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Petrophysical properties and hydrocarbon potentiality of Balkassar well 7 in Balkassar oilfield, Potwar Plateau, Pakistan

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Abstract: The Balkassar Oilfield is located in the eastern Potwar sub-basin, and lies on the Soan Syncline southern flank of the Himalayan collisional regime. In this study, petrophysical properties of reservoir rock of the Chorgali Formation of Eocene age encountered in well 7 of the Balkassar Oilfield were evaluated for reservoir rock potentiality. A set of wireline logs containing neutron, density, gamma ray, spontaneous potential and resistivity logs of well 7 from Balkassar Oilfield were interpreted carefully to estimate porosity, water saturation and hydrocarbon saturation. The method used for this petrophysical analysis is spontaneous potential logs in calculating water resistivity followed by Archie's equation to convert water resistivity to water saturation. Based on the petrophysical analysis performed on the Balkassar well 7, the results show that about 21.1% average porosity, 33.5% water saturation and 66.5% hydrocarbons saturation were obtained for the Chorgali Formation. Thus, this indicates that Chorgali Formation has an average to good reservoir potential.

Keywords: Petrophysical analysis; Balkassar oil field; Chorgali Formation; reservoir potential

INTRODUCTION

The Balkassar oilfield is located in Potwar Plateau, within the Central part of Potwar Sub-basin that forms part of lesser Himalayan Foreland Fold and Thrust belt (Duory *et al*., 1989; Farah *et al*., 1984; Tahirkheli, 1979; Kazmi & Jan, 1997; Khan et al., 1986). The Balkassar oilfields are one of the major oil producing fields in the region. Balkassar oilfield is very important as it is host to proven hydrocarbon reserves (Kadri, 1995), however there is lack of information available regarding petrophysical data. As according to Kadri (1995), Ahsan *et al*. (2013) and Iqbal *et al*., (2015) the Balkassar has the potential to produce hydrocarbons. According to Aadil *et al*. (2014) and Khalid *et al*. (2015) the key to success for exploration of hydrocarbon is petrophysical analysis. Geophysical wireline logs are commonly applied to convert raw logs data into suitable information capable of providing estimation of oil and gas in the subsurface (Quijada *et al*., 2007). Wireline logs are very beneficial for defining the rocks characteristics such as, lithology, permeability and porosity which are the most significant properties of rocks in oil and gas exploration (Asquith *et al*., 2004). For qualitative description of reservoirs, Amigun & Odole (2013), Rider (1986) and Van Golf-Racht (1982), have reported on criteria used for porosity. Table 1 shows the criteria that has been adopted for this study.

Table 1: Criteria set by Rider (1986), for qualitative description of reservoir adopted for this study.

Qualitatively Evaluation of Porosity	
Average Porosity	**Qualitative description**
0-5	Negligible
5-10	Poor
10-20	Good
20-30	Very Good
>30	Excellent

The aim of this study is to interpret wireline logs of Balkassar well 7 to evaluate hydrocarbon potential of the reservoir rock Chorgali Formation. The main objectives are to identify the lithology and to calculate porosity, water resistivity, water saturation and hydrocarbon saturation.

LOCATION OF STUDY AREA

The Balkassar oilfield is located in the middle of the Potwar Plateau within the Upper Indus Basin, Punjab, Pakistan (Figure 1), and is part of the Himalayan Active Foreland Folds and Thrust Belt of northern Pakistan. Its coordinates are 32°55' N and 72°39' E. The location of Balkassar well 7 is shown in Figure 1b.

MATERIAL AND METHODS

This study uses one well, that is Balkassar 7 for investigation of Eocene reservoir rock of Chorgali Formation to evaluate its hydrocarbons potentiality. The well logs data for this study was provided by the Directorate General Petroleum Concessions (DGPC), Islamabad Pakistan.

Petrophysical analysis

The method used in this study was adopted from Zahid *et al*. (2014), Mehmood *et al*. (2015) and Hartmann & Beaumont (1999). The petrophysical analysis based on wireline logs (Gamma Ray, Neutron, Density, Resistivity, and Spontaneous-potential) for Eocene age Chorgali Formation encountered in the Balkassar well 7 was conducted. The analysis were made to calculate porosity, formation water resistivity, water saturation and hydrocarbon saturation. All of these parameters are very useful in investigating the reservoir hydrocarbon potential.

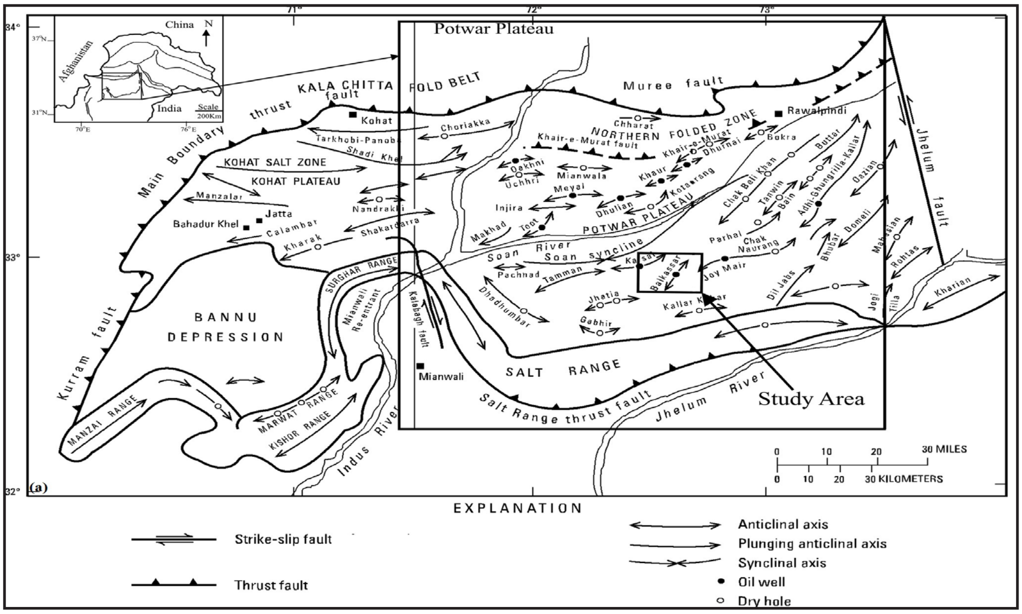

Figure 1a: Structural geology map of Potwar Plateau (modified after Khan *et al*., 1986; Gee & Gee., 1989; Kazmi & Rana, 1982; Khan *et al*., 1986).

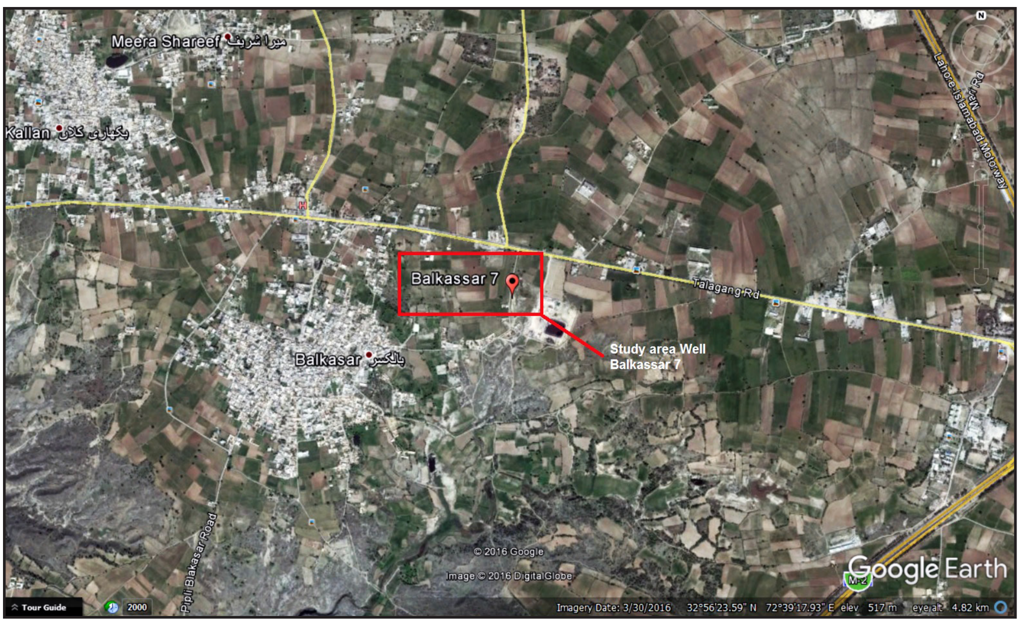

Figure 1b: Google Map showing Balkassar well 7 location.

Procedure for finding different parameters from logs

The parameters that were directly read from the log track are:

- Formation depth (in ft)
- Bulk density of formation (RHOB) scale 1.95 to 2.95
- Bulk resistivity of the formation (LLD) scale 0-2000 ohm.m
- Spontaneous potential (SP) scale 0-100mv
- Neutron porosity (NPHI) scale 0.45 to -0.15
- Saturation of hydrocarbon (SH)

Schlumberger log interpretation charts along with several equations were used to find out certain unknown values to determine saturation of hydrocarbons in Chorgali Formation encountered in Balkassar 7 well. The equations and charts include:

1. Bottom-hole temperature of 180 °F and 72 °F surface temperature was given on wireline logs and these two were used in equation (Figure 2a). Formation temperature was determined by using Equation: Tf = Ts + Df (BHT-Ts/TD)
2. Corrected Rmf Mud filtrate resistivity and Rm resistivity of mud at formation temperature (Figure 3a).
3. Self-Potential was determined directly by reading it from SP curve on log chart.
4. For measuring Rmf/Rwe ratio, Figure 3b was used to measure the value.
5. Rwe was determined by dividing the corrected value for Rmf by the ratio of Rmf/Rwe value.
6. For Rwe the equation is: Rwe= Rmfeq/(Rmfeq/Rwe)
7. Rwe correction to Rw were done by using Figure 2b, and the value of Rwe calculated in step 5 to determine the correct Rwe value.
8. Saturation of water was determined by Archie's equation:

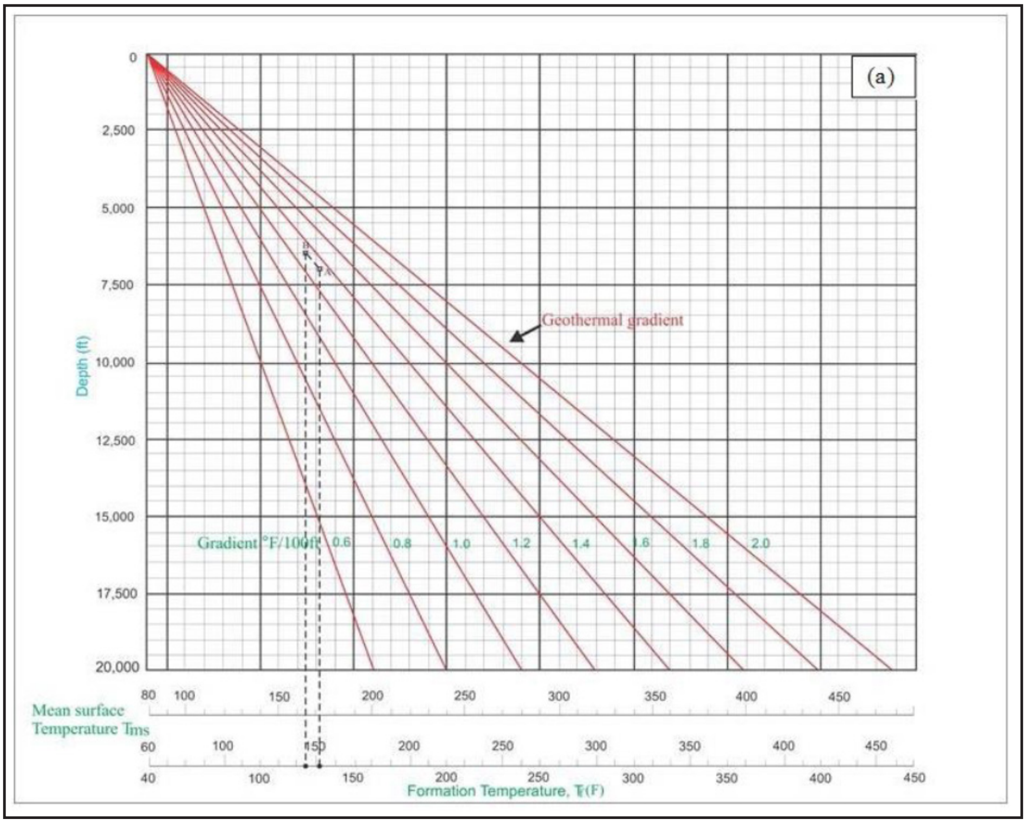

Figure 2a: Determination of formation temperature at various depths (Schlumberger, 1977).

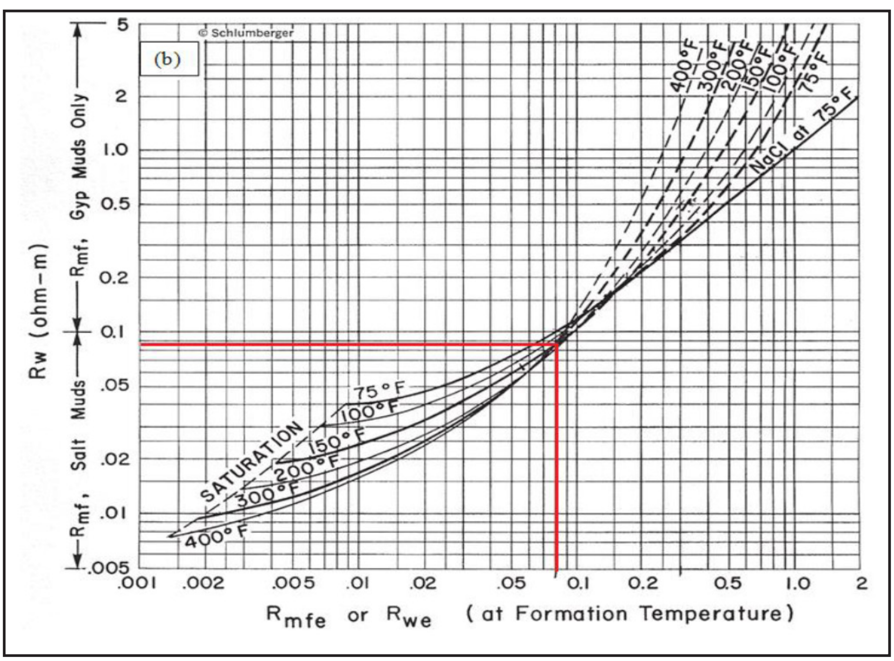

Figure 2b: Determination of Rw from Rwe (Schlumberger, 1977).

$$S_w = \sqrt{\frac{R_w}{\phi^m * R_t}}$$

9. Saturation of hydrocarbon can be determined at a given temperature by equation: SH=1-Sw

As the mud filtrate resistivity values were obtained these values were utilised in Figure 2b to convert them to equivalent mud filtrate resistivity. Then this equivalent mud filtrate resistivity values were used in a formula shown in step 6 to get equivalent water resistivity. This equivalent water resistivity was converted to water resistivity and ultimately this water resistivity was used in Archie's equation to obtain water saturation.

As the mud filtrate resistivity in log header was measured at surface temperature which needs to be corrected at

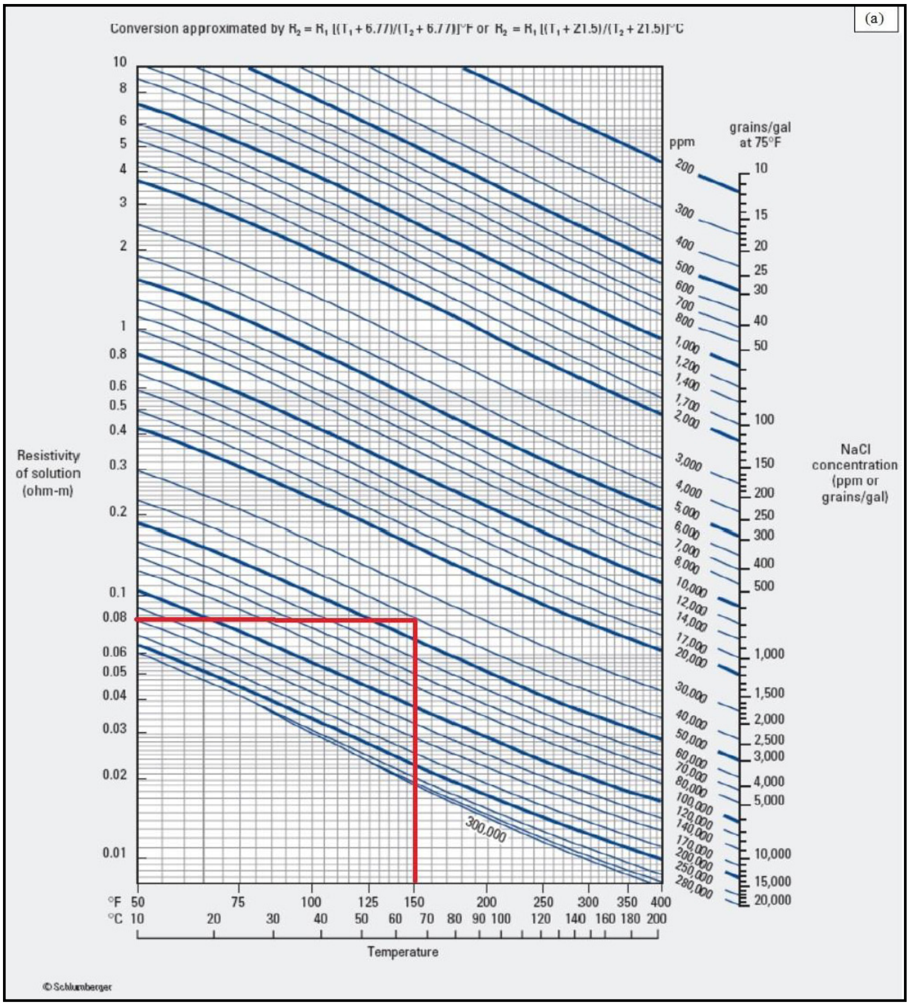

Figure 3a: Correction of Rmf and Rwe according to temperature (Schlumberger, 1977).

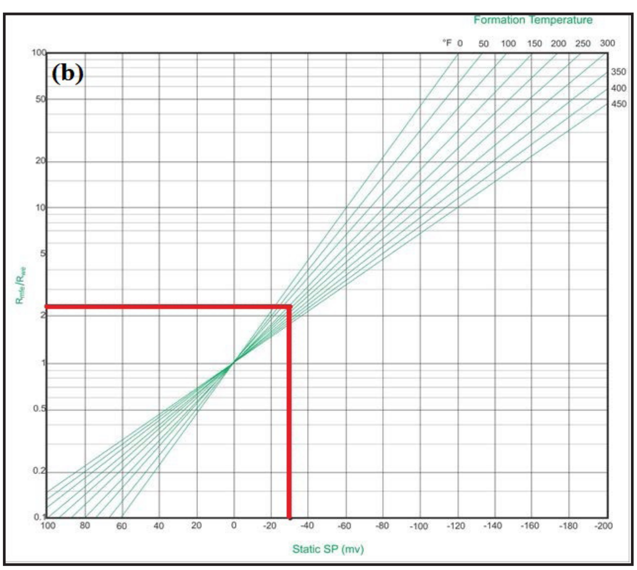

Figure 3b: Rmf/ Rwe determination from Self-Potential (Schlumberger, 1977).

formation temperature for each value at certain depth to get mud filtrate resistivity at formation temperature, for this correction Figure 3a was utilised.

RESULTS

The parameters derived from the above methodology were used for reservoir quantitative interpretation. The analysed petrophysical parameters computed for Chorgali Formation are shown in Table 2.

CONCLUDING REMARKS

Evaluation on the petrophysical properties were performed by careful interpretation and analysis of well logs of Balkassar well 7. The average porosity indicates a suitable reservoir ranges from 16% to 27%, average water saturation is 33% and hydrocarbon saturation is 67% indicating an average hydrocarbon potential (Table 2). Based on the statistical analysis performed, it can be concluded that the Chorgali Formation encountered in Balkassar well 7 possess average petrophysical properties and have an average potential to produce hydrocarbons.

Table 2: Values for the different parameters calculated for well logs analysis.

Depth (ft)	Temp	RHOB	ΦD	SP	Φ (N.D)	Rt (LLD)	Rwe	Rw	Sw	SH	Lithology
7864	156.1	2.69	0.32	-29	0.27	390	0.59	0.69	33%	67%	Limestone
7891	156.4	2.67	0.30	-11	0.16	1230	0.31	0.67	38%	62%	Limestone
7919	156.7	2.71	0.14	-31	0.25	1630	0.32	0.71	24%	76%	Limestone
7946	157	2.66	0.19	-33	0.23	1810	0.31	0.42	36%	64%	Limestone
7974	157.3	2.62	0.12	-46	0.24	1690	0.36	0.68	28%	72%	Limestone
8001	157.6	2.69	0.29	-31	0.22	1770	0.34	0.45	37%	63%	Limestone
8029	157.9	2.63	0.27	-33	0.18	980	0.32	0.49	39%	61%	Limestone

Note: The average saturation of hydrocarbon (**SH**) calculated is 66.5%. The abbreviated parameters are described in the text.

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