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ORIGINAL ARTICLE

The use of polar angle, polar arm and other physical attributes in rock characterization

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Abstract Sandstone reservoirs and other rock type properties can be variable from the time of deposition up to their burial. Rock texture and structure in addition to diagenetic changes control the reservoir characteristics, fluid flow and accumulation during the sediment burial process. In this study, investigation is concerned with the determination of selected samples petrophysical characteristics and their relation to some of the physical properties. These properties constitute an essential constraint. Particular focus will concentrate on the determination of the reservoir characterization and their correlation to the determined polar angle and polar arm. Accomplishment of this target is accustomed to the determination of other physical attributes properties. Among targeted attributes state the rock quality index (RQI) associated to the flow zone indicator (FZI) and the fractal dimension (D_f). The overall is intended to make an attempt for reservoir description leading to its qualitative and quantitative assessment. Thus, the anticipated rock and fluid properties including polar angle and polar arm parameters are of fine prediction towards reliable information on the considered samples. As a result, in the case study, aimed factors have proved diverse statements. They were of a big contribution towards the reservoir quality index, its heterogeneity and the rock type porosity. They were also of big interest in proving the fluid flow circulation rate and storage.

1. Introduction

Reservoir systems can be made of different types of lithology, thus different types of pores, pore throats and their geometry. Generally, these parameters can be from matrix, vugs or fracturing system. According to this nomenclature, study of cores by the use of logs or microscopical analysis as well as SEM (Scanning Electron Microscopy) will be of great issue to define the type of pores, their scale and their geometry. Different studies in that focus were achieved (Ning et al., 1993; Asquith, 1995). In the case study, selected samples of sandstone were used and different processes starting from microscopical analysis to the petrophysical measurements leading to their characterization versus projected physical properties were investigated. Similar approach is also intended to predict better understanding of the fluid flow and accumulation. This

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challenge can be set in order to classify the probable complexity of different reservoirs as well as their possible degree of heterogeneity based a necessary core study. Thus, and in order to move towards the reservoir characterization, selected samples from KSA sandstone outcrops were subjected to be defined for their physical properties represented by the fractal dimension (D_f), rock quality index (RQI) and its attributes. Polar angle and polar arm were planned for more support concerning essentially the pore type. Definition of these parameters based on their related equations has guided this investigation to set the fluid flow distribution with a particular view on pore system distribution regions based on the polar angle and polar arms curves. The overall was also aimed to evaluate the likely heterogeneities distribution according to the physical properties changes.

2. Methodology

2.1. Core samples description

Reservoir core samples consist on some fine to medium sandstones collected from different outcrops areas in KSA. Selected core samples were relatively less compact and presenting heterogeneous sorting varying from well sorted to moderately sorted grains. Rocks types are dominated by quartz grains. According to the classical ternary taxonomy, the samples can be classified as quartz arenite. Details concerning the material description are in (Benzagouta, 2013).

2.2. Experimental work

Experimental work was led to work out on physical fluid properties and to determine their values. In this investigation the basic factors to be considered are the petrophysical characteristics. Laboratory measurement has allowed obtaining permeability and porosity results (Table 1). Results, which are depending on facies analysis textural characteristics, are variable from few millidacrcies to Darcy unit according to the respective sample. This variation is essential in defining the fluid flow governing the porous media. Thus, the use of permeability and porosity becomes essential in requiring parameters for the determination of other physical attributes such as rock quality index, flow zone indicator, fractal dimension, polar angle and polar arm.

2.3. Methodology for physical properties calculation and results

The physical characteristic are performed according to different related equations. Combination of the overall will be instructive of reservoir quality, its heterogeneity and complexity beyond other series aspects.

2.3.1. Rock quality index (RQI)

Among these physical properties characterizing the reservoir in the case is the rock quality index (RQI):

$$RQI = 0.0314^{*}(k_{core}/\Phi_{core})^{0.5} \text{ (Soto etal., 2010)} \quad (1)$$

This equation is mainly established to assess the reservoir quality based on its characteristics which are related to reservoir description beyond fluid properties. It is based on permeability and porosity measurement in the laboratory. However, for the case fractured reservoirs, Rock Quality Index (RQI) can be approached by the following equation (Ohen et al., 2002) where,

$$RQI = 0.0314^{*}(k_{core}/\Phi_{core}^{2m-1})^{0.5} \quad (2)$$

According to Eq. (2), the cementation exponent (m) can be introduced to calculate rock quality index (RQI) in the case of fractured system. Ohen et al. (2002) equation can depend indirectly on other parameters such as tortuosity (τ), surface area per unit grain volume (S_{gv}), grain shape (F), clay content (Vsh), pore level interconnectivity and fractured flow zone index (FZI) (Ohen et al., 2002).This equation can also be referred to Archie equation (1942) and Schlumberger (1995). Interpretation of the results coming out from these equations should be referred to the criteria of Archie reservoirs conditions from Non-Archie conditions. Workflow chart for these conditions is well set in (Worthington, 2011).Thus, restrictions and conditions for applications are highly requested (Ohen et al., 2002; Worthington, 2011).

2.3.2. Flow zone indicator determination (FZI)

The reservoir description can be based on flow zone indicator (FZI) or hydraulic flow unit (HFU). This latter factor can be defined and used for any reservoir classification forecasting the flow properties governing porous medium. Determination of FZI is related to normalized porosity index (θ_z). Normalized porosity index (θ_z) is defined as:

Table 1 The main calculated physical parameters and petrophysical results.

Φ%	k (mD)	Φz %	RQI	FZI	r (μm)	θ	D_f
13	112	15	0.92165	6.16798	6.39794	1.41575	2.1
17	803	20	2.15806	10.5364	10.7886	1.47837	2.2
16	16.4	19	0.3179	1.66898	2.13611	1.13296	2.05
15	225	18	1.21612	6.89133	7.13998	1.43164	2.13
23	1725	30	2.71932	9.10381	9.45727	1.46545	2.37
30	1760	35	2.40506	5.6118	6.12877	1.40906	2.47
23	461	30	1.40578	4.70629	5.11006	1.37755	2.16
18	116	22	0.79712	3.63131	3.986	1.32499	2.1
13	272	15	1.43629	9.6121	9.8134	1.46925	2.13
16	576	19	1.884	9.891	10.1319	1.47242	2.18
14	272	16	1.38404	8.50199	8.72339	1.45666	2.14
13	271	15	1.43365	9.59442	9.79581	1.46906	2.13