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Research paper

Assessment of organic richness and hydrocarbon generation potential of Raniganj basin shales, West Bengal, India

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A R T I C L E I N F O

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A B S T R A C T

High energy prices and severe energy shortage has led shale gas to become the focus of study and exploration in many countries. India, like many other countries around the world with shale gas potential recognizes the strategic importance of developing its shale gas resources. For the purpose of shale gas assessment, the authors have selected sixty six borehole shale samples of different formations from different parts of Raniganj basin, West Bengal, India. Rock eval pyrolysis and total organic carbon (TOC) analysis and petrographic characterization of the shales were carried out. Shales from Barakar (Lower Permian), Barren Measures (Upper Permian) and Raniganj Formation (Upper Permian) are marked by 'good' to 'excellent' TOC content, input of type III organic matter and are capable of generating oil and thermogenic gas upon thermal cracking. Igneous intrusives (dykes and sills) in the formations occurring in and around the areas of Sitarampur (Si) and Kulti (Ku) in western part of the basin might have resulted in cooking of the shales, increasing their maturities (estimated vitrinite reflectance, VRo) as indicated by the Barren Measures shales of shallow depths from the above mentioned areas. Majority of the samples are marked by low oxygen index (OI) values.

1. Introduction

The arrival of shale as hydrocarbon reservoir has drawn attention for deeper understanding and research (Montgomery et al., 2005; Jarvie et al., 2007; Loucks et al., 2009). Shales are unconventional gas systems where it acts as both source and reservoir rocks for gas mainly methane and are classes of continuous petroleum accumulations (Schmoker, 1995; Jarvie et al., 2007). The process of adsorption plays an important role in unconventional resource plays and accounts, in part, for the retention of oil that is ultimately cracked to gas in shale-gas systems (Jarvie, 2012). Organic matter in shale typically ranges from below 1 wt % to more than 20 wt % and is responsible for in situ gas generation which is stored in the micropore structure of organic matter (Loucks et al., 2009) and clay minerals (Chalmers and Bustin, 2007; Ross and Bustin, 2009). Hydrocarbon generative potential of shales depends on the amount, type and maturity of the organic matter present in it (Tissot and Welte, 1978; Sykes and Snowdon, 2002). Rock eval pyrolysis and TOC analysis, the most widely used method for screening the petroleum generation potential, provides information on the quantity and type of organic matter in a sedimentary rock, in addition to the level of organic maturation (Espitalié et al., 1977). In this paper the authors have tried to assess the hydrocarbon generative potential of borehole shale samples from different formations of Raniganj coal basin, West Bengal, India through rock eval pyrolysis and TOC analysis and organic petrography.

Raniganj coal basin, sub-basin of Damodar Valley basin (part of a group of basins collectively named the 'Gondwanas'), is the birthplace of the Indian coal industry and has been a centre of geological activities for more than two centuries. Official record on occurrence and extraction of coal in Raniganj basin dates back to 1774. Since then it has been trodden over by numerous geoscientists and exploiters. However as exploration has focused on the coal deposits, relatively little geologic data is available on the shales of different formations in this basin.

After US, the shale gas revolution is knocking at the doors of the Indian gas market and has attracted the attention of scientists, technologists and policy makers (Varma and Panda, 2010; Varma et al., 2014a,b; Mani et al., 2014). India, like many other countries around the world with shale gas potential, recognizes the strategic

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importance of developing its shale gas resources. In January 2011, Oil and Natural Gas Corporation Limited (ONGC) struck gas at its pilot shale gas well RNSG-1, drilled by Schlumberger at Icchapur, near Durgapur, West Bengal, in eastern part of Raniganj sub-basin of the Damodar Valley (LNG World News, 2011). The well was drilled to a depth of around 2000 m and reportedly had gas shows at the base of the Permian Barren Measures Formation (985–1843 m).

2. Geological setting

Raniganj coal basin, the easternmost intracratonic rift basin of the Damodar Valley, has a semi-elliptical, elongated shape, and covers an area of 1900 km^2 between the Damodar and Ajay rivers. It is bounded by latitudes 23°22′N and 23°52′N, and longitudes 86°36′E and 87°30′E (Gee, 1932). The Raniganj basin is one of the few coal basins of peninsular India where both the Lower Gondwana (Permian) and Upper Gondwana (Triassic– Lower Cretaceous) formations are present (Gee, 1932). The Gondwana Supergroup is about 3,200 m thick and is subdivided into six formal units. The Gondwana formations were deposited in the tectonic trough with faulted boundaries i.e., northern and southern faulted boundaries, on either side of the Damodar river which flows on the faulted trough. The Raniganj coal basin is faulted down on the south and west, the southern boundary being a series of faults, shows an en echelon pattern with a general strike of E–W dipping towards the major faults mostly towards more faulted southern boundary. The dip of the strata varies from 5° to 10°. Besides the boundary faults, there are also oblique and cross faults in the field with a general strike of NW–SE dipping towards north–east. The field is traversed by igneous intrusions of dolerites or basalt and lamprophyres. The lower Gondwana formations were deposited over the Precambrian basement. The generalized stratigraphic succession and the geological map of Raniganj coal basin with the study area is shown in Table 1and Figure 1 respectively.

The areas from where the samples have been collected are marked in Figure 1. Kuldiha area (K in Fig. 1), easternmost part of the basin, is marked by a thick succession of Cenozoic sediments from surface and in then followed by Supra-Panchet (Upper Triassic) and Panchet (Lower Triassic) Formations. In the North-eastern portion of the basin lies Jaggannathpur (marked as J). In Icchapur area (I, east of central part of the basin) the first Formation encountered below the soil and weathered mantle is Panchet Formation (Lower Triassic). Moving westwards, the Andal area (A) is encountered. Here Raniganj Formation (Upper Permian) is encountered first. In the western part of the basin lies Sitarampur (Si) and Kulti (Ku) areas, wherefrom samples belonging to Barren Measures (Ironstone shales) Formation (Upper Permian) were collected.

3. Materials and methods

3.1. Collection of samples

For the purpose of assessing the hydrocarbon prospectivity of shales from Raniganj coal basin, a total of sixty six borehole samples were collected from different parts of the basin belonging to different Formations. Location, depth and stratigraphic formation of the samples are provided in Table 2.

3.2. Rock eval pyrolysis

Rock-Eval 6 was used for carrying out Rock Eval Pyrolysis (REP) and TOC analysis of the samples. Firstly the samples were washed, dried, crushed to powder and screened through BSS 60 mesh size (– 250 micron size) and were well homogenized prior to carrying

Table 1
Generalized stratigraphic succession of Raniganj coal basin (after GSI, 2003).

Age	Formation	Lithology	Maximum Thickness (m)
Recent and Quaternary		Alluvial and residual soils; lateritic capping.	90
		----------------------Unconformity------------------------------------	
Tertiary		Light grey mudstone and siltstone with bands of marlstone; white, soft fine grained clayey sandstone, mottled clay and loose sand with pebbles of vien quartz; occasionally lignite at the basal part.	300
		----------------------Unconformity------------------------------------	
Cretaceous	Igneous intrusive	Basic (dolerite) dykes; Ultrabasic (mica-peridotite, mica-lamprophyre, lamprophyre) sills and dykes.	—
Cretaceous	Rajmahal Formation	Greenish grey to black, fine to medium grained vesicular porphyritic basalt and volcanic breccia; weathered aphanitic basalt at places; one to five inter-trappeans consisting of grey shale, fine grained sandstone and carbonaceous shale.	120
		----------------------Unconformity------------------------------------	
Upper Triassic*	Supra-Panchet/ Durgapur Beds	Massive, very coarse to coarse quartzose sandstone, conglomeratic at places; bands of dark red silty shale.	300
		----------------------Unconformity------------------------------------	
Lower Triassic*	Panchet Formation	Coarse grained greenish yellow and greenish grey soft, micaceous, cross-bedded sandstone with slump structures; khaki green fissile silty shale; alternate bands of yellow coarse grained immature sandstone and bright reddish brown claystone with calcareous concretions; conglomeratic at the base.	600
Upper Permian*	Raniganj Formation (Lopingian *)	Grey to light grey fine and medium grained micaceous felspathic sandstone with calcareous clayey matrix in the upper part; siltstones and shales, often interlaminated with fine grained sandstone; carbonaceous shales and coal seams.	1150
Upper Permian*	Barren Measures/ Ironstone Shales (Guadalupian *)	Dark grey to black micaceous or carbonaceous, fissile shlaes with ferrugineous laminae and thin bands of dense, hard, cryptocrystalline clay ironstones; rarely interbanded with fine grained sandstone.	600
Lower Permian*	Barakar Formation with Karharbari Formation (?) at base (Cisuralian- Early Sakmarian to Kungurian *)	Very coarse to medium grained arkosic sandstones, often cross-bedded; grey and carbonaceous shales, at times interbanded with fine grained sandstone; fire clay lenses and coal seams; pebbly and carbonaceous in lower part.	750
Lower Permian*	Talchir Formation	Tillite or diamictite with sandy or clayey matrix at the base; medium to fine grained khaki or yellowish green feldspathic sandstone; siltstone, silty shale, needle shale and rhythmite with dropstones.	500
		----------------------Unconformity------------------------------------	
Precambrian	Chotanagpur Gneissic Complex	Granite gneiss with migmatitic gneiss, hornblende schist, hornblende gneiss, metabasic rocks, pegmatite and quartz veins etc.	—

(Explanation: * = age according to Mukhopadhyay et al., 2010)