Comments on Maturation of Coals

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Introduction

Traditionally coals (peat, lignite, bituminous and anthracite) are regarded as humic and a Type III kerogen (Hunt, 1996; Tissot and Welte, 1984; Stach et al. 1982; Van Krevelen, 1961). Over 80% of the world's coals are humic, and the vitrinite composes more than 70% of their macerals. Humic coals are the product of peat formation, mainly land plant material deposited in swamps in the presence of oxygen (Hunt, 1996). As the peat is buried progressively deeper, it changes with time and temperature to lignite, bituminous coal, and anthracite. Thus, from the traditional point of view lignite is a humic coal.
Our investigation indicates that coals are not humic in a true sense, but that they attain humic character during the course of their burial and maturation history. The purpose of this paper is to find the probable underlying reasons for this phenomenon. Location map of the study area is given in Figure 1.

Panandhro Lignites and Carbonaceous Shales

Results of the Rock-eval pyrolysis of samples taken form the Panandhro mine (Figure 2) are given in Table 1, and their plot to illustrate the kerogen type is given in Figure 3. A qualitative, transmitted-light, thin-section study was conducted in order to investigate the maceral content of these lignites and carbonaceous shales (Figure 2).

Plot of hydrogen index vs. Tmax diagram indicates that only three samples, all from carbonaceous shale, were found to contain Type III kerogen organic matter, which has potential to generate gas and condensate (Table 1, Figure 3). The remaining samples of lignites and carbonaceous shale were found to contain Type II kerogen organic matter, which has potential to generate both oil and gas (Figure 3). Petrographic study of the lignites indicates relatively higher amounts of resinite maceral of the liptinite group, along with the other macerals of the vitrinite and the inertinite groups. Earlier studies have also reported higher resinite macerals (up to 19%) in their samples (Singh and Singh, 2005). Based on this evidence, together with the classification of organic matter by Tissot and Welte (1984) and the the maturation of organic matter proposed by Hunt (1996), it is thought that lignites, in general, are sapropelic rather than humic.

Why Some Coals Are Not Humic

Over 80% of the world's coals are of bituminous to sub-bituminous type, Paleozoic to Mesozoic in age; therefore, the conclusion that coal is humic is based in large measure on analyses of coals of these ages. However, earlier studies did not take into account the fact that bituminous coal passes through the stages of peat and lignite before reaching their bituminous stage. Biogenic and thermogenic processes release hydrogen during maturation of organic matter due to the temperature and time effect (Hunt, 1996).

Van Krevelen (1961) studied the coalification tracks of different macerals based on H/C and O/C ratios. He found that after a certain time interval liptinite and vitrinite macerals follow the path of inertinite. This evidence indicates that liptinite macerals with higher atomic H/C ratio during peat formation alter thermally and biogenically during the later stages of lignite formation, as well as development of bituminous coal and anthracite. This is also supported by the higher reactivity of Type II kerogen in comparison to Type III kerogen (Hunt, 1996). Therefore, during the thermal history of organic matter, Type II kerogen will be the first to react, with consequent decrease in their hydrogen content. Thus, anthracite has the lowest H/C ratio and highest reflectivity due to the increased aromatization of its structure. Consequently, it is difficult to study the individual macerals of anthracite under the microscope.

Sahay (2006) studied sixteen samples of sub-bituminous to bituminous coal of Early Permian age, in terms of their atomic H/C ratio, in order to investigate the kerogen type. He found all samples were of the Type III kerogen. The important aspect, however, is that Type III kerogen represents the present type of organic matter. It does not quantify the original amount and type of organic matter present during the peat stage. The results of that study indicate that the original amount of the organic matter of these sub-bituminous to bituminous coals may have been higher during the peat stage. Comparing this evidence with the characteristics of Paleocene-Eocene lignite samples of the Panandhro mine indicates that coals are not originally humic, but that they attain humic character during the course of their maturation history, with the removal of the hydrogen content by biogenic and the thermogenic processes. Based on the previous work by the referenced workers and the results of this study, a revised classification of organic material in coal is given in Table 2.

Conclusion

This study suggests that coals are probably not humic throughout their history of development--that they attain humic character during their maturation history.

Acknowledgments

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References

Espitalie, J., Laporte, J. L., Madec, M., Marquis, F., Leplat, P., Paulet, J., and Boutefeu, A., 1977, Methode Rapide de Characterisation des Roches Meres de leur Potentiel Petrolier et de leur Degre d'Evolution: Revue de L'Insitut Francais du Pétrole, v. 32**,** p. 3–42.

Hunt, J.M., 1996, Petroleum Geochemistry and Geology: W.H. Freeman and Company, New York, 743 p.

Sahay, V.K., 2006, Determination of GCV equivalence value from carbon, hydrogen of coal with a note on present Coal Bed Methane generation potential of Wardha valley coalfields, Vidarbha region, Maharashtra: Journal of the Geological Association and Research Centre, v. 14, p. 50-52.

Saraswati, P.K., and Banerjee, R.K., 1984, Lithostratigraphic classification of the Tertiary sequence of northwestern Kutch: Proceedings X, Indian Colloquium on Micropaleontology and Stratigraphy, p. 369-376.

Singh, A., and Singh, B.D., 2005, Petrology of Panandhro lignite deposit, Gujarat, in relation to palaeodepositional condition: Journal of Geological Society of India, v. 66, p. 334-344.

Stach, E., Mackowesky, M., Teichmuller, M., Taylor, G.H., Chandra, D., and Teichmuller, R., 1982, Stach's Textbook of Coal Petrology: Gebruder Borntraeger, Berlin, 3rd edition, 535 p.

Tissot, B., and Welte, D.N., 1984, Petroleum Formation and Occurrence, 2nd edition: Springer Verlag, Heidelberg, 699 p.

Van Krevelen, D.W., 1961, Coal: typology-chemistry-physics-constitution: Elsevier Science, Amsterdam, 514 p.

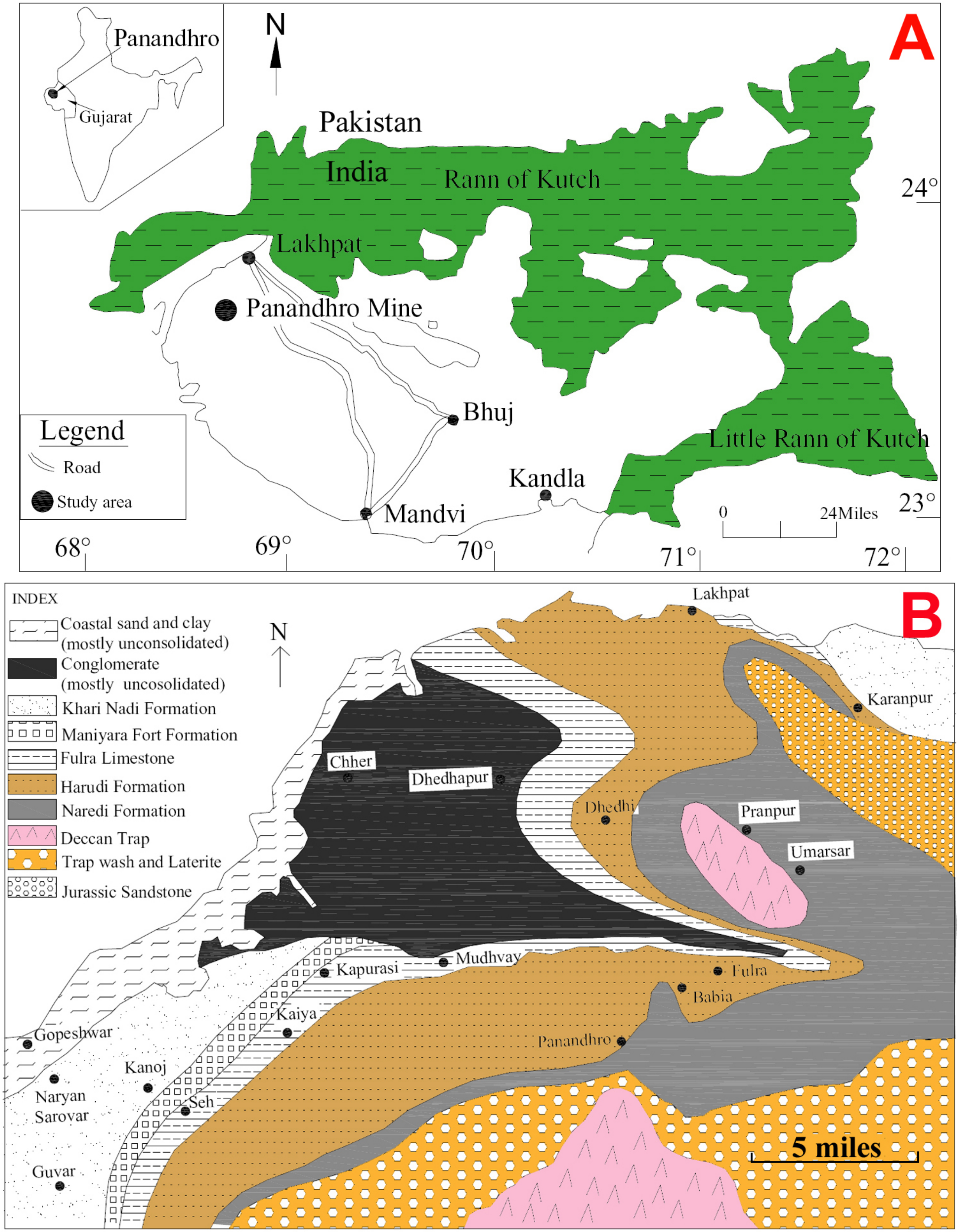

Figure 1. A. Location map of Panandhro lignite mine in the Kutch basin of western India (after Singh and Singh, 2005). Rann and Little Rann are mud and salt flats. B. Geological map of northwestern part of Kutch basin, showing location of Panandhro (after Saraswati and Banerji, 1984).

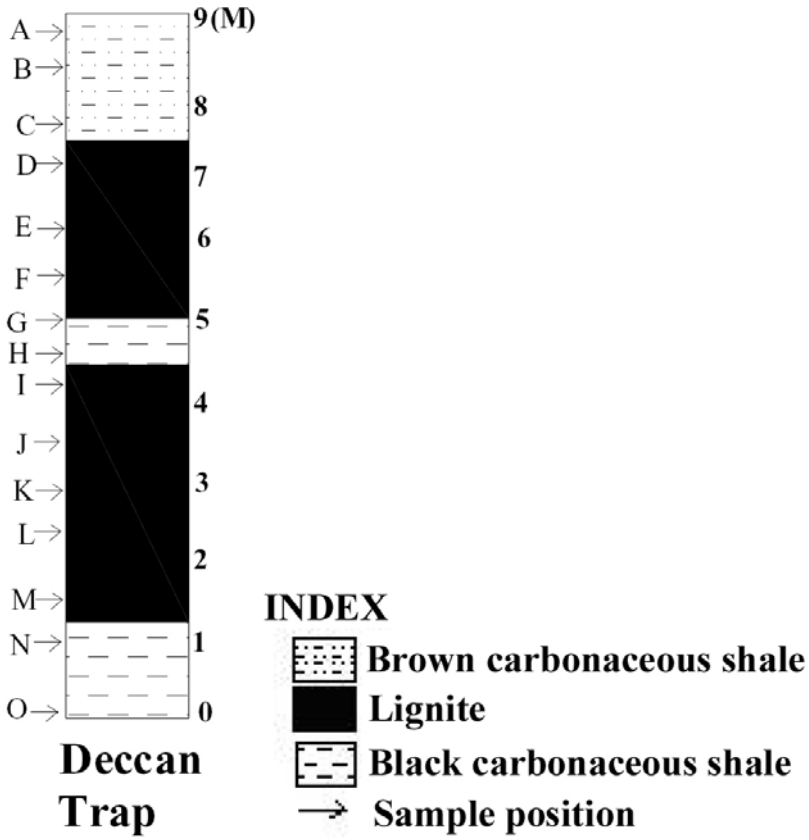

Figure 2. Lithologic section at the Panandhro mine.

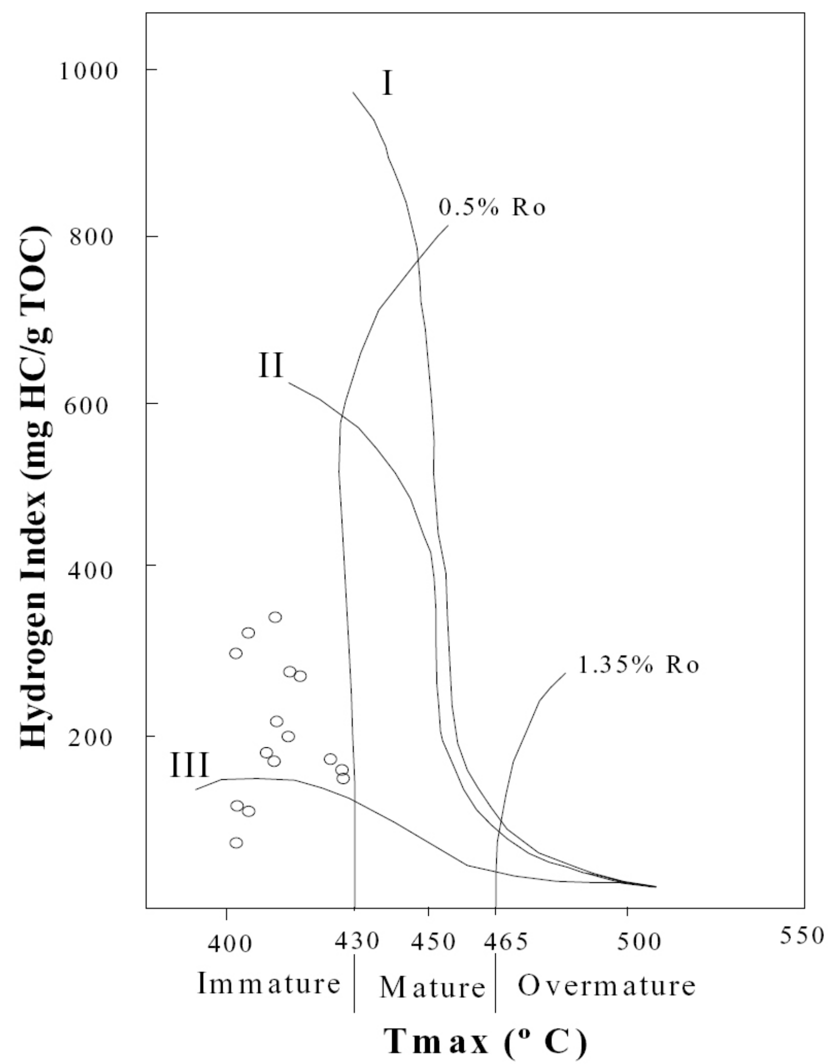

Figure 3. Kerogen types in lignites and carbonaceous shales from Panandhro (after Espitalie et al., 1977).

Lithology	Sample No.	Depth (m)	TOC %	S1 (mg/g rock)	S2 (mg/g rock)	PI= S1/(S1+S2)	HI (mg /g TOC)	Tmax cor. (°C)
Carb. Shale	A	9	9.17	0.35	12.66	0.03	138	428
	B	8.4	10.42	0.43	15.66	0.03	150	429
	C	7.9	11.78	0.54	19.47	0.03	165	429
Lignite	D	7.4	55.73	8.53	146.56	0.05	263	417
	E	6.7	54.19	6.81	108.17	0.06	200	415
	F	5.9	53.71	6.04	105.75	0.05	197	417
Carb. Shale	G	5.1	20.01	4.56	60.57	0.07	303	409
	H	4.8	13.29	1.84	15.77	0.10	119	407
Lignite	I	4.5	53.83	14.21	160.40	0.08	298	411
	J	3.8	48.60	5.18	82.13	0.06	169	415
	K	3.1	57.90	13.86	190.87	0.07	330	415
	L	2.4	35.25	4.90	61.95	0.07	176	415
	M	1.7	44.80	8.03	115.99	0.06	259	418
Carb. Shale	N	1.0	19.64	1.96	20.97	0.09	107	411
	O	0.5	20.46	1.78	16.08	0.10	79	405

Table 1. Results of Rock-eval pyrolysis of Panandhro lignites and carbonaceous shales.

Maturation	Rank	Microscopic and Chemical Parameters, Kerogen Type and Coal Type			
		Vitrinite Reflectance	H/C	Kerogen type	Coal type
Diagenesis	Peat	0.2	1.5	II	Sapropelic
	Lignite	0.3	1.4	II	Sapropelic
	Sub-bituminous	0.4 0.5	1.3	II	Sapropelic
Catagenesis	High volatile bituminous		1.1	II	Sapropelic
	Medium volatile bituminous	1.0	0.85	III	Humic
	Low volatile bituminous	1.5	0.7	III	Humic
	Semi-anthracite	2.0	0.5	III	Humic
Metagenesis	Anthracite	2.5	0.38	IV	Humic
	Meta-anthracite	4.0 5.0	0.25	IV	Humic

Table 2. Revised classification of organic matter in coal.