Petrophysical Analysis of Habib Rahi Limestone of Mari Gas Field Using Open Hole Wire Line Logs of Well Mari Deep-06 Central Indus Basin Pakistan (A Case Study)*

Quaid Khan Jadoon[1,2,3], Muhammad Zahid[1,2,3], and Ramiz Gardezi[1,2,3]

[1]School of Earth and Environmental Sciences, James Cook University, Townsville City QLD, Australia (quaid.jadoon@my.jcu.edu.au)
[2]Statoil ASA, Stavanger, Norway
[3]Institute of Geology, University of Azad Jammu and Kashmir, Muzaffarabad, Pakistan

Abstract

The Well Mari Deep-06 was drilled to evaluate an exploration prospect in the Mari Gas Field, Pakistan. A significant gas reservoir discovery has been made within the Habib Rahi Limestone. A conventional suite of wireline logs including gamma ray, caliper, sonic, density, neutron, dual laterolog were acquired for formation evaluation purposes. The log analysis has done on PRIZM module of GeoGraphix. The GWC (Gas water contact) is at 2,494 ft. The average effective porosity value is 0.21v/v. The trends of the neutron-density cross plot indicates that there is a small contribution of dolomite in the reservoir. The low density and low neutron porosity cluster also indicate the presence of gas. The gross reservoir thickness is 328 ft., the net reservoir thickness is 244 ft. and the net pay thickness is 168 ft. Habib Rahi age is middle Eocene with the top at 2,206 ft and the limestone thickness is 350 ft.

Introduction to Area

The study area is located in Central Indus basin, on the Thar slope platform, which gently slopes westwards. The Mari Gas Field is located at Daharki Ghotki, Sindh, approximately 96 kilometers north of sukkur. The regional structural area is commonly referred to as the Mari-Kandkhot High. This High was created in Late Cretaceous by extensional tectonics, which resulted in response to a spreading axis between Madagascar and the Indian continent. The Mari-Kandkhot High (Figure 1) trends NW-SE, and is separated from Jacobabad Khairpur high. The Mari structure is similar to Khairpur High. During Late Tertiary, the Mari Anticline was formed due to inversion. Multiple reservoirs have been successfully tapped in the Mari deep and Pirkoh Limestone, Habib Rahi Limestone, Sui main Limestone at shallow level, and Lower Goru sandstone at deeper level (After Naseer et al., 2007).

The Mari Gas field was introduced by Esso Eastern Inc. (EEI) who discovered this field in 1957 with the drilling of first well – Mari X-1. It was drilled to the depth of 11,110 feet. The gas was encountered at the depth of 2,300 feet in Lower Kirthar ZN-„B‟ Limestone formation,

commonly known as the Habib Rahi Limestone. The field was brought on production in 1967 when the required infrastructure was established to supply 30 MMSCF/Day gas to fertilizer plant of Esso Pakistan Fertilizer Company Limited – now Engro Chemical Pakistan Limited.

Objective of Study

The aim of the study is to build a petrophysical model, which includes the evaluation of the hydrocarbon potential, and to trace out the development of the formation porosity in the shallow reservoir of the Mari Gas Field. The reservoir characteristics calculated are primary porosity, secondary porosity, total porosity, effective porosity, shale volume or clay content, water saturation, hydrocarbon saturation, Cut-off selection for clay, porosity and water saturation, gross reservoir thickness, net reservoir thickness, minerals volume to resolve lithology.

Data Used

For the evaluation of the well, a suite of wireline logs in the depth interval of 1,447 - 9,319 ft has been used. These logs include gamma ray, caliper, density, neutron, dual lateral log, microspherical focused and sonic logs. There were no core analyses available.

Methodology

For petrophysical analysis, different techniques are applied. The detail for each technique is as follows:

1. Shale Volume. The linear shale volume methodology is applied to calculate the shale volume.

Volume of shale = $(GR_{log} - GR_{clean}) / (GR_{shale} - GR_{clean})$
The values for GR parameters are GR_{clean} = 45 API and GR_{shale} = 100 API.

2. Total Porosity. The estimation of total porosity is done by averaging the porosity computed from RHOB (Bulk Density) and NPHI. The equations are as under:

PHID = (RhoM – RHOB) / (RhoM – RhoF)

Where RhoM = matrix Density, 2.71 gcm^3, RHOB= Bulk Density, RhoF = Fluid Density of 1, and PHIT = (PHID + PHIN)/2 (PHIT = Total Porosity, PHIN = Neutron Porosity, and PHID = Density Porosity) (Figure 2).

3. Effective Porosity. The effective porosity is calculated by correcting the shale effect from total porosity.

PHIE = PHIT * (1 – Volume of Shale)

Where PHIE = Effective porosity and PHIT = Total Porosity.

4. Water Saturation. This includes the identification of the pure limestone interval with the lowermost resistivity value that is used in addition to formation water resistivity to plot the Pickett (Figure 3). The Resistivity of water (RW) computed from the picket plot is 0.11 ohmm used for water saturation determination. The saturation exponent "n" is kept at two and cementation factor "m" at two and lithological constant "a" kept at one. The water saturation was computed by using Archie's equation. $(Sw)^n = (a*Rw/ (RT * PHIE^m)$

5. Pay Cut-offs. For the reservoir interval of 2249 ft – 2496 ft, the cut-offs parameters are shown in Table 1.

6. Lithology. This best technique for Lithological determination is a crossplot of Apparent Matrix Density (RHOma) and Apparent Matrix Volumetric Cross Section (Umaa)

CURVE AVAILABLE   TECHNIQUE
PEF+DENSITY   THREE MINERAL ANALYSIS USING DENSITY AND PEF

The Umaa and RHOma were derived as follows:

  RHOma= (RHOB –PHIE*RhoF)/ 1-PHIE
  U = PEF * ((RHOB + 0.1883) / 1.07) UMA = (U – 0.398 * PHIE) / (1 – PHIE)

Discussion

The evaluated reservoir interval 2,249 - 2,496 ft has limestone as the major lithology (Figure 4). The reservoir properties are shown in Table 2. The fluid identification and their contacts have been reliably marked on porosity and resistivity logs. The transition zone starts from 2,463 ft. The gas water contact marked at the depth of 2,490 ft as shown in Figure 5. The top of water zone marked at the lowest deep resistivity value and minimum separation in RHOB and NPHI curves.

Conclusion

The results of petrophysical analysis show that reservoir zones from 2,249 - 2,496 ft are gas bearing. The reservoir rock is limestone. The contact between the gas and water is at 2,494 ft depth. The reservoir zone with their average reservoir properties are summarized in the Table 2.

Acknowledgement

Selected Reference

Kazmi, A.H., 1982, Tectonic Map of Pakistan: Geological Survey of Pakistan, 1 sheet.
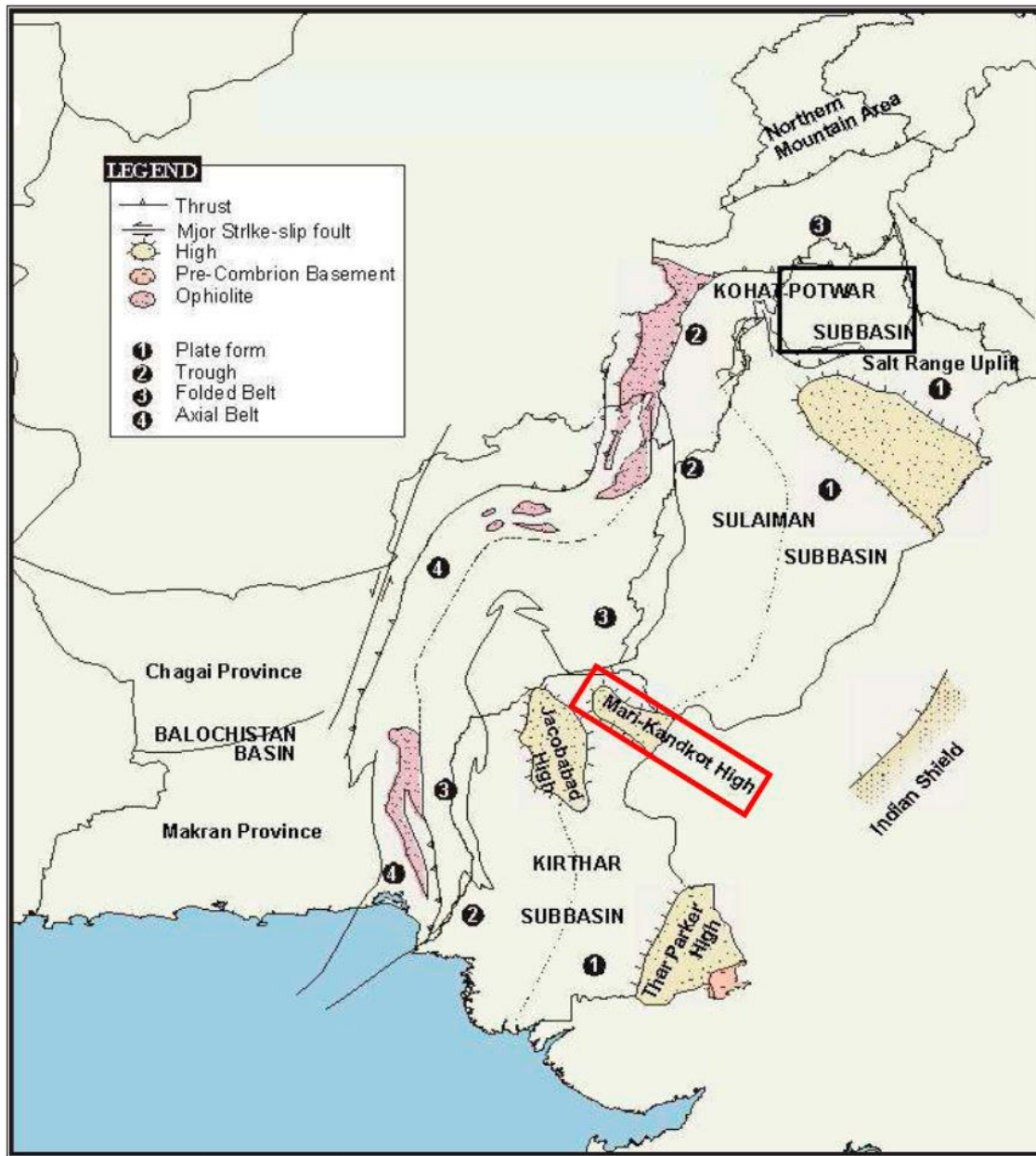
Figure 1. Location map showing the study area, map showing Tectonic Zone of Pakistan. Mari-Kandkhot High is highlighted by red box (After Kazmi, 1982).
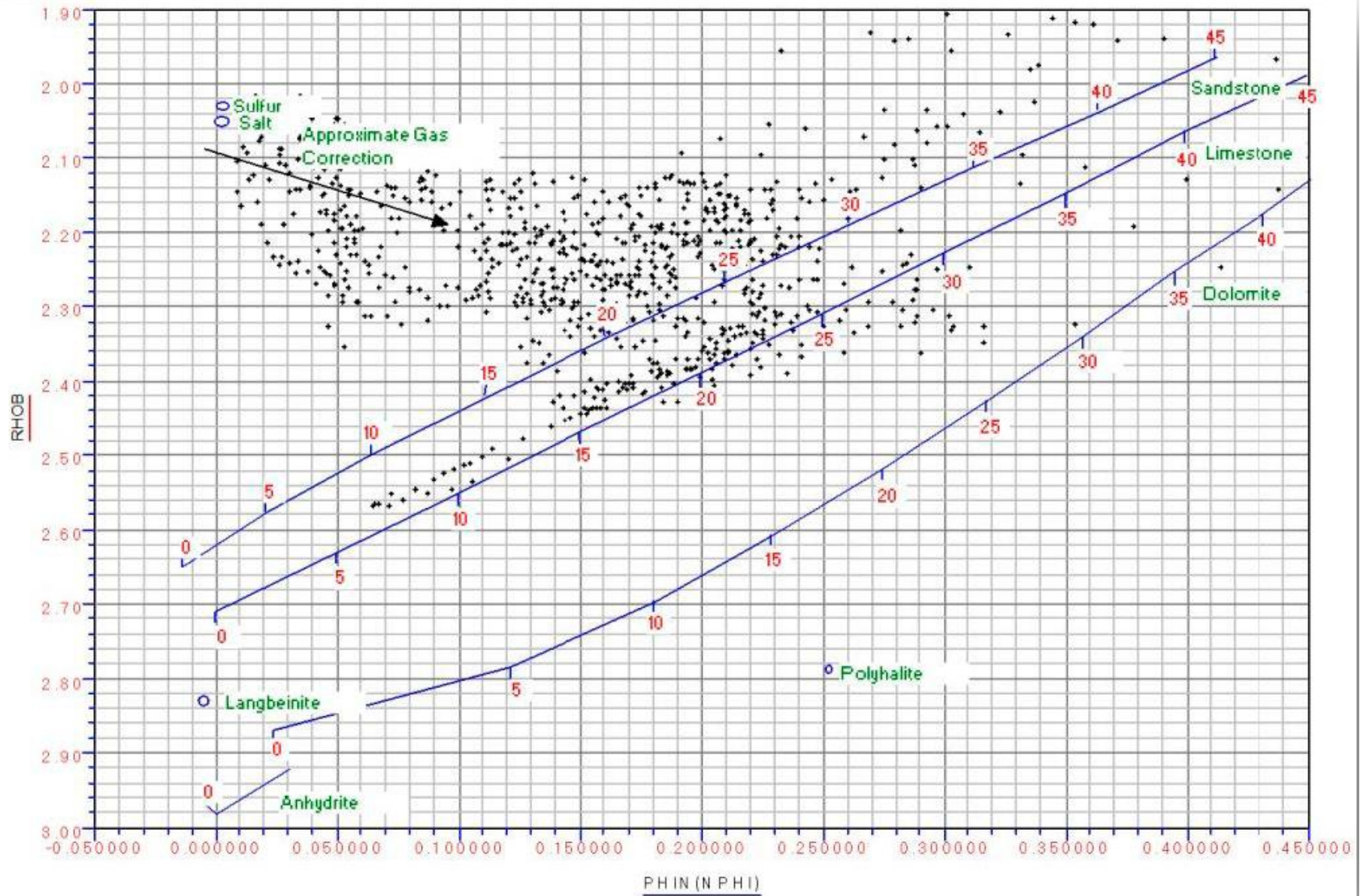
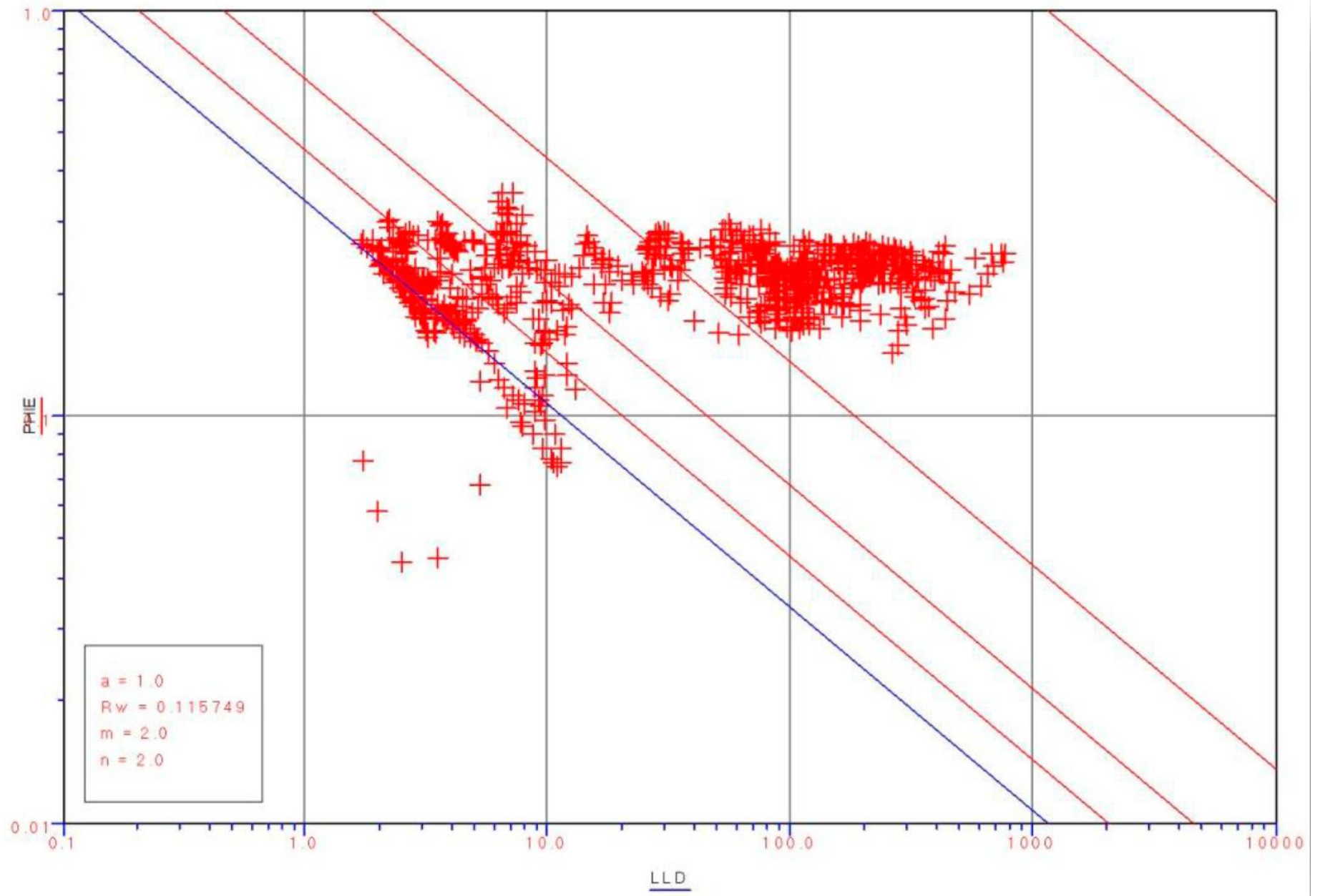Figure 2. Neutron-Density cross plot for lithology and porosity determination.

Figure 3. Picket Plot for Rw determination.

AGE	FORMATION		DEPTH	LITHOLOGY	DESCRIPTION
MIOCENE-PLIOCENE	SIWALIK				Sandstone, loose, unconsolidated, variegated coloured, coarse - medium grained, with interbedded silt micaceous and clays, brown - buff coloured.
EOCENE	KIRTHAR	DRAZNDA	1648		Marl, sandstone and calcareous shales
		PIRKOH	1740		Limestone, white, fossiliferous
		SIRKI	1987		Shale, greenish grey, soft.
		HABIB RAHI LST	2206		Limestone chalky, micritic, fossiliferous
	LAKI FM	GHAZIJ	2556		Shale greenish grey, silty and calcareous with thin limestone interbeds.
		SUI MAIN LSt	3660		Limestone, whitish – grey fossiliferous midam hard.
P.AL.	RANIKOT		4047		Sandstone with shale interlayers.
UPPER CRETACEOUS	PARH LSt		4558		Limestone, finely crystaline and argilaceou
	UPPER - GORU FORMATION		4588		Marl with shale layers, silty and calcareous, with limestone interlayers soft to medium hard.
LOWER CRETACEOUS	LOWER GORU FORMATION				Shale calcareous silty with interbeds of limestone and siltstone thinly bedded, calcareous, soft to medium hard.
		E UNIT	7550		
		D UNIT	7835		
		C UNIT	8300		Sandstone, fine grained with shale calcareous and siltstone.
		B UNIT	8630		Sandstone and siltstone sometimes argilaceous, medium hard to very hard with shales
					sandstone and siltstone interbeds fine to very fine grained, grey to dark grey medium to very hard.

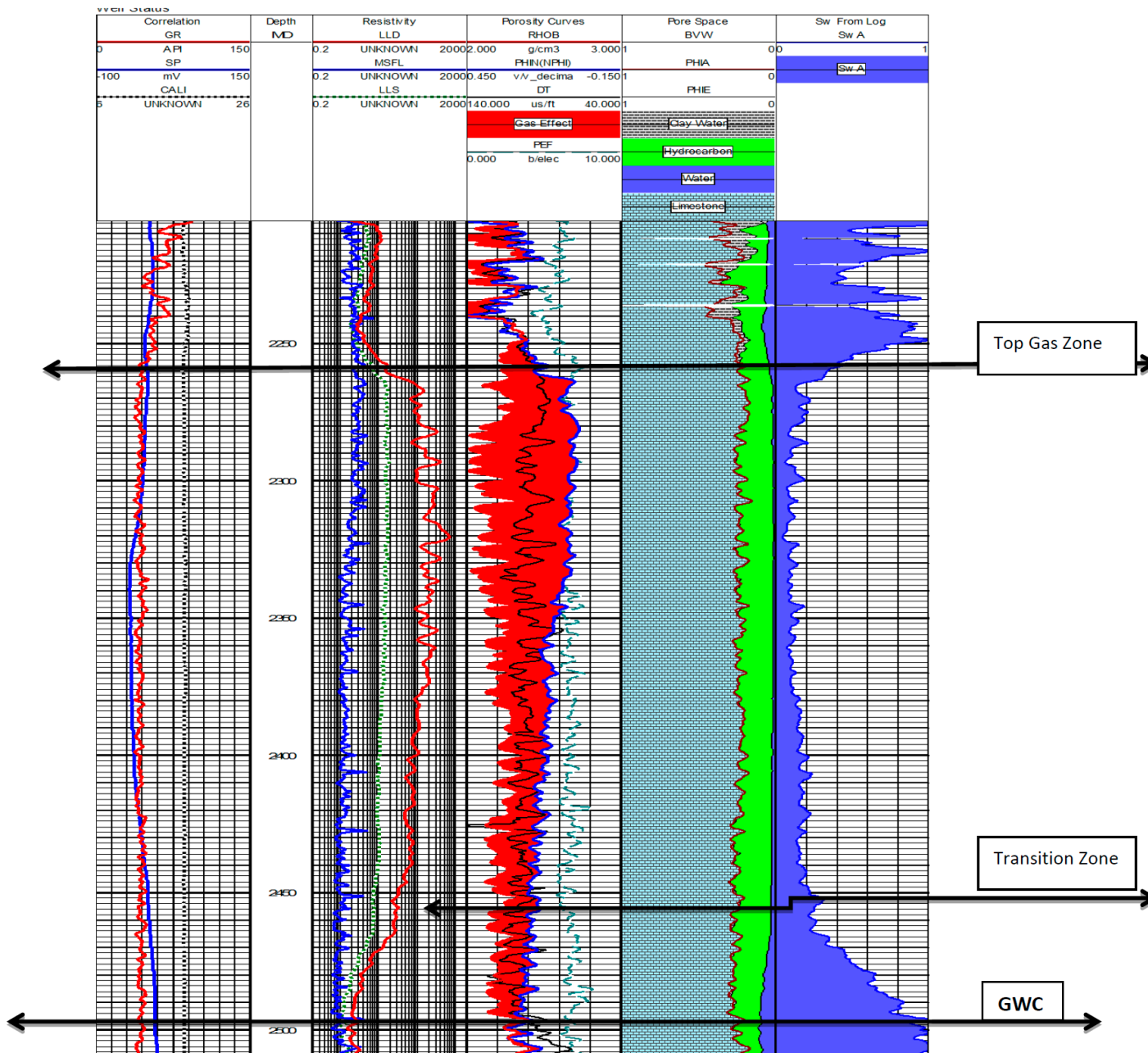Figure 4. Habib Rahi limestone Formation is the gas reservoir.

Figure 5. Answer log of reservoir zone.

Zone Name	Top Depth (FT)	Base Depth (FT)	Vshale <	PHIE >	Sw <
Habib Rahi Limestone	2249	2496	30 %	08%	50%

Table 1. Cut off parameters.

Zone Interval			Net Reservoir				Net Pay			
Zone name	Top (FT)	Base(FT)	Thick (FT)	N/G	Porosity (V/V)	Sw (%)	Thick (FT)	Porosity (V/V)	Sw (%)	Remarks
HRL	2249	2496	351	0.7	0.21	0.4	169	0.21	0.4	Gas

Table 2. Net reservoir and net pay details.