and lower parts and thickness of the studied unit is about 580 meters (fig. 2).

Result and discussion

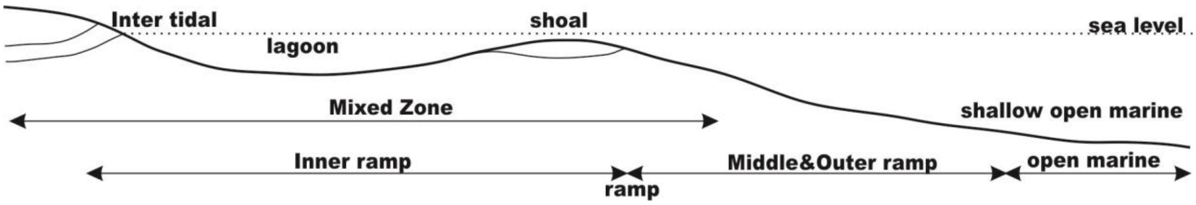
Petrographic study on thin sections prepared from cuttings and cores resulted in the recognition of 10 microfacies and two lithofacies. The Fahliyan Formation in the Abadan Plain consists of two carbonate and mixed carbonate-siliciclastic (mixed zone) members. All carbonate facies belts and lithofacies have been described in table 1 using Dunham (1962), Embry and Klovan (1971) textural classification scheme and Flügel (2010) descriptions for microfacies analysis.

Depositional environment

Base on table 1 the carbonate member has been deposited in various sub-environment of carbonate ramp (shallow open marine, outer/mid ramp and inner ramp). Main factor that result from petrographical data in table 1 are: presence of shoal that is an important factors in the carbonate ramp (Elrick and Read, 1991), absence of a reef causes the algae in the lagoon area transfer to deeper parts of the open marine, presence of pellets in the shoals facies belts indicates the transfer of low energy to the highest energy regions.

Combination of these factors, in particular dispersion lagoon benthic foraminifers in another subenvironment indicates a carbonate ramp environment (Flugle, 2010). Apparently, the sedimentary sequence of the carbonate member have been deposited in a carbonate ramp, containing important shoal facies and lagoon expansion. In Fahliyan Formation, dissolution and vuggy porosity usually exist in lagoon facies near intertidal sub-environment (fig. 3H). In another study presented by Jamalian *et al.* (2011) carbonate ramp in another area of Zagros Fold-Thrust Belt has been explained.

Table 1. Carbonate ramp and mixed carbonate-siliciclastic sub-environments.



Env.	Facies	Microfacies	Thin section Discretion	Flugel
Carbonate ramp	Open marine	Radiolarian Sponge spicule Wackestone	Dark brown-brown matrix, 10-30% sponge spicule, 10-20% radiolarian, rarely algae and shell fragments (fig. 3 A and B).	RMF 5
Carbonate ramp	Outer/ Middle ramp	Bioclast Packstone/Wackestone	10-20% coral, Sponge spicule and radiolarian less than 10%, 10% peloid, bivalve, in all thin section echinoid spicules existed, rarely green algae. Benthic foram such as: *Pseudocyclammina conica* (fig. 3 C).	RMF 7
Carbonate ramp	Inner ramp – Shoal	Bioclast Grainstone/packstone	Great variety of benthic Foram such as: *Pseudocyclammina conica and Pseudocyclammina elangata,* 10% stromatoporoids, 10% Peloid, corals that don't exist at all thin section (fig. 3 D).	RMF 26
Carbonate ramp	Inner ramp – Shoal	Bioclast Peloid Grainstone/Packstone	More than 30% Peloid, 10-20% Bioclast such as: echinoid, bivalve, red algae, shell fragments (fig. 3 E).	RMF 27
Carbonate ramp	Inner ramp – Shoal	Ooid Peloid Grainstone	30% peloids that good rounded and sorted, 20% Ooids, micritization in same grain (fig. 3 F). The main properties in shoal facies are sparry cement, physical compaction.	RMF 29
Carbonate ramp	Inner ramp – Lagoon	*Trocholina* Wackestone	20-30% *Trocholina,* loss than 10% green algae, rarely sponge spicule (fig. 3 G).	RMF 20
Carbonate ramp	Inner ramp – Lagoon	*Pseudocyclammina* Bioclast Floatstone	Less than 10% coral, Bioclast: echinoid, gastropod, green alge, *Pseudocyclammina elangata,* partly dolomitization, micritization, dissolution, moldic and vuggy porosity (fig 3 H).	RMF 13
Carbonate ramp	Inner ramp – Lagoon	*salpingoporella* Bioclast Packstone/Wackestone	30-40% green algae such as: *Salpingoporella dinarica, Salpingoporella muhlbergi, Munieria baconica, Clypeina jurassica,* less than 5% worm tube, stylolite whit trace of oil stain, micritization (fig. 3 I). Partly dolomitization, micritization, dissolution, moldic and vuggy porosity are the main diagenetic feature in lagoon facies.	RMF 17
Carbonate ramp	Inner ramp – Inter tidal	Peloid Intraclast Packstone	Alternation of peloid and intraclast, 10-20% peloid, 20-40% interaclast, rarely green algae and Bioclast, fenestral porosity (fig. 3 J). Widespread dissolution and abundant vuggy porosity indicated in this facies (Flugle, 2010).	RMF 22
carbonate–siliciclastic (Mixed zone)		Sandy Mudstone-Argillaceous Limestone	5-10% sand whit good rounded and sorted Quartz grain, high Argillaceous and some fossil fragment such as: *Trocholina* (fig. 3 K).	
carbonate–siliciclastic (Mixed zone)		Sandstone/Siltstone	"Quartz arenite". Quartz grain, good sorted and bad rounded, dolomitic and calcite cement (fig. 3 L). Thickness of this lithofacies between 0.5 to 6 meter (inter bedded) changed.	
carbonate–siliciclastic (Mixed zone)		Calcareous Claystone	Partly named Marl in graphic well log. Due to drill by PDC bit, any allochems or orthochems can't determine in thin section of Mixed member. This part have highest API in GR log. Thickness of this lithofacies between 1 to 20 meter changed.	

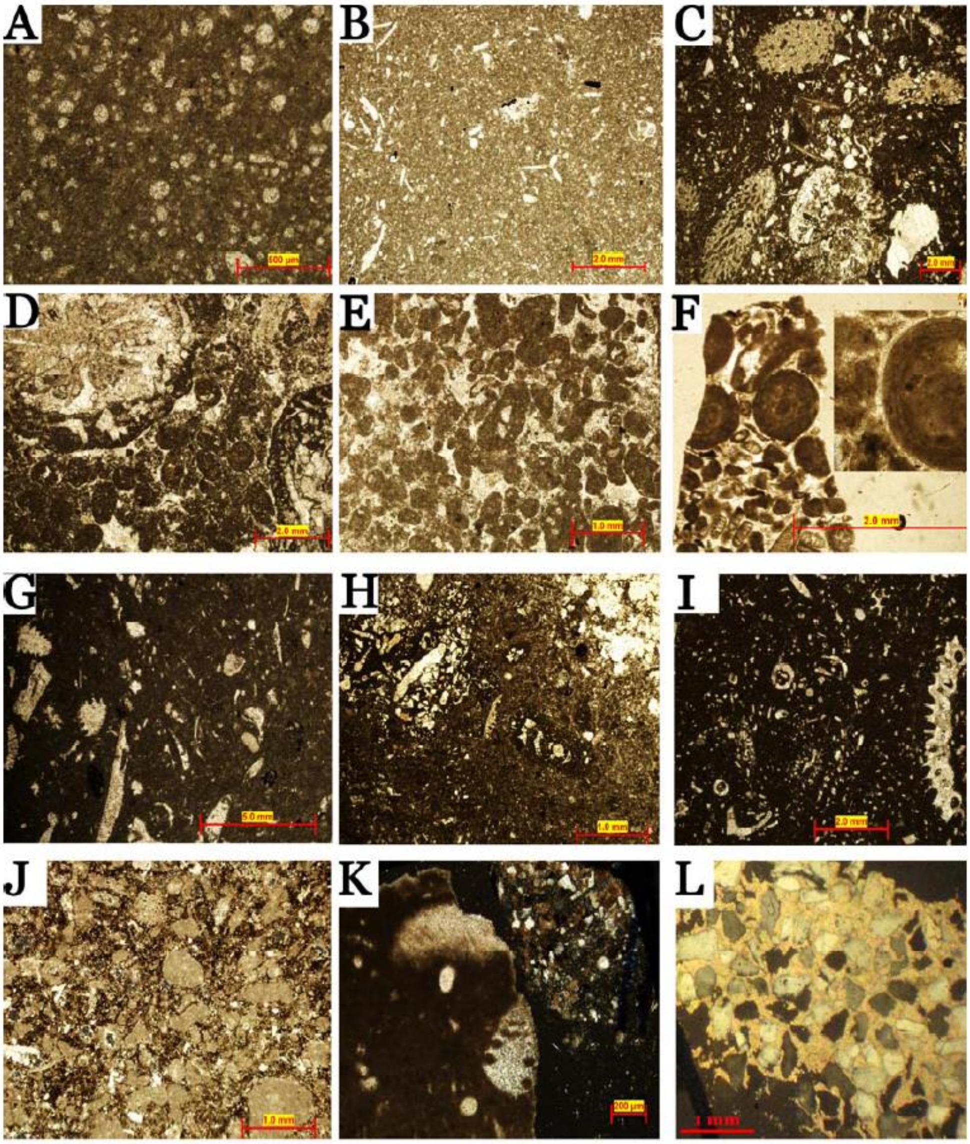


Fig. 3, Microfacies of the Fahliyan Formation. A- Radiolarian Wackestone, open marine facies, sample 4191 meter at well A, PPL (Plane Polarized Light). B) Sponge spicule Wackestone, open marine facies, sample 4801 meter at well C, PPL. C- Bioclast Packstone/Wackestone, Outer/Middle ramp facies, sample 4236 meter at well A, PPL. D) Bioclast Grainstone/packstone, shoal facies, sample 4235 meter at well B, PPL. E) Bioclast Peloid Grainstone/Packstone, shoal facies, sample 4118 meter at well A, PPL. F) Ooid Peloid Grainstone, shoal facies, sample 4189 at well C, PPL. G) *Trocholina* Wackestone, lagoon facies, sample 4328.5 meter well C, PPL. H) *Pseudocyclammina* Bioclast Floatstone, lagoon facies, sample 4305 meter at well C, PPL. I) *Salpingoporella* Bioclast Packstone/Wackestone, lagoon facies, sample 4443 meter at well C, PPL. J) Peloid Intraclast Packstone, Inter tidal facies, sample 4303 meter at well C, PPL. K) Sandy Mudstone-Argillaceous Limestone, Mixed zone lithofacies, sample 4001 meter at well B, XPL (Cross Polarized Light). L) Calcareous Claystone, Mixed zone lithofacies, sample 3848 meter at well A, XPL.

There is not a lot of information about depositional environment of mixed zone in Fahliyan Formation. Lower Cretaceous sedimentary sequences in Persian Gulf have been deposited calcareous, marl and sandstone layers in mixed carbonate-siliciclastic sedimentary environment (Sharland *et al.*, 2001; Davies *et al.*, 2002). Based on petrographical studies (table1) the mixed member is composed of three parts: Calcareous Claystone, sand beds and argillaceous limestone. According to the results of these studies and other articles that were published such as Sharland *et al*. (2001) Davies *et al*. (2002) the upper part of Fahliyan Formation deposited in mixed carbonate-siliciclastic environment. The mixed carbonate-siliciclastic member succession shows shallow marine carbonate features (base on benthic foraminifera fig. 3K) along with claystone and thin sand beds. Evidences of this are in the upper part of Fahliyan: clay stone with sand bed that increases in thickness toward the West of area and carbonate sequence thickness that increases toward the East of area (fig. 4, B and C wells).

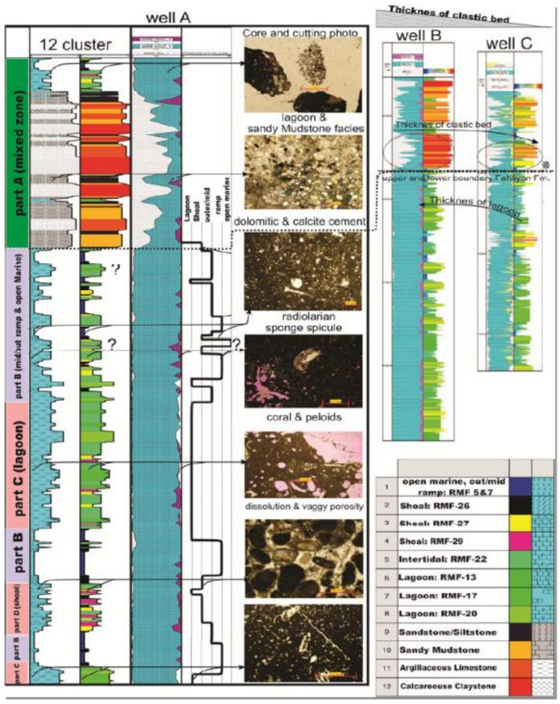


Fig. 4. A, B and C wells electrofacies (12 cluster) are shown. Well A, 12 cluster validated by petrographical data (core and cutting). B and C wells flatted in a border (upper and lower parts of Fahliyan Formation). Attention to thickness of clastic sediment is reduced from West to East (fig.1 2D seismic cross section).

Electrofacies

All electrofacies determination methods were derived from same data grouping and dissociating of groups from statistical point of view (Tavakoli and Amini, 2006).

Electrofacies determination can be based on cluster analysis, artificial neural networks and fuzzy logic. Each of these methods has features and defects. Electrofacies provided based on neural networks and fuzzy logic cannot directly process data with many variables. Therefore a method is needed to process given number of variable data directly. Cluster analysis is one of the computational methods for data with multiple variables.

Multidimensional methods are divided totally into geometric or Statistical Categories. Geometric methods including hierarchical and optimization procedure are repeated. Statistical methods are includes of Parametric and nonparametric methods (Shin-Ju and Rabiller, 2000). Non-parametric method which is based on probability density function (PDF) methods, is divided into geometric division, multi-dimensional cube, K Nearest Neighbor (KNN) and Divided graphing techniques. Determining the lithofacies which is based on MRGC and KNN methods is a non-parametric statistical method that can be used to determine the clusters which are similar to lithofacies (Al-Bulushi *et al*., 2009; Helle and Bhatt, 2002; Tavakoli and Amini, 2006).

As previously stated, gamma ray, sonic, density, neutrons and resistivity loges were used in MRGC method as model logs to determine clusters. After evaluation of volume of shale, sand, dolomite, and calcite (Limestone) by using Multimin method of the Geolog software, these volume were used as associated logs. All clusters (7 cluster, 9 cluster and 12 cluster) in MRGC method were modeled by K-NN. After checking the number of clusters and the weight given to logs, it's been showed that the 12 clusters established in geology are most compatible with the number of facies. Due to the effect of the logs on the model mentioned, the cluster pattern is appropriate for facies belts. Although clustering is determined by MRGC, the number of clusters are optional but there must be a model of the number of clusters. The 12 cluster model is equal to the amount of facies determined in table 1.

Once a petrographic facies shows the greatest changes in properties, they can be replaced by electrofacies. As shown in fig. 4 (between A and B parts well A) the changes are visible in the boundary between the parts of upper and lower Fahliyan Formation. In the petrography of carbonate member, the maximum porosity and dolomitization are associated with the lagoon. These petrophysical characteristics can be identified by logs (fig. 4 part C of well A). As a result of the pattern, lagoon facies equate with clusters that have the most dolomite and porosity. Petrographic studies indicate that cementation prevents the interparticle and vuggy porosity in shoal facies, and therefore, the lowest reading of gamma ray log and fastest response of sonic log are related to shoal facies. The Cluster that has the less porosity, dolomite volume, gamma, sonic, density and neutrons logs than lagoon facies is related to shoal facies pattern (fig. 4 part D of well A). In this study open marine and mixed carbonate-siliciclastic facies have minimum effective porosity, but the amount of argillaceous limestone in the open marine carbonate facies is greater than the other carbonate facies. As a result, the cluster of lowest effective porosity, dolomite and highest gamma ray in carbonate cluster is attributed to open marine facies, therefore common petrophysical characteristics between middle and outer ramp can't be detected in cluster analysis (homogenous rock type electrofacies can't completely determine geological facies (fig. 4 question mark part B of well A)). MRGC method can't identify clusters in carbonate ramp facies belts because of similar petrophysical properties. Therefore in homogenous rock type, cluster analysis can't determine geological facies.

Due to the lack of the core data from mixed carbonate-siliciclastic, cuttings samples is used. The maximum reading of gamma ray and sonic logs (shale volume) and the minimum of effective porosity are related to electrofacies that are recognized for mixed carbonate-siliciclastic zone (fig. 4 part A of well A). Some shalely beds overlying the limestone and thin sandstone strata.

Therefore drastic changes which occurs in the petrographic facies are recognizable by petrophysical logs. Electrofacies have excellent performance in mixed carbonate-siliciclastic facies (heterogenetic rock type in petrography such as mixed carbonate–siliciclastic environment can be an acceptable electrofacies model). Accordingly, the separation of its facies is easier than electrofacies that are related to carbonate ramp environment.

The results of electrofacies are shown in Fig. 4 (A, B and C wells). After the models are provided, educational data should be validated by acceptable petrographic facies; As a result, electrofacies models have been validated by the core facies (Fig. 4 well A). The produced model will be applicable, only if it is correlated in nearby oil fields.

Electrofacies and petrography studies expected that Sea level changes (retrogradation and progradation) can be detected by electrofacies and Lateral changes in sedimentary environment can be identified from B to C wells. Thickness of lagoon sub-environment is increased by approaching to the top of Burgan-Azadegan paleohigh (west Abadan Plain (fig. 1B)). Also, the clastic sediments from the west of Fahliyan Formation to the east is reduced in thickness (fig.4 well B toward well C). These result are due to flatting the boundary of the upper part of Fahliyan Formation on a border.

Conclusion

Fahliyan Formation in Abadan plain deposited in two carbonate and mixed carbonate-siliciclastic (mixed zone) environments. MRGC method which can identify difference between carbonate ramp and mixed carbonate-siliciclastic environments due to obvious changes in rock types and petrophysical logs has been quite successfully.

The evidence shows that carbonate facies deposited in a carbonate ramp from the lower part of Fahliyan Formation. MRGC method can't identify clusters in carbonate ramp facies belts because of similar petrophysical properties (standard deviation and cumulative frequency are similar). Therefore homogenous rock type cluster analysis can't determine geological facies.

Mixed carbonate-siliciclastic deposited in shallow marine environment at the upper part of Fahliyan Formation. The changes in petrophysical logs in mixed carbonate-siliciclastic environment are obvious therefore identifying this kind of environment is similar to heterogenic rock type.

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.

Al-Bulushi N, King PR, Blunt MJ, Kraaijveld M. 2009. Development of artificial neural network models for prediction water saturation and fluid distribution. Journal of Petroleum Science and Engineering **68(4)**, 197-208.

Askari AA, Behrouz T. 2011. A fully integrated method for dynamic rock type characterization development in one of Iranian off-shore oil reservoir. University of Tehran, Journal of chemical and petroleum engineering **45(2)**, 83-96.

Bastani Kahrizak A, Bidhendi MN. 2015. Determination of rock typing in one of carbonate reservoir in South of Iran by using of MRGC method and hydraulic flow. Journal of Biodiversity and Environmental Sciences **6(4)**, 571-575.

Berberian M. 1995. Master blind thrust faults hidden under the Zagros folds: active basement tectonics and surface morphotectonics. Tectonophysics **241**, 193–224.

Davies RB, David MC, Horbury AD, Sharland PR, Simmon MD. 2002. Early to mid-Cretaceous mixed carbonate-clastic shelfal systems: examples, issues and models from the Arabian Plate. Gulf Petro Link, Bahrain, Geo Arabia **7(3)**, 541-598.

Dunhum RJ. 1962. Classification of carbonate rocks according to depositional texture. In: Ham, W.E. (Ed.), Classification of carbonate rocks. Memoir **1**, American Association of Petroleum Geologists 108-121.

Elrick M, Read JF. 1991. Cyclic ramp-to basin carbonate deposits, Lower Mississippian, Wyoming and Montana: a combined field and computer modelling study. Sediment Petrol **61**, 1194–1224.

Embry AF, Klovan JE. 1971. A Late Devonian reef tract on northeastern Banks Island, NWT. Bulletin of Canadian Petroleum Geology **19**, 730-781.

Flugel E. 2010. Microfacies of Carbonate Rocks: analysis, interpretation and application. Springer 320-405.

Folk RL. 1974. Petrology of Sedimentary Rocks. Austin, Texas, Hemphill Publishing Company **78703**, 162-177.

Helle HB, Bhatt A. 2002. Fluid saturation from well logs using committee neural networks. Petroleum Geosciences **8(2)**, 109-118.

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

Kadkhodaie-Ilkhchi R, Rezaee R, Moussavi-Harami R, Kadkhodaie-Ilkhchi A. 2013. Analysis of the reservoir electrofacies in the framework of hydraulic flow units in the Whicher Range Field, Perth Basin, Western Australia. Journal of Petroleum Science and Engineering **111**, 106–120.

Sharland P R, Archer R, Casey DM, Davies RB, Hall SH, Heyward AP, Horbury AD, Simmons MD. 2001. Arabian plate sequence stratigraphy. Special Publication, Geo Arabia **2**, 239-247.

Shin-Ju Ye, Rabiller P. 2000. A new tool for electro-facies analysis: Multi-resolution graphbased clustering. SPWLA **41st**, Annual Logging Symposium 4-7.

Shin-Ju Ye, Rabiller P. 2005. Automated electrofacies ordering. Petrophysics **46(6)**, 409-423.

Tavakoli V, Amini A. 2006. Application of multivariate cluster analysis in logfacies determination and reservoir Zonation, case study of Marun Field, south of Iran. University of Tehran, Journal of Sciences **32(2)**, 69–75.