Estimation of porosity of Khewra Sandstone of Cambrian age by using Helium Porosimeter and its application in reservoir evaluation

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Abstract

Estimation of petrophysical properties of the rock formations played decisive role in all the processes of petroleum exploration. The Cambrian sequence is well established as reservoir rocks in the various parts of the world from where petroleum is being tapped. The Cambrian sequence has been encountered in the Potwar area and limited petroleum is being produced from the Adhi Oil Field. The Khewra Sandstone of the Cambrian sequence is outcropped in the Khewra Gorge, Salt Range Pakistan below an unconformity of the Tobra Formation. For the assessment of porosity & reservoir characterization Helium Porosimeter has been used, six samples of the upper horizon were collected from various locations of the Khewra Gorge and the Khewra Choha Sadden Shah road side section; cores were prepared from these samples according to the instrument standard. The results of this study revealed that the upper horizon of the Khewra Sandstone Formation has good porosity ranging from 18.76% to 21.07%, porosity varied in different parts of the formation. These results are in good agreement with the internationally reported values for petroleum reservoirs of the Cambrian sandstone.

Key Words: Khewra Sandstone, geology, petro-physical properties, porosity, reservoir.

1. Introduction

In the present times, the economy of the world is predominantly controlled by the energy sector. The energy resources and reserves are being used as indicator of economy and political stability of a country. Petroleum related energy reserves of a country constitute its most important assets. The role of hydrocarbon availability, its exploration and development is directly related to the overall development and prosperity of the country. The petroleum exploration and its exploitation have gained special importance over the past few decades to meet world's increasing demand of energy. Due to its importance this field has gained special attention of scientists and various hydrocarbon agencies and a number of new geophysical techniques and methods have been developed to explore and exploit the hydrocarbon buried in subsurface geological formations. One of the very basic and stronger tools to evaluate formation characteristics and estimate potential for hydrocarbon development is porosity of the reservoir rocks.

The lithology of the Khewra Sandstone has been described by Shah [1] as," the formation consists predominantly purple to brown, fine grained sandstone. The lower most part of the formation is red, flaggy shale. The sandstone is mostly thick bedded to massive. Sedimentary features like ripple marks mud cracks etc are common in the formation."

A number of researchers have attempted to evaluate the reservoir properties especially the petrophysical properties. Ahmed et al [2] have predicted the porosity and water saturation using seismic inversions for the Habib Rahi Limestone ,Mari Gas Field Central Indus Basin Pakistan as, "The main advantage of using seismic acoustic impedance for studying reservoir properties is that it can be used wherever seismic data exist , provided that well logs are available,- for calibration. The porosity prediction

is good match with actual average log data of Hahib Rahi Limestone". Yunbei & Weikang [3] have analyzed the Logs for the carbonate reservoir with high porosity but with low permeability and concluded that, " the cross plot technique can be used to calculate the accurate porosity but it is still difficult to calculate the effective porosity whose pores connected by the big to medium throats only depends on conventional logging methods".

Luffel et al [4] while determining the relationship between porosity and permeability at reservoir stress have accepted the authenticity of the porosity determined by, "a common method of measuring core porosity to measure the grain volume by the use of Helium and the bulk volume by immersion in mercury. The method is reliable when carefully performed and was used for most of the ambient porosities". Kim & Schechter [5] reported that, "Matrix porosity is relatively easy to measure and estimate compared to fracture porosity. On the other hand, fracture porosity is highly heterogeneous and very difficult to measure and estimate. When matrix porosity of naturally fractured reservoirs (NFRs) is negligible, it is very important to know the fracture porosity to evaluate reservoir performance". Keeping in view the future exploration in the Cambrian sequence, the focus of this study is to determine the porosity of the upper horizon of the Khewra Sandstone Formation by using the Helium Porosimeter to strengthen the reservoir characteristics.

2. Methodology

The procedure adopted for the investigation of the porosity of the Khewra Sandstone Formation of the Cambrian age is given as follows:

Field Sampling

Keeping in view the variations in the depositional environment and their expected effect on porosity, the sampling strategy adopted was to obtain samples from only upper horizon and also to cover the horizontal spreading of outcropped formation. Six samples from the Khewra Sandstone Formation of the Cambrian age, each 1-2 cubic feet were collected from the Khewra Gorge and the Khewra-Choha Sadden Shah link road to the Khewra Gorge (Figure-1).

Core Preparation

To fulfill the instrument requirements, standard cores are needed to obtain representative volume for the determination of porosity. Accordingly fresh cores were prepared from the rock blocks. Core samples were placed into oven at 105^0 C for three hours and then into evacuated desiccators for cooling them to ambient temperature to minimize contamination due to condensation from the atmosphere.

Calculations

The Helium Porosimeter "TPI-219 of Cortex System, Inc, USA" was used for the experimental assessment of the porosity of reservoir rocks by observing the instructions of the manufacturer, 98-105 psi pressure. The readings were taken and the results were calculated by the following equation, given by Cortex System [6].

$$V_{REF} = \frac{V_{BILLETSREM\quad OVED}}{\left(\frac{P_{REFREM}}{P_{CUPREM}}\right) - \left(\frac{P_{REFFULL}}{P_{CUPFULL}}\right)} \quad (1)$$

$$V_{DEAD} = \left|\left(\frac{P_{REF}}{P_{DV}}\right) - 1\right| V_{REF} \quad (2)$$

$$V_{TOTAL} = \left|\left(\frac{P_{REF}}{P_{TOTAL}}\right) - 1\right| V_{REF} \quad (3)$$

$$V_{PORE} = V_{TOTAL} - V_{DEAD} \quad (4)$$

$$POROSITY\quad, percent = \left(\frac{Pore\ \ Volume\quad cm^3}{Bulk\ \ Volume\quad, cm^3}\right)100 \quad (5)$$

3. Results and Discussion

Results obtained for porosity by using the Helium Porosimeter are given in Table 1.These results

Table 1: Results of the various samples analyzed for porosity from the Khewra Sandstone Formation

Sr. No	Sample identification No	Location	Porosity %
1	KSS-1	Upper thick bed, Khewra Gorge	20.00
2	KSS-2	Upper thick bed, Khewra Gorge	19.00
3	KSS-3	Upper thick bed, Khewra Gorge	21.07
4	KSS-4	Upper thick bed, Khewra Gorge	20.96
5	KSS-5	Khewra- Choha Sadden Shah link road to Khewra Gorge	18.80
6	KSS-6	Khewra- Choha Sadden Shah link road to Khewra Gorge	18.76
7	Average value	-	19.77

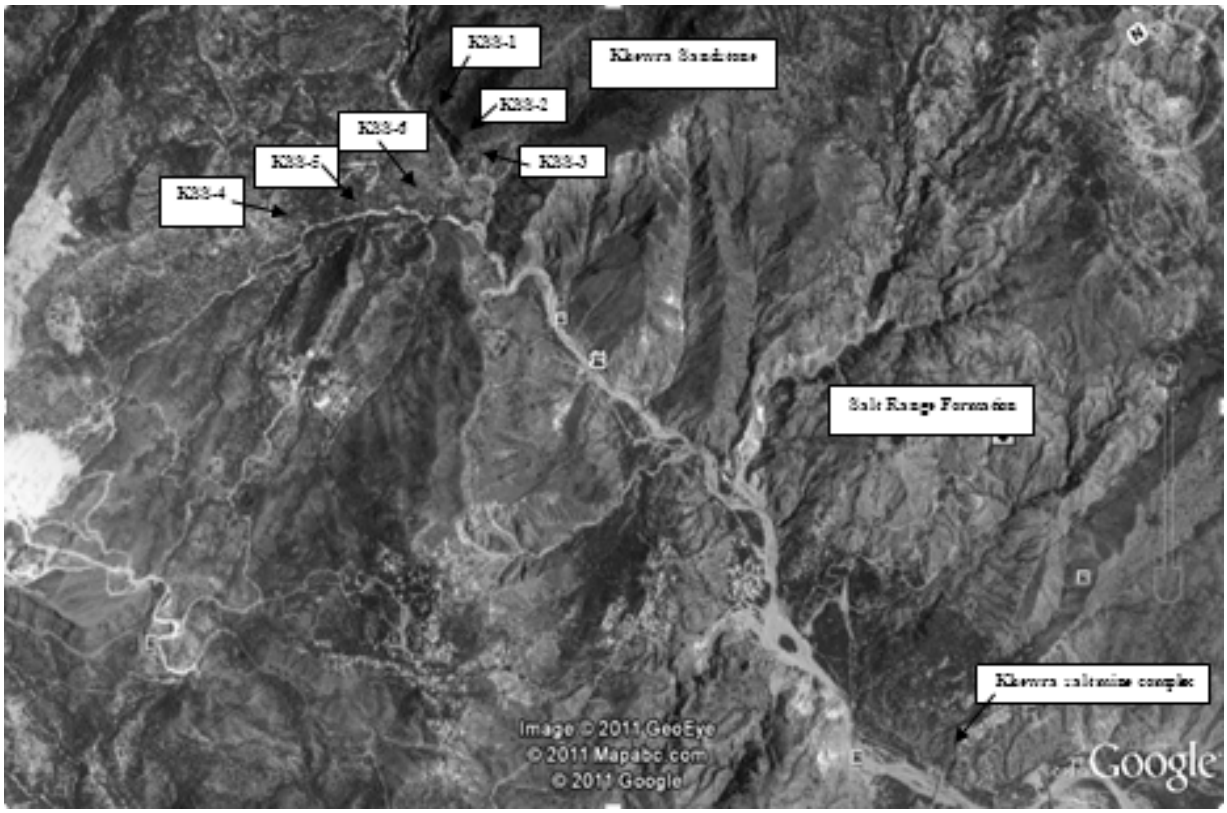

Fig. 1: Study area of Khewra Gorge & surrounding tracks, with approximate locations of samples (Google Earth [7]

Table 2: Comparison of present work with reported values of porosity by wireline logs & dye injection method

Sr. No.	Formation	Location	Depth (ft)	Average porosity %	Method	Reference
1	Khewra Sandstone	Zone-5	14281-15350	8.76	Wireline logs	Jamil et al [8]
2	Khewra Sandstone	Khewra Gorge	Outcrop sample	13	Dye injected thin section	Saqib et al [9]
3	Khewra Sandstone	Khewra Gorge	Outcrop sample	19.77	Helium Porosimeter	Present work

indicate that the average value for porosity of the Khewra Sandstone Formation is 19.77 percent, which agrees well with the potential petroleum reservoir. The lower part of the Khewra Sandstone is fine grained tight sandstone and the upper horizon is a petroleum reservoir. In the Adhi Oil Field petroleum production is from the Khewra Sandstone, Siddiqui et al [10] described," the oil field has been on production since 1980 and produces oil and gas from Sakesar Limestone and gas condensate from Tobra & Khewra clastics".

A comparison of these results with porosity determined by well logs has also been drawn. Jamil et al [8] during their research for thesis on the formation evaluation at 4354-4680 ft depth using wireline logs interpretation calculated average porosity of 8.76% for the Khewra Sandstone (Table-2). Saqab et al [9] measured the porosity of 13 % for Khewra Sandstone with dye injection method which is closer to the present study. We believe that the average value of 8.76% determined by logs is probably true for lower tight horizons of the Khewra Sandstone; hence the porosity in the Khewra Sandstone decreases with depth. Similar results indicating decrease in porosity with depth have been reported for sandstone of the Cambrian age by John [11],"Porosity values collected

from core analyses and geophysical logs from the Upper Cambrian Mount Simon Sandstone in the Midwest Regional Carbon Sequestration Partnership (MRCSP) region indicate a predictable decrease in porosity with depth".

According to Siddique et al [10]," in Tobra and Khewra reservoirs the aquifer has not been encountered so far. About top 20 m of Tobra and top 30 m of Khewra are hydrocarbon bearing from Adhi - 11 in south to Adhi -14 in the north, for a distance of about 10 km, with the exception of Khewra in Adhi - 14 where the gross pay is considerably reduced due to reservoir deterioration".

Our results of 18.76 % to 21.07 % are comparable with the porosity values reported internationally for good petroleum reservoirs by McFarland [12],"Porosity varies from 0% to 50% depending on the amount of alteration both physical and chemical the rock had been subjected to. Typically, porosity values for the Gulf Coast both onshore and offshore range between 10 % and 30 % while interior basins in the US have much lower porosity values of 5% to 15%".

4. Conclusion and Recommendations

The porosity values determined with the Helium Porosimeter for the Khewra Sandstone ranging from18.76 % to 21.07 % are representative of potential petroleum reservoir. The porosity values obtained are higher than reported values determined through well logs and dye injection methods, which is a positive sign and hence it is suggested that further exploration should be focused on the Cambrian sequence located below the petroleum reservoir being exploited from Potwar Plateau.

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6. References

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