GENERATION AND MATURATION OF HYDROCARBONS IN CEPU AREA, CENTRAL JAVA

by

B. Situmorang *

Ludin Tambunan **

ABSTRACT

Production from the Cepu area occurs from the Tuban and Kawengan Formations. Studies of organic richness and thermal maturity of thirty eight conventional core samples from four wells penetrating the units by use of Rock-eval pyrolysis method reveal that a high total organic content ($\geq 0.50\%$) occurs in part of the Tuban Formation whereas a low total organic content ($0.17 \pm 0.07\%$) is observed in the Kawengan Formation. Thermal maturity range is immature to mature with T-max ranging from 339°C to 435°C with the mature stage being confined to the Tuban Formation. The main kerogen type is structured kerogen (type III), with limited occurrence of unstructured kerogen (type II).

Those results suggest that generation of gas occurred probably in the Tuban Formation, vertically migrated and trapped at relatively shallow depths. It also implies that the more mature source-beds with marine kerogen could be found in the deeper sedimentary section.

I. INTRODUCTION

Despite the long history of exploration for petroleum hydrocarbons in the onshore portion of the Northeast Java basin, only recently that organic geochemical studies form part of an exploration campaign in that area. With this condition, our under - standing on the prospectiveness of the basin is greatly improved and further exploration activities can be carried out in a more effective way.

Basically, organic geochemical study is concerned with identification of two main parameters, i.e. the organic richness of the sediments, and the degree of thermal maturity by which the organic materials could have been changed into petroleum hydrocarbons. Apart from that, additional parameters such as potential hydrocarbon yield and kerogen type are also required, so that the extent of hydrocarbon generative areas can be better be delineated and the type of any hydrocarbon that may be generated can be predicted. It should be emphasized that all those information have to be integrated with geological and geophysical data so that the hydrocarbon potential of the area can be more precisely determined.

In the following account, we present the preliminary results of organic geochemical studies of thirty eight conventional core samples from the Kawengan oil field in Cepu area, Central Java. The cores represent the Mio-Pliocene Tuban and Kawengan Formations, which is penetrated by Kw-90, Kw-95, Kw-103 and Kw-107 wells, and recovered from the following depths :

Kw-90 : two cores of the Kawengan Formation from the depth of 661.5 to 667.5 m and fourteen cores of the Tuban Formation covering the depth of 1450 to 2169 m.

Kw-95 : fifteen core of the Kawengan Formation from the depth of 730 to 756 m and four cores of the Tuban Formation covering the depth interval of 803 to 822.5 m.

* Geological Research Group, PPPTMGB "Lemigas"

** Geochemical and Geothermal Research Group, PPPTMGB "Lemigas"

Kw-103 : two cores of the Kawengan Formation (801 - 803 m)

Kw-107 : one core of the Tuban Formation (871 - 877 m).

Although we have been able to recognize potential source rocks, however, further geochemical studies are still needed in order to clarify the remaining potential of the area, especially in an effort to locate possible subtle traps.

II. GEOLOGIC SETTING

The location of the Cepu area and its principal producing oil fields is shown on the outline map presented in Fig. 1. Detailed stratigraphy and sedimentation history as well as structural and tectonic framework of the area have been published elsewhere, therefore, it will not be throughly discussed in this article.

The Cepu area is located in the southwestern portion of the Northeast Java basin. Since the end of the last century, various geological works have been carried out in this area which resulted in the discovery of several oil fields, the largest one being the Kawengan oil field which was discovered in 1894. The WNW-ESE trending Kawengan structure consists of several culminations and is built up by a large and narrow range of hills consisting mostly of glauconitic calcarenites with highly fossiliferous marls intercalated by glauconitic calcarenites layers cropping out on the culminations. The NE flank is dipping 15 - 25^{o}, occasionally steeper (30 - 45^{o}) in some places, whereas the SW flank is very steep or even overturned (Lemigas & BEICIP, 1969). The structure is also cut by several transverse faults.

Subsurface data clearly indicate that the Kawengan structure is an asymmetric upthrust anticline with the NE block being displace southwards (Fig. 2). It is also apparent that the axis of the anticline in

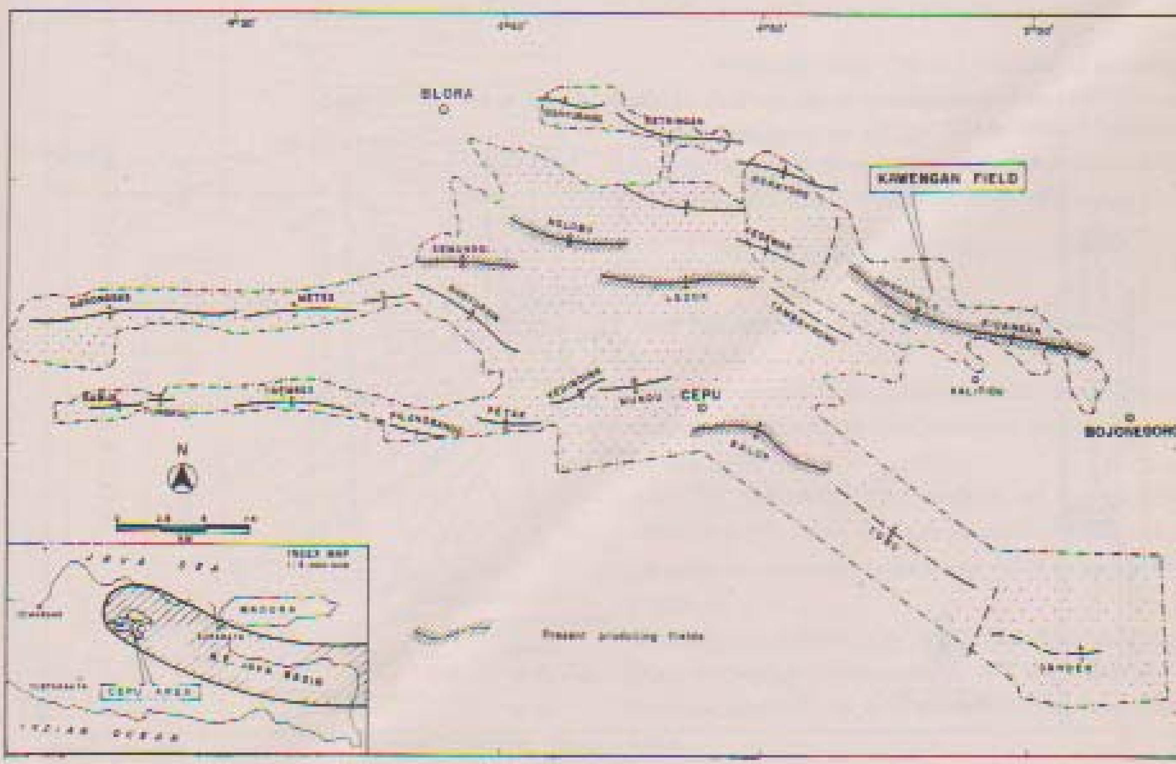
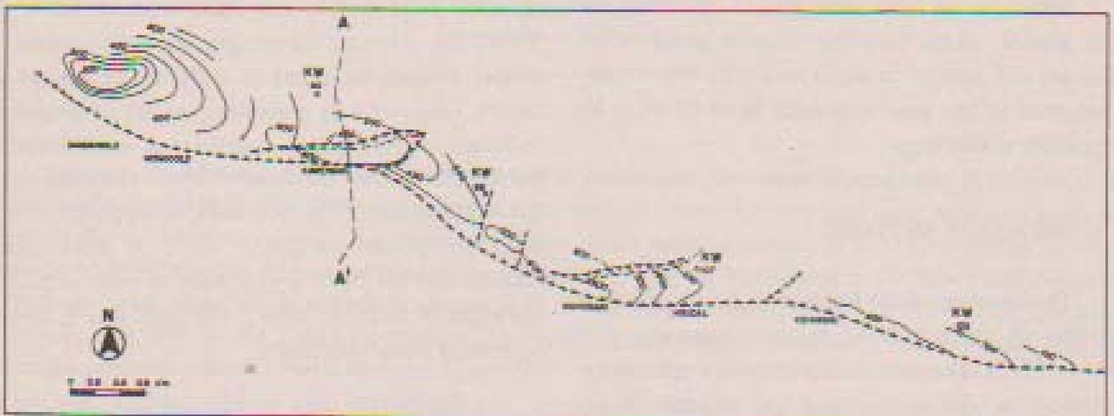


Figure 1
Location map

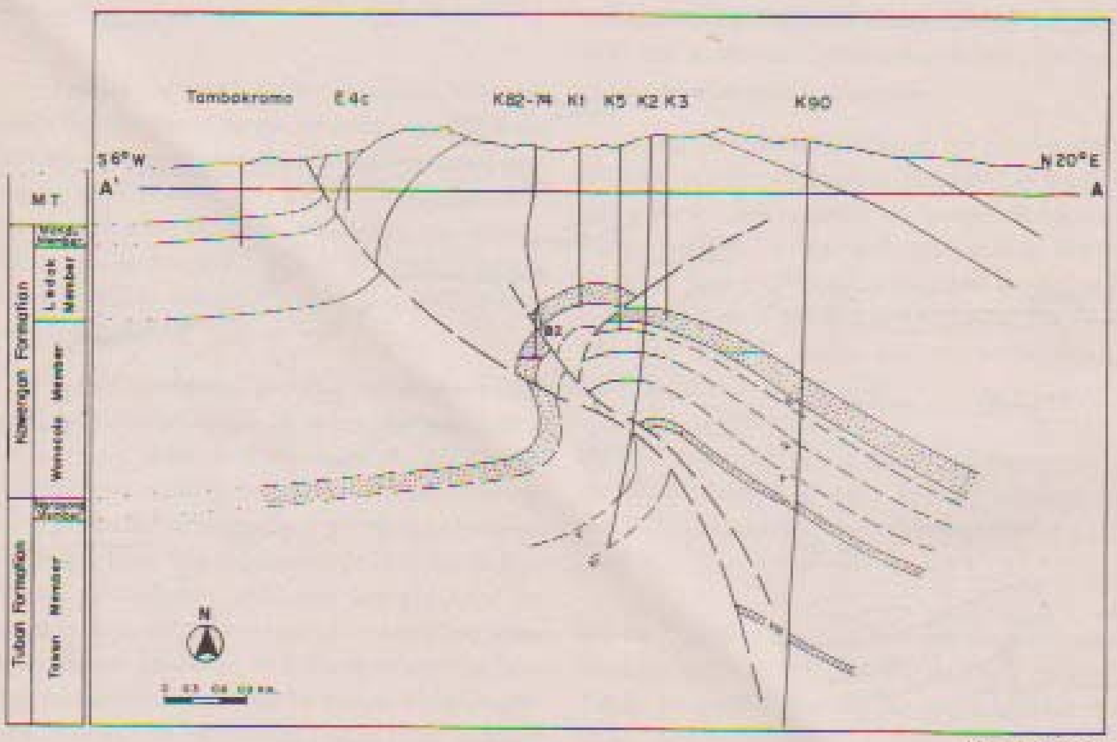
depth is shifted 200 to 300 m northwards with respect to the anticlinal axis at the surface. Overthrusting appears to be diminished at greater depth. As regards steeper portion of the NE flank, it corresponds in depth to reverse faults are striking E-W, approximately parallel with the anticlinal axis. These phenomena are thought to related to Middle Miocene-Recent compressional deformation recognized elsewhere in the Western Indonesian back-arc basins (Situmorang et al., 1983; Situmorang & Yulihanto, 1985).



(LEMIGAS & BEICIP, 1969)

Figure 2a

Structure contour map, top of Ngrayong Member



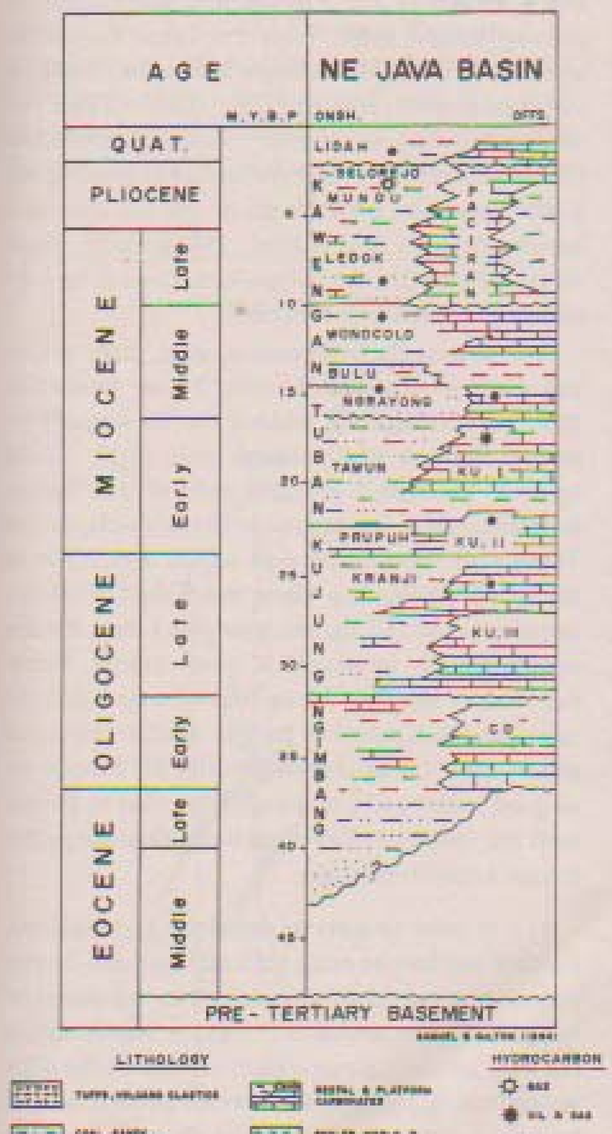
(Martin, 1961)

Figure 2b

Tectonic cross section across Kawengan culmination

A generalized stratigraphic column for the onshore portion of the Northeast Java basin is presented in Fig.3. The sediments range from Late Eocene to Pleistocene in age, with thickness of more 5.000 m.

The Tertiary sedimentary section consists predominantly of sandstone, clays, shales, limestones and marls which were deposited in a littoral and neritic to bathyal environments accompanied by reefal development in some places.



(Samuel & Gultom, 1984)

Figure 3

Generalized stratigraphic section, NE Java Basin

There is no evidence for non-deposition and or hiatus in Cepu area. Continuous sedimentation appears to prevailed since the Paleogene. As already mentioned, upthrusting and reverse faulting of the the Kawengan structure is related to Middle Miocene-Recent compressional deformation. What might occured was an initial gentle compression which resulting in a broad flexuring. It was subsequently followed by maximum compression during Plio-Pleistocene, giving rise to structural style now recognizable in Kawengan structure. Similar explanation has been put forward by Davies (1984) to explain the lack of an unconformity at the base of the Late Miocene Keutapang Formation in the North Sumatra basin.

III. ANALYTIC TECHNIQUES

Pyrolysis analysis by use of Oil Show Analyser were accomplished in the following manner :

Approximately 100 mg samples of granulated whole rock are progressively heated to 600° C with a temperature program of 30° C/minute in a helium atmosphere, and evolved hydrocarbon vapours and CO_2 are monitored as a function of temperature.

Six main parameters are measured (Fig. 4), i.e. :

Area S_0 represents the quantity of gas already present in the rock.

Area S_1 represents the hydrocarbons already present in the rock which are distilled off at temperatures below ca. 300° C.

Area S_2 represents the amount of hydrocarbons which are generated through thermal cracking of the kerogen at temperature between 300° C and 600° C (Cycle 1).

Area S_3 represents CO_2 which has been generated from the kerogen concomitant with the generation of hydrocarbons. It is not considered in the present work.

Area S_4 represents the amount of organic CO_2 evolved from combustion of the residual organic carbon.

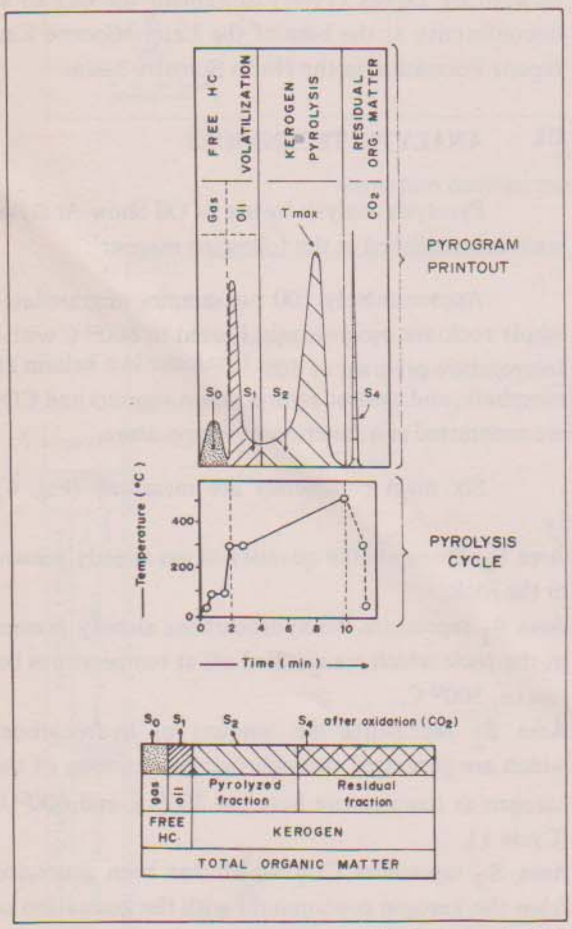
T-max is the temperature recorded at the maximum of the pulse S_2.

TOC is determined with the formula :

$$TOC : 82\% (S_0+S_1+S_2) + \frac{12}{44} S_4 \text{ ..... (Rad, 1984)}$$

The amount $S_1 + S_2$ measures the total genetic potential of the rock, expressed in kg of hydrocarbons per ton of rock (kg/ton).

The maturity of source - bed is predicted on the basis of temperature index T-max which can be plotted against hydrogen index (HI) to determine the kerogen type.



(Espitalie et.al., 1977)

Figure 4

Example of program prinout obtained with pyrolysis method

IV. RESULTS AND DISCUSSIONS

The results of geochemical analysis can be seen in Tables 1, 2, 3 and 4. Ten samples with high organic matter content (TOC : 0.53 - 2.30 %) appear to be confined to the clay-shale section of the Tuban Formation, i.e. from the depth intervals of 1550 - 1774 m, 1841 - 1842 m and 2168 - 2169 m in Kw-90, and from 803 to 822.5 m depth in Kw-95. The remaining samples (eight from the Tuban Formation and twenty from the Kawengan Formation) display a low organic matter content (TOC : 0.07 - 0.34%). The minimum limits of organic matter concentration (TOC) recognized by most geochemist as essential for a source-rock are 0.5% for shales and 0.2% for carbonates (Welte, 1965; Philippi, 1969). Hence, those values indicate that the Tuban Formation can be considered as a potential source-bed.

As regards hydrocarbon yield, high potential yield is exhibited by the Tuban Formation (0.22 to 1.81 kg/ton), whereas the Kawengan Formation shows a low potential yield (0.26 0.13 kg/ton). The highest potential yield of 2.28 kg/ton is obtained from one sample of the sandy clay of the Tuban Formation at the dept of 821.5 -822.5 m in Kw-95 well. Following Tissot and Welte (1978), potential yield of 2.0 kg/ton is used as a basis for discriminating the formation of hydrocarbons. Potential yield of less than 2.0 kg/ton indicates that the rock has some potential for gas whereas the value greater than 2.0 kg/ton is distinctive for a moderate to good source rock. It appears then, that in general both the Tuban and Kawengan Formations are probably gas source formations.

In order to generate petroleum hydrocarbons, a source-bed have to reach sufficient maturity. In this paper, the temperature recorded at the maximum of the peak S_2 (see section 3, T-max) is used to define the stage of thermal maturation reached by the organic matters. A T-max of 430° is used as the minimum limit for a source-bed to be thermally matured (Espitalie *et.al.*, 1977). As shown in Table 1, most of core samples of the Tuban Formation in Kw-90 exhibit T-max values greater than 430° C. It suggest that this part of the Tuban Formation has reached sufficient temperature for hydrocarbon generation. The remaining core samples which represent the uppermost part of the Tuban Formation and the Kawengan Formation appear to be in an immature to early mature stage.

The plot of hydrogen index (HI) vs T-Max for all samples is depicted in Fig. 5. The main types of kerogen in the Tuban and Kawengan Formations are type III and a small amount of type II. It means that the organic matters in those rock units are mainly structured kerogen which tend to serve as a gas source. The organic matters in Kw-95 and Kw-103 are unstructured kerogen which have a high potential for both oil and gas, however, they have not achieved maturity for generation of hydrocarbons.

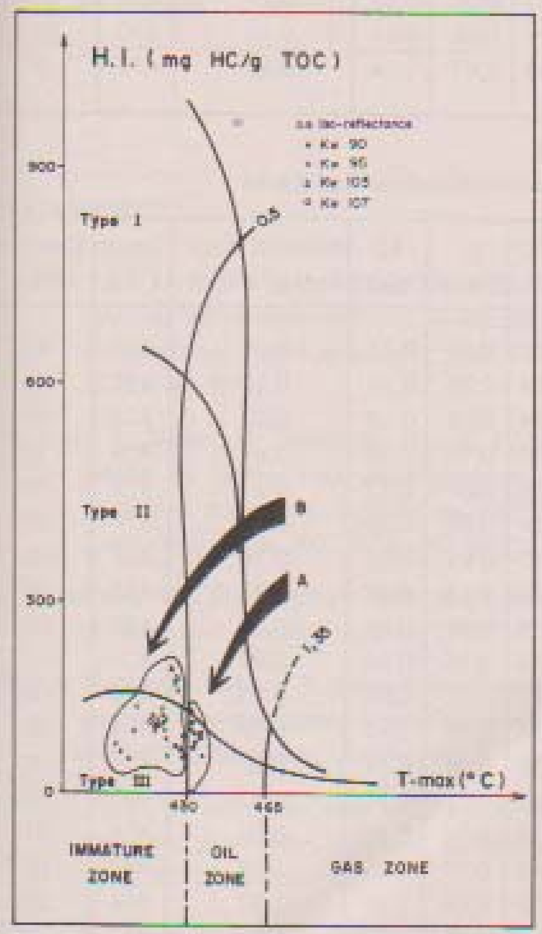


Figure 5
Plot of hydrogen index (HI) vs T-max

V. CONCLUSIONS

Organic geochemical studies performed on core samples of the Tuban and Kawengan Formations from Cepu area indicate that the Tuban Formation shows good TOOC value (average 0.75 %), and is thought to be a good source-bed. The maturity level is relatively high (T-max $>$ 430° C), with gas-prone type kerogen (type III) being the main constituent of the organic matters. It implies that gas which accumulated at shallow depths (such as in the Balun area) is probably sourced from the clay-shale section of the Tuban Formation. Thermally mature hydrocarbon source beds with marine kerogen may be present at greater depths, from which the oils that trapped in the upper part of the Tuban Formation (the Ngrayong Sand) and the Kawengan Formation are originated. Hence, deeper prospects are expected to occur in this area to which further exploration efforts should be directed. Structural accumulations may not be the prime target in this highly explored area. Future discovery trends of new reserves can probably be expected from subtle traps, for which detailed research of stratigraphy, paleostructure, paleogeography and geochemistry must be carried out.

ACKNOWLEDGEMENTS

Thanks are due to the management of the Research and Development Centre for Oil and Gas Technology "Lemigas" for permission to publish this paper and to our colleagues in the Exploration Section of the present PPT MIGAS Cepu for their helps in obtaining the core samples. Mr. Indra Siregar and his staff have undertaken geochemical analysis. Discussion with Mr. Imam Budiarto on analytic techniques is appreciated. Typing and retyping of the manuscript was carried out by Miss Nurkartikaningsih.

Table 1
Results of geochemical analysis of conventional cores of Kw-90

No.	Samples	Depth (m)	Lithology	Formation	TOC (%)	S1 (mg/g)	S2 (mg/g)	Potential Yield (kg/ton)	Tmax (^oC)	Kerogen Type
1.	A2	661.5 – 664	clayey sand	Kawengan	0.18	0.13	0.03	0.16	431	III
2.	A3	664.5 – 667.5	clayey sand	Kawengan	0.26	0.17	0.29	0.46	426	III
3.	A4	1450 – 1453	clay	Tuban	0.25	0.03	0.27	0.30	431	III
4.	A5	1550 – 1552	clay	Tuban	1.00	0.06	0.94	1.00	434	III
5.	A6	1596 – 1597	clay	Tuban	1.17	0.08	1.10	1.18	435	III
6.	A7	1700 – 1700.3	sandy clay	Tuban	1.59	0.11	1.04	1.15	430	III
7.	A8	1742 – 1744	shale	Tuban	0.90	0.06	0.76	0.82	434	III
8.	A9	1790 – 1792	clayey sand	Tuban	0.37	0.04	0.26	0.30	432	III
9.	A10	1841 – 1842	shale	Tuban	0.99	0.07	0.92	0.99	435	III
10.	A11	1886 – 1887	sandy clay	Tuban	0.39	0.04	0.22	0.26	428	III
11.	A12	1976 – 1977	sandy clay	Tuban	0.36	0.03	0.28	0.31	425	III
12.	A13	1981 – 1982	shale	Tuban	0.32	0.04	0.23	0.27	427	III
13.	A14	2015 – 2016	shale	Tuban	0.25	0.03	0.25	0.28	431	III
14.	A15	2072 – 2073	shale	Tuban	0.31	0.02	0.27	0.29	428	III
15.	A16	2119 – 2120	shale	Tuban	0.28	0.01	0.21	0.22	430	III
16.	A17	2168 – 2169	shale	Tuban	0.53	0.07	0.74	0.81	431	II

Table 2
Results of geochemical analysis of conventional cores of Kw-95

No.	Samples	Depth (m)	Lithology	Formation	TOC (%)	S1 (mg/g)	S2 (mg/g)	Potential Yield (kg/ton)	Tmax (^oC)	Kerogen Type
1.	B1	730 – 731	sandy marl	Kawengan	0.15	0.06	0.21	0.27	419	III
2.	B2	737 – 738	sandy marl	Kawengan	0.14	0.02	0.14	0.16	427	III
3.	B3	738 – 739	sandy marl	Kawengan	0.14	0.03	0.17	0.20	424	III
4.	B4	740 – 741.5	sandy marl	Kawengan	0.19	0.10	0.33	0.43	426	II
5.	B5	741.5 – 742.5	sandy marl	Kawengan	0.14	0.04	0.17	0.21	419	III
6.	B6	742.5 – 743.5	sandy marl	Kawengan	0.14	0.03	0.16	0.19	424	III
7.	B7	744.5 – 745.5	sandy marl	Kawengan	0.13	0.04	0.14	0.18	421	III
8.	B8	745.5 – 746.5	sandy marl	Kawengan	0.26	0.14	0.24	0.38	417	III
9.	B9	746.5 – 747.5	sandy marl	Kawengan	0.09	0.01	0.06	0.07	435	III
10.	B10	747.5 – 748.5	sandy marl	Kawengan	0.34	0.15	0.44	0.59	424	III
11.	B11	749.5 – 750	sandy marl	Kawengan	0.14	0.02	0.08	0.10	424	III
12.	B12	750.5 – 751	sandy marl	Kawengan	0.14	0.03	0.17	0.20	424	III
13.	B13	751 – 752	sandy marl	Kawengan	0.28	0.05	0.24	0.29	424	III
14.	B14	752 – 753	sandy marl	Kawengan	0.07	0.01	0.11	0.12	427	II
15.	B15	755 – 756	sandy marl	Kawengan	0.19	0.04	0.19	0.23	424	III
16.	B32	803 – 808	clay	Tuban	0.83	0.17	0.96	1.13	422	III
17.	B34	815 – 816	clay	Tuban	2.30	0.65	1.15	1.80	414	III
18.	B39	820.5 – 821.5	sandy clay	Tuban	1.06	1.18	0.63	1.81	402	III
19.	B40	821.5 – 822.5	sandy clay	Tuban	1.00	1.59	0.69	2.28	399	III

Table 3
Results of geochemical analysis of conventional cores of Kw-103

No.	Samples	Depth (m)	Lithology	Formation	TOC (%)	S1 (mg/g)	S2 (mg/g)	Potential Yield (kg/ton)	Tmax (°C)	Kerogen Type
1.	C2	801 – 802	sandy marl	Kawengan	0.14	0.05	0.29	0,34	427	II
2.	C3	802 – 803	sandy marl	Kawengan	0.16	0.08	0.32	0.40	426	II

Table 4
Results of geochemical analysis of conventional cores of Kw-107

No.	Samples	Depth (m)	Lithology	Formation	TOC (%)	S1 (mg/g)	S2 (mg/g)	Potential Yield (kg/ton)	Tmax (°C)	Kerogen Type
1.	D2	871 – 877	shale	Tuban	0.43	0.12	0.49	0.61	423	III

REFERENCES

Davies, P.R., Tertiary structural evolution and related hydrocarbon occurrences North Sumatra Basin, *Proc. Indones. Petrol. Assoc., 13th Ann. Conv.*, 1, 19 – 49, 1984.

Espitalie, J., Madec, M., Tissot, B., Mennig, J.J. and Leplat, P., Source rock characterisation method for petroleum exploration, *Offshore Tech. Conf.*, Paper 2935, 439 – 42, 1977.

Lemigas and BEICIP, *Northeast Java Basin*, Unpublished report, Lemigas, Jakarta, 1969.

Martin, *Kort overzicht van de geologie en olieveering van het Kawengan terrein*, Unpublished report, DJ. 50321, Pertamina, Jakarta, 1951.

Philippi, G.T., On the depth, time and mechanism of petroleum generation, *Geochem. Cosmochim. Acta.*, 55 (12), 1021 – 49, 1965.

Rad, F.K., Quick look source evaluation by pyrolysis technique, *Proc. Indones. Petrol. Assoc., 13th Ann. Conv.*, 2, 113 – 24, 1984.

Samuel, L. and Gultom, L., *Daur pengendapan di cekungan-cekungan minyak Indonesia Barat*, Ikatan Ahli Geologi Indonesia, Pertemuan Ilmiah Tahunan 13, Bandung, 18 pp, 1984.

Situmorang, B., Siswoyo, Thamrin, M. and Yulihanto, B., Heat flow variation in Western Indonesian basinal areas : Implication on basin formation and hydrocarbon potential, *Proc. Indones. Petrol. Assoc., 12th Ann. Conv.*, 1,157 – 69, 1983.

Situmorang, B. and Yulihanto, B., The role of strike slip faulting in structural development of the North Sumatra Basin, *Proc. Indones. Petrol. Assoc., 14th Ann. Conv.*, 1, 21 – 38, 1985.

Tissot, B.P. and Welte, D.H., *Petroleum formation and occurrence*, Springer Verlag, Berlin, 538 pp, 1978.

Welte, D.H., Relation between petroleum and source rock, *Amer. Assoc. Petrol. Geol. Bull.*, 49(12), 2246 – 68, 1965.