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Assessment of Shale Gas characteristics of Barren Measures Formation, Damodar Valley Basin, India

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Abstract

Shale gas characteristics of core shale samples of Middle Permian Barren Measures Formation have been assessed for this study. All the samples are collected from Raniganj, West Bokaro and South Karanpura sub-basins within Damodar Valley Basin, India. Organic geochemical characteristics such as organic matter content, type of organic matter and thermal maturity have been investigated using Rock-Eval pyrolysis. Biomarker analysis, using gas chromatography – mass spectrometry, has been performed in order to understand the source and depositional environment of organic matter from the samples. Pore space distribution and pore morphology are inferred from the results of field emission scanning electron microscopy and mineralogy of the same has been analysed using X-ray diffraction analyses.

Introduction

Shale gas, often called the game changer of the future energy market, has recently emerged as a viable alternate for conventional hydrocarbon based energy sector. According to EIA 2014 [1], shale gas is one of the very few unconventional resources which have shown some potential in providing security to the increasing energy demands of the world. Shale gas, a type of natural gas, is generated from very low permeable organic rich shale layers (conventionally good source rocks). The gas from the matured organic matters remains trapped within the shale layers and hence the source rock acts as a reservoir for the "Shale Gas".

The Middle Permian Barren Measures Formation of the Damodar Valley Gondwana Basin is considered as one of the potential gas shales of India. Present study attempts an evaluation of shale gas attributes of the Barren Measures Formation.

Experimental Details

Samples: Core shale samples are collected form Raniganj, West Bokaro and South Karanpura sub-basins for this study.

Rock-Eval pyrolysis: All the samples were crushed into fine powder (60-100 mesh) and analysed in Rock-Eval 6 pyrolyser manufactured by Vinci Technologies®.

Biomarker Analysis (GC-MS): Bitumen was extracted from the powdered samples by sonication, using a solvent mixture of dichloromethane (DCM) and methanol (MeOH) (9:1) for 30 min. The extracts were then decanted and separated into aliphatic and aromatic fractions by column liquid chromatography using activated silica gel (100-200 mesh) using *n*-hexane and a mixture of *n*-hexane and dichloromethane (4:1), respectively. The saturate fractions were then analyzed by an Agilent

5975 mass spectrometer attached to a 7890 gas chromatograph for biomarker analyses. Compounds were identified on the basis of their retention time and by comparing the mass spectra form various publications.

FE-SEM analysis: Small sub-samples (0.5 cm – 0.5 cm) were cut and coated with gold to prevent electrostatic charging. The samples were then analysed in a Carl Zeiss Ultra-55 FE-SEM system equipped with Oxford EDX system has been used with an accelerating voltage 5.00 kv.

XRD analysis: The samples were powdered and mixed with distilled water to make thick slurry onto unglazed glass slides. The air dried samples were scanned on a Rigaku Geigerflex X-ray diffractometer, from 3° to 30° 2θ at 1° 2θ/min scan speed, using nickel filtered K_{α} radiation (40 kV and 30mA). Subsequently the samples were scanned after treating with ethylene glycol (100°C for 1 hour) and were finally scanned after heating at 400°C for 2 hours under the same instrumental settings.

Results and Discussion

Rock-Eval study revealed that all the analysed samples are dominated by type III kerogen. The total organic content (TOC) values range from 2.8 to 7.71%, 2.66 to 6.18% and 3.05 to 9.38 % for Raniganj, West Bokaro and South Karanpura samples respectively. The Rock-Eval T_{max} values of 438-448°C for the Raniganj samples correspond to vitrinite reflectance of approximately 0.7-0.9 % which indicates early to peak thermal maturity [2]. On the other hand the T_{max} values of West Bokaro (443-452°C) and South Karanpura samples (436-454°C) correspond to calculated vitrinite reflectance of 0.8-0.9% and 0.7-1.0% respectively pointing towards attainment of peak thermal maturity conditions. A Hydrogen Index (HI) versus T_{max} cross-plot demonstrates some of the samples are falling into oil window whereas a few have reached wet gas window (Figure 1a). A S_2 versus TOC cross-plot shows most of the samples have good to excellent hydrocarbon generation potential (Figure 1b).

Overall biomarker distribution is characterized by *n*-alkanes (*m/z* 57), bicyclic sesquiterpanes (*m/z* 123), tricyclic terpanes (*m/z* 123), hopanes (*m/z* 191) and steranes (*m/z* 217). A pristane/n-C_{17} versus phytane/n-C_{18} crossplot shows that the given samples are rich in terrigenous organic matters and were deposited under sub-oxic environments [3]. As suggested by carbon preference index (CPI) values ranging from 1.54 to 2.27, the predominance of odd carbon numbered *n*-alkanes over even ones points towards major contribution of higher plants to the TOC. Terrestrial depositional conditions are also supported by different biomarker parameters like predominance of C_{29} sterane over C_{27} and C_{28} steranes and higher moretane/hopane ratios (0.46-0.58). Homohopane ratios like C_{31} and C_{32} 22S/22(S+R) ratios (0.51-0.59) indicate that the samples have attained early to peak thermal maturity.

Pore spaces observed in the FE-SEM images of the analysed samples are predominantly intergarnular mineral matrix pores. Along with this, the presence of natural fractures is also very frequent. The intergranular pores are observed to occur in two different modes, firstly within interlayered spaces between flaky clay minerals and mica and secondly in between other non-elongated mineral grains. Pores within the flaky minerals are slit shaped and show a preferred alignment parallel to the laminae of the minerals whereas the pores in between non-elongated minerals don't show any preferred orientation and are irregular in shape. Pore size ranges from 50 nm to up to 1.2 micrometer in length. Few large macro pores have been observed in the studied samples, which are non-elongated and irregular in shape. At some parts, the flaky minerals exhibit folded geometries and the elongated pores are found to be present along the zone of maximum curvature. In other areas, the layered silicate minerals are showing evidences of brittle fracturing where few pores are developed along the zigzag line of intersection of the minerals. These structures may have developed due to folding of layers of mica and clay minerals.

XRD results show presence of quartz, muscovite and kaolinite in the studied shale samples.

Conclusions

Based on the organic geochemical parameters such as TOC content, thermal maturity and the presence of Type-III kerogen, it can be inferred that the Barren Measures Formation has an excellent gas generation potential. The samples mainly fall in the oil to wet gas window and hence dry gas maturity can be expected at greater depths. FE-SEM image analyses depict the presence of both micro and nano pores in the studied samples. The pores are mainly occurring within the mineral matrix as intergranular pores. The XRD analysis results indicate presence of quartz, muscovite and kaolinite in the shales.

References

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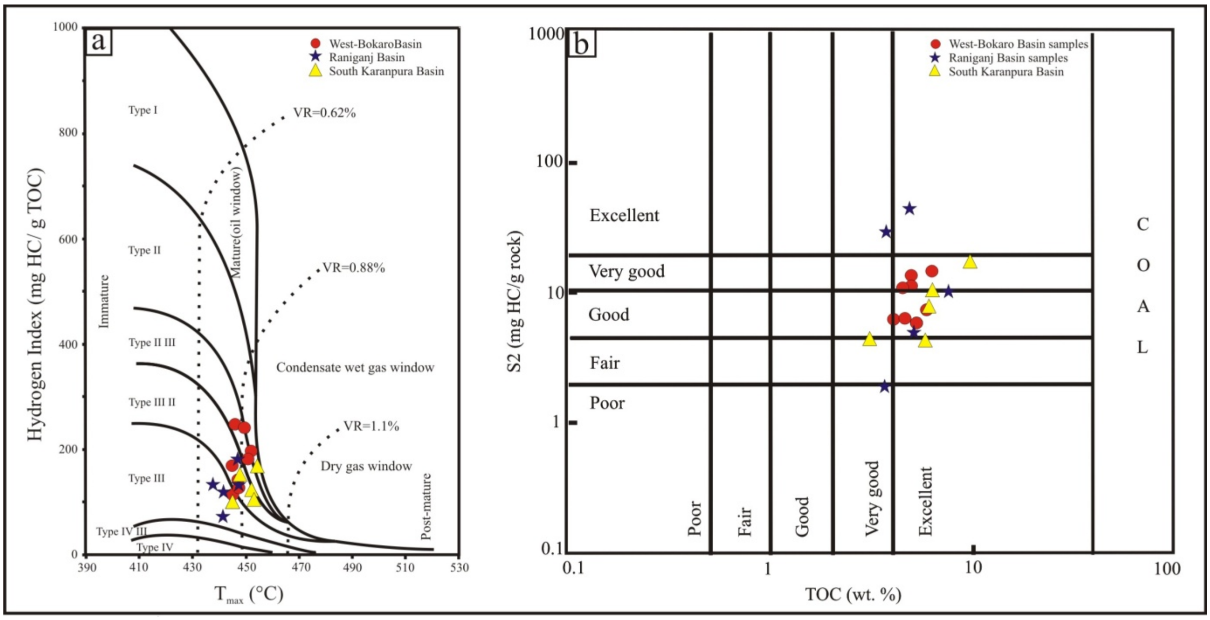

Figure 1. (a) HI vs. T_{max} cross-plot and (b) S_2 vs. TOC cross-plot, of the Barren Measure shale samples, Damodar Valley Basin, India