Geol. Soc. Malaysia, Bulletin 32, November 1992; pp. 155 – 164

An organic petrological and organic geochemical study of North Sea Middle Jurassic Brent coals and coaly sediments

ABDULLAH W.H.
Department of Geology,
University of Malaya,
59100 Kuala Lumpur.

INTRODUCTION

The possibility of coal and coaly sediments acting as oil source rocks, in addition to an important source of gas, has in the past ten years been widely discussed by authors such as Durand and Paratte (1983), Bertrand (1984), Thompson *et al.* (1985), Saxby and Shibaoka (1986), Khorasani (1987), Horsfield *et al.* (1988), Bertrand (1989) and Hunt (1991). In the North Sea area, the Middle Jurassic coaly sequences, in particular coals from the Ness Formation of the Brent Group, have been identified to have the potential to generate commercial quantities of petroleum (e.g. Oudin, 1976; Heritier *et al.*, 1980; Thomas *et al.*, 1985).

In this study four coal samples from the Ness Formation and two organic-rich sediments (a carbonaceous shale and a carbargilite) from the Tarbert Formation have been examined by means of organic petrological and organic geochemical methods. These samples were obtained from a single North Sea borehole. The shallowest and the deepest samples studied are approximately 200 m apart in depth. Figure 1 shows the lithostratigraphy of the Middle Jurassic Group penetrated by the borehole.

EXPERIMENTAL

Petrology

Crushed core chips were mounted in a slow-setting resin and polished. Microscopical examination was carried out principally under oil immersion. Maceral compositions of the coals were obtained by fixed-interval point counting in two stages; firstly, in reflected, plane-polarised light and, secondly, in "blue-light" excitation, using an exciter filter at 530 nm, to determine the proportion of fluorescing liptinitic macerals in the samples. Reflectance measurements on vitrinite were carried out in plane-polarised, reflected light using a 2 μm aperture on the photometer to restrict the measurement field.

Geochemistry

Approximately 10 g of powdered coal samples were Soxhlet extracted for 72 hours using dichloromethane/methanol (93:7). The coal extracts were

Paper presented at GSM Petroleum Geology Seminar 1991

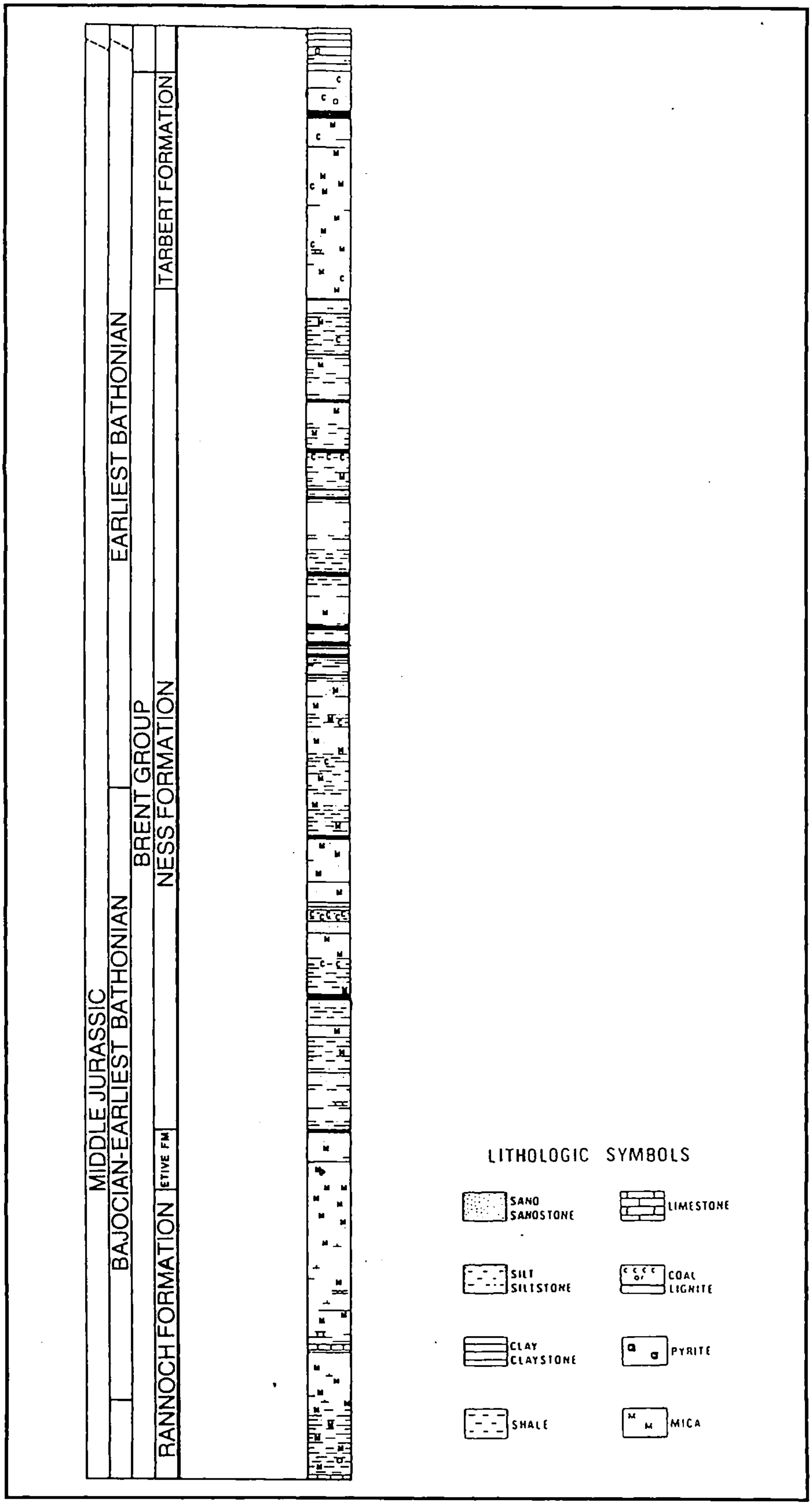

Figure 1: The lithostratigraphy of the Middle Jurassic Brent Group.

separated into three subfractions: aliphatic hydrocarbons, aromatic hydrocarbons and polar compounds using column chromatography. The saturated fractions were analysed by a gas chromatograph fitted with a 30 m, 0.2 mm i.d. fused silica DB-1 column connected to a flame ionazation detector.

Approximately 5 mg of crushed coals were analysed by Rock-Eval pyrolysis (method described by Espitalie *et al.*, 1977). The total organic carbon (TOC) content of the samples were determined using a LECO instrument.

RESULTS AND DISCUSSIONS

Coal Rank

The measured vitrinite reflectance values of the five investigated coal samples are given in Table 1.

The organic-rich shale and the carbargilite samples possess the lowest vitrinite reflectance displaying mean values of 0.57%Ro and 0.56%Ro, respectively, and have the lemon-yellow alginite fluorescence colour characteristic for this rank of coal (Figs. 3 and 4). Sporinite fluoresces yellow to yellow-orange (Fig. 5). A distinct odd over even predominance of higher molecular weight n-alkanes, particularly in the shale sample, producing a CPI value of 1.3 (Table 2; Fig. 6a), supports the suggested early maturity of this sample.

Coal samples from the Ness Formation are of relatively higher maturity, as suggested by vitrinite reflectance analysis, compared to samples from the Tarbert Formation. As expected, a gradual increase in maturity with depth is displayed.

Tmax values agree reasonably well with vitrinite reflectance data as indicated by Tmax value of between 435°C and 441°C, typical of early maturity.

Depositional Environment

The Brent Group is regarded as the product of a wave-dominated delta which is analogous to the present Niger Delta (Budding and Iglin, 1981). The total organic carbon content of all the samples studied reflects the difference in their lithology. For example, high TOC values for the coals, an intermediate value for the sample consisting of a mixture of coal and carbargilite, and a lower value for the shale.

The coals of the Ness Formation are considered to have developed in a peat-swamp type environment. A wide range of organic lithotypes are present, indicating changing depositional conditions within the coal swamps. In support, the pristane/phytane ratio (Pr/Ph) of these coals varies from a fairly low 2.6 to a fairly high 7.8 (Table 2). The maceral analysis of the coals and the coaly sediments is shown in Table 1. Figure 7 shows the maceral group composition for the samples. Coals of the Ness Formation are generally very rich in vitrinitic and/or inertinitic components, with moderate occurrence of liptinitic materials and generally low occurrence of clay minerals. Some samples contain minor

Table 1: Vitrinite reflectances and maceral analysis of the Brent coals and coaly sediments.

				Maceral Analysis (I – IV: Kerogen Type)				
				I	II	III	IV	
Fm.	Sample	Lithology	%Ro	Alginite	Other Liptinite	Vitrinite	Inertinite	Mineral Matter
TARBERT	T1	Shale	0.57	8	21	Tr	11	60
	T2	Carbargilite	0.56	4	18	18	22	38
NESS	N1	Coal	0.65	0	7	70	22	1
	N2	Mixed litho. coal + car-bargilite	0.68	2	15	30	33	20
	N3	Coal	0.69	2	9	11	74	4
	N4	Coal	0.70	0	10	32	55	3

Table 2: Organic geochemical data

Fm.	Sample	Saturated hydrocarbon				TOC & Rock–eval		
		n-alkane maxima	CPI $nC_{25}–nC_{31}$	Pr/Ph	nC_{25}/nC_{17}	TOC	HI	Tmax
TARBERT	T1	C_{25}	1.3	3.8	1.8	11.3	303	441
	T2	C_{15}	1.1	3.2	0.3	N.D.	N.D.	N.D.
NESS	N1	C_{19}	1.0	3.8	0.8	77.6	228	438
	N2	C_{17}&C_{25}	1.3	7.8	2.5	59.3	323	435
	N3	C_{17}	1.0	2.6	0.5	72.0	188	439
	N4	C_{17}	1.0	5.9	1.0	75.8	255	438

Abbreviations

%Ro : Percent mean reflectance of vitrinite in oil (random reflectivity)
Tr : Trace
N.D. : Not determined
CPI : Carbon preference index (after Bray and Evans, 1961)
Pr/Ph : Pristane/phytane
TOC : Total organic carbon (% wt)
HI : Hydrogen index (mgHc/g TOC)
Tmax : Temperature at which thermal cracking is greatest (°C)

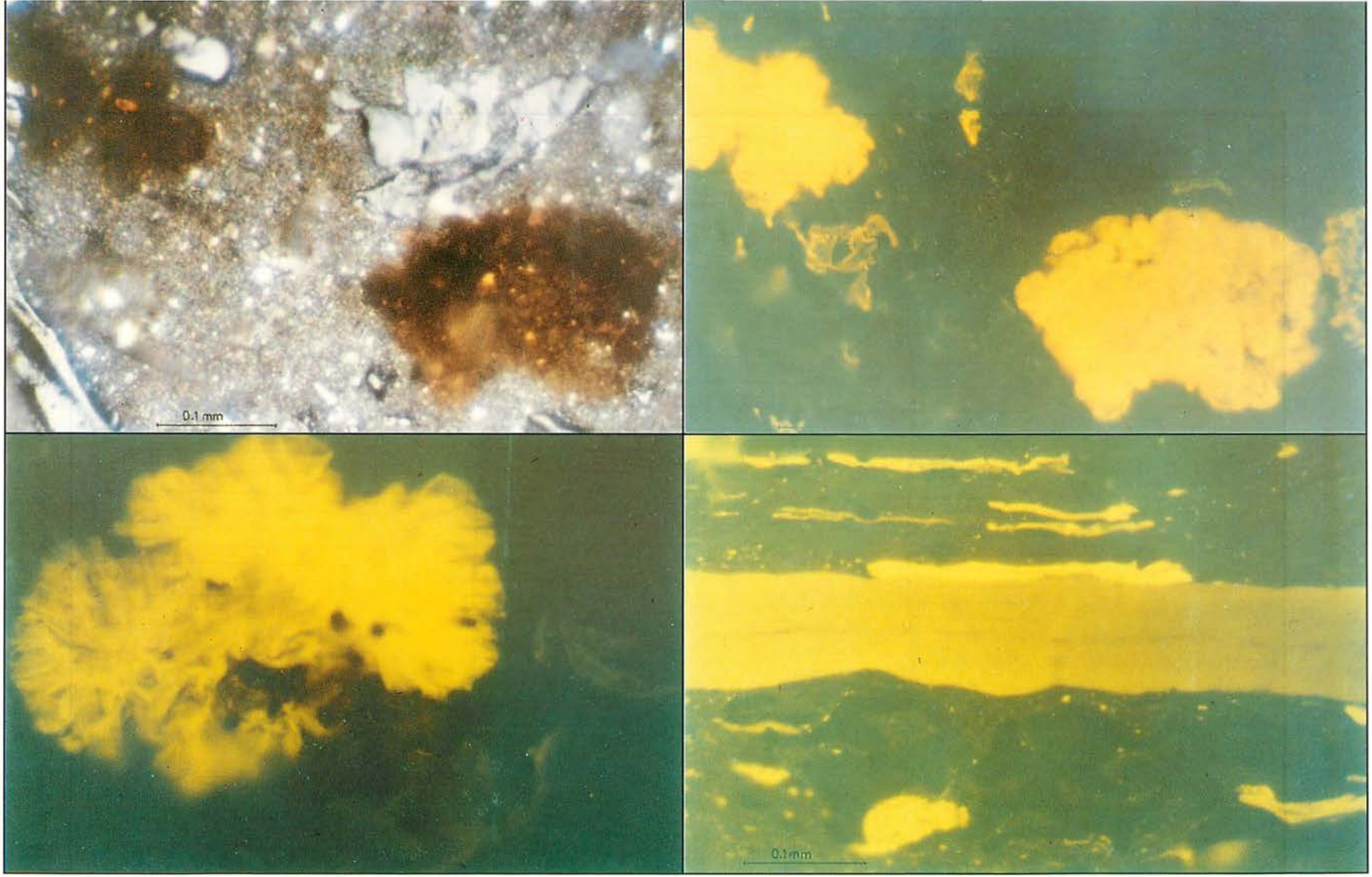

Figure 2: Two algae colonies of *Botryococcus* sp. and inertinitic particles in shale sample (T1).
Figure 3: Photomicrograph of same view as Figure 2 showing the fluorescence of the alginite macerals.
Figure 4: Radial gelatinous bodies of a *Botryococcus*-type algal colony in the shale sample (T1).
Figure 5: Microspores and part of a megaspore in the carbargilite sample (T2).
All photomicrographs are taken under reflected light. Figure 2 is taken using white light, Figures 3, 4 and 5 taken using u.v. light.

0.1 mm

a
b
c

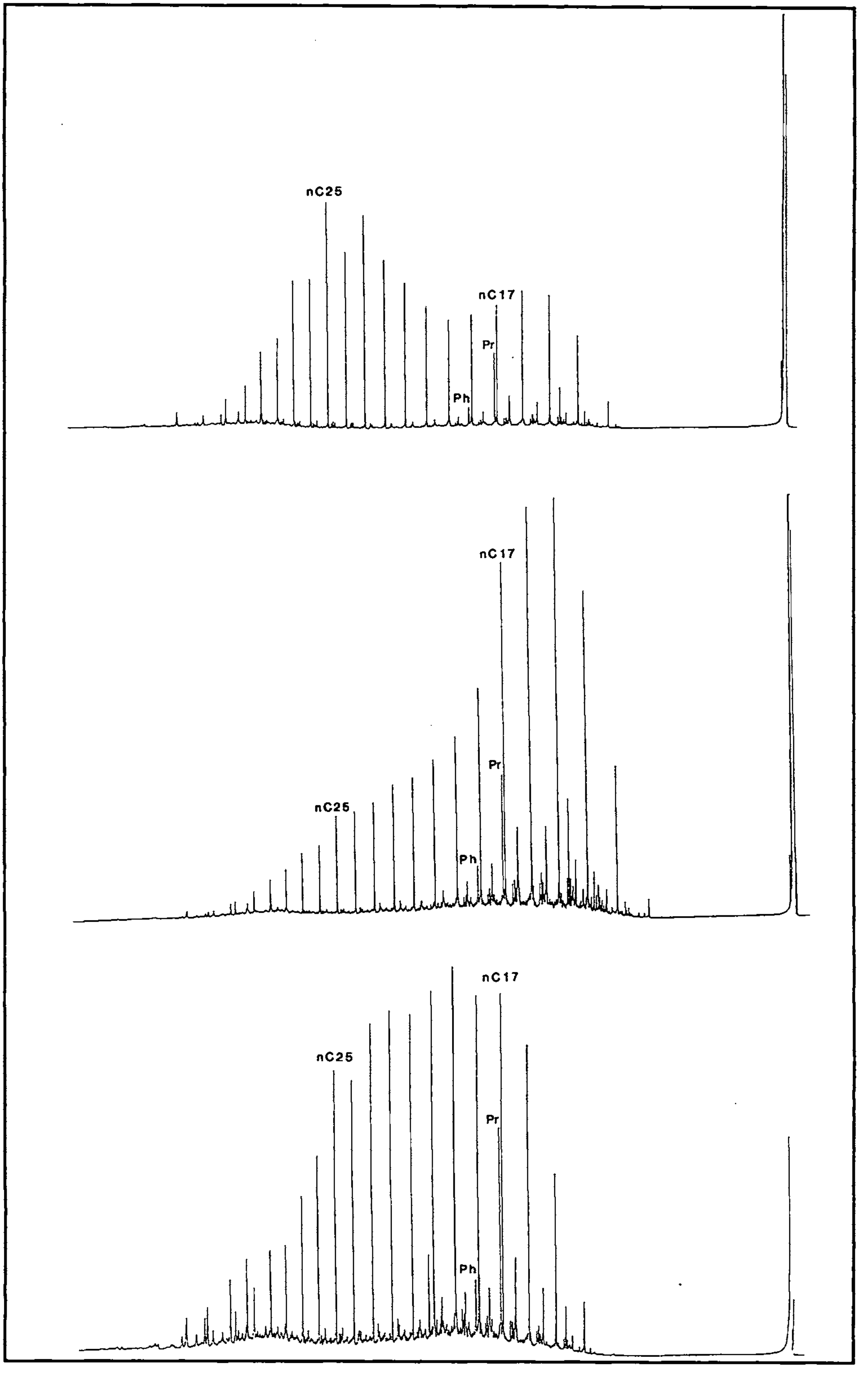

Figure 6a–c: The saturated gas chromatograms of the Brent coals and coaly sediments. a) T1 : Shale; b) T2 : carbargilite; and c) N1 : coal.

d

e

f

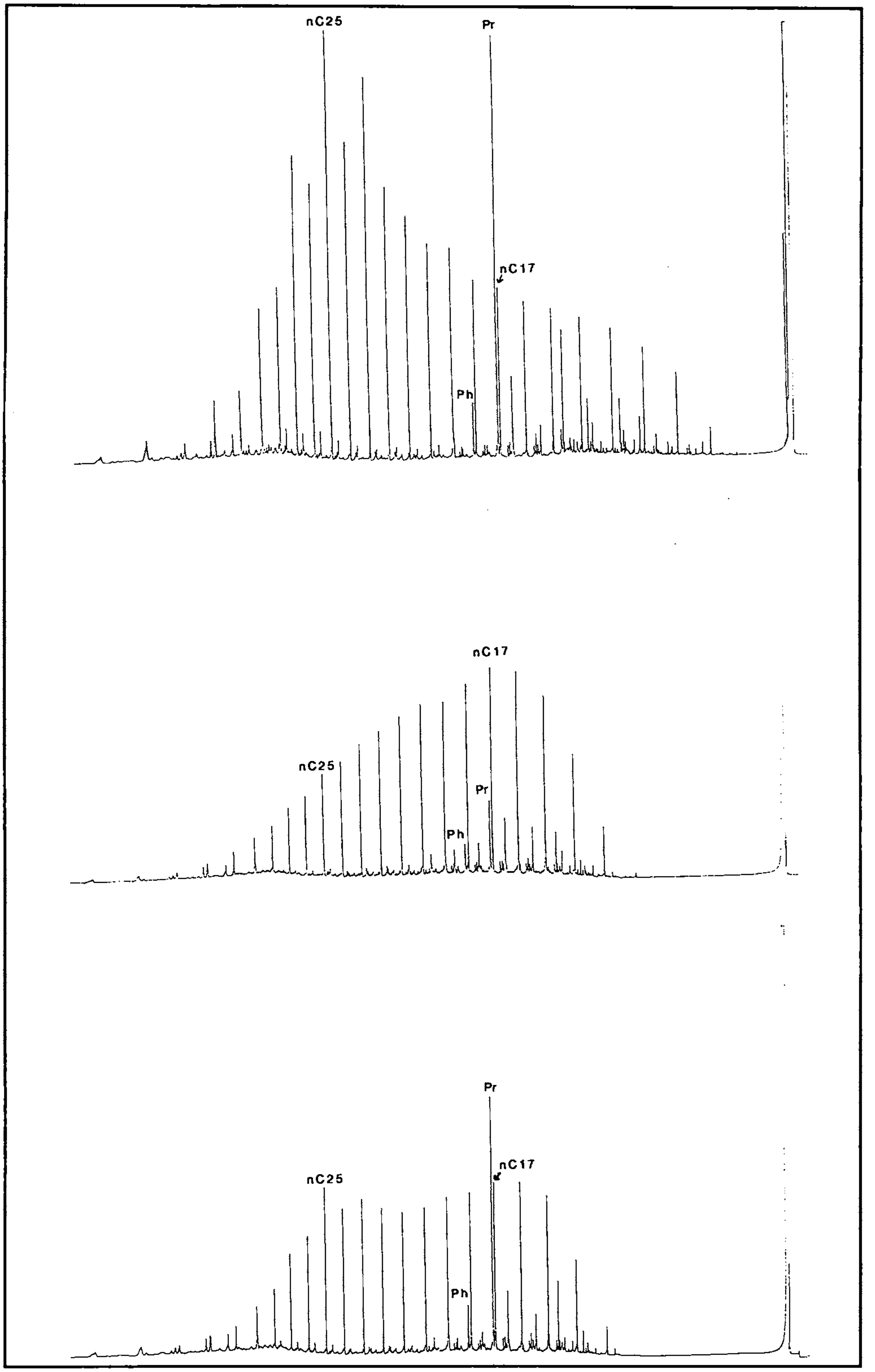

Figure 6d–f: The saturated gas chromatograms of the Brent coals and coaly sediments. d) N2 : mixed lithology of coal and carbargilite; e) N3 : coal; and f) N4 : coal.

alginite and are generally lacking in banded texture, suggesting the coals are of detrital hypautochthonous origin.

The shale and the carbargilite samples of the Tarbert Formation contain significant amount of inertinite and liptinite. Vitrinite is very common in the carbargilite sample but occurs only in trace amount in the shale sample. The occurrence of reasonably well-preserved *Botryococcus*-type alginite (Figs. 2, 3 and 4) in the shale and carbargilite suggest a lacustrine depositional environment for these samples. In support, the saturate gas chromatogram fingerprint (Fig. 6) of the carbargilite sample is dominated by low molecular weight n-alkanes, although the shale sample shows a bimodal n-alkane distribution. The Pr/Ph ratio of these samples is relatively low with values of less than 4.0 being displayed suggesting that they have been deposited under less oxidising conditions than the peat-swamp coals of the Ness Formation. The shale sample has a very high TOC content of 11.3%, supporting the less oxidising condition of deposition, typical of a lacustrine depositional environment.

Oil-Generating Potential

The oil-generative potential of a source rock is directly related to its content of hydrogen-rich organic matter (which is often quantified by hydrogen indices, HI). Thus, the accumulation of hydrogen-rich liptinitic material, e.g. algae, spores, cuticles and resins, which are common constituent of coals, will consequently lead to a sediment of high hydrocarbon generating potential. However, the maceral composition cannot be related easily to the chemical properties of the organic matter because it is only one aspect of the microfacies. In the samples analysed, hydrogen indices vary between 188 mgHc/gTOC to 323 mgHc/gTOC. These are within a similar range as those reported by Bertrand (1989) for a group of Jurassic coals from the North Sea.

Samples with high liptinite content, T1, T2 and N2 (see Table 1) possess among the highest HI values of greater than 300 mgHc/gTOC (see Table 2; HI value for T2 was not determined). The shale sample (T1) with a very high TOC content of 11.3%, is considered to have a good oil-generating potential, particularly as the sample contains predominantly a mixture of type Iand II kerogen. It is interesting to note that those samples which contain greater amounts of "waxy" kerogen materials (measured by nC_{25}/nC_{17} ratio of extracts) have relatively high HI values (see Table 2). Sample N3, with a kerogen composition of predominantly inertinite, has the lowest HI value and possesses among the lowest nC_{25}/nC_{17} ratio among the samples analysed.

In the Southeast Asia region, such as the Mahakam delta, Kalimantan and the Ardjuna Basin, NW Java, coals that have been regarded to have contributed to the generation of liquid hydrocarbons in these areas possess HI values in the range of 150 mgHc/gTOC to 350 mgHc/gTOC (Thompson *et al.*, 1985; Horsfield *et al.*, 1988). Thus, by comparison to these Southeast Asian coals, the data presented above suggests the Brent coals and coaly sediments possess reasonably good oil-generating potential.

CONCLUSION

The results from this investigation of the Brent coals and coaly sediments from the North Sea indicate that the coaly sediments of the Tarbert Formation were deposited under freshwater lacustrine conditions, while the Brent coals of the Ness Formation, being richer in vitrinite and inertinite, are considered to have been deposited in peat-swamps or flood plain deposits.

The Ness Formation coals and the Tarbert Formation coaly sediments are generally early mature and possess fairly high HI values for samples consisting predominantly of type III and IV kerogen. Significant amounts of liptinitic kerogen are present in most of these samples. A reasonably good oil-generating potential can be expected from these coals and coaly sediments.

ACKNOWLEDGEMENT

The author wishes to acknowledge the assistance of Norsk Hydro, Bergen who supplied the core material for this study and the University of Malaya, Kuala Lumpur for the financial support.

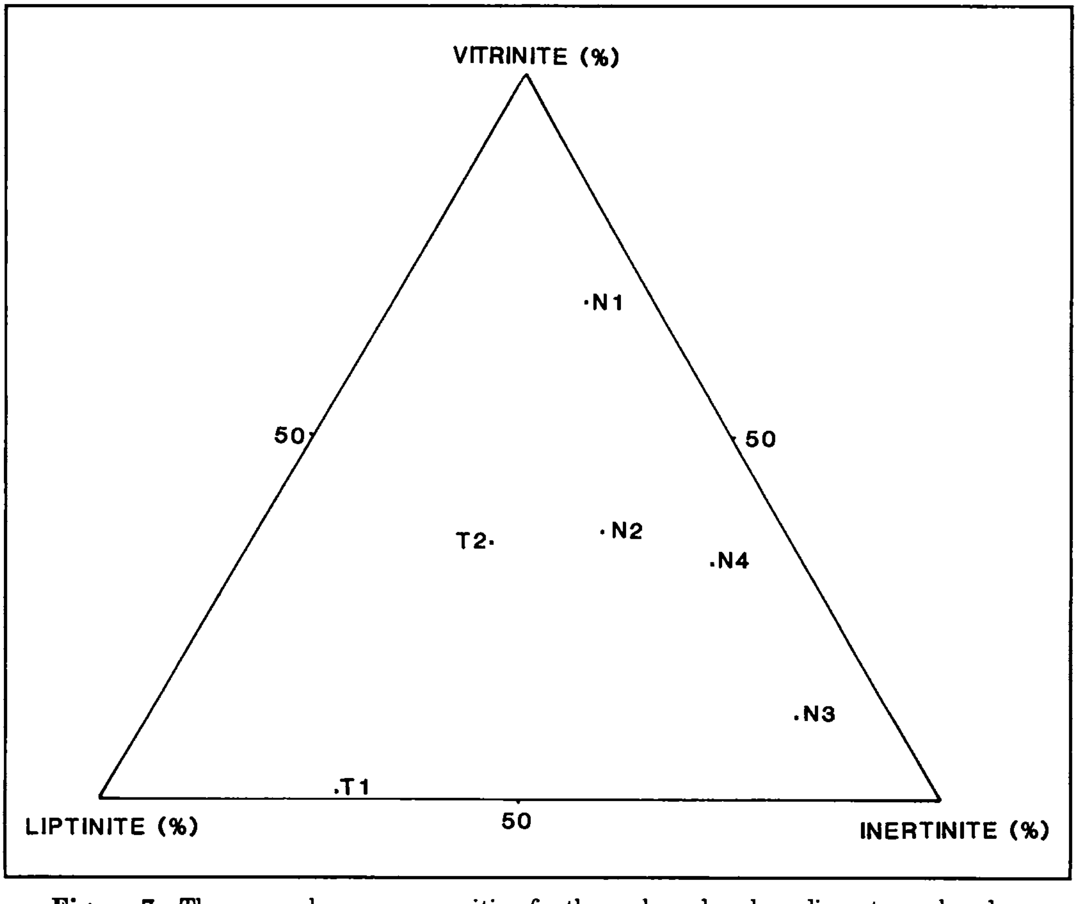

Figure 7: The maceral group composition for the coals and coaly sediments analysed.

REFERENCES

BERTRAND, P., 1984. Geochemical and petrographic characterization of humic coals considered as possible oil source rocks. *In : Advances in Organic Geochemistry 1983* (Edited by Schenck, P.A., de Leeuw, J.W. and Lijmbach, G.W.M.), 481-488.

BERTRAND, P.,1989. Microfacies and petroleum properties of coals as revealed by a study of North Sea Jurassic coals. *In: Int. J. Coal Geology,* **13**, No.1-4 Special Issue, 575-595. Elsevier. Amsterdam.

BRAY, E.E. AND EVANS, E.D., 1961. Distribution of n-paraffins as a clue to recognition of source beds. *Geochim. Cosmochim Acta* **22**, 2-15.

BUDDING, M.C. AND IGLIN, H.F., 1981. A reservoir geological model of the Brent sands in Southern Cormorant. In *Petroleum Geology of the Continental Shelf of NW Europe* (Edited by Illing, L.V. and Hobson, G.D.), Ch. 29. London.

DURAND, B. AND PARATTE, M., 1983. Oil potential of coals. *In: Petroleum Geochemistry and Exploration of Europe* (Edited by Brooks, J.), 285-292. Blackwell Scientific Publication, Oxford.

ESPITALIE, J., MADEC, M. AND TISSOT,B., MENNIG, J.J. AND LEPLAT, P., 1977. Source rock characterization methods for petroleum exploration. *9th Annual Offshore Technology Conference*, 439-444. Houston.

HERITIER, F. E., LOSSEL, P. AND WATHNE, E., 1980. Frigg Field – large submarine-fan trap in Lower Eocene rocks of the Viking Graben, North Sea. *In: Giant Oil and Gas Fields of the Decade 1968-1978* (Edited by Halbouty, M.T.). *AAPG Memoir*, **30**, 59-79.

HORSFIELD, B., YORDY, K.L. AND CRELLING, J.C., 1988. Determining the petroleum-generating potential of coal using organic geochemistry and organic petrology. *In: Advances in Organic Geochemistry 1987* (Edited by Mattavelli, L. and Novelli, L.), 121-129. Pergamon Press.

HUNT, J.M., 1991. Generation of gas and oil from coal and other terrestrial organic matter. *Organic Geochemistry*, **17**, No.6, 673-680. Pergamon Press. Oxford.

KHORASANI, G.K., 1987. Oil-prone coals of the Walloon Coal Measures, Surat Basin, Australia. *In: coal and coal-bearing strata: Recent Advances* (Edited by Scott, A.C.) *Geological Society Special Publication* No **32**, 303-310.

OUDIN, J., 1976. Geochemical study of the North Sea basin. *Bull. Cent. Rech. Pau* **10**, 339-358.

SAXBY, J.D. AND SHIBAOKA, M., 1986. Coal and coal macerals as source rocks for oil and gas. *Appl. Geochem.* **1**, 25-36.

THOMAS, B.M., MOLLER-PEDERSEN, P., WHITAKER, M.F. AND SHAW, N.D. , 1985. Organic facies and hydrocarbon distributions in the Norwegian North Sea. *In: Petroleum Geochemistry in Exploration of the Norwegian Shelf* (Edited by Thomas, B.M., *et al.*) 3-26. Norwegian Petroleum Society. Graham and Trotman, London.

THOMPSON, S., COOPER, B.S., MORLEY, R.J. AND BARNARD, P.C., 1985. Oil-generating coals. *In: Petroleum Geochemistry in Exploration of the Norwegian Shelf* (Edited by Thomas, B. *et al.*), 59-73. Graham and Trotman, London.

Manuscript received 9th October 1992