Journal of Himalayan Earth Sciences Volume 48, No. 1, 2015 pp.59-63

Petrophysical analysis of Lockhart Limestone with porosity and thickness correlation of exposed Lockhart Limestone at Nathia Gali with subsurface Lockhart Limestone of Chanda deep-01 well in Upper Indus basin

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Abstract

The research mainly involves the petrophysical analysis of Chanda deep-01 and to mark the best reservoir zone while second part of the research work was to correlate the Lockhart Limestone of Chanda deep-01 with exposed Lockhart Limestone at Nathia Gali in Hazara region on the basis of porosity and thickness. To interpret petrophysical properties, different logs were used which include gamma ray log, neutron log, density log, long latero log, spontaneous potential and sonic log. Exposed Lockhart Limestone unit was studied in the field and petrographically analyzed. The thickness acquired from field was 242m while porosity estimated by thin section study was about 11% .The petrophysical properties calculated at Chanda deep-01 well estimated the thickness to be 170m and porosity to be 9.5% along with volume of shale 5.5% and water saturation 29.3%. In the same zone, hydrocarbon saturation turned out to be 70.6%. These values confirmed Lockhart limestone to be the best reservoir in Chanda deep-01 well. The exposed unit in Hazara was then correlated and the porosity difference with subsurface unit in Chanda deep-01 was estimated to be 1.86%. The changes in porosity at different locations of same formation were interpreted to be due to overburden pressure, facies changes, diagenesis and pressure dissolution.

Keywords: Nathia Gali; Chanda deep-01; Porosity; Petrophysics and correlation.

1. Introduction

Currently, the most prolific area for exploration in Upper Indus Basin is Kohat basin. In early nineties a number of wells were abandoned (Tolanj-1, Kahi-1 and Sumari-1). The Shakardara block, situated in district Kohat, was awarded to ZPCL (Zevar Petroleum Company Limited) and OGDCL (Oil and Gas Development Company Limited) (Operator) in December 1994.

Datta Formation, Lumshiwal Formation, Wargal Formation, Tredian Formation and Kingriali Formation are the reservoir rocks of Kohat sub basin (Kadri, 1995). The first exploratory well Chanda-01 was drilled in 1999 to the target depth of 4,788 meters. A second well Chanda deep-01 was drilled in 2000 to a target depth of 5,100 meters. It was an exploratory well located 1.84 km east of Chanda-01, which also established commercial discovery in Data and Lumshiwal Formations. Chanda-02 was spudded on June 17, 2005. It was drilled as a development well to a depth of 4995m. The well was subsequently completed in Datta and Kingriali Formation and commercial production started on July 17, 2006. Chanda Deep-01 is located at Shakardarra town, Kohat District, Khyber Pakhtunkhwa, having coordinates of 33°14' 39.31"N and 71°31'2.05"E.

1. Geology of the area

The Kohat Foreland and Thrust belt became part of the terrigeneous Indo-Gangetic foreland basin by early Miocene and is represented by sedimentary rocks, ranging in age from Paleocene to Pliocene (Khan et al., 1986). The oldest rocks exposed in the area are of Paleocene age and mostly consist of limestone and shale (MonaLisa and Khan, 2010). These rocks were deposited in a restricted fore deep marine environment due to the loading of the Indian plate margin and represent the first record of the Himalayan convergence (Pivnik and Wells, 1996). This sequence is conformably overlain by a complex assemblage of shale, carbonate, evaporate and clastic rocks, which were deposited in a restricted marine basin and represent a tectonically isolated portion of the Tethys sea situated between northwestern Indian continental margin and the southern Asian margin (Paracha, 2004) (Fig. 1).

2. Methodology

The first part of paper includes the study of exposed unit at Nathia Gali, calculation of its porosity, thickness and interpretation of results while the second part includes identification of reservoir and marking zone of interest in the

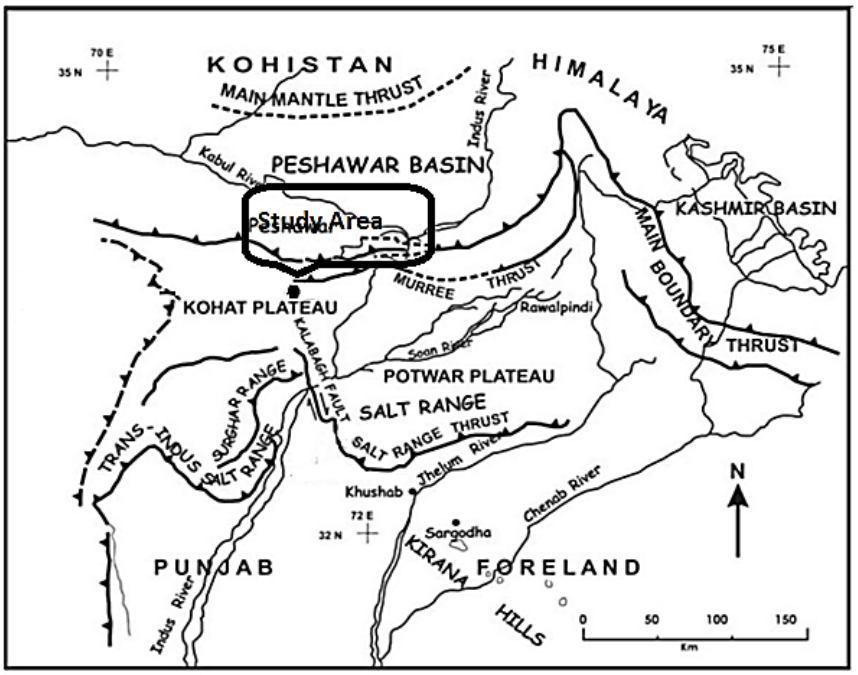


Fig. 1. Tectonic map of North Pakistan showing the location of study area (Kazmi and Rana, 1982).

Deep-01 well. The calculated petrophysical properties include shale volume (Vsh), porosity (φ), water saturation (Sw) and hydrocarbon saturation (Shc). These petrophysical properties are determined by, Electrical logs, Natural Gamma Ray Log, Gamma Ray Density Log and Sonic Log.

3.1. Study of exposed unit

The Lockhart Limestone dominantly nodular and massive with subordinate shales intercalation (Fig. 2a). The nodules are generally 1.5- 6 centimeters in length and 1-5 centimeters in width. The limestone is dirty to light grey on weathered surface and grey to dark grey on fresh surfaces (Naggapa, 1959; Shah, 1977; Latif, 1970, 1976; Munir et al., 2005; Ahsan and Chaudhry, 2008). This formation acts as a reservoir in Chanda deep-01 well. It is also exposed in Kohat region. During field work at Nathia Gali the tectonic thickness of Lockhart Limestone is measured about 242 meters, some interbedded shale beds of 4 to 5 meter were also observed in Lockhart Limestone at different intervals (Fig. 2b-2c). The exposed Lockhart Limestone is highly folded due to extensive tectonic activity. That is why the thickness was measured across the bedding to avoid incorrect measurement.

Fig. 2a. Outcrop view of Lockhart Limestone in the Nathia Gali. Nodular bedding is a typical feature of the formation.

Fig. 2b. Shows the measurement of thickness, across the bedding plane of Lockhart Limestone.

Fig. 2c. Outcrop view of Lockhart limestone at Nathia Gali, black arrow indicate thickness trend of the formation Interbedded Shale in Lockhart Limestone.feature of the formation.

3.2. Thin section study

The rock samples have been taken from the exposed unit of Lockhart Limestone in Nathia Gali. The thin sections are made for the petrographic study and porosity calculation. The limestone is highly fossiliferous and consists of Lockhartia sp (Davies, 1930), Miscellena sp, Ranikothalia sp (Davies, 1926) and Assilina sp (Davies and Pinfold, 1937) (Fig. 3a and 3b). The thin sections show high porosity (fractured porosity).

3.2.1. Porosity calculation

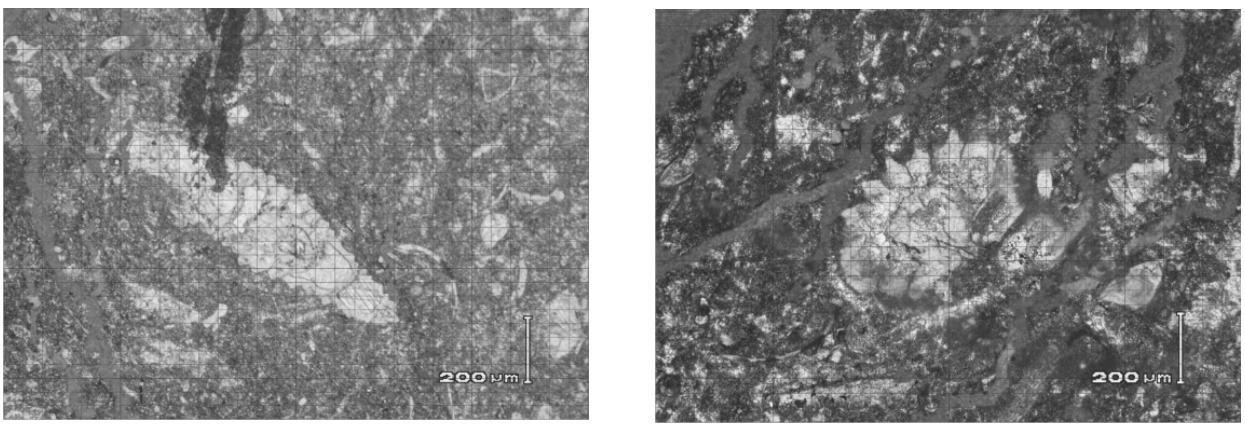
The porosity from thin sections was calculated by making grid 30/30 on each of thin section. Then the blue boxes were calculated and divide it by 900 boxes (Gihm and Bristow, 1998) (Fig. 4a and 4c).

3.3. Petro-physical calculation by using well logs

Well logging is the practice of measuring the properties of the geological strata through which a well has been drilled. A well log is the trace or record of the data from a down-hole sensor tool plotted versus well depth. To measure these properties, sources and sensors loaded into housings called sondes can be lowered into an existing borehole (a technique called wireline logging) or can be mounted in a collar behind the drilling head for taking measurements while the well is being drilled (called LWD) (Jonathan, 2008).

4. Results and discussion

Lockhart Limestone has a thickness of 170 m from the depth of 4229m to 4399m, while the calculated porosities are sonic porosity 3.6%, neutron porosity 6.7% and density porosity 11.4% in addition to that total porosity and effective porosity of Lockhart Limestone turns out to be 9.1% and 8.4% respectively (Table 1). The volume of shale was 19.5%, water and hydrogen saturation is 29.3% and 70.6% respectively (Fig. 5). Based on these results it is concluded that Lockhart limestone is well within reservoir zone.



(a) (b)

Fig. 3. Thin section of Lockhart Limestone showing Miscellanea miscella (a) and Lockhartia sp (b).

Table 1. Relationship between Porosity, volume of shale, water saturation and hydrocarbons saturation of Lockhart Limestone.

Formation	Porosity					Volume of Shale	Water Saturation	Hydrocarbon Saturation
	Sonic	Neutron	Density	Total	Effective			
Lockhart Fm	3.6 %	6.7%	11.4%	9.1%	8.4%	5.5%	29.3%	70.6%

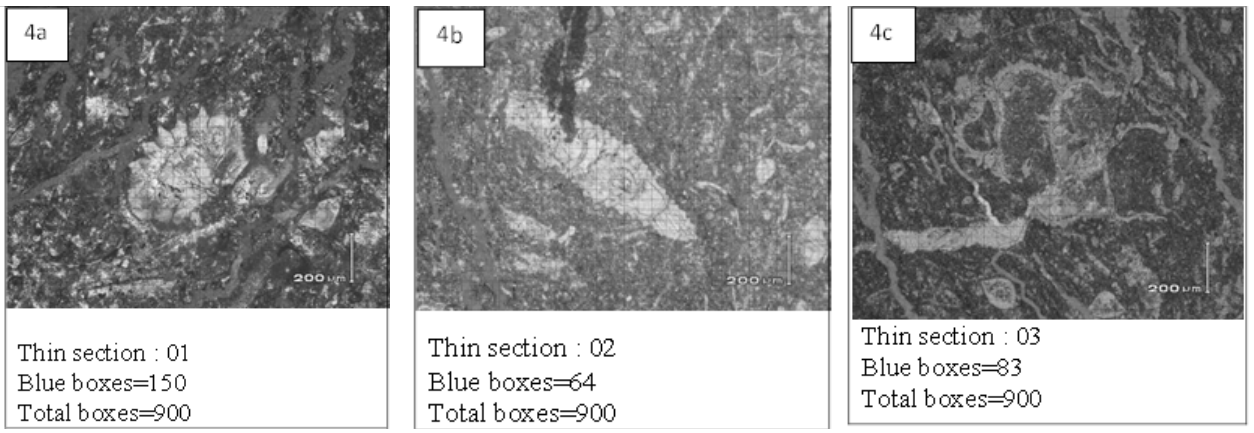


Fig. 4. Photomicrographs of Lockhart Limestone.

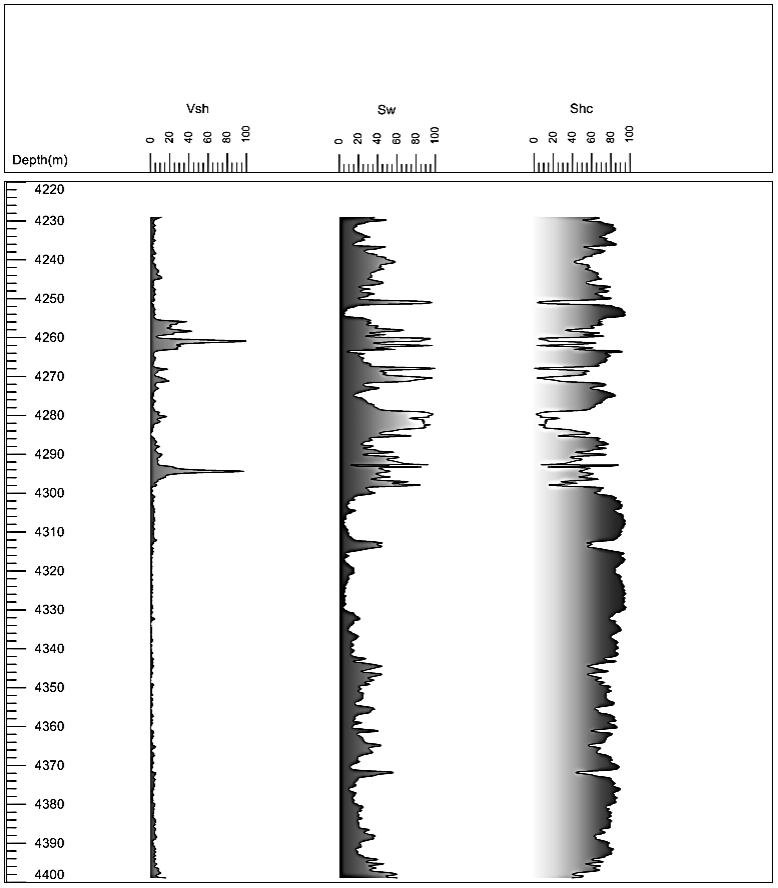


Fig. 5. Relationship between volume of shale, water saturation and hydrocarbon saturation of Lockhart Limestone.

The Lockhart Limestone of the hazara region has been subjected to several episodes of tectonic activities thereby developing high fracture porosity. Visual estimates of porosity obtained in thin section study are about 11%. The correlation of Lockhart Limestone at Chanda deep-01 well was carried out with the exposed well and the result are shown in table 2.

Table 2. Relationship between subsurface and exposed unit of Lockhart Limestone.

Formations	Thickness (m)	Porosity
Lockhart Limestone (Chanda Deep-01)	170	9.1%
Lockhart Limestone (Exposed unit at Nathia Gali)	242	10.96%

5. Conclusions

The Lockhart Limestone is interpreted as best reservoir zone in Chanda Deep-01. Minor changes in porosities of the well and outcrop are due to burial diagenesis and subsequent tectonic overprinting.

Thickness of Lockhart Limestone in Chanda deep-01 is 170 meter while exposed thickness at Nathia Gali is 242 meters. The difference in thickness of ~ 72 meters is attributed to lateral facies changes, diagenesis, pressure dissolution and tectonism.

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