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TIGHT CARBONATE RESERVOIR CHARACTERIZATION

ХАРАКТЕРИСТИКА ПЛОТНОГО КАРБОНАТНОГО КОЛЛЕКТОРА

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Abstract. With reference to the reservoir characterization regarding the Khuff Formation – Khurtam Member (KSA), better reservoir quality prediction can be assigned to the characterization of its physical properties. These properties determination are depending on facies description. These properties can be erratic according to the diagenetic change and control on pore geometrical attributes and reservoir characterization. In this investigation, permeability and porosity have been measured in the laboratory. Rock Quality Index (RQI), flow zone index (FZI) as well as porosity groups have been calculated. The use of different determined physical and petrophysical parameters and their plots have defined two Flow Zone Indicators (FZI) characterized by a restricted distribution of porosity permeability and rock quality index. Different approval statements were made by correlation process. These confirmation and data support made of the considered reservoir as relative tight reservoir and tight reservoir. The use of the R35 was organized to make an approval to different statements with reference to the considered reservoir which can be classified as relative tight reservoir and tight reservoir. The R35 was carried out to approve not only that the reservoir is relative tight and tight but it can be classified in the range within the range of nano to microporous system.

Аннотация. Что касается характеристики коллектора относительно пласта Хуфф – член Хуртам (Саудовская Аравия), лучшим прогнозом свойств коллектора является характеристика его физических свойств. Определение этих свойств зависит от описания фаций. Эти свойства могут быть непостоянными в зависимости от диагенетического изменения и контроля геометрических свойств поры и характеристики коллектора. В данном исследовании проходимость и пористость измерялись в лаборатории. Был вычислен показатель прочности пород (RQI), плотность гидравлического потока (FZI), а также группы пористости. Использование различных установленных физических и нефтефизических параметров и их структур

определило два показателя плотности гидравлического потока (FZI), которые характеризуются строгим распределением проходимости пористости и показателем прочности пород. Различные заявления об утверждении были сделаны в процессе параллелизации. Это подтверждение и информационное обеспечение сделано о рассматриваемом коллекторе как об относительно - плотном коллекторе и плотном коллекторе. Использование R35 было организовано для утверждения различных заявлений касательно рассматриваемого коллектора, который можно классифицировать как относительно - плотный коллектор и плотный коллектор. Был использован R 35 для утверждения не только того, что коллектор относительно-плотный и плотный, но также, что его можно классифицировать в диапазоне нано и микроскопической системы.

Keywords: permeability, rock quality index, flow zone indicator, Winland R_{35}, Tight Carbonate Reservoir.

Ключевые слова: проходимость, показатель прочности пород, плотность гидравлического потока, Winland R_{35}, плотный карбонатный коллектор.

1. Introduction

The first khuff Formation which include the Khartam Reservoir Formation has been discovered in 1948. It is of Permo-Triasic in age. The term Khuff was introduced by Steineke and Bramkamp (1952 b). The formation was formally defined by Steineke et al (1958). In 1966 Powers et al modified and published the measured and described section of the Khuff limestone of Bramkamp et al (1945 unpub. Rep.). Powers et al (1966) subdivided their reference section of the amended Khuff Formation into four lithologic units as follow: from top to bottom are aphanitic – calcarentic limestone, aphanitic limestone, dolomite and limestone, and dolomite and shale. Delfour et al (1983), in their subdivision of the Khuff Formation introduced the Khartam and Midhnab members, which were discarded by Powers et al (1966). The two members, Khartam limestone and Midhnab shale were originally introduced by Holm et al (1948 unpub.rep.).The Khuff Formation was divided by Delfour et al (1983) into five informal members, and the uppermost member is named Khartam member.

Al –Jallal (1987) studied effect of diagenesis on reservoir properties of the Permian Khuff Formation in the Ghawar Field of Eastern Saudi Arabia. He stated that, the reservoir development of reservoir quality seems to be controlled by the lateral changes in facies deposition and more effectively by the diagenesis effect. A.S Alsharhan et al (1994) have stated that the Khuff carbonates are found within a complex formations constituted of dolomite, limestones and anhydrates. The development of their H-C exploration and exploitation are still depending on more detailed reservoir description.

Later in (1997) subdivided the Khuff Formation, in the Bahrain Field, into four flow units based on Neutron and Density logs. These units from top to base are K0, K1, K2, and K3. Vaslet et al (2005) subdivided petrographically and sedimentologically the Khartam Member of the Permian- Triassic Khuff Formation of Central Saudi Arabia into two units: A lower unit of dolomite and clayey limestone and an upper unit consisting of oolitc limestone.

Florian Mauer et al (2009), from the availability of outcrops, found better input for studying the Permo-Triasic Khuff Reservoirs. This was of big contribution towards the improvement of exploration and Oil accumulation prediction.

Bastin Koehrer et al (2011) studied the lateral continuity and geometry of potential reservoir grainstone geobodies in outcrops of the Upper Khuff Formation time-equivalent strata in the Jebel Al Akhdar area (Oman Mountains, Sultanate of Oman). Such data may be useful for correlation and modeling of subsurface reservoirs.

In the Kingdom of Saudi Arabia, the Permian Khuff Formation is a part of the Unayzah Formation. It has been described by Al-Laboun (1987) as the result of the cyclic transgression and regression occurring during that period.

In the case study, and owing to a suitable approach for better understanding of the H-C potential, investigation will be carried out towards the Khartam Reservoir Formation which is a part of the Permian Khuff Formation. It will focus essentially on the determination of the physical characteristics and their attributes in order to acquire improved reservoir information prediction.

Law and Curtis (2002) defined low-permeability (tight) reservoirs as having permeabilities less than 0.1 millidarcies. Therefore, the term "Tight Gas Reservoir" has been coined for reservoirs of natural gas with an average permeability of less than 0.1 mD (1 x 10-16 m^2).

Recently the German Society for Petroleum and Coal Science and Technology (DGMK) announced a new definition for tight gas reservoirs elaborated by the German petroleum industry, which includes reservoirs with an average effective gas permeability less than0.6 mD.

2. Methodology

The identification of the carbonate Khartum formation was based on their physical parameters determination. These physical parameters calculation were applied for 64 samples. These samples were collected from Khartam Member of the Permo-Triassic Khuff Formation. Permeability and porosity determination in addition to the RQI, normalized porosity index (ϕ_z) , Flow Zone Index (FZI) were targeted. These parameters were conducted to make mainly an assessment for the fluid flow circulation and accumulation.

2.1 Permeability Porosity measurement:

The permeability and porosity were measure in KACST using Helium porosimeter, model HP-401 and electronic field gas permeameter. Permeability and porosity were defined at the laboratory, whereas the aimed physical parameters were calculated according to different related equations.

Table 1 shows the permeability and porosity as set from the experimental work in the laboratory based on Khartum selected limestone samples. Results on these characteristics were exploited for investigating the fluid physical properties. Among these physical characteristics:

2.2 Rock Quality index (RQI)

RQI = 0.0314* (Soto et al., 2010) (1).

This equation is mainly established to assess the reservoir quality based on its characteristics related to reservoir description beyond fluid properties and fracture system.

2.3 Normalized porosity index (ϕ_z)

The normalized porosity was aimed to evaluate the reservoir quality based on its fluid circulation and accumulation. It is aimed to be set as main parameter for the evaluation of the flow zone indicator. It can be calculated according to Soto (1010) as follow:

$$\phi_z = \phi_{core} / (1-\phi_{core}) \text{ (Soto et al., 2010)} \qquad (2).$$

For the case study this term was determined from the experimental work laboratory (ϕ_{core})

2.4 Flow Zone Indicator

Determination of the ϕ_z and the RQI were intended to resolve the flow zone indicator (FZI) evolution. Thus, flow zone indicator as specified by (Amaefule et al., 1993) is derived from the RQI and normalized porosity index (ϕ_z) as follow:

$$FZI = RQI / \phi_z \text{ (Amaefule et al., 1993)} \qquad (3).$$

Determination of this parameter will support the samples data not only on rock quality index and its attributes but also on the hydraulic flow units. This latter parameter can be used for characterizing the degree of heterogeneity when the fluid flow permeability and storage are not constant.

Xu et al (2012) used the concept of rock quality index to distinguish between various carbonate lithofacies. They reported that the reservoir quality in carbonate rocks enhanced towards grainstone facies or marine sandstone . On other wards, high values of rock quality index correspond generally to grainstone carbonate.

3. Results and Interpretation

According to the obtained results on physical parameters (table 1), variation on each factor corresponding, can be related to the variation of Khartam reservoir deposits. Thus, these acquired results constitute fundamental factors controlling the quantitative and qualitative fluid flow circulation and accumulation. In that purpose the use of measured petrophysical characteristics versus each other (fig 1) has revealed two populations corresponding to two probable types of reservoir zones. These zones are: zone one and zone two. Zone one can be characterized as relatively tight, whereas the second zone is almost tight. The relative tight zone is mostly characterized by permeability values oscillating from 1 md to 19 md with an average permeability of 5.16 md (fig 1. and table1). The average porosity for this zone was found to be almost 11 % (table1). Within the tight zone permeability and porosity values are in the range of 0.28 md to 0.99 md 8 % respectively (figure 1 and table 1).

Table 1. Parameters characterizing the two zones in Khartam member of the Permo-triassic Khuff Formation

	K (md)	ϕ (%)	RQI (μm)	FZI (μm)	R_{35} (μm)
Relative tight zone	5.16	10.64	0.22	2.87	0.29
Tight zone	0.65	7.57	0.095	1.47	0.15

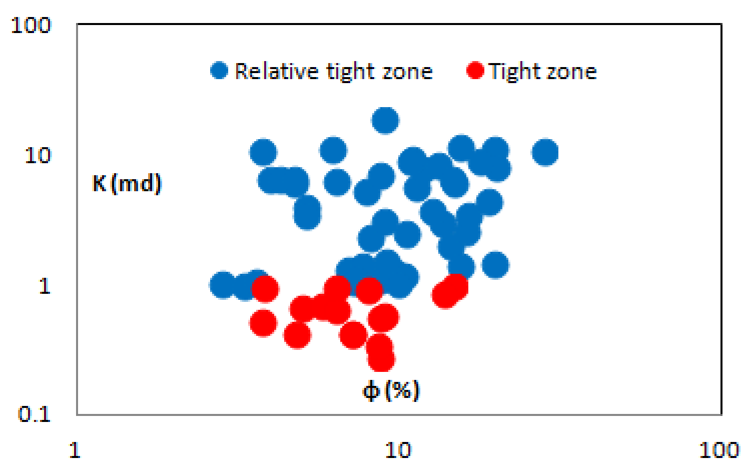

Figure 1. Permeability versus porosity

Further support can be obtained through the use of RQI (Rock Quality Index) versus the measured petrophysical characteristics. The acquired plot also corresponds to almost two concentration zones. Similar results are in harmony with the previous correlated parameters. In the plot of permeability versus rock quality index (figure 2), the RQI values range from 0.08 µm to 0.22 µm with an average value of 0.53 µm in the case of relative tight zone. However, within the tight zone, RQI values vary from 0.05µm to 0.16µm (figure 2 and table 1).

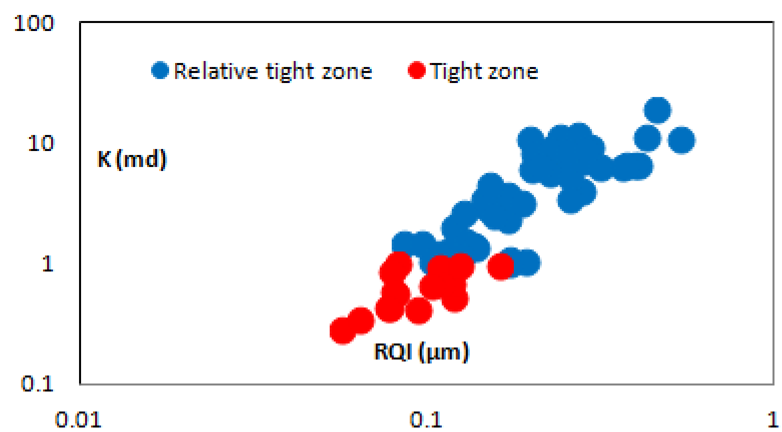

Figure 2. Permeability versus rock quality index

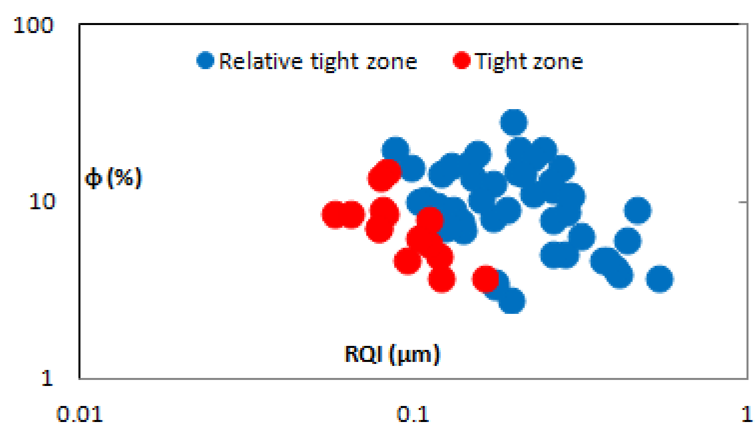

Figure 3. Porosity versus rock quality index

Concerning the samples respective porosity versus the same parameters (figure 3) the presence of the two reservoir zones is confirmed. The use of FZI versus permeability and porosity (figure 4 - 5) has also demonstrated the possible presence of the two population zones.

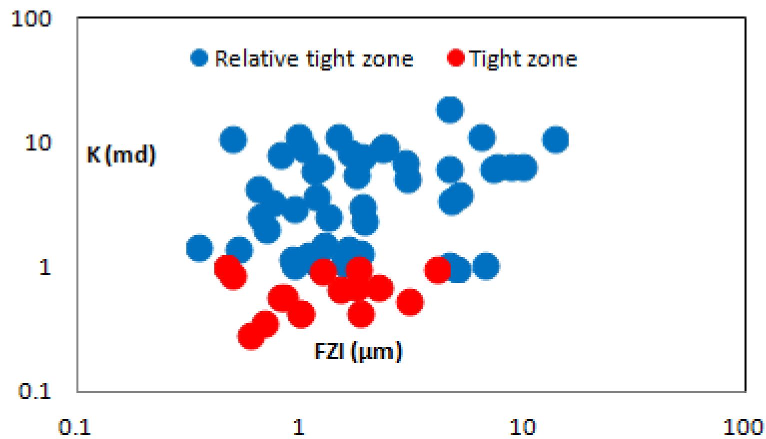

Figure 4. Permeability versus flow zone indicator

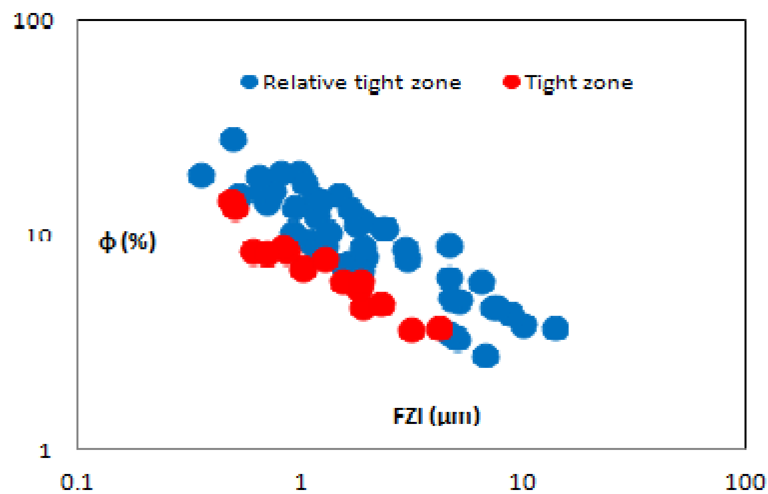

Figure 5. Porosity versus flow zone indicator

Since flow zone indicator is related to permeability, porosity, rock quality index and normalized porosity index ($Ø_z$), the obtained results can also support the statement of not only the presence of two zones population but also the reservoir heterogeneity type. By the use of these parameters classification, the Khartum reservoir can be allocated to the Wackstone and fine grains limestone type (Xu et al 2012). Further support of the fine-grained limestone behavior of Khartam Member of the Permo-Triassic Khuff Formation can be achieved through Winland pore radius corresponding to 35% mercury saturation. This parameter is correlated to permeability and porosity (figure 6 and figure 7).

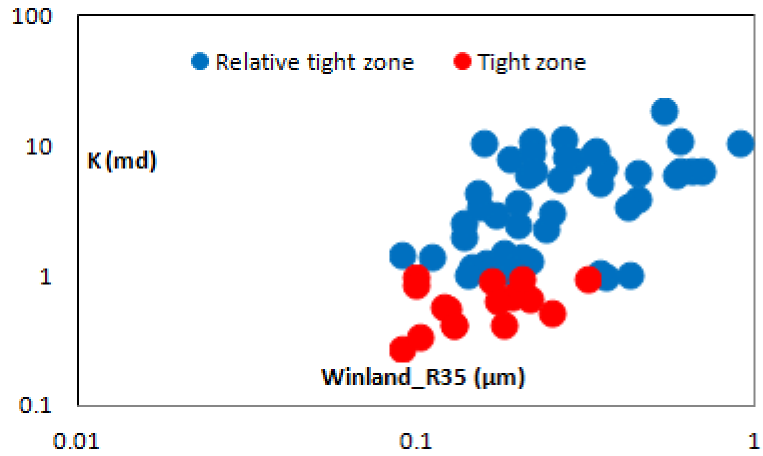

Figure 6. Permeability versus Winland R3

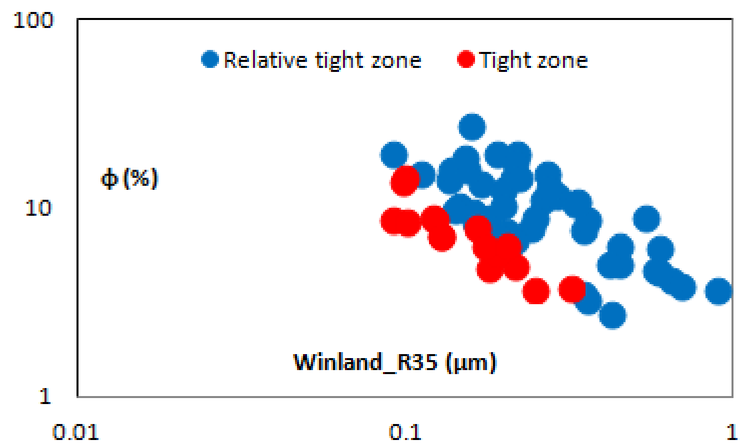

Figure 7. Porosity versus Winland R35

It confirmed respectively the statement on the existence of the two populations regarding the case study reservoir. According to Winland (In Pittman, 2001) classification, the overall obtained results can fit the nanoporosity to microporosity rock type. Therefore the Khartum carbonate reservoir and according to the different physical paramers which have been correlated to each have revealed a limited reservoir physical properties.

4. Conclusion

1. On the basis of permeability-porosity relationship two flow units have been identified for Khartam Member of the Permo-Triassic Khuff Formation.

2. Based on the obtained results the Khartam reservoir can be classified as relatively tight reservoir and tight reservoir.

3. Physical properties which are depending mainly on the textural properties of the deposit and fluid flow: rock quality index, flow zone indicator and R_{35} and their plots versus permeability and porosity characterized two reservoir clusters. These groups are also indicator of the Khartam reservoir heterogeneity degrees despite its tightness.

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