Journal of Nepal Geological Society, 2004, Vol. 29, pp. 35-38

Source rock potentiality of Ib-Valley Coals, Mahanadi Coalfields Limited, Orissa, India

***Sonali Guha and K. N. Singh**
School of studies in Geology, Vikram Ubiversity, Ujjain-456010, India
*(*E-mail: drsonaliguha@indiatimes.com)*

ABSTRACT

Rock eval pyrolysis is instrumental in rapid evaluation of maturation and source rock characteristics by providing vital information about the quantity, type and thermal maturity of organic mater. The Ib-Valley coal deposits have been characterized for their source rock potentiality and thus to explore the chances of their involvement in hydrocarbon generation.

INTRODUCTION

Organic matter plays the role of a common source for both coal and petroleum. The quantity and type of organic matter i.e. kerogen present in coal and their tectonic and burial history helps in the determination of oil and gas prospects (Dow 1977; Espitalie et al. 1977; Tissot and Wilet 1984; Singh and Singh 1995; Kissops et al. 1996; Peterson et al. 1996; Garcia Gonzalez et al. 1997). The thick sediment-coal seam intercalations predominant in the Lower Gondwanas provide a favourable set-up for hydrocarbon generation (Casshyap 1970).

The present paper is an assessment of the source-rock generating capabilities of coals of a part of Ib-Valley area, 8 km west to Sambalpur, Orissa (Fig. 1). Representative samples from each of the four seams were selected for pyrolitic investigations and finally four sets of samples were studied to determine their hydrocarbon generative capacity. The pyrolitic study of Ib-Valley coals was done with the help of Rock-Eval pyrolyser-version II manufactured by Delsi Inc. (Guha 2002) (Table 1).

DISCUSSION OF PARAMETERS

The potentiality of a rock type to generate hydrocarbons is dependent on factors such as a) quantity of organic matter b) type of organic matter and c) source rock maturity.

a) Quantity of organic matter

The amount of organic matter present in a rock is expressed in terms of the Total Organic Content (TOC) in weight% of the dry rock. Although a standard has been generalized to show that rocks with TOC% less than 0.5% have negligible generative capacity, higher TOC values (upto 60-70%) are not a guarantee for potential source rocks. For complete reliability, supporting data are usually provided.

In rocks with <0.5%TOC, the hydrocarbons are very less and hence not expelled. In this case the kerogen is highly oxidized, resulting in low potentiality (Table 2 and 3). The gradual increase in TOC values is marked by subsequent changes from a complete oxidizing environment to a highly reducing one. This change directly influences the source rock generating potentiality. Thus, a TOC value above 2% signifies a reducing environment with excellent source capacity. This is applicable on the Ib seam, Lajkura seam and Hingir-Rampur seam, which have TOC contents at 50 and above.

In spite of not being a sufficient factor, determination of TOC is necessary of kerogen quality.

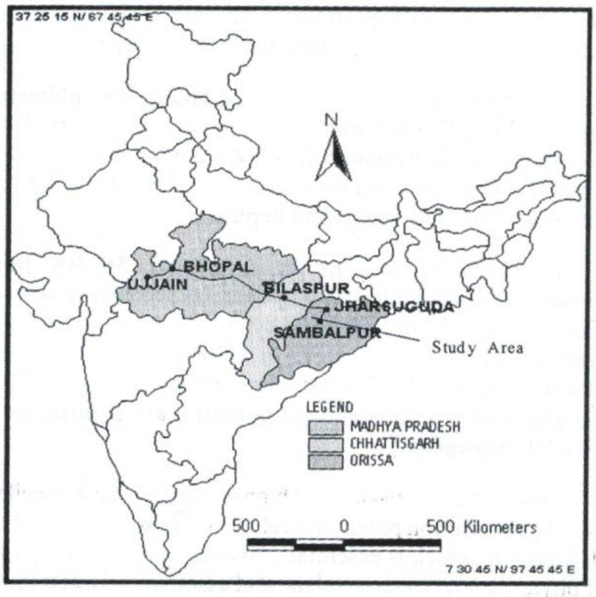

Fig. 1: Location map of the study area

Table 1: Results of Pyrolitic studies

Seam	Qty (gm)	Tmax	S1	S2	S3	PI	S2/S3	PC	TOC	HI	OI
Ib	6.3	429	21.42	86.19	11.58	0.20	7.44	8.96	52.25	164.95	22.16
Hingir Rampur	6.1	433	22.95	65.08	10.49	0.26	6.2	7.33	50.0	130.16	20.98
Lajkura	5.7	430	17.01	71.57	7.89	0.19	9.07	7.38	52.25	136.97	15.10

Table 2: Standards for source rock generating potential

Quantity	TOC (wt%)	S1	S2
Poor	0-0.5	0-0.5	0-2.5
Fair	0.5-1.0	0.5-1.0	2.5-5.0
Good	1.0-2.0	1.0-2.0	5.0-10.0
Very Good	>2.0	>2.0	>10.0

Table 3: Indications of source rock potentials based on TOC values.

TOC Values (wt%)	Source Rock Implications
<0.5	Negligible source capacity
0.5-1.0	Possibility of slight source capacity
1.0-2.0	Possibility of moderate source capacity
>2.0	Possibility of good to excellent source capacity

b) Type of organic matter

The capacity of a rock to generate hydrocarbons or carbon dioxide is expressed in terms of mg of hydrocarbons (HC) or carbon dioxide (CO_2) per gm. of rock sample and represented by S1, S2 and S3. The values of S2 and S3 are normalized in terms of the organic carbon content of the sample and the resulting values are termed as hydrogen index or HI (S2/TOCx100) and oxygen index or OI (S3/TOCx100). This hydrogen index gives indication of the type of organic matter i.e. kerogen.

The relation between source potentiality of immature kerogens and hydrogen index is denoted in Table 4 and 5. Accordingly, the kerogen type has been interpreted.

Hydrogen indices below 150 mg HC/g TOC indicate a type 'III' or 'IV' kerogen with absence of potential oil-generating lipids. Although, less favorable for oil generation, type 'III' kerogen can prove to be convenient gas sources for rocks buried at significant depths.

Hydrogen indices in the range of 150-300 have moderate liquid hydorcabon potential consisting of type 'III' kerogen along with some type 'II' kerogen. Kerogen type 'II' is more prominent in hydrogen indices above 300 and signified by relatively high hydrogen and low oxygen contents. Gas and oil potential are significant in type 'II' kerogens.

Values of hydrogen indices higher than 600 have excellent liquid hydrocarbon potential (Table 4). These indicate a type 'I' kerogen, which is essentially hydrogen rich and consists of phytoplankton, marine algae and associated forms. These oil-yielding kerogens are rare in comparison to the other types.

In the studies conducted, the HI value of Lajkura seam shows a value above 150, while those of Hingir-Rampur and Ib lie below it. This associates a type 'III' kerogen with some type 'II' kerogen for Lajkura seam and type 'III' along with type 'IV' for Hingir-Rampur and Ib seams. A moderate liquid and gas potentiality can thus be attributed for Ib-Valley coals.

c) Source Rock Maturity

The degree of maturity of a source rock depends upon the time and temperature governing its subsidence. Vitrinite reflectance is considered as the most popular parameter of determining the stage of maturity because of its correlation with coal rank, burial depth and hydrocarbon generation phases. The reflectance is reported as Ro where 'o' indicates the measurements made with the epoxy plugs immersed in oil. The study of maturity parameters indicates the possible oil-generation window. Generally, 0.6% Ro is considered as the onset of oil generation, the peak is supposed to be at about 0.9% Ro while the termination of liquid hydrocarbon generation is presumed to be approximately at 1.35% Ro (Table 6).

Ib-Valley coals with an average reflectance of 0.59%, lies in close proximity to the level of onset of oil generaton.

Other maturity parameters such as Tmax and Thermal Alteration Index (TAI) are correlated with reflectance values to determine the maturation stage. Tmax values near 435 ^{0}C-445 ^{0}C are indicative of top oil window while the bottom oil window is usually around 470 ^{0}C (Table 6).

Table 4: Source potential of immature kerogens based on hydorgen indices.

HI (mg HC/g TOC)	Principle Product	Relative Quantity
<150	Gas	Small
150-300	Oil and Gas	Small
300-450	Oil	Moderate
450-600	Oil	Large
>600	Oil	Very Large

Table 5: Correlation of source potential with hydrogen indices and organce cabon.

Type	HI	S2/S3
Gas	0-150	0-3
Gas and Oil	150-300	3-5
Oil	>300	>5

Table 6: Correlation of source rock potential with production index.

Maturation	PI{S1/(S1+S2)}	Tmax (0C)	Ro (%)
Top Oil Window	~0.1	~435-445	~0.6
Bottom Oil Window	~0.4	~470	~1.4

DISCUSSION

Horsfield et al. (1988), Horsfield (1989) and Powell and Boreham (1991) formulated that HI below 300 has no significant influence of hydrogen index (HI) in source rock generation. However, Powell (1988), Hunt (1991), Noble et al. (1991) opined that HI between 220-300 has source rock effectiveness. The HI vs OI plot (after Peters 1986) places the Ib-Valley coals in zone II (Fig. 2).

The same plot (after Van Krevelen 1961) gives an intimation of organic facies deposition also. The bottom set beds as obtained in the present investigation represent deposition in undisturbed quiet environments with probable oxygen-deficient water mass. These coals have higher HI than OI due to preservation of some marine organic matter. Thus, they indicate a better hydrocarbon source prospect (Waples 1979).

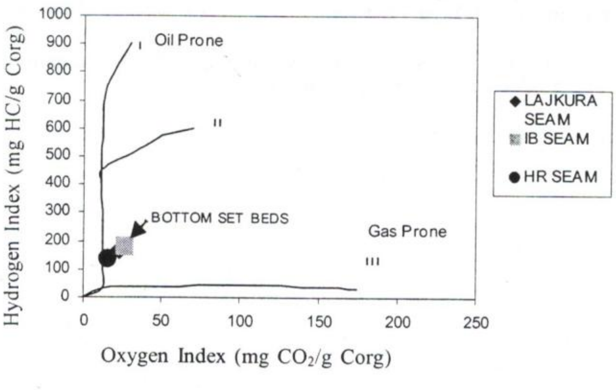

Fig. 2: Plot of HI vs OI representing hydrocarbon generative type and organic facies (after Van Krevelen and Schuyer 1957; Peters 1986)

Pyrolysis temperature T_{max} is an index of maturity since with increasing temperature the kerogen becomes more resistant to pyrolysis. Tmax refers to the temperature when maximum pyrolysis occurs. The oil generative threshold T_{max} value for petroleum-bearing rocks varies consequently with the quality of organic matter. Inspite of the favourable values for Production Index (PI) and T_{max} obtained as >0.1 and 435 ^{0}C respectively, Peters (1986) is of the view that these are not very reliable criteria for determination of thermal maturity, especially for Type 'III' kerogen. HI vs Tmax plot (after Espitalie et al. 1980) indicates a type 'III' kerogen for the Ib-Valley coals (Fig. 3).

A positive correlation (r=0.87) between reflectance values and Tmax has been obtained (Fig. 4, Espitalie et al. 1980).

Type 'III' kerogen is derived essentially from terrestrial plants and comprises of much identifiable vegetal debris. Microbial degradation in the depositional basin is suppressed due to rapid burial of sediments. It is rich in oxygen and poor in hydrogen content. The kerogen type 'II' is related to marine sediments, in which organic material comprising of phytoplankton, zooplankton and bacterial matter is deposited in an anaerobic environment. In type 'I' kerogens, the abundance of lipids may originate from either selective accumulation of algal material or as a result of intense biodegradation of organic matter during deposition.

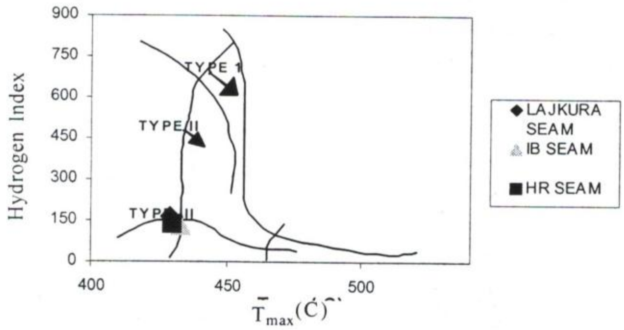

Fig. 3: Binary plot of T_{max} against hydrogen index representing type of organic matter (after Espitalie et al 1980)

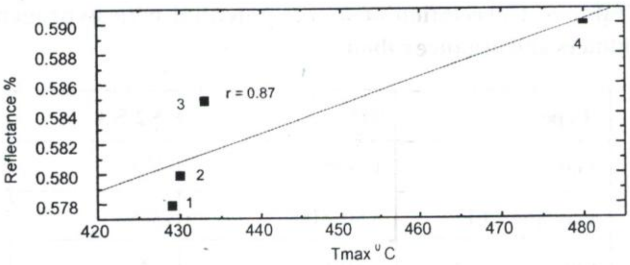

Fig. 4: Binary plot relating reflectance and T_{max} values of Ib-Valley coals (after Espitalie et al. 1980).

CONCLUSION

The source rock maturity of the studied coals belong to the more gas prone type 'III' keregen, as the HI has been found to be below 150 in most of the cases. However, the Ib seam has shown HI value of more than 150, which is indicative of moderate liquid potential. The other values such as TOC, S1 and S2 are indicative of favorable potentiality of source rock.

ACKNOWLEDGEMENTS

The authors are thankful to the officers of ONGC, Dehradun for their co-operation in pyrolitic analysis. The authors acknowledge Prof. Pramendra Dev, Head, S.S. in Geology, for his guidance and cooperation.

REFERENCES

Casshyap, S. M., 1970, Sedimentary Cycles and Environment of Deposition of the Barakar Coal Measures of Lower Gondwana, India. Jour. Sed. Petrology, v. 40, pp. 1302- 1317.

Dow, W. G., 1977, Kerogen Studies and Geological Interpretation. Jour. Geochem. Expl., v. 7, pp. 77-79.

Espitalie, J., Madec, M., and Tissot, B., 1980, Role of mineral matrix in kerogen pyrolysis influence on petroleum generation and migration, AAPG, v. 64, pp. 59-66.

Espitalie, J., Madec, M., Tissot, B., Menning, J. J., and Leplat, P., 1977, Source Rock Characterisation Method for Petroleum Exploration. Proc. 1977, Offshore Technology Conference, v. 3, pp. 439-442.

Garcia-Gonzalez, M., Surdam, R. C., and Milton, L. L., 1997, Generation and Expulsion of Petroleum and Gas from Almond Formation Coal, Greater Green River Basin, Wyoming. A.A.P.G. Bull., v. 81, pp. 62-81.

Guha, S., 2002, Petrological and Geochemical Environment of Coals and Associated Sediments, South-eastern part of Ib-River Valley, Mahanadi Coalfields Limited, Orissa, Ph.D. Thesis (Unpublished), Vikram University, Ujjain, M.P.

Horsfield, B., 1989, Practical Criteria for Classifying Kerogen; Some Observations from Pyrolysis-Gas Chromatography. Geochim. Cosmochim. Acta, v. 53, pp. 891-901.

Horsfield, B., Yordy, K.L., and Creeling, J. C., 1988, Determining the Petroleum Generating Potential of Coals Using Organic Geochemistry and Organic Petrography. Organic Geochemistry, v. 13, pp. 121-129.

Hunt, J. M., 1991, Generation of Gas and Oil from Coal and other Terrestrial Organic Matter. Organic Geochemistry, v. 17, pp. 673-680.

Kissops, S. D., Allis, R. G., and Funnell, R. H., 1996, Carbon Dioxide Generation from Coals in Taranaki Basin, New Zealand: Implications for Petroleum Migration in Southeast Asian Tertiary Basins. A.A.P.G. Bull., v. 81, pp. 545-569.

Noble, R. A., Wv, C. H., and Atkinson, C. D., 1991, Petroleum Generation and Migration from Talang Akar Coals and Shales Offshore N.W. Java, Indonesia. Organic Geochemistry, v. 17, pp. 363-374.

Peters, K. E., 1986, Guidelines for Evaluating Petroleum Source Rock Using Programmed Pyrolysis. A.A.P.G. Bull., v. 70 (3), pp. 318-329.

Peterson, H. I., Rosenberg, P., and Andsbjerg, J., 1996, Organic Geochemistry in Relation to the Depositional Environments of Middle Jurassic Coal Seams, Danish Central Graben and Implication for Hydrocarbon Generative Potential. A.A.P.G. Bull., v. 80, pp. 47-62.

Powell, T. G., 1988, Developments in Concepts of Hydrocarbon Generation from Terrestrial Organic Matter, In: H.C.Wagner, L. C. Wagner, F. F. H. Wong and F. L.Wong, (Eds.), Petroleum Resource of China and Related Subjects. Circum-Pacific Council for Energy and Mineral Resources, Earth Sciences Series, v. 10, pp. 807-824.

Powell, T. G. and Boreham, C. J., 1991, Petroleum Generation and Source rock Assessment to Terrigenous Sequence: An Update. Australian Petrol. Explor. Assoc. Jour., v. 29, pp. 114-129.

Singh, K. N. and Singh, R. P., 1995, Source Rock Potential for Hydrocarbon Generation of Johilla Coals, Son Valley, Madhya Pradesh, India. Ind. Jour. Geol., v. 67 (3), pp. 186-190.

Tissot, B. P. and Wilte, D. H., 1984, *Petroleum Formation and Occurrence*. Springer Verlag, 699 p.

Van Krevelen, D. K., 1961, *Coal- Typology, Chemistry, Physics, Constitution*. Elsevier, 514 p.

Van Krevelen, D. K. and Schuyer, J., 1957, *Coal Science*. Elsevier, 352 p.

Waples, D. W., 1979, Simple Method for Source Rock Evaluation. Bull. A.A.P.G., v. 63, pp. 239-245.