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Investigation of Petrophysical Parameters of Kangan Reservoir Formation in One of the Iran South Hydrocarbon Fields

Mostafa Kiakojury[1], Seyed Jamal Sheikh Zakariaei[1], Mohammad Ali Riahi[2]

[1]Department of Petroleum Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2]Department of Geophysics, University of Tehran, Tehran, Iran
Email: mostafakiakajoori95@gmail.com

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Abstract

This article studies the properties of k4 Kangan reservoir Formation zone in one of hydrocarbon fields in south of Iran. To do this, some petrophysical parameters such as porosity and permeability in sedimentary facies, porosities and diagenesis of k4 Kangan Formation were measured and the quality of k4 Kangan Formation is studied through analyzing petrophysical data. This study investigates the role of sedimentary facies, types of porosity and controlling diagenetic evolution on k9 Kangan reservoir Formation in one of hydrocarbon fields of south of Iran. In this study, macroscopic and microscopic studies are done on thin sections of Kangan Formation (k4) and the facies and sedimentary environment affecting reservoir formation in two wells of South Pars field. In order to study the microscopy of 166 thin sections, two wells (2 × 3) are used from core of the South Pars. Using polarized microscopy, allochems, the major complications of diagenesis and facies are investigated and dolomite rock textures are classified. The average total porosity and effective porosity of Kangab well are 20.47% and 19.21%. The results show that saturation, porosity and lithology, k4 zone of Kangan Formation reservoir has good conditions.

Keywords

Kangan Formation, Porosity and Permeability, Diagenesis, Petrophysics, Lithology

1. Introduction

In Iran, because of the huge reserves of oil and gas and economic dependence on these valuable resources, the exploration and exploitation of oil and gas fields has always been of particular interest. Due to the growing need for oil and gas reserves, it is felt necessary to explore hydrocarbon resources and to develop methods that are more reliable in identifying and exploring these reservoirs. On the other hand, Triassic Kangan Formation has the largest gas field in the Middle East and in the world. For this reason, the study of this formation is important in order to have a better understanding of reservoir properties of Kangan formation, sedimentary environment and its diagenetic processes. Petrographic analysis of thin sections shows that effective diagenetic processes on Kangan formation including olomitization, dissolution, neomorphism, compression and micritization. The dissolution process by creating different types of secondary porosities, such as mouldic, vuggy, channel and inter-crystalline (intergranular) porosity, has a significant effect on increasing porosity, but the most important factor in the formation of a reservoir rock in the deposits of the Kangan Formation is the dolomitization process. Cementation is associated with the reduction of porosity, in particular the porosity that is filled in parts of the sequence by anhydrite. Sometimes this process retains the initial porosity by preventing mechanical compression. Assessment of reservoir properties includes study of petrophysical variables such as porosity, permeability, fluid saturation and lithology change. In studying hydrocarbon reservoirs, determination of petrophysical properties of reservoir is one of the most important key variables in the management, production, expansion and estimation of hydrocarbon reservoirs. Determination of petrophysical properties of reservoir is one of the most important key factors in the management, production, expansion and estimation of hydrocarbon reservoirs. In reservoir engineering and petrophysical studies, knowledge of the type and degree of porosity in the reservoir is very important. The porosity of the servoir rock is not the only important factor. The porosities should act effectively and the porosity of the rock is connected to each other. In other words, the rock should be permeable to allow hydrocarbon substances to move into the reservoir rock and accumulate there. As the distribution of pores, the reservoir rock is one of the main controllers of the fluid flow in the rock, determining the type and size of the pores has an important role in reservoir assessment, optimization of wells in a field and anticipation of renewable hydrocarbon sources. On the other hand due to the limitations of cores in oil fields (such as high cost, low oil recovery in cores and changes in core orientation at core drilling), determining the type and radius of the pores has always been confronted basic problems. As mentioned before, the study of sedimentary facies, pore types, and diagenetic evolution controls on the quality of the Kangan Formation is important since it helps to reach valuable underground resources using petrophysical data. This article studies the properties of k4 reservoir zone in Kangan Formation which is one of the hydrocarbon fields in the south of Iran. In this regard, some petrophysical parameters such as porosity and permeability of deposited facies, pores and diagenesis of k4 Kangan Formation, were measured and the quality of k4 reservoirs was studied through analyzing petrophysical data. In fact, the aim of this article is to study sedimentary formations, types of porosity and diagenetic control on evolution of porosity using petrophysical data and to investigate their effect on the quality of k9 reservoir zone in Kangan Formation, in one of the hydrocarbon fields in the south of Iran. To study more dimensions of this subject, the following hypotheses are presented.

1.1. The Main Hypothesis

It is feasible to study the effect of sedimentary facies, types of porosity and diagenetic evolution control on the quality of reservoirs using petro physical data in Kangan Formation in one of hydrocarbon fields in the south of Iran.

Sub Hypotheses

- It is feasible to study the effect of sedimentary facies on the quality of the reservoir in Kangan formation in one of hydrocarbon fields in the south of Iran using petrophysical data.
- It is feasible to study the effect of types of porosity on the quality of the reservoir in Kangan formation in one of hydrocarbon fields in the south of Iran using petrophysical data.
- It is feasible to study the effect of diagenetic evolution control on the quality of the reservoir in Kangan formation in one of hydrocarbon fields in the south of Iran using petrophysical data.

So far, many studies have been carried out on sedimentary facies, diagenetic processes, type and geometry of pores in different formations such as Kangan Formation k4 [1] [2]. No comprehensive research has been done on the effect of sedimentary facies, types of porosity and diagenetic evolution controls on the reservoir quality especially in Kangan k4 using petrophysical data. So this article presents an innovative research. Kangan Formation is located in South Pars field of Iran. South Pars gas field has two gas reservoirs of Kangan (Late Permian) and Dalan (Early Triassic) in the Zagros sedimentary basin. This gas field is located on the common border line between Iran and Qatar (**Figure 1**).

Figure 1. The location of South Pars hydrocarbon Field in the Persian Gulf.

1.2. Theoretical Foundations

Due to the subject of this article, the following terms are explained:

Facies: This term was first introduced by reference [3]. In this definition, the facies are referred to the specific characteristics of a sedimentary unit. These characteristics include lithologic and fossil features. These properties include: color, layering, composition, texture, sedimentary structures and fossil elements. As there are significant differences between the fossil and lithologic characteristics, two types of facies *i.e.* lithofacies and biofacies are recognized [3].

Diagenetic processes in Kangan Foramtion: Different diagenetic processes associated with atmospheric diagenetic environment, seafloor and burial diagenetic environment are seen in facies of Kangan Formation. The most important processes are dissolution, cementation, micritization by microorganisms, compaction, recrystallization, dolomitization and anhydritization [1].

Reservoir Quality: By determining the hydraulic flows, it is possible to separate the reservoir sections from non-reservoirs. Each of these hydraulic flow units is defined based on the relationship between porosity and permeability of different reservoir sections and indicates the quality of the reservoir in that section [4].

Sedimentary environment: The sedimentary environment is part of the earth where sedimentary materials are deposited. It is distinguished physically (depth, sedimentation rate, direction of water flow, specific weight, and water temperature), chemically (oxidation and reduction, pH of the environment, salinity) and biologically (existence or absence of organisms or fossils) from the adjacent environment [5].

2. Literature Review

Reference [6] studied the facies, sedimentary environment and diagenetic evolution control on the quality of reservoir in Upper Permian Upper Dalan Formation in Kish Gas Field (Zagros offshore basin). Kish gas field in Zagros off shore basin is located between Iran and Qatar and is based on a 222 m thick continuous core. The quality of the reservoir was severely affected by the changes in the rock fabrics and subsequent diagenetic alterations. The types of porosity are reinter-particle, moldic and connected vug. The interparticle relationship between porosity and permeability shows that different crystal sizes do not affect the reservoir quality. That study shows that pervasive pore-filling anhydrite mineralization decrease significantly the porosity and permeability, but the size of pores is slightly affected by it. In 2016, the effect of sediment and diagenetic control on reservoir properties was examined in the Permian Triassic sequence in the west of the Persian Gulf. This study provides information on the profile of facies and diagenesis and the properties of reservoirs in the Golshan Field in the Western Persian Gulf. The results show the effect of sedimentary processes on the quality of reservoirs. Among the diagenetic processes, cementation, calcite and anhydrite have a significant destructive effect on reservoir quality in prefabricated porous facies. The results also suggest that there is a close relationship between sedimentary facies and diagenetic processes in the Kangan Dallansequence [7]. Reference [2] studied the diagenesis of k4 Kangan formation in south Pars field with an emphasis on the dolomitization and anhydritization. Diagenesis includes changes that have occurred since the sediment was deposited before the onset of metamorphism. K4 Kangan formation (Lower Triassic) is the reservoir rock of South Pars Gas Field which is located in Dehram Group. Dolomitization, anhydritization, micritization, dissolution and cementation are effective diagenetic processes in Kangan formation. Identified Dolomites in this formation include fine grained dolomites, medium grained dolomites, medium to coarse grained dolomites, coarse grained dolomites or cement dolomites and saddle dolomites. Poikilotopicanhydrite, anhydrite nodules, pore-filling and pervasive anhydrite cement, layered anhydrite, fracture-filling anhydrite and anhydrite veins are of various types of anhydrites in Kangan k4 formation. The porosities in this sequence include intra-particle porosity, inter-particle porosity, moldic porosity, vuggy porosity, crystal porosity, shelter porosity and fenestral porosity. In another study, the diagenesis and reservoir characteristics of k4 Kangan formation and the upper section of Dalan formation in one of gas fields of Persian Gulf was investigated. The gas field is located in Persian Gulf and in south east of port of Bushehr. To investigate iagenetic processes, petrographic analyses were conducted on 162 thin sections obtained from cores of Kangan formation and the upper part of Dalan formation in well A of X field. Dissolution, dolomitization, cementation, compaction and anhydritization were important diagenetic processes which affected the reservoir characteristics of under studied facies. Among those processes compaction, cementation and anhydritization reduced the quality of the reservoir but dissolution and dolomitization increased its quality [8].

3. Statistical Population and Research Samples

In this study, the statistical population is one of the hydrocarbon fields in south of Iran. To do the study, 166 thin sections of two wells from core of Kangan k4 formation were used as diagenetic samples, 85 of which were used in experimental studies. After preparing the rock samples and microscopic thin sections, the plaques which were made from Kangan formation were studied.

4. Methods

In this research, the data were collected from reports, published theses, related texts, geographic and topographic maps, internet websites, library of Geological organization and Islamic Azad University. The data were analyzed using GIS software. By investigating the microscopic and macroscopic characteristics of thin sections of Kangan Formation (k4), the facies and sedimentary environment affecting the reservoir quality of the formation in two wells of one hydrocarbon field in south of Iran was studied. In microscopic study, 166 thin sections of two wells (3 × 2) with a core of one of the hydrocarbon fields of southern Iran are used. Using polarized microscopy, allochems, the major complications of diagenesis and facies were investigated and using Sibley and Gregg classification (1987), dolomite rock textures were classified. The main goal of petrophysical researches is to study the properties of rocks and their relation with fluids inside them. Petrophysical assessment is the science of interpreting the information collected from well logs. The first step in assessing petrophysical data is collecting digital data. The digital data is entered into the software and the logs are drawn. Then according to Schlumberger log interpretation charts book environment a land mud invasion corrections are done [9]. To interpret logs and to choose different petrophysical techniques, it is necessary to have information about the lithology of the formation, properties of the drilling fluid and the characteristics of fluid inside the rock. The aim of this article is to assess reservoir properties such as petrophysical parameters like porosity, permeability and saturating fluids, lithological variations and properties of hydrocarbon such as useful and useless thickness and useful hydrocarbon column. The quality of k4 Kangan reservoir is studied through analyzing petrophysical data. The main petrophysical charts such as neutron, density and sonic log data were used to determine porosity.

5. Results

5.1. Determining Lithology

One of the main procedures in assessing reservoir properties is lithology identification which helps separate zones with reservoir properties from zones without these properties. Lithology identification is fulfilled using four crossplot techniques. One of the applications of Dipole Sonic Imager is lithology identification. In current Dipole Sonic Logging, two components are considered for solid parts. The first component is matrix which contains main aggregates and cement and the second is shale components. In lithology, some properties such as mineral texture, shale volume and liquid content may influence on the response of the Imagers. Texture contains parameters of texture components related to matrix and the characteristics of bed and the structure of the gap. Data obtained from cores, drilling and Well Logging Imagers helps to estimate the lithology of rocks exactly.

Shale volume calculation:

Equation (1) shows shale volume which was calculated using corrected gamma ray (CGR) [10].

$$V_{sh} = \frac{\left(CGR - CGR_{\min}\right)}{\left(CGR_{\max} - CGR_{\min}\right)} \tag{1}$$

With this technique the minimum and maximum of CGR in understudied wells were calculated. In Equation (1) $CGR_{\min}$ is the minimum value at non-shale formations (clean) and $CGR_{\max}$ is the value that is read at a 100% shale formation. This equation does not have any unit. In this equation, CGR (corrected gamma ray) relates to the desired depth. Shale volume calculated in A and B wells are 1.88 and 1.12 percent respectively and the shale volume average in both wells is 1.54 percent. The desired well is considered non-shale and clean.

Calculating porosity:

Petrophysical properties of reservoirs such as porosity are the most important controllers of quality and quantity performance of the reservoir. The calculation of porosity is done using neutron, density and sonic porosity logging. Neutron porosity logs are used to calculate porosity. This tool shows hydrogen frequency or index. Neutron porosity logs response to the volume of water filled the pores. Neutron porosity log is calibrated for limestone, so in calcareous lithology the value of neutron porosity log is equal to the amount of porosity but dolomitic sandstone lithology should be corrected for matrix. The amount of porosity is obtained by Equation (2) in which ϕ is real porosity, a and b are experimental constant values and N is the value of used tools [11].

$$\lg \phi = aN + b \tag{2}$$

In non-shale formations (clean), porosity is calculated by density logging through Equation (3) [11]. According to this equation, matrix and density of the fluid determine porosity.

$$\varphi_{\mathrm{D}} = \frac{\rho_{\mathrm{ma}} - \rho_{\mathrm{b}}}{\rho_{\mathrm{max}} - \rho_{\mathrm{f1}}} \tag{3}$$

Based on this equation, matrix density of formation was 2.9 gram per cubic centimeter and fluid density was 1 gram per cubic centimeter. In sonic porosity logging, difference in sound speed causes separation and recognition of rock properties in a way that the less density of the filling fluid, the less speed of sound. **Figure 2** shows sonic graphs by which sonic porosity was calculated. In these graphs, solid lines on the chart are made using curves and Wiley formula related to Rimmer equation.

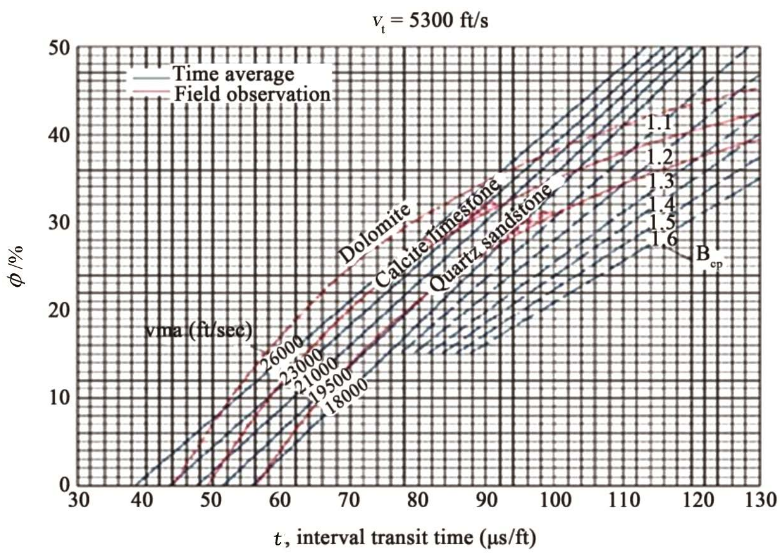

Figure 2. Sonic graphs for calculating porosity.

Porosity can be calculated using sonic chart and Equation (4) [11] (Fertle *et al*., 1987).

$$\varphi_s = \frac{DT_{Log} - DT_{ma}}{DT_{fl} - DT_{ma}} \tag{4}$$

where DT_{ma}: the time in which the wave passes through formation matrix, 45 (ms/ft).

DT_{fl}: the time in which the wave passes through the fluid, 185 (ms/ft) (**Table 1**).

Table 1. Calculating porosity by sonic logging.

Depth/m	Wave passing time/(ms·ft^{-1})	Porosity by sonic logging/%
2610	59.52	11.12
2724	67.39	16.95
2861	55.38	6.88
2953	68.83	16

In resistance logging technique, Archie equation was used to calculate porosity. This technique is used when the sample is saturated with water and porosity is calculated using Equation (5) [12]. In the following equation m and a are experimental constant values, R is the resistance of filter mud and R_{xo} is the washed resistance zone:

$$\phi = \left[\frac{aR_{mf}}{R_{XO}}\right]^{\frac{1}{m}} \tag{5}$$

Determining lithology using Crossplot technique:

Usually four crossplot techniques are used to determine lithology:

1) Neutron-density crossplot.

2) Sonic-neutron crossplot.

3) M-N plot technique.

4) MID plot technique.

Among double charts, neutron-density crossplot is the best technique for separating different minerals. In this study, lithology, permeability and porosity of Kangan formation were calculated using this crossplot. Neutron-density crossplot has maximum resolution and it can best determine porosity in different lithologies. In Neutron-density crossplot, three lines are drawn which are related to sandstone, limestone and dolomite. To calculate porosity using this chart, density response is plotted against neutron porosity. Based on the distance between the point and the matrix lines, the position of plotting shows the percentage of the lithology. **Figure 3** and **Figure 4** show neutron-density crossplot that are used to determine lithology in the wells. The horizontal axis shows porosity calculated through neutron logging in calcareous (limestone) lithology and the vertical axis shows porosity calculated by density logging in calcareous lithology. As neutron logging is used, density logging in limestone is read from the straight line which is related to limestone figure. The numbers on lithology lines show the porosity.

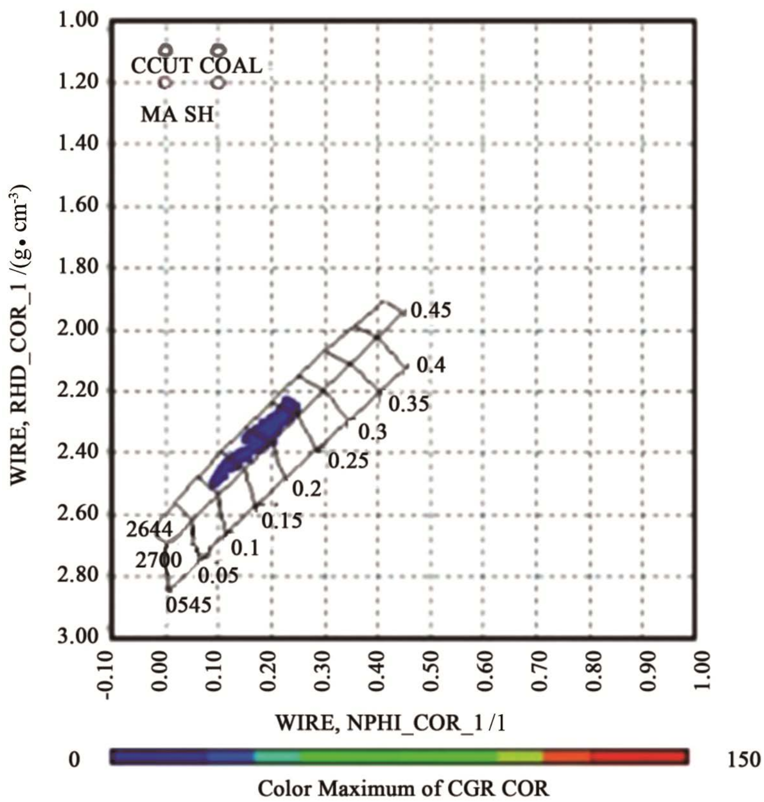

Figure 3. Neutron-density cross-plot of well A.

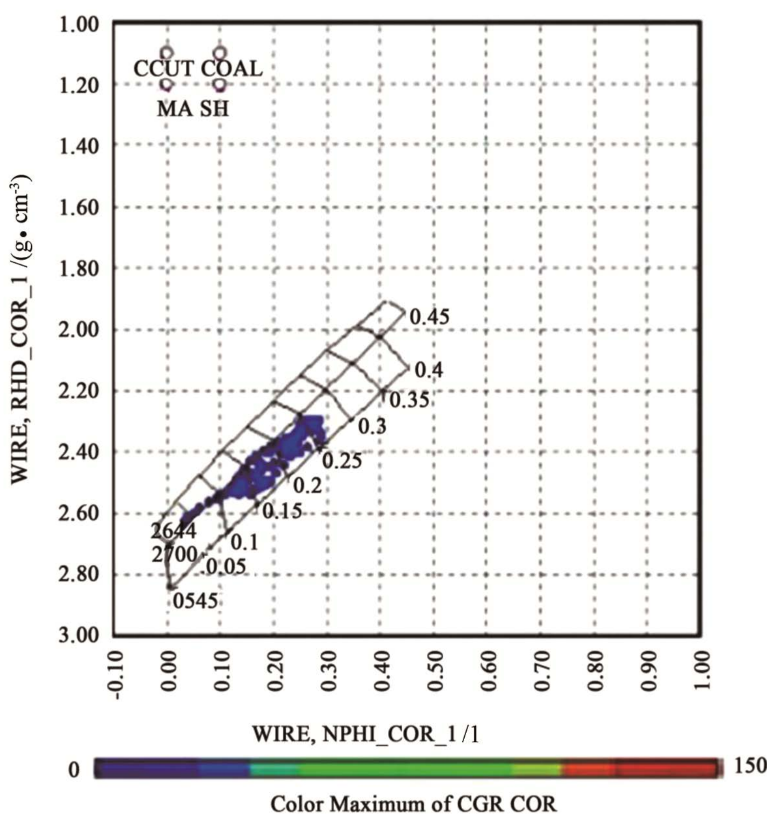

Figure 4. Neutron-density cross-plot of well A.

In sonic-neutron crossplot, the resolution between different lithologies is close to neutron-density crossplot. In graphic logging, it is enough to draw sonic plots against neutron. The plot position is a point which shows the distance from the point to matrix line and presents lithology percentage. These figures have low resolution in the presence of volatile minerals. Figure 5 and Figure 6 indicate sonic-neutron crossplot of understudied wells. The results confirm the lithology and porosities obtained from neutron-density crossplot.

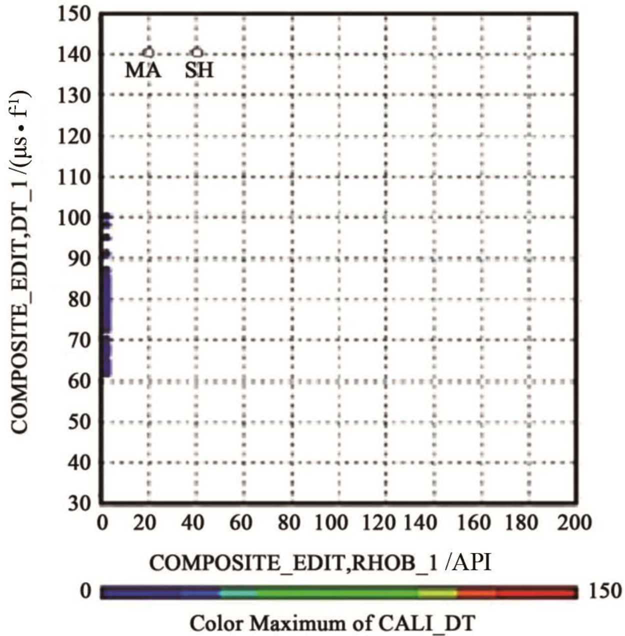

Figure 5. Sonic-neutron crossplot in well A.

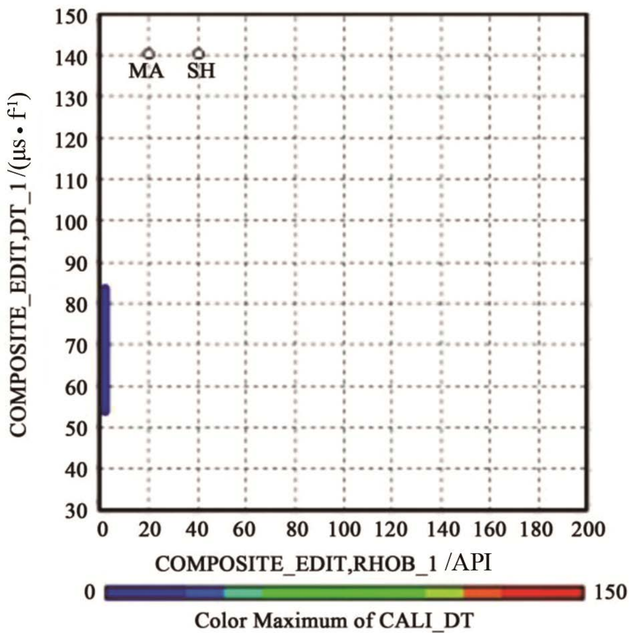

Figure 6. Sonic-neutron crossplot in well B.

For determining lithology, M-N crossplot is used with three porosity logs. M-N crossplot is actually used to eliminate the effect of porosity and to determine triple mineralogical composition. To draw this crossplot, *M* and *N* are drawn against each other. The value of *M* and *N* is calculated using [13] the following equation:

$$M = \left[\frac{\Delta t_f - \Delta t}{\rho_b - \rho_f}\right] \times \frac{0}{01} \tag{6}$$

$$N = \left[\frac{\phi N_f - \phi N}{\rho_b - \rho_t}\right] \tag{7}$$

In this equation, two diaphragms are used for calculating M or N so the effect of porosity and lithology is eliminated to a large extent. Thus M and N are just the lithological functions. One of the main applications of M-N crossplot is determining secondary porosity. **Figure 7** shows the M-N crossplot of under studied well. In M-N crossplot, when the points are plotted above calcite-dolomite line, and the formation contains gas, it shows that there is a secondary porosity. In Kangan formation, the samples are above calcite and dolomite points (Northeast of crossplot), which indicates the formation contains gas. There is no photoelectric factor in well B, so no M-N crossplot is drawn for well B.

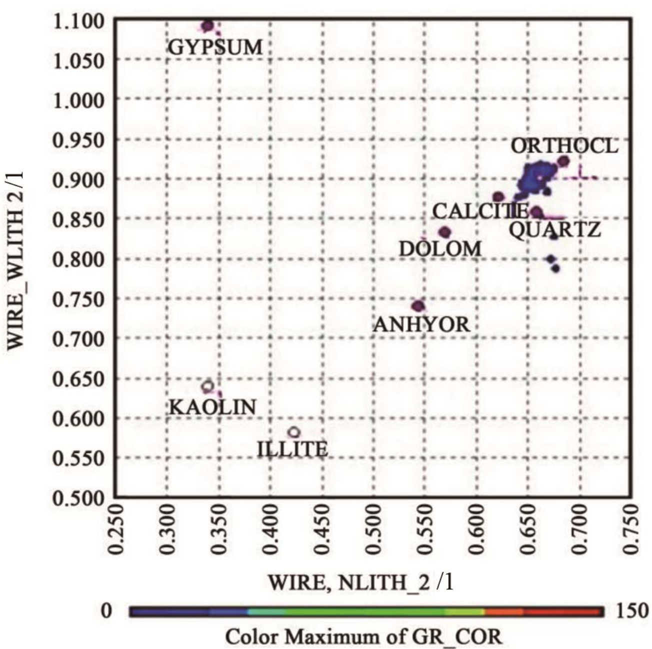

Figure 7. M-N crossplot of well A.

In MID crossplot, in order to determine the lithology, first the nominal values of matrix *i.e.* (Δt_{ma}), (ϕN_{ma}) and (ρ_{ma}) should be determined. Neutron-density crossplot is used to calculate the nominal values of (ρ_{ma}) matrix, and Sonic-neutron crossplot is used for calculating (Δt_{ma}). After determining these two

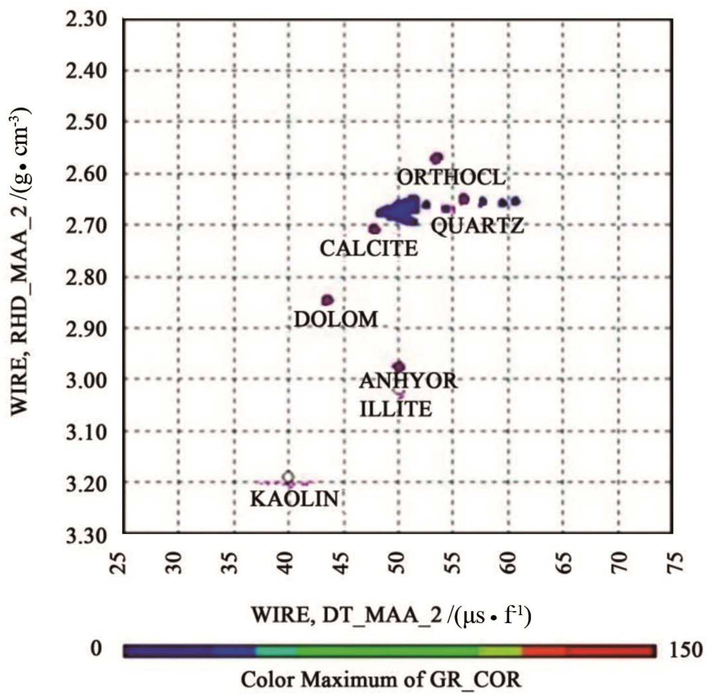

Figure 8. MID-plot for well A.

parameters, MID plot was drawn. **Figure 8** shows MID plot for well A.

Using neutron-density crossplot, most of the under studied formation was evaluated and lithological components such as limestone and dolomite were recognized. In some parts of the formation, a low amount of shale was found, as well.

5.2. Calculating Porosity Using Double Logging

This technique does not need any primary information and the type of porosity and lithology are determined and calculated using neutron-density crossplot, sonic-neutron crossplot and sonic-density crossplot. In calculating through neutron-density crossplot, the porosity is determined based on the values of neutron log. In **Figure 9**, neutron log is drawn against the density log. As is indicated in **Figure 9**, the gas source reduced the value of neutron log and the density of the rock which resulted in the reduction of density value. Comparing neutron with density double logging, the result indicates that the presence of gas can separate these two logs which are called the effect of rotor. Using Equation (8), the porosity is calculated through neutron-density crossplot [11] (Fertle *et al.,* 1987).

$$\varphi_{\text{N-D}} = \frac{(\rho_{\text{b}} - \rho_{\text{m1}})\phi N(\rho_{\text{m2}} - \rho_{\text{m1}})}{(\rho_{\text{f}} - \rho_{\text{mz}})\phi N2 - (\rho_{\text{m2}} - \rho_{\text{mz}})} \tag{8}$$

In the porosity calculation method, using the sonic-neutron crossplot, porosity is determined based on the neutron values versus sonic log. Using this crossplot both porosity and lithology are measured (**Figure 10**). Using sonic-density

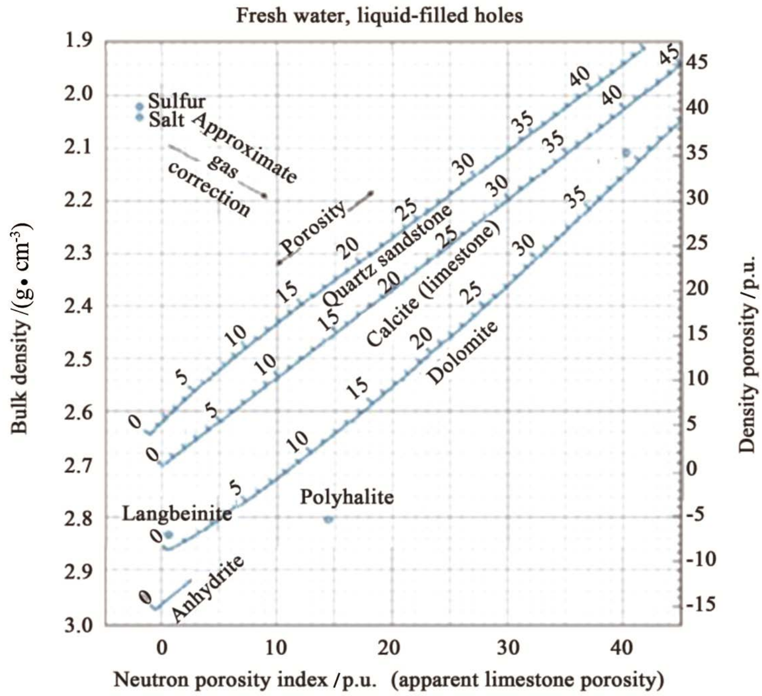

Figure 9. Neutron-density crossplot.

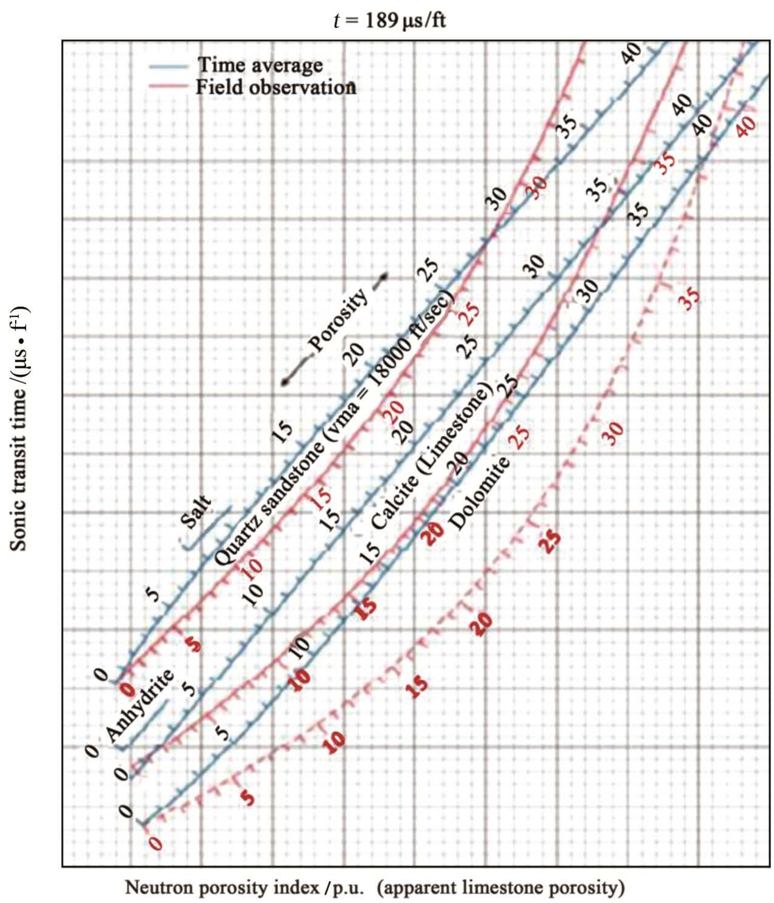

Figure 10. Sonic-neutron crossplot.

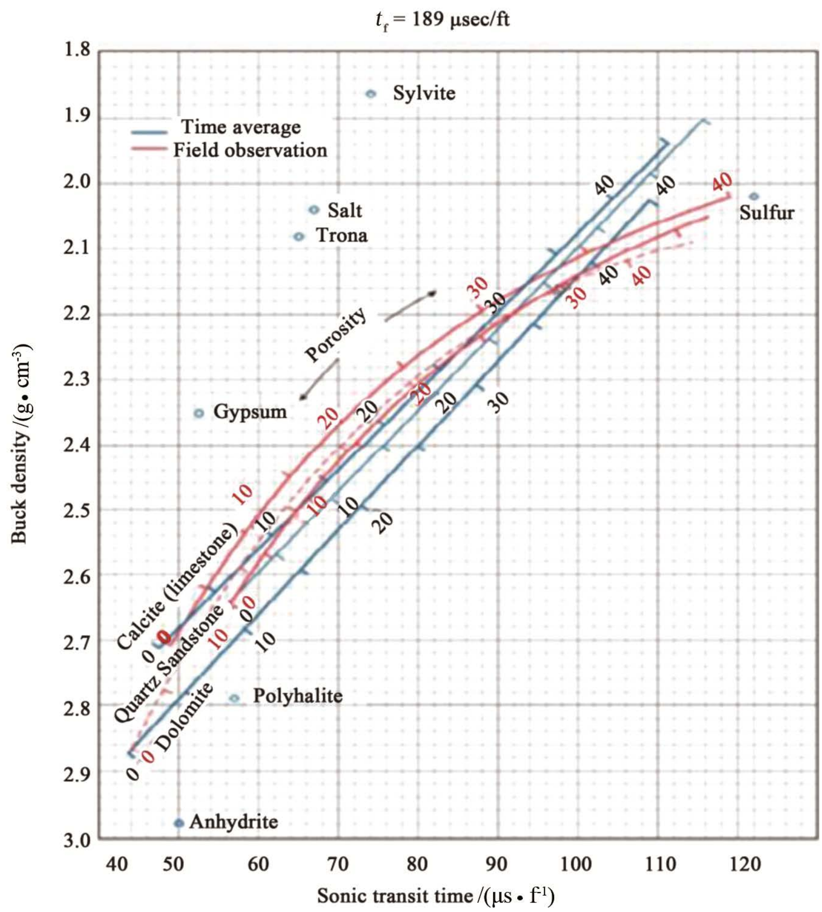

Figure 11. Sonic-density crossplot.

curve, porosity is calculated through drawing the values of density logging versus sonic logging (**Figure 11**).

5.3. Final Results of Petrophysical Assessment

Final results of petrophysical assessment and loggings of A and B wells are indicated in **Figure 12** and **Figure 13** with a scale of 1/1000. Based on the results shown in **Figure 12**, the first right column shows the amount of porosity and the second column shows components of the formation lithology. As is shown in the figure, the dominant lithology is calcareous in the formation (the blue parts) and in some distances there is a little amount of dolomites (the purple parts). These results are correlated with geological reports as well as drilling operations. The average of effective porosity and the total porosity calculated in both A and B wells are shown in **Table 2**.

5.4. Facies of Kangan Foundation

Kangan formation consists of following three facies:

1) Clean carbonates facies,

2) Clay and shalebaseline, and

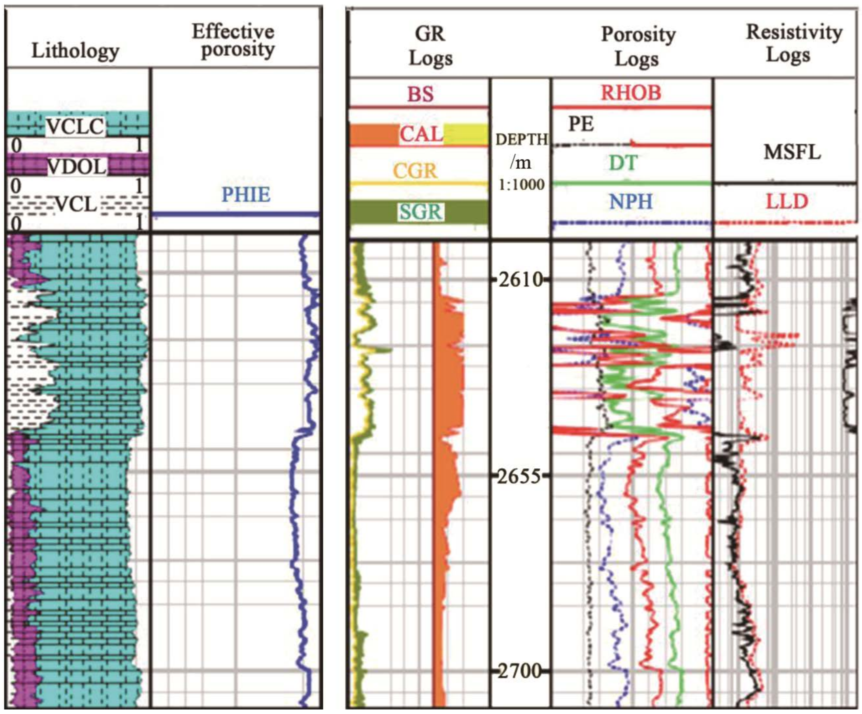

Figure 12. The results of petrophysical assessment in Well A (the first column from left shows Calliper, SGR, CGR and IBS loggings; the second column is related to depth and the next columns are related to NPHI, DT, RHOB loggings which are used to calculate the porosity as well as resistance logging).

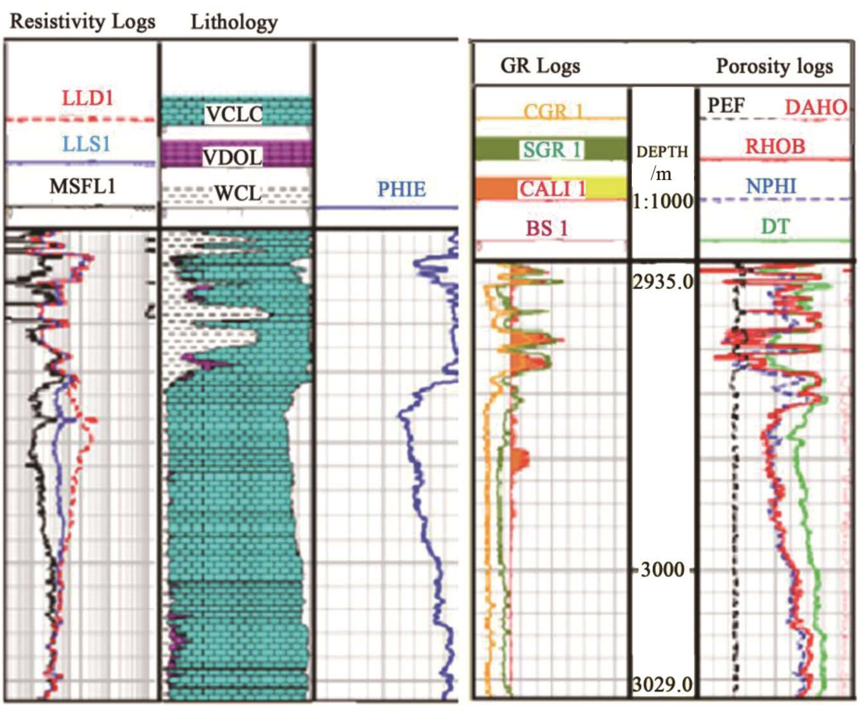

Figure 13. The results of petrophysical assessment in Well B (the first column from left shows Calliper, SGR, CGR and IBS loggings; the second column is related to depth and the next columns are related to NPHI, DT, RHOB loggings which are used to calculate the porosity as well as resistance logging).

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Table 2. The average of effective porosity and total porosity calculated in Wells A and B.

well name	Calculated porosity (%)	
	Total (PHIT)	Effective (PHIE)
Well A	21.14	19.87
Well B	19.38	18.55
The average	20.47	19.21

3) Carbonate-evaporatefacies.

5.5. The Effect of Sedimentary Facies on the Quality of Kangan Formation

Investigation on the effect of sedimentary facies on the quality of Kangan formation indicates that these facies have been created in sabkha environment/tensile zones, ponds, underwater bumps, damns and open seas are related to a carbonate ramp. The most important aggregates of carbonate facies are Ooids, Peloid, Intraclasts, Oncoid and skeletal fragments such as bivalves, gastropods and ostracods. Furthermore, in facies of Kangan formation, different diagenetic processes are observed which are related to atmospheric, marine and burial diagenetic environments. The most important diagenetic processes are dissolution, cementation, micritization by microorganisms, compression, recrystallization, dolomitization and anhydritization. The investigation into core samples from thin sections of carbonate-evaporite facies shows that in Kangan formation anhydrate exists in different thickness and forms which had been formed simultaneously with depositing or in different diagenetic procedures. Anhydrate is widely seen with dolomites. It is also found in the form of independent facies or with various fabrics inside the carbonate facies of this formation. In the Kangan Formation (k4), the anhydrite facies are in laminate, layer and bulk form, with a thickness of several millimeters to several centimeters and sometimes more than one meter. Sulfate minerals are susceptible to various diagenetic processes, especially dissolution, recrystallization and replacement. The diversity of primary and secondary environments for sulfate mineral formation as well as the diversity of diagenetic processes in them has led to the absence of the same classification for the mentioned minerals.

5.6. Anhydrite Textures and Fabrics in Kangan Formation

The main anhydrite textures and fabrics in Kangan formation are:

1) Single nodules: These anhydrate nodules are found in various sizes, ranging from several millimeters to several centimeters. They have changeable forms but they mostly are in spherical and elliptical shapes. Microcrystals to macro crystals are found in them and sometimes they are stretched.

2) Chicken wire netting (poultry netting): The compressed arrangement of anhydrite nodules has led to the emergence of this kind of texture. Anhydrate nodules are surrounded by thin veins of host rock sediment. The host sediment in most samples of this texture is microcrystal dolomite.

3) Enterolithic: In this texture anhydrate nodules are interwoven and have created irregular and folded laminates or layers.

4) Lens: This fabric is a good sign of initial gypsum minerals which are turned to anhydrate through diagenetic processes and usually it is less than one centimeter.

5) Tabular/blade shaped: This fabric is mostly found with anhydrate lens fabric and lens fabric is the result of the conversion of gypsum.

6) Rose: This fabric is like bundles of roses which normally have several stalks with lengths of a few millimeters. This fabric is mostly found with other fabrics such as tabular and lens.

7) Spherulites/fan shape: Aggregation of anhydrate with stretched crystals makes spherulitic/fan shaped form. This fabric is found less than other fabrics.

8) Filler cement: This fabric is one of the most abundant fabrics in facies of Kangan formation especially in facies with greenstone texture. Usually anhydrate cement is spathic and forms between the grains, crystals, inside skeletal-grains, fenestrals, mud cracks, veins and molds due to the dissolution of orogonite grains such as Gastropods, Bivalves and Ooids. In some samples, anhydrate cement is found in the form of poikilotopic cement. This type of cement is especially found in ooid facies in a way that a single anhydrate cement crystal encloses some ooids.

In general, studies show that most textures and fabrics in sedimentary facies are formed simultaneously with deposition processes or at initial stages of diagenesis procedures.

5.7. Determining the Type of Porosity

Using 3 modes of velocity-deviation log (Positive, negative and zero velocity deviations), different types of porosity in k4 Kangan carbonate formation are determined.

5.8. Velocity-Deviation Log

Velocity-deviation log which is created by combining sonic-neutron crossplot and neutron-density crossplot, is an appropriate tool for collecting information about the dominant type of porosity in a well. There is always little difference between calculated porosities using these two techniques. The difference is regarded as secondary porosity which is related to fracture and vuggy porosity.

5.9. The Way of İnterpreting Velocity-Deviation Log

1) Positive velocity deviation (near to 1000)

In this range, the measured sound speed is greater than the calculated velocity. This mode shows porosities whose bed is a strong and cemented rock, and pores which are not linked well and do not have proper permeablity. In this range usually the dominant porosities are reinter-fossil, mouldic and vuggy porosities.

2) ±500 velocity-deviation

±500 velocity-deviation (near to zero) indicates inter-crystal, inter-grain or micro porosity. This range, except for cases where sucrose dolomite makes inter crystal porosity due to diagenesis, shows mild effect of diagenesis. This group has a better permeability than the previous group.

3) Negative velocity-deviation

The range that shows negative velocity-deviation can be interpreted in three ways:

a) Collapsing horizons in well can cause differences in calculated velocity and measured one. In this range, the measured sound speed is less than actual sound speed.

b) Fracture porosity can make negative velocity-deviation. Contrary to the fact that fracture porosity is regarded the same as secondary porosity and in the range of high velocity with positive velocity-deviation. The results of previous studies show that fracture in small and large scale reduces sound velocity so fracture porosity is in the range of negative velocity-deviation.

c) Negative velocity-deviation can be due to free gases in the reservoir as free gases reduce sound velocity.

5.10. Method of Drawing Negative Velocity-Deviation Diagram

First, environmental correction of neutron and density logs is done using Geolog software. Then the volume of shale (V_{sh}) is calculated through GR diagram and the following equations. The effect of shale on the amount of porosity that is determined by neutron and density logs, is corrected, too [10].

$$V_{sh} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \quad (9)$$

According to the above equation, GR_{min} is the minimum of GR figure which is related to intervals free from shale and GR_{max} is the value that is read from GR diagram of shale layer. So the volume of shale in both wells is calculated using the following equation [10] (Qasim al-Askari *et al.*, 2010):

$$\phi = \phi_N - V_{sh} \times \phi_{Nsh} \quad (10)$$

According to above equation, the effect of shale on porosity determined through GR diagram is corrected and ϕ_{Nshc} is the corrected value of porosity determined through neutron log; ϕ_N is the porosity read from neutron log and ϕ_{Nsh} is the porosity read from neutron log in shale layer. Thus according to the following equations, the nominal porosity determined through density log is calculated and its shale effect is eliminated [12].

$$\phi_{Da} = \frac{\rho_{ma} - \rho_{log}}{\rho_{ma} - \rho_{fl}} \tag{11}$$

ϕ_{Da} is the nominal porosity read from density log, ρ_{ma} is matrix density and ρ_{fl} is the fluid density. In the next step, nominal porosity (ϕ_{Da}) affected by shale is corrected using the following equation [12].

$$\phi_{Dshc} = \phi_{Da} - V_{sh} \times \phi_{Dsh} \tag{12}$$

In the next step, using the following equation, porosity determined with neutron lg(ϕ_N) is combined with density lg(ϕ_D) and neutron-density porosity is calculated [12]:

$$\phi_{ND} = \sqrt{\frac{\phi_N^2 + \phi_D^2}{2}} \tag{13}$$

It should be mentioned that in the above equation the corrected values of neutron and density diagrams are used.

6. Conclusion

Studying textures and fabrics existing in facies of Kangan formation indicates that most of those textures and fabrics are formed simultaneously with depositing or at the beginning stage of diagenesis. Some nodules are related to dry and hot environment. These nodules are made of inter-hole concentrated fluids through embedded or displacement procedures and in the capillaries of upper part of ferrite zone under Sabkha. These crystals which grow inside deposits are found in matrix of sediments above tensile zone and above inter-tensile zone. Continuing calcium sulfate saturation inside inter-hole fluids, gypsum and anhydrate nodules grow and join together. As a result, chicken wire netting or enterolithic wrinkles are created. Petro physical data of Kangan formation shows that based on the lithology of the studied zone, the dominant sediment is limestone while in some distances it is dolomite. The results indicate that anhydrate nodules mainly expand in upper parts of peritidal parasequences of Kangan facies. Anhydritization may primarily happen due to the increase of salinity of salt water or as a result of an increase in the temperature which occurs when the sea level decreases. This may show that some sedimentary parts of Kangan formation temporarily falls out of water. This phenomenon is very important in stratigraphic studies. In general, the results show that k4 reservoir of Kangan formation is in good conditions regarding saturation, porosity and lithology.

7. Research Suggestions

Due to the importance of prediction and investigation of petro physical properties of carbonate reservoirs and their porosity and permeability, it is suggested that future studies use modern techniques based on statistical probabilities. Multivariate statistical methods (clustering system, variance analysis, artificial neural networks, multidimensional fit, standard correlation analysis, etc.) are among these modern techniques which are based on statistical probabilities and are used in analyzing the characteristics of hydrocarbon wells. It is also suggested that techniques of determining thin zones with high porosity be used in future studies.

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