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Rock Eval Pyrolysis Study of Permian shales from Raniganj Coal field, India

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Abstract

In this study, core samples of Permian shales of Raniganj field were analysed to evaluate their gas generation potential using Rock Eval pyrolysis techniques. The Total Organic Content (TOC) of the shale units of Barren Measures 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 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 the Permian shales are signifying fair to excellent gas generation potential.

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1. Introduction

The current success in the exploration and development of shale gas resources in The United States of America [1,2, 5]has created interest in the assessment of shale gas resource potential of India. The Indian sedimentary basins have vast potential of shale gas resources. In India, shale gas is an emerging unconventional energy resource, after inspiring from the US multi-fold growth in production during past decade. India has 26 sedimentary basins with varying thick shale beds of Tertiary and Gondwana age covering an area of about 3.14 lakh km^2. These basins have been explored extensively for the coal, lignite and conventional hydrocarbon resources, however, shales as reservoir have not been explored because of heterogeneous characteristics. Therefore, very limited information is available on shale occurrence, composition, organic/clay content, maturity, mineralogy and pore distribution to treat shale beds as the potential gas reservoir. The Permian shales of Raniganj field (figure 1) are considered as the most prospective shale gas plays of India [12,14,15]. This paper presents the gas generation potential and reservoir properties of Permian shales including Barakar, Barren Measures and Raniganj shales of Raniganj Basin, however, the study is mainly focused on Barren Measures Shale. This paper also discusses the key geological factors and processes in order to identify prospective shale gas fairway over Raniganj field.

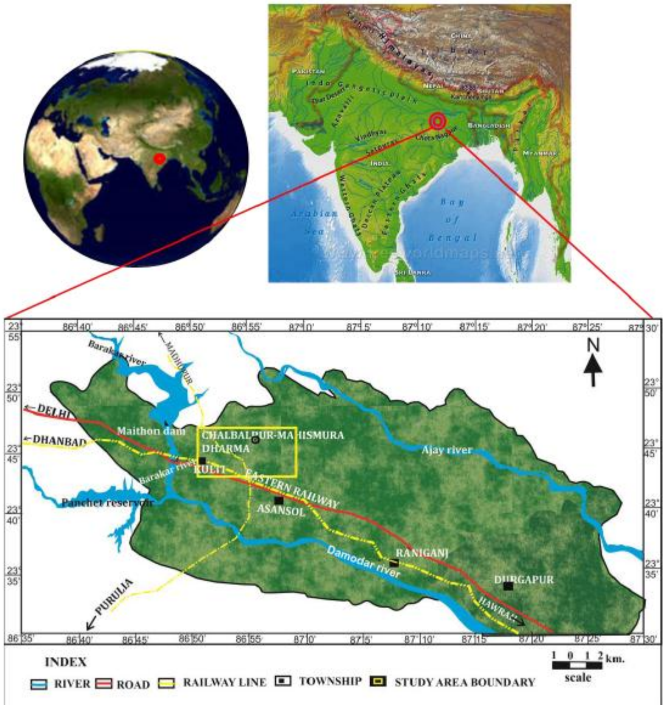

Figure 1 Map of Study area, Raniganj Coal Field, India

2. Geological Setting

The Gondwana basins in India are intra- cratonic in nature, surrounded by Pre- Cambrian terrains, correspondingly occur as separate outliers along the three major directions: (1) Son–Narmada and Damodar–Koel Valley, running East–West, (2) Son–Mahanadi Valley, with a NW–SE trend, and (3) Pranhita–Godavari Valley, which trends in a NNW–SSE direction. The Gondwana successions of Damodar Basin in peninsular India accumulated in a number of discrete sub-basins during the Permo-Triassic period. The belt of Gondwana basins lies within the Chotanagpur Granite Gneiss belt and the main sub-basins are Hutar, Auranga, Karanpura, Bokaro, Jharia and Raniganj [3,4,6]. They have faunal and floral characteristics similar to the equivalent strata of South America, South Africa, Australia and Antarctica [8, 9]. Raniganj field is the easternmost depository within the Damodar Basin, a typical half-grabben type E-W trending and westerly plunging synform. Depositional environment of the field is mainly terrestrial (fluvial and lacustrine) with local marine transgressions during the Sakmarian –Artinskian period [9,16]. The litho- stratigraphy of the field is presented in table 1. The stratigraphy is signified by Talchir Formation (glaciogenic) of early Permian age at the base, overlying the Pre- Cambrian metamorphic rocks unconformably. The Barakar and Raniganj Formations are overlaying the Talchir deposits. The Barakar Formation is characterized by conglomerate, light grey to light yellowish/ brownish, gritty to pebbly, arkosic to sub-arkosic, cross-bedded sandstone and siltstone, interbedded with grey/black shale and thick coal seams [8, 9]. The Barren Measures Formation is sandwiched between Barakar and Raniganj Formation, fluvial–lacustrine origin and devoid of coal [16]. The alluvial deposit of the Panchet Formation is also barren of coal and it overlies the Raniganj Formation. The Barren Measures of Permian age is recognized as the shale gas prospective horizon based on thickness (>1000m), areal extent and higher content (>2%) of organic matter [8]. Thickness of Barren Measures Formation ranges from 91m to 330m in the study area. However, thickness is more (750-850m) towards the southern margin as compared to the northern margin and best developed (>1000m) in the depressions (Durgapur and Raniganj Depressions) of Raniganj field (ONGC 2010). This paper describes the organic richness, kerogen type, gas generation potential and thermal maturity as well as the reservoir properties of Barren Measures of Raniganj field in Burdwan district of West Bengal.

Table 1: General Stratigraphy of Raniganj field

Geological age		Formation	Thickness (m)
Tertiary		Bangal basin clay, sand and limestone	300+
……………………………………………… ……….unconformity…………………..			
Jurassic –Cretaceous		Rajmahal trap intratrappeans	85+
……………………...unconformity………………….			
Triassic Late		Supra- Panchet	200-300
………………………………………….Angular unconformity………..			
Triassic Early		Panchet	~600
…………………………………………..………unconformity (local)…………………			
Permian Late	Damoda group	Raniganj	1000
		Barren Measures	900
		Barakar	600
Permian Early		Talchir	300
………………………………………unconformity ………………..			
Precambrian		Metamorphic granite gneiss, schists with pegmatite and intrusive of metadolerite, dolerite, lymprophyre	

3. 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.

4. Results and discussion

The dark grey to black colour of the studied shale samples from Barren Measures indicates high content of organic matter. The laboratory measured TOC value ranges from 3.75 wt. % to 20.9 wt. %. In this study, the original TOC (TOC_O) differs from the present day TOC (TOC_P) content ($TOC_P/0.64 = TOC_O$) and it is higher than present day TOC [7]. The PI of studied samples shows a range of 0.06 to 0.24mg HC/ g TOC and indicates in situ petroleum generation of matured sediments [7, 10]. 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 [13, 14]. 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. Low HI (<125.34 mg HC/g TOC) designates a greater potential to generate gaseous hydrocarbon [14, 15]. The original S2 and original HI were determined using the mathematical equations [15, 17]. The original generation potential (original S2 mg hydrocarbons / g rock) of studied sample is calculated numerically i.e. original S2=TOC change / 0.083 + present S2. The original S2 values ranges from 5.11 to 32.6 mgHC/g rock. Thus original HI value is calculated using the equation Original HI = Original S2 / Original TOC x 100. The studied samples show original HI value of 80.78 to 138 mg HC/g TOC. OI value ranges from 1.50 to 22.66 mg CO_2/g TOC with an average of 7.13 mg CO_2/g TOC. The cross plot between HI and OI of samples (Figure 2) denotes the presence of type III, gas prone kerogen [14, 15]. HI versus Tmax cross plot was analysed for kerogen type determination and presence of type III kerogen was identified (Figure 2). The plot of TOC versus S2 visualizes gas prone organic matter, capable in producing mainly gas which is derived from humic and continental higher plants [14, 15, 17]. For Type III organic matter, a Tmax of 434ºC is the boundary between immature and mature kerogen (oil production zone) whereas a Tmax of 465ºC as the boundary between mature and over-mature kerogen (gas-production zone).

Analysis of all the crucial Rock-Eval parameters (HI, OI and Tmax) refers early to late maturity level of the shales (figure 3). Since Tmax obtained from Rock-Eval pyrolysis indicates the level of thermal maturity, it is possible to convert Tmax to Ro. The conversion can be mathematically expressed as Ro (calculated) = (0.018) (Tmax) – 7.16 [11]. 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.

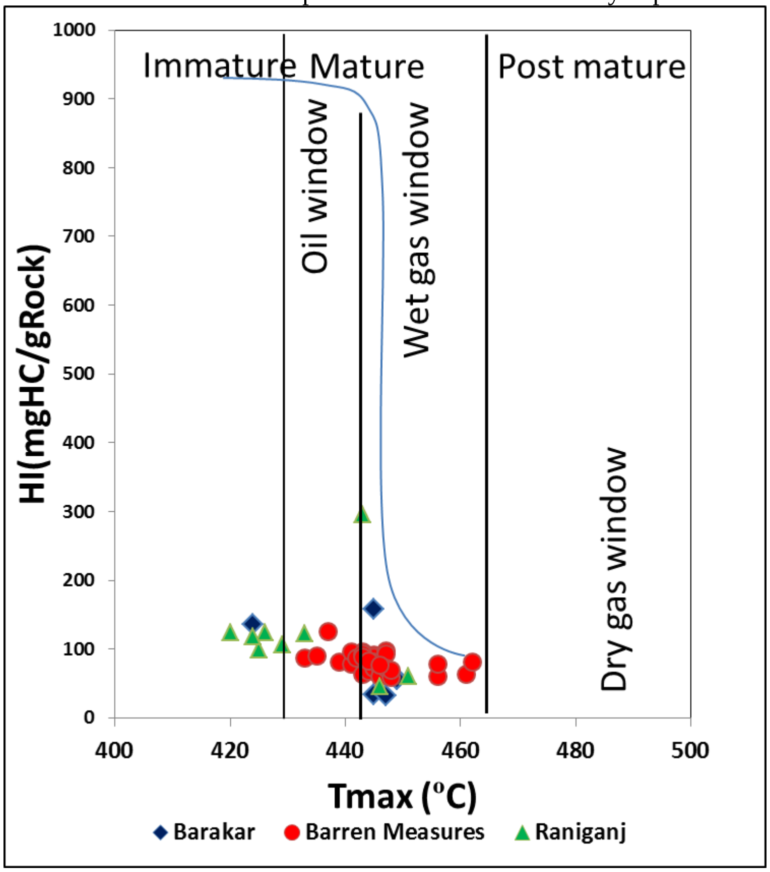

Figure 2: plot of HI vs Tmax

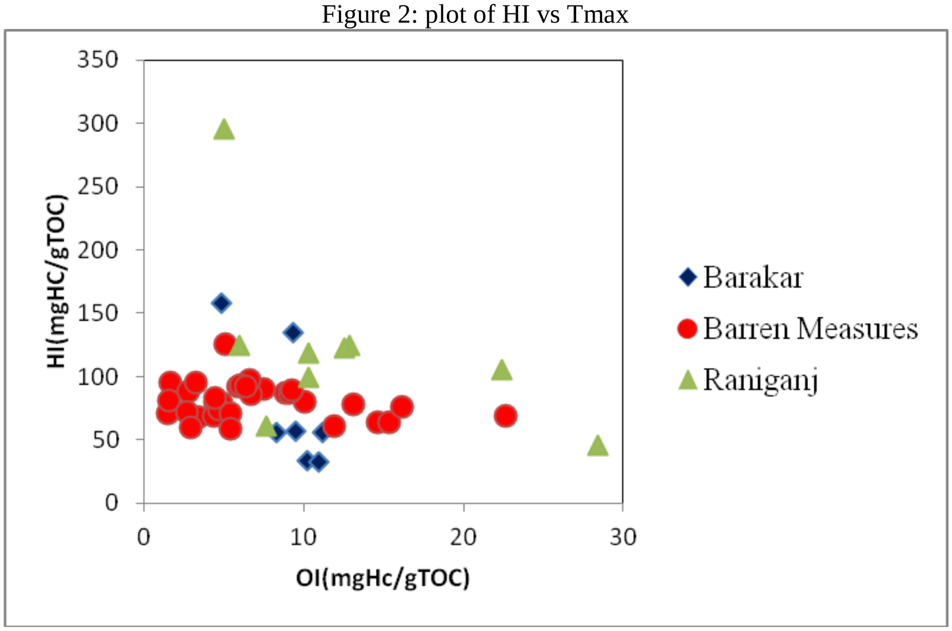

Figure 3: plot of OI vs HI

5. Conclusion

Organic geochemistry and petrographic analyses suggest the Barren Measures shales content ranges from 4 to 20 wt% TOC 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. Different types of pore systems are envisaged including both primary and secondary porosity. The diagenetically developed pore systems are anticipating storage capacity for gas accumulation. The Barren Measures may have excellent prospects for shale gas exploration if the exploration strategies are focused considering the depth factor. In general, it may be concluded that the deepest and thickest shale sections of the sediments, will have the most favorable conditions for hydrocarbon generation prospectivity.

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