PaperID **AU113**
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Organic Geochemistry, Microstructure and Pore system Characterization of Gas Shales: a Case Study from Raniganj Basin, India

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Summary

In this study, core samples of Permian shales of Raniganj field were analysed to evaluate their gas generation potential using Rock Eval pyrolysis techniques. Micro structure and pore system are examined using scanning electron microscopy, microcomputer tomography and BET techniques. The Total Organic Content (TOC) of the shale units of Barakar, Barren Measures and Raniganj Formations ranges from 3.75 wt% 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 to 1%) organic matters in Barren Measures with gas prone type III kerogen. The study investigates the effect of burial history on the preservation and maturation of organic matters. The organic richness, kerogen type and thermal maturity the Permian shales are signifying fair to excellent gas generation potential. To understand the pore system of these rocks, the total porosity, pore-size distribution, organic geochemistry, mineralogy, and image analyses by were performed. As a tight reservoir, the most of the pores in shale are micro to nano pores. Compared to conventional reservoirs, the pore structure of shale presents strong heterogeneity and anisotropy.

Introduction

The current boom in the exploration and development of shale gas resources in The United States of America (Curtis 2002; Jarvie 2007) has created interest in the assessment of shale gas resource potential of India. The Indian sedimentary basins have vast potential of shale gas resources. The Permian shales of Raniganj field are considered as the most prospective shale gas plays of India (Misra 2009; Varma et al 2014; Boruah and Ganapathi, 2015). This paper presents the gas generation potential of Permian shales including Barakar, Barren Measures and Raniganj shales of Raniganj field, and also discusses the key geological factors and processes in order to identify prospective shale gas fairway over Raniganj field.

Methodology

The Total Organic Content (TOC) was determined by using LECO EC-12 carbon analyser. Rock-Eval pyrolysis technique has been used to determine the petroleum potential and the thermal maturity of the kerogen occurring in a rock. The hydrocarbon generation potential of Barren Measures shale samples was assessed using the Rock Eval 6 pyrolyser (Turbo version-Vinci Technologies). The calculated parameters of Rock Eval i.e. the hydrocarbon potential or hydrogen index (HI) is defined by 100 × S2/TOC. The oxygen index (OI) is defined as 100 × S3/TOC, where S3 is the CO_2 released during the pyrolysis. Both the measured and calculated parameters from Rock Eval pyrolysis, helps in determination of kerogen type, hydrocarbon generation efficiency and maturation. The hydrocarbon generation and maturation processes are highly controlled by time, temperature, pressure, depth of burial etc. Therefore, the experimental temperatures were set comparatively higher than normal subsurface conditions, so that appreciable reaction for the generation of hydrocarbons can occur in a reasonably short time and amount of generated hydrocarbons relative to the total potential of the source rock can be estimated.

The SEM photomicrographs were taken using JEOL, JSM-6460 LV Scanning Electron Microscope operating at 10 to 20 kV to bring out the desired features under high magnification up to 20,000X.

BET technique along with along with scanning electron microscopy is carried out on Micromeritics ASAP 2010™ instrument for considering the adsorption effect to understand the shale gas transport in micro and nano-pores.

Results and discussion

The laboratory measured TOC value ranges from 3.75 wt. % to 20.9 wt. %. In this study, the original TOC (TOCO) is calculated and found to be deviation from the present day TOC (TOCP) content (TOCP/0.64 =TOCO) i.e higher than present day TOC (Jarvie and Lundell 1991). However, the black colour and high measures TOC wt % indicated the deposition of the shales in anoxic environment. The PI of studied samples shows a range of 0.06 to 0.24mg HC/ g TOC and indicates in situ petroleum generation (Peters & Moldowan 1993) of matured sediments. Generally, the commercial gas shale producing horizons show PI values ranges from 0.6 to 1.5, where shales with greater than 0.1 PI can generate excellent quantity of hydrocarbon (Ross and Bustin 2008). It is observed that the samples of Barren Measures shale have the HI ranging from 58.45 to 125.34 mg HC/g TOC with an average HI of 80.56 mg HC/ g Rock (fig 1). Low HI (<125.34 mg HC/g TOC) designates a greater potential to generate gaseous hydrocarbon (Boyer et al 2006)(fig1). The samples are showing the maturity range of 0.6-1.0%. The highly matured sediments of catagenesis stage at shallow depth, where increasing maturity trend with respect to depth, implies the geological control on both sediment deposition and thermal maturation. It also supports the presence of dry gas generation window of Barren Measures towards south- east part of the field at structurally depocentres.

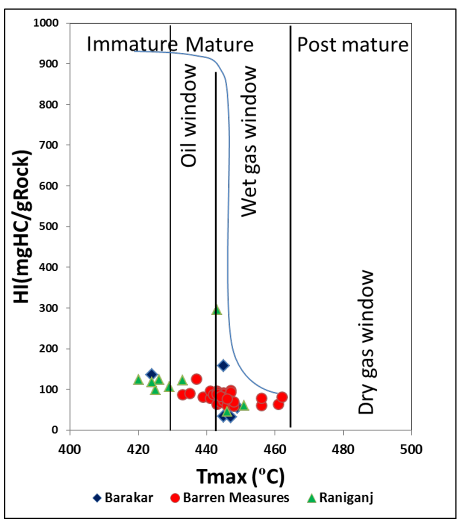

Fig.1: plot of HI vs Tmax

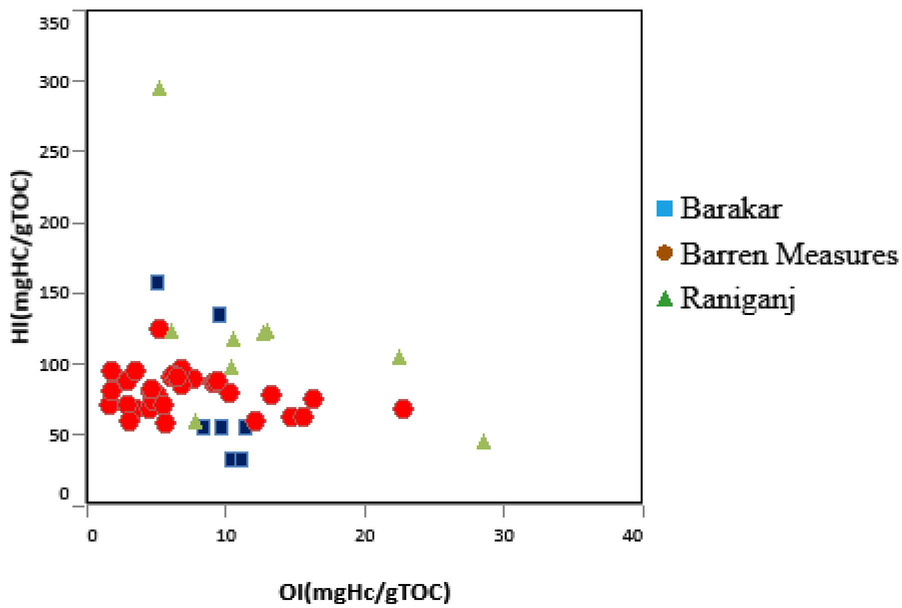

Fig.2: plot of OI vs HI

The different types of pores (Fig 3) in Barren Measures shales were analysed using SEM, TEM and m CT technique, and are classified as: (a) intergranular porosity, (b) intragranular porosity, (c) secondary porosity developed due to diagenesis, dissolution activities etc.; (d) matrix porosity and (e) porosity associated with organic matter. Dissolution of different types of cements and unstable detrital grains generate secondary porosity in Barren Measures Formation, while the nano pores of~ 10nm to 500nm in diameter were resolved in Transmission Electron Microscopy (TEM) images.

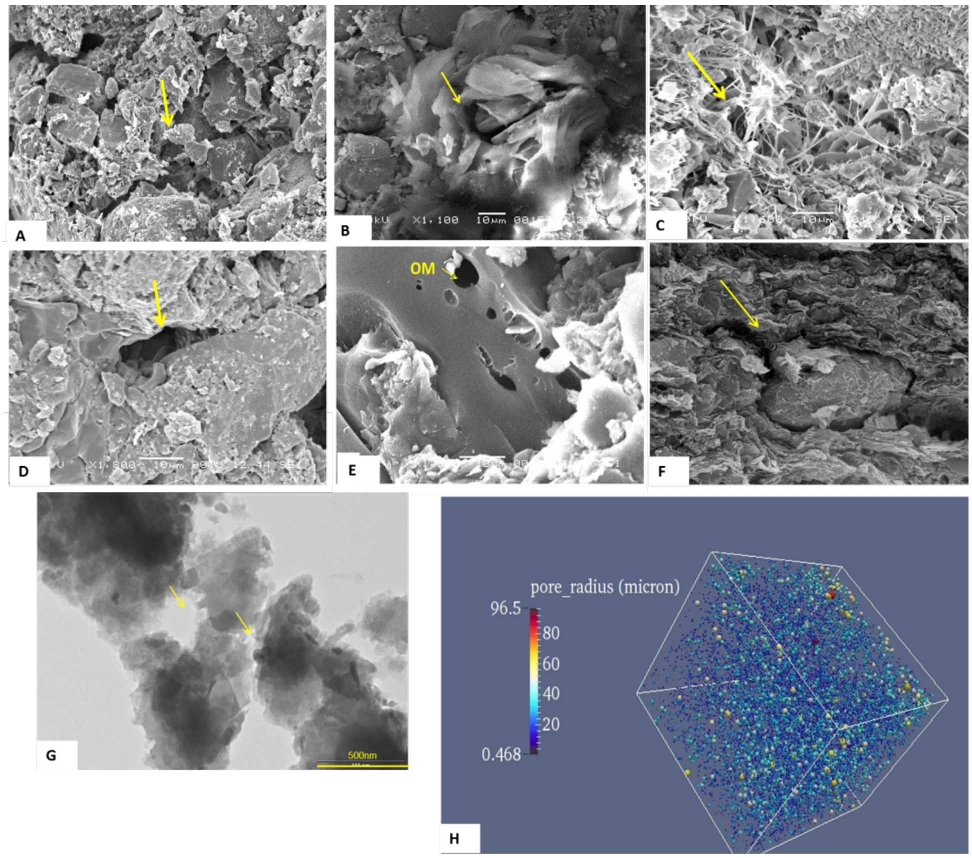

Fig 3: Pore systems in shales; A. micro pores on the rock surface coated with clays; B. intergranular pore within the chlorite clay structure; C. pores within the clays, illite bridging nature; D. Intergranular pore at grains and matric contact; E. Organic matter hosted pores, dissolved pore; F. Micro channel at grain contact; G. TEM image showing nano pores less than 500nm; H. m CT image showing 3D internal structure of pore network within the shale.

The pore size distribution, as interpreted by BET show that some of the samples have larger peak at 4nm (40A°) to 10 nm (100A°) while few samples have pores below 20nm (200A°) and most of the pores are in the range of 20nm (200A°) to 55nm (550A°). BJH adsorption average pore size diameter ranges from 5.4921nm (54.921A°) to 29.754nm (290.754A°).

However, the analyzed shale properties including organic geochemistry, pore morphology, sizes and microstructure are identical to most of the US commercial gas shales, especially Antrim shale of Michigan Basin and also New Albany shale of Southern Indiana and Northern Kentucky.

Conclusion

Organic geochemistry analyses suggest the organic richness of Permian black shales in Raniganj Field and consist of mainly Kerogen type III, deposited in anoxic condition and matured comparatively at shallower depth. The thermal maturity of the shales is controlled by the burial history of the sediments. Comparatively, the Barren Measures may have excellent prospects for shale gas exploration if the exploration strategies are focused considering the depth factor. In general, based on the thermal maturity trend i.e. increasing with respect to depth, the deepest and thickest shale sections of the sediment will have the most favorable conditions for hydrocarbon generation prospectivity. The shale properties are identical to most of the US commercial gas shales, furthermore, the brittle nature of Barren Measures and micro scale fabric heterogeneity will help stimulate the development of variable fractures and make the shale susceptible for multistage hydro fracturing.

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