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Organic richness and gas generation potential of Permian Barren Measures from Raniganj field, West Bengal, India

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The organic geochemistry of shales in terms of its organic richness, hydrocarbon source potential, thermal maturity, depositional environment, etc., are essential stipulations for shale gas resources assessment. In this study, a total of 32 core samples of Permian Barren Measures from four boreholes in Raniganj field of Damodar Basin were analysed to evaluate their gas generation potential using Rock–Eval pyrolysis techniques. Petrographic analysis brings out the lithofacies of Barren Measures as carbonaceous silty shale, iron rich claystone and sand-shale intercalation. The total organic content (TOC) of the shale units of Barren Measures ranges from 3.75 to 20.9 wt%, whereas hydrogen index (HI) ranges from 58.45 to 125.34 mg HC/g TOC. Present study suggests early to late maturated (0.6–1%) organic matters in Barren Measures with gas prone type III kerogen. The study analysed the effect of burial history on the preservation and maturation of organic matters. The organic richness, kerogen type, thermal maturity and petrographic properties of Barren Measures signify fair to excellent gas generation potential.

1. Introduction

The current boom in the exploration and development of shale gas resources in USA (Curtis 2002; Montgomery et al. 2005; Jarvie et al. 2007; Ross and Bustin 2007) has created interest in the assessment of shale gas resource potential of India. The total organic content, thermal maturity, absorbed gas fraction, volume of gas in place, mineralogy etc., are the important parameters of shale gas generation and retention (Curtis 2002; Law and Curtis 2002; Jarvie et al. 2007). Whether the shale formation can produce oil or gas, depends on a number of factors like (i) quality and quantity of organic matter, (ii) type of kerogen, (iii) duration and scale of heating (Boyer et al. 2006), etc. Unlike the conventional petroleum reservoir systems, shale reservoirs are continuous (Jarvie et al. 2007), have low porosity (<10%), and are ultra permeable (< 1Md) with a wide range of compositional variation (Herge et al. 2004; Loucks et al. 2009; Kuila and Prasad 2013). The shale rock with more than 2% total organic content (TOC) often has significant source potential. When TOC is between 1 and 2%, depositional environment intermediates between oxidizing and reducing, if TOC is above 2%, it indicates reducing environment with excellent hydrocarbon source potential (Demaison and Moore 1980; Bissada 1982; Peters 1986; Leckie and Kalkreuth 1988; Bacon et al. 2000; Dembicki 2009). The amount and type of organic matters preserved in the sediments are not only controlled by the depositional environment but also by the productivity of the water, physical conditions in the area of deposition and mineral constituents of the sediments (Barker 1974; Banerjee et al. 1998; Bacon et al. 2000). The shale with high quartz, feldspar and carbonate content have low Poisson's ratio and high Young's modulus points towards high brittleness, thus results in development of fracture in

Keywords. Barren Measures; Raniganj; Rock–Eval pyrolysis; shale gas; TOC.

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Application of Micro Computer Tomography (μ CT) in Resolving Barren Measures Shale Properties

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Abstract—The microstructure of Barren Measures Shales of Raniganj Field has been investigated using micro-computed tomography (μ CT). The results show fabric anisotropy and complex pore structure among the different shale samples imaged. The shales of Barren Measures are primarily composed of varying amounts of clay minerals, quartz, and kerogen with a range of porosity 3 to 5%. Pores are isolated and interconnected including intergranular, matrix hosted and/ or organic matter hosted in nature. Three-dimensional internal structures of the shales were generated from serial sectioning and imaging of the samples and it depicted kerogen and pore connectivity across the volumes. The internal microstructure of shales is essential in understanding the micro scale reservoir heterogeneity. It controls the key aspects of reservoir development and fluid flow through the shales.

Index Terms— Micro Computer Tomography; shale gas; reservoir characterization; Barren Measures, pore, micro scale, shales

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1 INTRODUCTION

Rocks and fluid properties are key parameters for the development of petroleum reservoirs. In contrast to the conventional reservoirs, unconventional shale gas reservoirs have micro scale reservoir heterogeneity and complex pore systems. Micro-computed tomography (μCT) is an advanced technology for micro scale geological investigations. It is a fast and nondestructive technique to generate images that correspond to serial sections through an object. Successive contiguous images are assembled to create three dimensional depictions. Visualization of μCT data allows the imagining of internal structure and flow media in petroleum reservoir rocks. Petrophysical applications, fluid migration, fractures in rock, etc., with the help of x-ray CT were studied earlier by different researchers [1] [2] [3] [4] [5]. The fractures in shale and internal structure of gas shale core samples investigations were discussed in earlier literatures [6] [7]. This paper is to assess the petrophysical properties and fabric anisotropy of Barren Measure shales from Raniganj Field using micro computed tomography. Raniganj field is located in West Bengal and partly in Jharkhand state. It is situated about 185 Km North-West of Kolkata. The present study area is the part of the Raniganj Coalfield, between latitudes 23°46ˈ00˝ N & 23°43ˈ00˝ N and longitudes 86°52'00"E & 86°55'30" E. Here, the Permian Gondwana sediments are represented by Talchir, Barakar, Barren Measure and Raniganj Formations. As the early researchers have reported the shale gas generation potential of Barren Measures [8] [9], it is crucial to understand the internal microstructure and fluid flow mechanism within the rock.

2 MATERIALS AND METHOD

2.1 Sample Preparation

Shale core samples were collected from the organic rich Barren Measures Formation of Raniganj Field in India. Within the study area, the Barren Measures Formation is comprised of a thick sequence of monotonous grey to black micaceous and often carbonaceous shales, with thin sand- shale intercalation at the base. Thin bands of hard and tight ironstone layers are encountered in the boreholes of the area. Small irregular sand patches are often seen within the black shales and these are presumed to have originated by biogenic activities filled with angular to sub angular coarse sand. The samples were selected from conventional core of Barren Measures shale unit, from a borehole located in north western part of Raniganj Coal field, for μCT investigation. Two cylindrical

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Unconventional Shale Gas Prospects in Indian Sedimentary Basins

Geology

KEYWORDS : Unconventional energy resources, Shale gas, shale reservoirs.

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ABSTRACT

Natural gas is rapidly substituting fuel to suffice the growing energy requirement of today's world. The rising oil prices, high input cost in exploration and production of hard oil resources and relative abundance of gas resources have fuelled the interest towards gas resources. As the consumption of natural gas is increasing rapidly, it is essential to identify and develop the available energy resources. India has the immense prospects of unconventional shale gas resources. Commercial exploration of these shale gas resources can effectively make the global natural gas curve more elastic. The commercial shale gas exploration requires exhaustive investigations of all the shale rock properties of hydrocarbon bearing shale beds having significant organic matter and maturity. This paper presents overview of shale gas resources as well as the prospective shale gas horizons in Indian sedimentary basins.

Introduction

Natural gas plays the key role in increasing energy demand. Its environmental soundness and multiple applications across all sections imply that natural gas will continue to play an important role in meeting the energy demand. But the gap between natural gas demand and supply has been increasing day by day. To bridge the gap between energy demand and supply, it becomes essential to go for the available alternative energy resources in the country. This has spurred the interest towards unconventional resources i.e. Shale gas, Coal Bed Methane, Gas hydrates, tight gas etc. Shale gas is the future energy basket for the mankind which has tremendous prospect worldwide even in India (fig 1) only it requires systematic and proper methodology for its delineation, exploration and development. Particularly USA and Canada have been contributing commercial shale gas production which is 20% of total gas production. India have tremendous prospects of shale gas in different sedimentary basins i.e. Cambay, Assam Arakan, Krishna – Godavary, Gondwana, Cauvery, Vindhyan etc. though all shales are not evaluated yet. It requires exhaustive investigation of the prospectiveshale horizons having significant shale volume, organic matter (> 3%) and maturity (gas window zone). Source rock evaluation can be made by using parameters like Total organic carbon content, rock eval pyrolysis, elemental analysis, vitrinite reflectance, gas chromatography, etc. Petrophysical analysis using SEM, XRD etc can help in detail mineralogical as well as clay mineralogy studies. Seismic attributes help not only to differentiate the shale pay horizon but also to identify the brittle zone i.e. the sweet spots for hydro- fracturing. Integrated logs with geological, geophysical, petrophysical, geochemical, geomechanical studies can help to identify the sweet spots for commercial shale gas exploration and exploitation.

Unconventional Shale Gas System

Shale is the fine grain sedimentary rock exhibits a wide variety of different geological ages, geographical areas and formations (Potter 1980). Unlike the conventional petroleum reservoirs, shale reservoirs are continuous (Jarvie 2007), low porosity (< 10%), low permeability (< 1mD) with variation in composition (Herge M et al 2004;Utpalendu, 2013). The hydrocarbon generating capability of shale is controlled by many factors such as total organic carbon content, thermal maturity, sorbed gas fraction, reservoir thickness, volume of gas in place, mineralogy, water saturation, fracture types, reservoir heterogeneity etc (Curtis, 2002; Law 2002).The shale can produce either oil or gas or both. It depends mainly on (i) quality and quantity of organic matter, (ii) type of kerogen, (iii) magnitude and maturity i.e. duration of heating to which they have been subjected (Boyer et al 2008). Shale rock itself can act both as source and reservoir rock for hydrocarbons. This may be due to two reasons i. e. (i) due to lack of micro- fracture for primary migration of gas or (ii) insitu cracking of oil into gas at greater depth and post mature zone due to higher geothermal gradient. After organic matter converted into hydrocarbon, its volume increases and exerts pressure on the surface of the source rock and creates microfactures or pathways for oil or gas expulsion from source rock to reservoir. But in certain cases hydrocarbon cannot expel from the source rock to reservoir. Hydrocarbon inside the source rock remains adsorbed onto the matrix and gets converted into oil or gas depending upon the types of organic matter and the source rock can also act as reservoir itself. Kerogen is a mixture of organic chemical compounds which constitutes a portion of the organic matter in shale. Kerogen is insoluble in normal organic solvents because of its huge molecular weight (> 1,000 daltons) of component compound. With increasing depth and temperature gradient organic matter get matured and passes through the stages of oil window at 60–160 °C and gas window at 150–200 °C both depend on time of the source rock is heated. The labile kerogen breaks down to form heavy hydrocarbons (i.e. oils), refractory kerogen breaks down to form light hydrocarbons (i.e. gases). The insitu hydrocarbon gas present within the shale sedimentary rocks is called shale gas which may be in the state of free gas or adsorbed gas or both. Unlike the conventional oil and gas, shale gas does not accumulate in a typical petroleum system (i.e. source rock, reservoir rock, seal or cap rock etc). The shale gas systems can be defined as the continuous type biogenic, thermogenic and combined biogenic-thermogenic gas accumulations characterized by wide spread gas saturation, subtle trapping mechanisms with short hydrocarbon migration distances. In shale rocks, gas can be accumulated in three forms: Gas is stored on the shale as adsorbed gas, within the intergranular porosity as free gas, within the natural fracture system as free gas. Shale gas may vary from area to area even in the same basin.This is due to the local changes in permeability which is highly depends on the both fracture intensity and fracture aperture width. Shale gas is unconventional natural gas that can be produced at neither economic flow rates nor in economic volumes unless the well is stimulated by a large hydraulic fracture treatment, a horizontal well bore, or by using multilateral well bores or some other technique to expose more of the reservoir to the well bore (Kent Perry and John Lee, 2007).

Shale gas prospects in Indian Sedimentary Basins

The first commercial shale gas production (1821) was from organic rich Devonian shale of Appalachian Basin which was economically marginal. After the great economic success of the Barnett Shale play in Texas the interest had spread in search for other sources of shale gas across the United States, Canada, Europe, Asia and Australia.The U.S. Energy Information Administration projects that the U.S. will produce 50% of its natural gas from unconventional sources by 2030. In 2005, approximately 10 trillion cubic feet (tcf) of conventional gas was produced in the U.S., versus 8 tcf of unconventional gas. Natural gas from shale accounted for about 6% of the gas produced in the U.S. (1.1 tcf). The majority of U.S. gas shale production came from four basins i.e. San Juan Basin, New Mexico, Antrim Shale of Michiga, Appalachian/Ohio shales and Barnett Shale, Fort Worth Basin, Texas. In India ONGC has started pilot project and drill 4 shale gas wells in Damodar Valley Mainly Cambay (in Gujarat), Assam-Arakan (in the North-East), Krishna Goda-

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Microstructure and Poresystem Analysis of Barren Measures Shale of Raniganj Field, India

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ABSTRACT

The parameters of shales in terms of its organic richness, thermal maturity, porosity, permeability, pore & fracture network, orientation of microfractures etc. are the crucial requisites for shale gas exploration and exploitation. In this study, Late Permian Barren Measures of Raniganj field, Damodar Basin were analysed using thin section petrography, scanning electron microscopy, helum porosimetry, micro computer tomography and x-ray Diffractometer, to assess their petrographic and reservoir characteristics. The Total Organic Content (TOC) of the shale units of Barren Measures ranges from 3.75 to 20.9 wt% with more than 50% quartz content. Carbonaceous silty shales have been analysed using Micro Computed Tomography (µ CT) system to evaluate pore system, fracture network, fabric anisotropy and mineral component of the shale and verified that allocations of pores and mineral grains in Barren Measures shales are highly anisotropic. A porosity range of 3% to 5% are achieved by µCT, where pores are mostly nanopores, micro pores, meso pores and macropores. Presence of scattered and pore filling organic matters are analysed in both thin section and SEM images, the morphology and sizes of pores behave a wide range from <10nm to >100µm.

KEY WORDS: Barren Measures shale, Fracture, Micro Computed Tomography (µ CT), Porosity, Shale Gas