



Petrophysical and Well Log Evaluation of Dry Holes in Fort Abbas area, Punjab Platform, Pakistan.

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Abstract: Present study is carried out in Punjab Platform, Central Indus Basin. It pertains to petrophysical analysis of well log data of Fort Abbas-01, Bahawalpur East-01 and Marot-01. Well Fort Abbas-01 had target depth of 1650 and hydrocarbon potentials were tested for Kussak and Khewra formations (Cambrian) and Salt Range formation (Pre-Cambrian). The well was declared dry and plugged abandoned. Petrophysical studies include Crossplot generation between log data of Neutron Porosity and Bulk Density. In three wells Neutron Porosity-Density Cross-plots show linear trend data values matching with limestone and dolomite lithology. It also includes calculation of porosity, volume of shale and proportion of water content in the Khewra Sandstone. Content of volume of shale varies from 5-25%. Average porosity trend indicates good to excellent which is from 20-35% in all three wells. The results show that water saturation is from 50 – 90 % in all three wells which exceeds the general value suitable for hydrocarbon accumulation. Well correlation shows presence of thick Salt Range and Cambrian formations in wells Bahawalpur East-01 and Marot-01. Permian is pinching out in Fort Abbas-01. Thinning of Paleocene and Mesozoic formations towards Marot-01 is also evident. All the strata is deepening towards north in well Bahawalpur East-01.

Keywords: Petrophysical, well log evaluation, Fort Abbas, Marot, Bahawalpur, Khewra, Salt Range.

1. INTRODUCTION

The project area Fort Abbas lies in the Punjab Platform. The studied areas located in the eastern part of Central Indus Basin. Fort Abbas concession is part of Punjab Platform which is a gentle eastward monoclonal rise at the Central Indus Basin and main reservoirs in this area include Kussak Formation, Khewra Sandstone and Salt Range Formation. Central Indus Basin from east to west is divided into Punjab Platform, Suleiman Fore deep and Suleiman Fold Belt. Punjab Platform is bound in the south by Sukkur rift zone and in the north by Precambrian Sargodha High. It extends to Bikaner

basin of India in east (Fig. 1). Evidence from wells and outcrops along the northwestern leading edge, of the Punjab Platform shows Paleozoic, Mesozoic and Cenozoic in moderate thickness are present over the basement (Platform). It continues as a platform area into India where petroliferous basins are locally formed (Raza et al, 1989).

2. MATERIAL AND METHODS

The wells lie in eastern part of Central Indus Basin. Bahawalpur East-01 is a dry well that lies in a desert area at 29°22' 07"N latitude and 72°09'07"E longitude. It has a distance of 75.21 km from Fort Abbas-01 and 42.83 km from Marot-01. It has 130.90m and 134.9m AMSL ground and K.B elevation respectively.

Marot -01 well is a dry well situated at 29°14'39"N latitude and 72°34'11"E longitude. The well has 14.00m and 143.00m AMSL ground and K.B elevation respective.

Fort Abbas-01 is a dry well located in the desert area at 28°58'31"N latitude and 72°41'54"E longitude about 29 km from Fort Abbas. It has a distance from well Marot-01 around 31 km. The ground elevation and the K.B elevation are 140.31 m and 143.96 m AMSL respectively (Riaz, 2003). Fort Abbas-01 is marked on seismic lines 931-FABS-33 & 931-FABS-16A.

Correlation of Wells

Well log data is interpreted to develop a stratigraphic framework and then reservoir intervals are

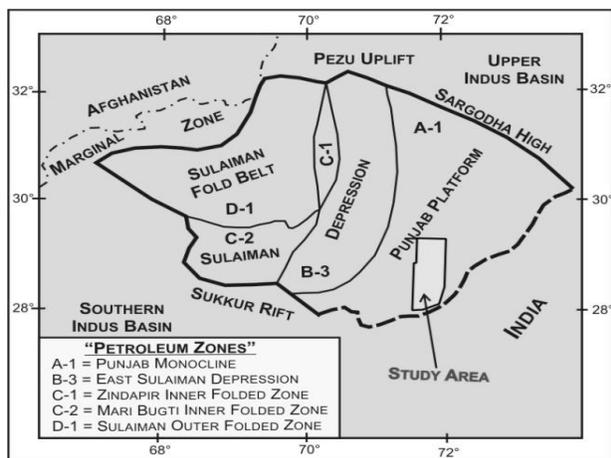


Fig 1: Map of Central Indus Basin showing Punjab Platform (Raza et al, 1989)

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mapped and predicted. The stratigraphic correlations established from different wells are giving a clue in different geological time about sediments' source and depo-centers of sediments (Goetz *et al*, 1977). The wells drilled on the west have not penetrated in the older rocks and the basement. In wells Bahawalpur East-1 and Marot-1, a paleo-high is drilled and the basement is encountered. The data of formation tops is used for correlation of wells (Fig 1). Pre-Cambrian strata thickness increases from SE to NW and from Fort Abbas-01 (SE) Cambrian strata thickness decreases in NW. In Fort Abbas-01 and Marot-01 wells a paleo-high is present in Paleozoic strata. The correlation confirms the deepening of strata from SE to NW (Fig 2).

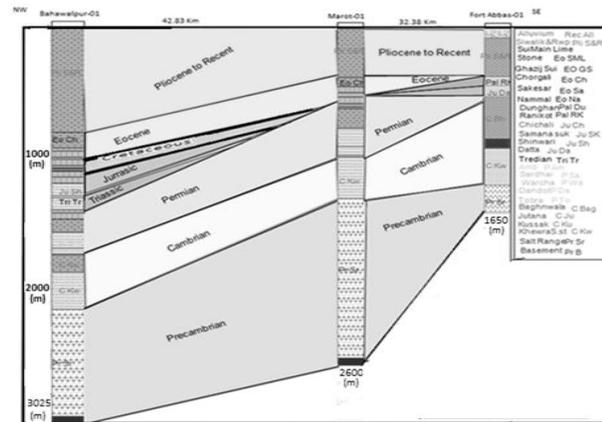


Fig 2: Wells Correlation of different wells

**Well Logs and Petrophysical study**

Well logging deals with recording various physical, chemical, electrical, or other properties of the rock/fluid mixtures penetrated by drilling a well into the earth. When log analysis is combined with other physical measurements on the rocks, such as core analysis or petro-graphic data, the work is called petrophysical analysis (Ahmad and Mateen, 1999). Petrophysical interpretation is performed for all the wells at Khewra Sandstone level (Fig 3).

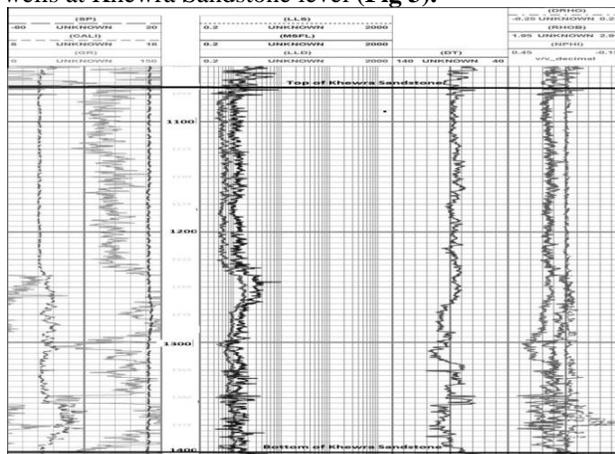


Fig 3: Well logs display of Fort Abbas-01 for Khewra Sandstone (1070m-1400m) Estimation of Volume of Shale (V<sub>sh</sub>)

**Lithological Interpretation from Wireline Logs & Cross-plots**

Lithological interpretation has been done by direct and indirect methods. Caliper(CALI), Gamma Ray (GR), Spontaneous Potential (SP), Sonic (DT), Density (RHOB), Neutron Porosity (NPHIP) and Resistivity (LLD, LLS, MSFL) logs often are used for this purpose (Rider, 2002).Gamma log interpretation based on the low count rates shows cleansand environments. Higher gamma count rates give clay or shale lithology for respective formation associated with tightly compact fine particles with less porosity and permeability. The SP is useful in detecting permeable beds, locating bed boundaries, determining water resistivity, shale indicator (Schlumberger, 1974). Spontaneous Potential log also gives information regarding lithology. The final analysis and discrimination between sandstone, limestone & dolomite is given by neutron-density cross plot(Rider, 2002).Zone of interest(Khewra Sandstone) is interpreted from wireline logs (Fig 3).

**Estimation of shale volume**

Gamma Ray gives shale volume(Dolan et al, 1987)

$$GI = (GR_{log} - GR_{min}) / (GR_{max} - GR_{min})$$

$$V_{sh} = 0.33 * (-1 + 2^{(2 * GI - 1)})$$

Whereas,

GR<sub>log</sub> = Gamma ray reading of formation

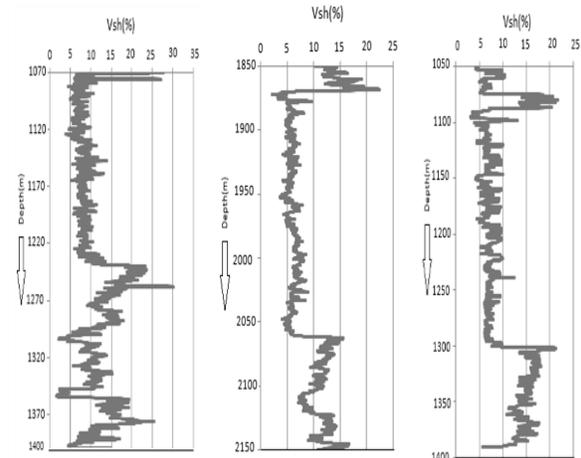
GI = Gamma Ray Index

GR<sub>min</sub> = minimum value of Gamma ray(clean sand or carbonate)

GR<sub>max</sub> = Maximum Value of Gamma ray(shale)

V<sub>sh</sub> = Volume of Shale

The log shows the V<sub>sh</sub> in the zone of interest for all wells. It indicates the zones having more clay or shale (Fig 4).



(a) Fort Abbas-01 (b) Bahawalpur East-01 (c) Marot-01

Fig 4: Volume of Shale for Khewra Sandstone Formation in wells

Clean and Shale baseline values are computed by the kingdom software for the GR log and SP log for the wells (Fig 5).

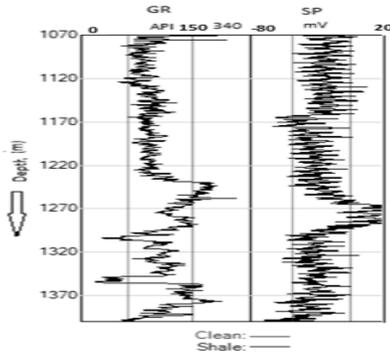
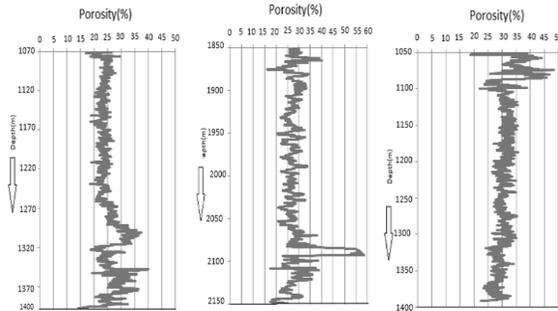


Fig 5: Clean(left) and Shale(right) baselines are displayed on the adjacent GR and SP logs of Khewra Sandstone of well Fort Abbas-01(1070m-1400m)

**Estimation of Porosity**

The porosity is computed from Neutron-Density cross plot. Porosity and permeability of sandstone depends largely upon primary depositional process and sediment texture (Slatt, 2006). Porosity logs for all the wells show 20-30% porosity range (Fig 6). Well consolidated sandstones may have 10 to 15% porosity; unconsolidated sands may have 30%, or more, porosity (Schlumberger, 1974). This suggests Khewra Sandstone could be fractured.

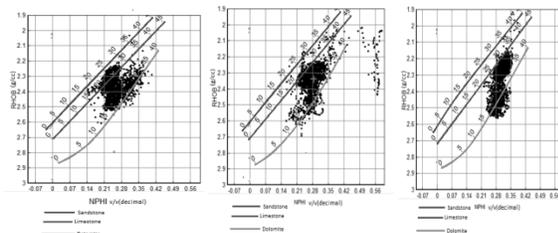


(a) Fort Abbas-01 (b) Bahawalpur East-01 (c) Marot-01

Fig 6: Porosity of Khewra Sandstone Formation in wells

**Neutron-Density Cross plot**

The relationship between Neutron Porosity and Bulk Density is given by a cross-plot for three matrices; sandstone (topmost line), limestone, and dolomite. The cross-plots show target zone has limestone dolomite-lithology also present with Sandstone. The annotated numbers show a percentage of porosity (Fig 7).



(a) Fort Abbas-01 (b) Bahawalpur East-01 (c) Marot-01

Fig 7: Crossplot of the Density and Neutron Porosity curves for Khewra Sandstone in the wells

**Estimation of Water Saturation(S<sub>w</sub>)**

Water saturation of reservoirs of Khewra Sandstone of Fort Abbas-01, Bahawalpur East Well-01 and Marot Well-01 is calculated from following Archie's equation (Rider, 2002).

$$S_w^n = \frac{a}{\phi^m} \frac{R_w}{R_t}$$

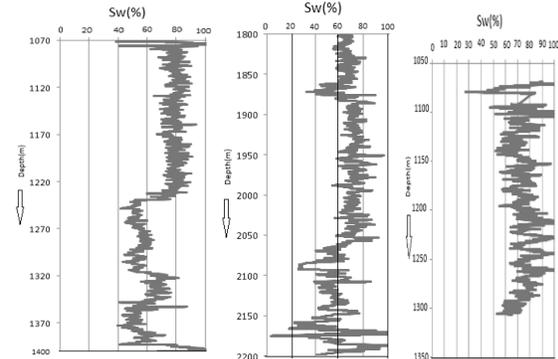
- S<sub>w</sub>= water saturation
- R<sub>w</sub>=water resistivity (formation)
- R<sub>t</sub>= Resistivity (LLd)
- Φ= porosity (Nphi)
- m=2(cementation factor)
- n=2(saturation exponent)
- a=1(tortuosity factor)

R<sub>w</sub> has been calculated with help of the following formula:

$$R_w = \Phi^2 \times R_t$$

- Whereas,
- Φ=porosity in clean zone
- R<sub>t</sub>=Observed LLd curve in clean zone

The water saturation in Khewra Sandstone for wells is given by logs (Fig 8). The zone containing formation water more than 60% is not favorable for hydrocarbons.



(a) Fort Abbas-01 (b) Bahawalpur East-01 (c) Marot-01

Fig 8: Water saturation of Khewra Sandstone Formation in wells

**3. RESULTS AND DISCUSSION**

**Petrophysical result of Fort Abbas-01(1070 m-1400m)**

It is concluded that matrix of mixed lithology having limestone, dolomite, and sandstone beds is present. The average porosity trend indicates well to excellent porosity. The formation porosity varies within range of 20-30%. The contents of volume of shale varies within 5-25% and the portion of pore space that contain formation water varies within 50-90% that is not favorable for accumulation of hydrocarbons. This well, Fort Abbas-01 was declared as dry, plugged and abandoned because it did not produce any hydrocarbons due to high water saturation.

**Bahawalpur East-01(1850m-2150m)**

It is concluded that the formation has poor reservoir quality suggesting distal setting. The formation porosity varies within 20-35%. The contents of volume of shale varies within 5-15% and the portion of pore space that contain formation water varies within 40-80% that assumed unfavorable for accumulation of hydrocarbons. The review of well data demonstrated that Bahawalpur East-1 has poor organic richness. As the well is located on paleo-high and did not encounter Infra-Cambrian formations which confirm the existence of paleo-highs during deposition of Infra-Cambrian sediments.

**Marot Well-01(1090m-1390m)**

It is concluded that the mixed lithology of limestone, dolomite, and sandstone is present in Zone of interest. The average porosity trend shows good porosity towards north and southeastern part of Marot Well-01. The formation porosity varies within 25-35%. The contents of volume of shale varies within 5-20% and the water saturation is too high (may be intensely fractured) that is not favorable for accumulation of hydrocarbons. The review of well data demonstrates that the water saturation is quite high. However the Paleo-lows could be explored further.

**4. CONCLUSIONS**

Petrophysical study gives following conclusions:

- Neutron-Density crossplot for zone of interest shows linear trend of the data values residing between the zone of limestone and dolomite.
- Well correlation shows Triassic to Cretaceous formations are pinching out and their thickness is increasing from South East to North West.
- Fort Abbas-01 well has average porosity trend good to excellent which is within 20-30%. The contents of volume of shale varies within 5-25% and the portion of pore space that contain formation water is varies within 50-90% that assumed not favorable for accumulation of hydrocarbons. Therefore this well was declared dry due to the improper seal within, over and around the Cambrian reservoir zone.
- In Marot-01 well the average porosity trend is good 25-35%. The contents of volume of shale vary within 5-20% and the water saturation is very high which means it is highly fractured.
- In Bahawalpur East-01 well the formation porosity varies within 20-35%. The contents of volume of shale varies between 5-15% and the portion of pore space that

contain formation water is varies in a range of 40-80% that also shows unsuitable value for hydrocarbon accumulation.

**5. RECOMMENDATION**

There have been exploration efforts on conventional structural traps and more efforts should be directed towards finding stratigraphic traps in the area. In west where the source rocks are buried deep enough a significant amount of hydrocarbons generation is expected.

**6. ACKNOWLEDGEMENT**

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