Journal of Nepal Geological Society, 2001, Vol. 23, pp. 13–18

Petrological basis for rank (maturity) determination of Permian coals from Pathakhera coal belt, Satpura Basin, M. P., India

R. Rakesh Shukla[1] and S. Siddharth[2]

[1]*Department of Geology, Banaras Hindu University, Varanasi–221005, India*

[2]*Department of Mining Engineering, Institute of Technology, Banaras Hindu University, Varanasi–221005, India*

ABSTRACT

The Permian coals from the Pathakhera Coalfield are sub-bituminous to high volatile bituminous in rank based on chemical (i.e. carbon and volatile matter) and petrographic (i.e. reflectance) parameters. These coals are characterised by Type III kerogen maturity. The depth of burial of coal-bearing horizons varies from 2,200 to 3,100 m, and the reflectance values of coals indicate 90–110 °C of maturation temperature.

INTRODUCTION

The Pathakhera Coalfield is one of the Tawa Valley coalfields, bordered by the Satpura Hills in the northeast and southeast. The altitude of bordering northeastern hills (usually trending due ENE-WSW) ranges from 4,877 to 1,107 m. The rocks constituting the Pathakhera Coalfield cover an area of about 90 km^2 and show the maximum development of coal seams in the Satpura Basin (Fig. 1). The Precambrian rocks make up the basement of the area. These rocks are mainly granites, gneisses, quartzites, amphibolites, and pegmatites. They are overlain by the Talchir rocks, which are exposed in the southwestern and eastern parts, and are represented mainly by greenish-grey shale and fine-grained khaki sandstone. The Talchirs are overlain by the Barakar Formation containing mainly coarse-grained sandstone and coal seams. The coal seams occur mainly in the middle part of the formation. The thickness of coal seams generally varies from 0.98 to 4.61 m in both the upper and lower workable seams. The Barakar Formation is overlain by the Motur and Bijori Formations. These rocks are intersected by a number of intrusives.

METHODOLOGY

Pillar samples of coal were collected from the workable seams of the productive coalmines of Pathakhera, Satpura, and Shobhapur. The coal samples of each section were studied megascopically and at the same time, seam profiles were constructed. The coal samples were crushed to 1 mm size fractions, and polished thin section were prepared using cold mounting material. The petrographic study of coal was carried out under the LeitzorthoPlan – Pol Petrological Microscope using polarised incident light. The oil immersion objective of 32X and Leitz immersion oil (No. DIN 58884) were used. The reflectance measurements were taken under monochromatic light (546 nm) for which Leitz monochromator 5-546-19 was used. Maceral and microlithotype were identified and characterised according to the guidelines and

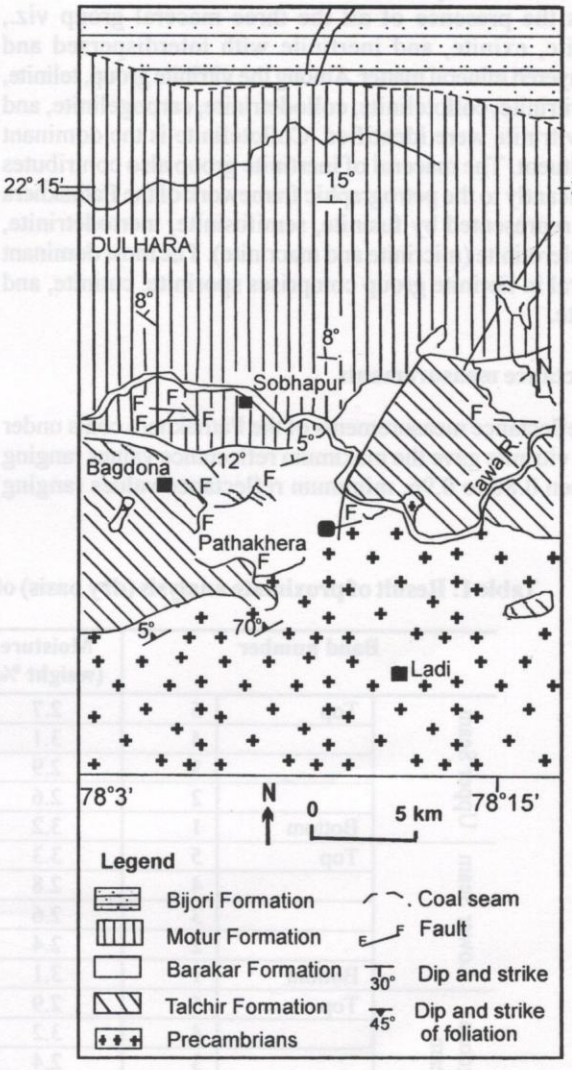

Fig. 1: Geological map of the Pathakhera area

the nomenclature recommended by the International Committee for Coal Petrology in 1975 and 1994. Around 500 counts were taken from every coal seam. Following the norms of Indian Standard (1977) proximate analysis was carried out. The ultimate analysis of coal samples was carried out on a computer-controlled elemental analyser.

RESULTS AND DISCUSSION

Petrographic characteristics

Petrographic composition of coal is an important criterion for qualitative assessment of a coal seam in a basin. Petrographic composition also indicates palaeo-depositional condition under which a coal seam was formed. Degraded vegetable tissues in the form of macerals document diagenetic and metamorphic changes during coalification experienced by the plant debris.

The microscopic examination of the Pathakhera coal shows the presence of all the three maceral group viz., vitrinite, exinite, and inertinite with interdispersed and interlayered mineral matter. Among the vitrinite group, telinite, semivitrinite, collotelinite, collodetrinite, carpogelinite, and detrovitrinite were identified. Collotelinite is the dominant constituent. The maceral of inertinite group also contributes significantly to the petrographic framework of the Pathakhera coals represented by fusinite, semifusinite, inertodetrinite, and sclerotinite (micrinite and macrinite). The most dominant maceral in liptinite group comprises sporinite, cutinite, and resinite.

Reflectance measurements

Reflectance measurements of the Pathakhera coals under oil on vitrinite gave the maximum reflectance values ranging between 0.86 to 0.96, minimum reflectance values ranging between 0.54 and 0.63, and mean reflectance values between 0.58 and 0.69.

Chemical characteristics

Fixed carbon varies from 45.10 to 50.30% (from 55.10 to 65.70%, on dry, ash-free basis), volatile matter from 29.40 to 33.10% (from 34.30 to 44.90, on dry, ash-free basis), whereas moisture and ash range from 2.2 to 3.2% and from 16.9 to 22.2%, respectively (Tables 1 and 2). Among the ultimate constituents, the carbon content ranges from 69.6 to 80.6% (from 79.1 to 90.6% on dry, ash-free basis), hydrogen content from 3.1 to 4.2% (from 4.2 to 4.9% on dry, ash-free basis), nitrogen content from 0.93 to 1.7% (from 1.03 to 2.6% on dry, ash-free basis) and oxygen content from 13.5 to 26.9% (Table 3). The comparative abundance of these elements in coal determines the rank and type of coal, which in turn helps determining the maturation path followed by the coal seam.

Rank/Maturity

The maturation study of coals is important not only to coal and coal-based industries, but also to oil and gas exploration activities. In the Pathakhera coals, the volatile content decreases with increasing reflectance whereas the fixed carbon content increases with increasing reflectance (Fig. 2). The plots based on German (DIN) and North American (ASTM) systems show that the rank of Pathakhera coals ranges between sub-bituminous and high volatile bituminous (Fig. 3). In another scheme of rank given by Kotter (1960), the cross plots clearly indicate the high volatile bituminous rank (Fig. 4). The boundary between the sub-bituminous and bituminous is marked by the alteration of lipid constituents and the beginning of the first coalification jump of liptinite. This alteration may possibly coincide with petroleum formation through decarboxylation and reduction processes (Brooks 1970). The onset of 'oil windows' is marked

Table 1: Result of proximate analysis (dry basis) of the coals from the Pathakhera Coalfield, M. P., India

Band number			Moisture (weight %)	Ash (weight %)	Volatile matter (weight %)	Fixed carbon (weight %)
Upper Seam	Top	5	2.7	18.7	32.2	46.4
		4	3.1	16.9	33.1	46.9
		3	2.9	17.4	29.4	50.3
		2	2.6	18.4	30.2	48.8
	Bottom	1	3.2	19.2	30.9	46.7
Lower Seam	Top	5	3.3	17.4	29.4	49.9
		4	2.8	16.9	30.3	50.0
		3	2.6	18.3	29.4	49.7
		2	2.4	17.9	29.6	50.1
	Bottom	1	3.1	19.2	29.8	47.9
Bagdona Seam	Top	5	2.9	17.3	30.4	49.4
		4	3.2	18.4	31.3	47.1
		3	2.4	20.3	32.2	45.1
		2	2.3	19.4	31.2	47.1
	Bottom	1	2.2	22.2	30.4	45.2

Table 2: Results of proximate analysis (dry, ash-free basis) of the coals from the Pathakhera Coalfield, M. P., India

Band number			Volatile matter (%)	Fixed carbon (%)
Upper seam	Top	5	39.7	60.30
		4	38.9	61.10
		3	37.6	62.40
		2	34.3	65.70
	Bottom	1	41.8	58.20
Lower seam	Top	5	42.8	57.20
		4	44.9	55.10
		3	41.7	58.30
		2	43.9	56.10
	Bottom	1	42.8	57.20
Bagdona seam	Top	5	39.7	60.30
		4	39.9	60.10
		3	38.9	61.10
		2	40.2	59.80
	Bottom	1	41.3	58.70

Table 3: Results of proximate analysis of ultimate constituents of the coals from the Pathakhera Coalfield, M. P., India

Band number			Dry basis				Dry, ash-free basis			
		Element	C	H	N	O	C	H	N	O
Upper seam	Top	5	80.6	4.2	1.7	13.5	90.6	4.9	1.4	3.1
		3	74.3	3.9	1.2	20.6	86.4	4.3	1.07	8.23
	Bottom	1	69.6	3.8	1.4	25.2	81.4	4.6	1.03	12.97
Lower seam	Top	5	72.1	3.8	1.2	22.9	87.3	4.2	1.09	7.41
		3	70.3	3.1	1.4	25.2	80.4	4.3	2.6	12.7
	Bottom	1	70.4	4.0	1.3	24.3	80.2	4.0	1.07	14.73
Bagdona seam	Top	5	69.9	3.2	0.93	25.97	79.7	4.2	1.3	14.80
		3	68.6	3.1	1.4	26.90	79.1	4.3	1.09	15.51
	Bottom	1	71.2	3.6	1.2	24.00	81.6	4.7	1.6	12.10

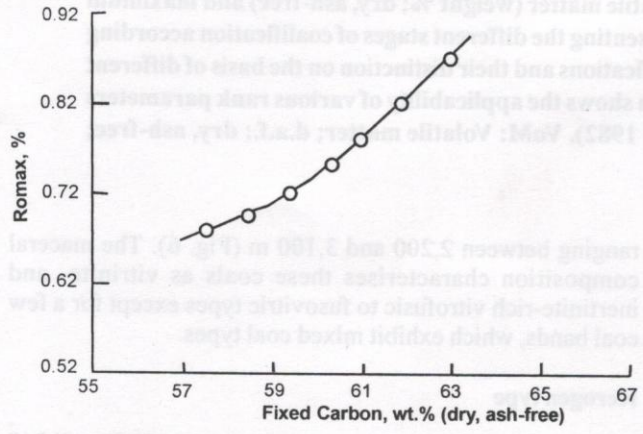

Fig. 2a: Relationship between maximum reflectance (Romax, %) of vitrinite and fixed carbon (weight %; dry, ash-free) in the Pathakhera coals

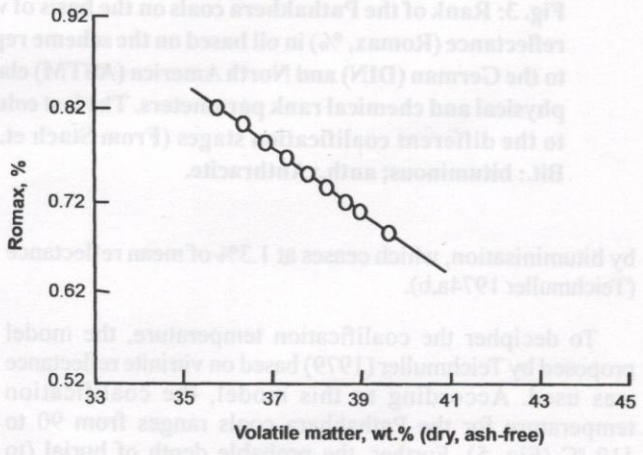

Fig. 2b: Relationship between maximum reflectance (Romax, %) of vitrinite and volatile matter (weight %; dry, ash-free) in the Pathakhera coals

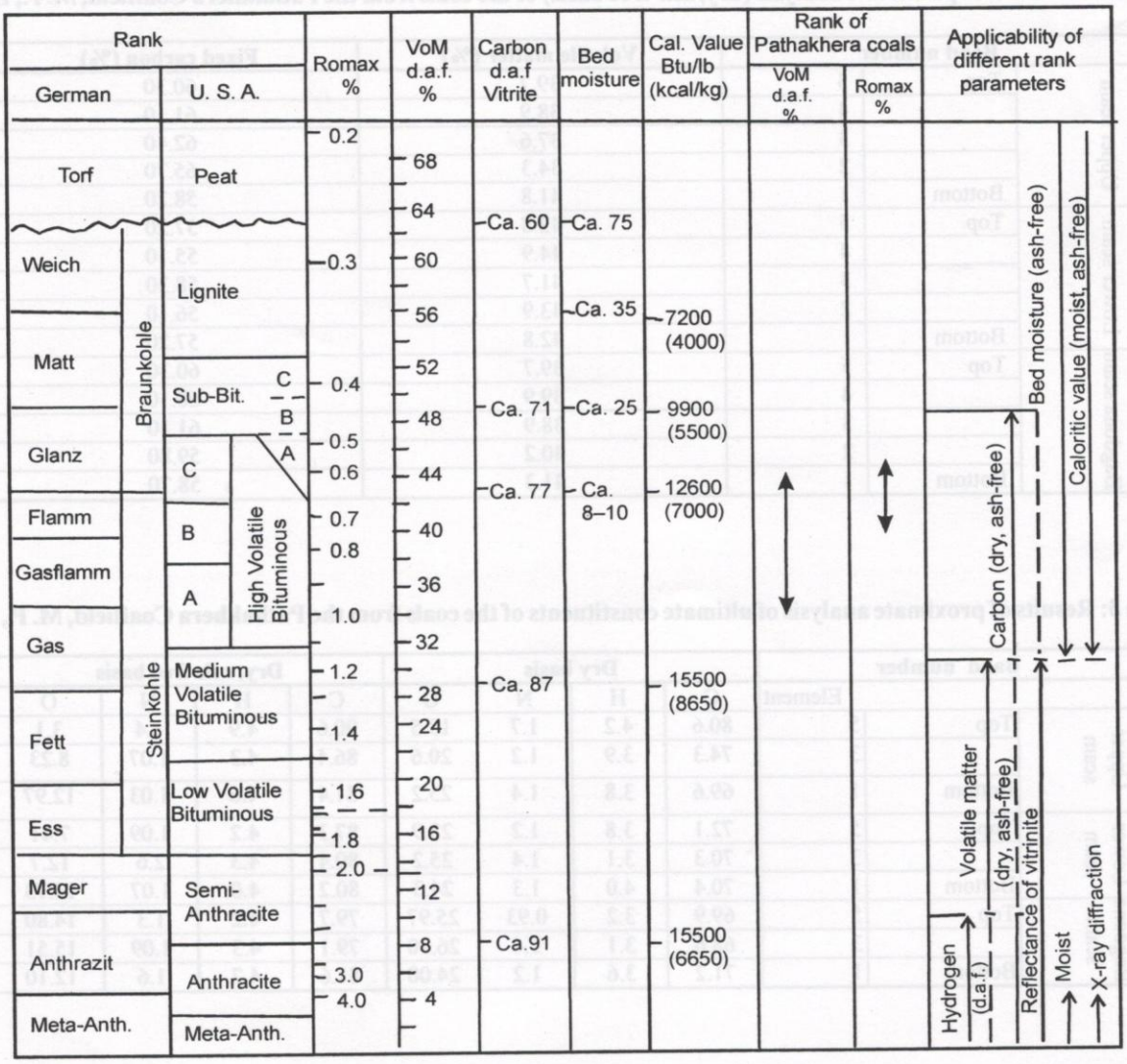

Fig. 3: Rank of the Pathakhera coals on the basis of volatile matter (weight %; dry, ash-free) and maximum reflectance (Romax, %) in oil based on the scheme representing the different stages of coalification according to the German (DIN) and North America (ASTM) classifications and their distinction on the basis of different physical and chemical rank parameters. The last column shows the applicability of various rank parameters to the different coalification stages (From Stach et. al. 1982). VoM: Volatile matter; d.a.f.: dry, ash-free; Bit.: bituminous; anth.: Anthracite.

by bituminisation, which ceases at 1.3% of mean reflectance (Teichmuller 1974a,b).

To decipher the coalification temperature, the model proposed by Teichmuller (1979) based on vitrinite reflectance was used. According to this model, the coalification temperature for the Pathakhera coals ranges from 90 to 110 °C (Fig. 5). Further, the probable depth of burial (to achieve the temperature of maturation) was also based on the standard burial path proposed by Teichmuller (1979), which is again based on the vitrinite mean reflectance. The mean reflectance value of coals yields the depth of burial ranging between 2,200 and 3,100 m (Fig. 6). The maceral composition characterises these coals as vitrinite- and inertinite-rich vitrofusic to fusovitric types except for a few coal bands, which exhibit mixed coal types.

Kerogen type

The plots of Pathakhera coals based on H/C and O/C ratios on the diagram proposed by Jones and Edison (1978) show that these coals have Type III kerogen maturity (Fig. 7). This type of kerogen consists largely of polyaromatic structures.

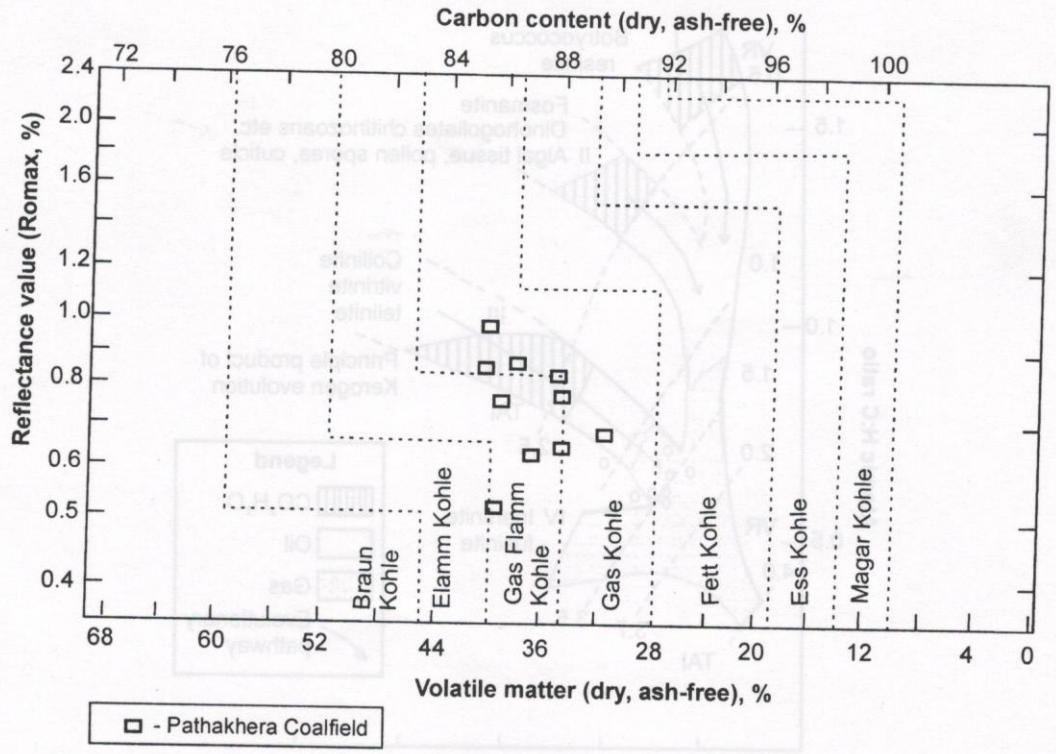

Fig. 4: Rank of the Pathakhera coals in the diagram proposed by Kotter (1960) using reflectance and volatile matter as parameters

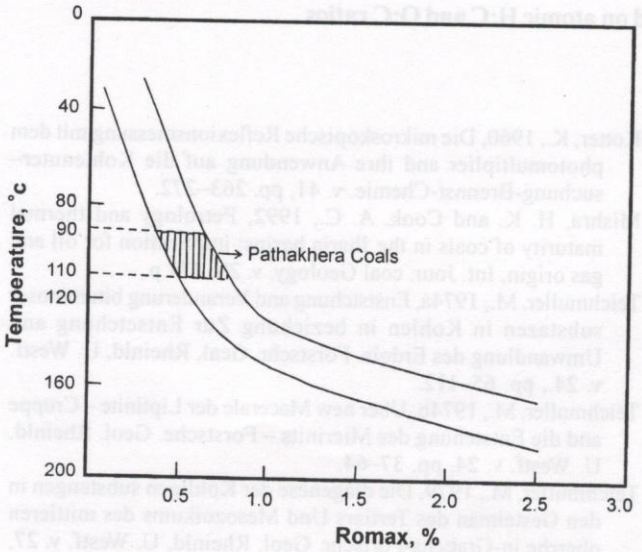

Fig. 5: Coalification temperature range of the Pathakhera coals inferred on the basis of the scheme proposed by Teichmuller (1979) based on the increase of vitrinite reflectance with temperature in four boreholes having different geothermal gradient (GG) of Upper Rhine Graben, Germany

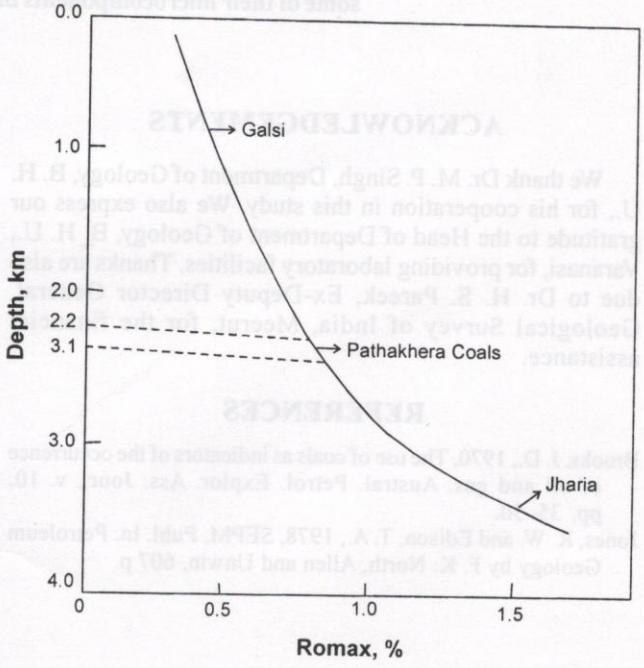

Fig. 6: Probable depth of burial of the Pathakhera coals inferred from the extrapolated gradient given for Jharia and Galsi basins by Mishra and Cook (1992)

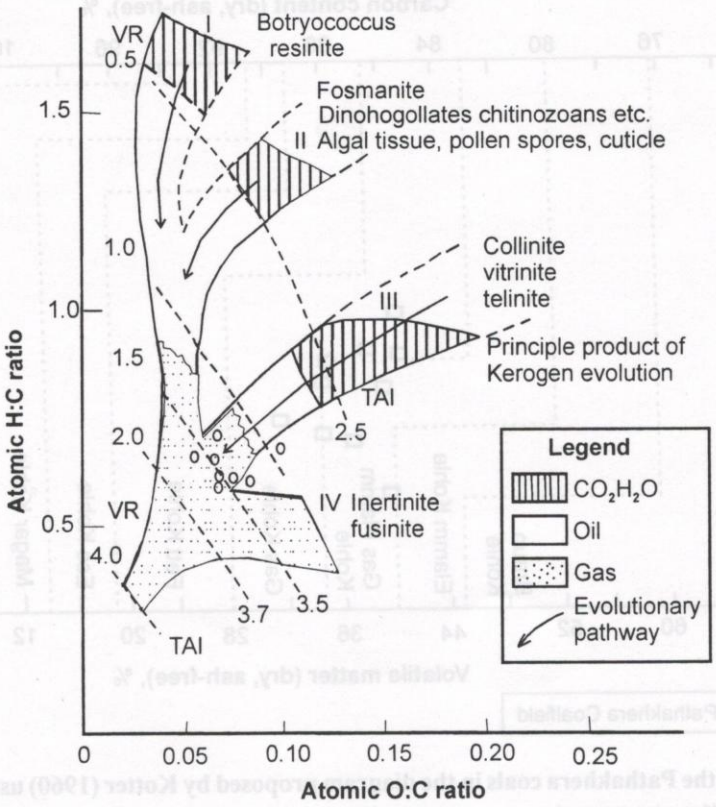

Fig. 7: Pathakhera coals on the diagram proposed by Jones and Edison (1978) showing thermal evolution pathways of four kerogen types and some of their microcomponents based on atomic H:C and O:C ratios

ACKNOWLEDGEMENTS

We thank Dr. M. P. Singh, Department of Geology, B. H. U., for his cooperation in this study. We also express our gratitude to the Head of Department of Geology, B. H. U., Varanasi, for providing laboratory facilities. Thanks are also due to Dr. H. S. Pareek, Ex-Deputy Director General, Geological Survey of India, Meerut, for the financial assistance.

REFERENCES

Brooks, J. D., 1970, The use of coals as indicators of the occurrence of oil and gas. Austral. Petrol. Explor. Ass. Jour., v. 10, pp. 35–50.

Jones, R. W. and Edison, T. A., 1978, SEPM, Publ. In: Petroleum Geology by F. K. North, Allen and Unwin, 607 p.

Kotter, K., 1960, Die mikroskopische Reflexionsmessung mit dem photomultiplier and ihre Anwendung auf die Kohlenuter–suchung-Brennst-Chemie. v. 41, pp. 263–272.

Mishra, H. K. and Cook, A. C., 1992, Petrology and thermal maturity of coals in the Jharia basins; implication for oil and gas origin, Int. Jour. coal Geology, v. 20, 277 p.

Teichmuller, M., 1974a, Enststchung and Veranderung bituminoser substazen in Kohlen in bezichung Zur Entsctchung and Umwandlung des Erdols. Forstschr, Geal, Rheinld, U. Westf. v. 24., pp. 65–112.

Teichmuller, M., 1974b, Uber new Macerale der Liptinite – Cruppe and die Entstchung des Micrinits – Forstsche. Geol. Rheinld. U. Westf. v. 24, pp. 37–64.

Teichmuller, M., 1979, Die diagenese der Kohligen substangen in den Gesteiman des Tertiars Und Mesozoikums des mittleren oberrhe in-Grabens-Fortschr. Geol. Rheinld, U. Westf. v. 27, pp. 19–49, Krefeld.