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Gas Filled and Total Porosity Measurement of Cambay Shale by Using LPP and NMR Techniques

Abstract

Exploration and Production of unconventional natural gas has moved to the platform of energy security and economy stability. In this context, the emergence of shale gas and shale gas reserves with their wide geographical distribution and their cost effective extraction could really turn out to be a game changer. Efficient extraction from these reservoirs require knowledge about pore structure, pore connectivity and organic matter content. In this work, a sample study on one of the tectonic blocks of prominent Indian shale i.e. Cambay Shale of Cambay Basin has been done to understand the porosity distribution at different depths and temperature. The study involves the use of integrated porosity measurement techniques mainly Low Pressure Porosity (LPP) and Nuclear Magnetic Response (NMR) Techniques. It has been observed that the samples are showing total porosity units in the range 1 % to 4% (at the depth interval of 1326m to 3600 m). However, when gas injection at low pressure, (the gas filled) results the porosity range from 11 % to 18% at the same depth interval. So, low to medium range porosity was observed in the drilled shale sections. There may be presence of some streaks of siltstone which may be contributing to the medium porosity of this shale.

Introduction

The immense volume of natural gas stored in unconventional reserves of India (mainly Shale, Tight gas, CBM etc.) makes them long-term energy resources. This can fulfill the India's current increasing energy demand. As per the estimates and assessments by EIA 2013, 584 TCF of shale gas and 87 billion barrels of shale oil in four prominent shale basins (i.e. Cambay, Damodar, Krishna Godavari and Cauvery) have been found. Efficient exploitation of these reservoirs require knowledge about pore structure, pore connectivity and organic content. As the porosity and permeability of unconventional shale reservoirs is low, their productivity strongly depends on their pore size, connectivity and porosity. The presence of tiny pores increases the chance of pore blocking and trapping which may lead to low recovery of hydrocarbons (Cui et al., 2009). It is therefore important to determine the porosity and permeability of these low permeable rocks to predict the oil and gas recovery. In general, Shale is composed of various minerals and empty pore/ fissures spaces, the volume and distribution of which strongly affects the shale behavior with respect to time. (Charola, 2004). A porous material is comprises of open and closed pores. Open pores are accessible to water and other fluids whereas closed pores are inaccessible to water. Open an Porosity which we will experimentally determine in the collected

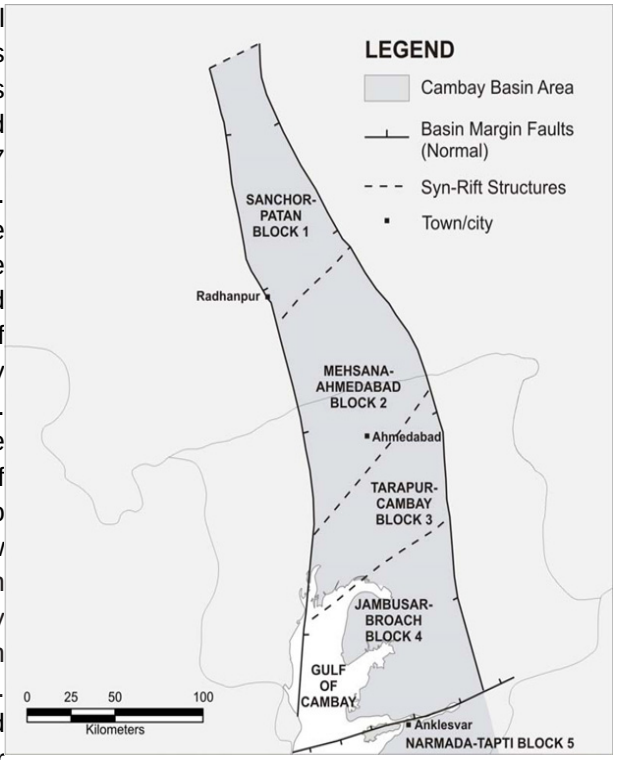

Figure 1. Study Area: Cambay Basin (Nanawati et al., 1995, Biswas et al., 1993)

The study area chosen for these laboratory investigations is Cambay Shale of North Cambay Basin (Figure 1). The Cambay shale is the main source rock in this basin with Total Organic Carbon (TOC) content ranges from 0.61 to 14.3 wt. % (average, 2.6 wt. %). More data is required to study the hydrocarbon potential of this shale. This study is a small scale attempt to understand the pore system of this shale for which laboratory techniques - Low Pressure Porosity (LPP) and Nuclear Magnetic Resonance (NMR) have been used. LPP and NMR were performed on 5 samples to assess the porosity distribution with respect to temperature and depth at low pressure conditions. Till now, no such study on the pore system of Cambay Shale have been performed with the combined use of aforementioned techniques.

Gas Filled and Total Porosity Investigations of Cambay Shale

Low Pressure Porosity Measurement

It is a Low Pressure porosity measurement technique which was conducted in LPP Set up AcuPyc II in The University of Oklahoma, USA. Sample was first weight and then placed into the metal cup as shown in Figure 2. The sample was later desiccated for 45 minutes and then tested in the set up for obtaining results. The data obtained from this test is tabulated in Table 1.

Figure 2. Sample Cup

Nuclear Magnetic Resonance Measurement

Five samples were tested using NMR Setup (Mettler PC 4400). Samples were polished first and then length and diameter were measured to obtain the accurate measurement. The polished samples were

then placed in the Sample tube for running the test in the setup. The data obtained from NMR set up is tabulated in Table 2.

Table 1: Gas Filled Porosity Data of Cambay Shale, Ahmedabad Mehsana Tectonic Block

SN	Depth	Temp.	LPP Gas Filled Porosity (%)	Bulk Density
1	**3600 m**	25.6	**11.2**	2.37
2	**1327 m**	25.0	**17.1**	2.08
3	**1326 m**	25.0	**18.10**	2.23

Table 2: Total Porosity Data of Cambay Shale, Ahmedabad Mehsana Tectonic Block

Sample	T2_peak,ms	T2_geom,ms	NMR Total Porosity (P.U)
3600 m (H)	0.28	0.27	**3.36**
3600 m (V)	0.35	0.32	**4.69**
1326 m	0.25	0.22	**6.33**
1327 m	0.22	0.22	**2.31**
C4	0.19	0.19	**3.49**

Results and Discussions

- Low Pressure Porosity measurement is a technique used to determine the porosity of powdered samples at pressure ranges 20-25 psi. Figure 3 represents the porosity variation at low pressure and at approximately constant temperature. The obtained porosity values at low pressure are in the range of 11 to 18 %.
- Nuclear Magnetic Resonance measurements respond to hydrogen atoms in the pore space. The T2 relaxation time is inversely proportional to the radius of pore. Surface relaxivity is the proportionality constant which ranges from 0.00037 to 0.46 µm/ms for sands (Dun et al., 2002). Example of T2 spectra of shale section of Cambay is shown in Figure 4. The red and green vertical lines define 3 ms and 33 ms relaxation time for clay bound water and capillary bound water. The spectra are dominated by the peaks below clay bound cut off and lie in between 0.05 to 3 ms with total porosity ranges 2 % to 6 %.

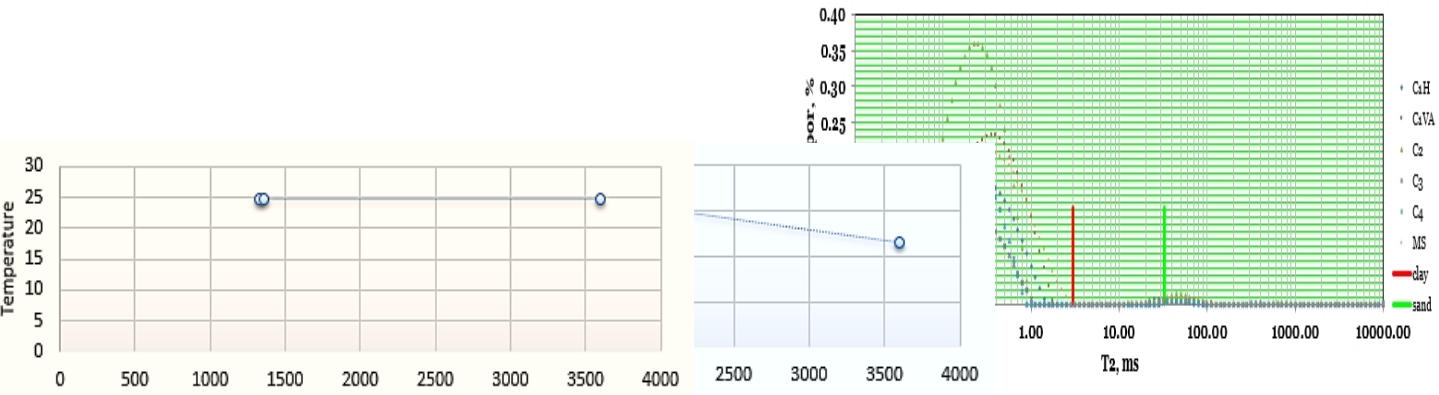

Figure 4. Nuclear Magnetic Response (NMR) Porosity of Cambay Shale, Ahmedabad Mehsana Tectonic Block. The red and green vertical lines define 3 ms and 33 ms cut off for clay bound water and capillary bound water. In this case, the spectra are dominated by the peaks below clay bound cut off and lie in between 0.05 to 3 ms with total porosity ranges

Acknowledgments

1. Conclusions

Figure 3. LPP Porosity of Cambay Shale

Conclusions

Gas filled porosity & Total Porosity of Cambay Shale of North Cambay Basin have been determined experimentally by using LPP and NMR at different depth intervals and temperature. The samples are showing total porosity units of 1 % to 4% and gas filled porosity of 11 % to 18% in the depth interval of 1326 m to 3600 m. At some depths, medium porosity values can be observed which may be due to the presence of “streaks of siltstone” in between the “Shale”. Till now, an integrated study on shale samples of Cambay have not been performed and considering that, this study is a “small scale contribution” which gives an insight to the porosity distribution of this siltstone rich shale. The data if augmented with more petrophysical and geomechanical data, can be helpful in preparing a fairway map for the entire basin which will be a unique work in the shale gas exploration and development activities of India.

Acknowledgements

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