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OIL FAMILY CHARACTERISATION OF JABUNG AREA, JAMBI SUB-BASIN

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ABSTRACT

Jabung area and whole Jambi Sub-Basin, Sumatra has been a prolific target of exploration since 1990. A number of oil and gas fields have been discovered and produced. Yet, the petroleum system of the region has not been fully understood since there has no detail geochemical study been conducted. This paper attempts to understand one of the geochemical aspects of Jabung area, namely oil family study. A variety of oil families will indicate a presence of various source rocks and the history of oil generation, migration, accumulation, and alteration. Some rock samples. The families of oils were determined by statistical analysis on biomarker and carbon isotopes of the oil samples. Oil to source correlation was applied to interpret the most likely source/s of the existing oils. Maturation modeling of the expected source/s was conducted to establish the history of oil generation and migration.

Organofacies attribute of the oils show that the oils of the Jabung area were mainly sourced by organic matter derived from higher terrestrial-land plants. Two families which are subtle in the characteristics were resulted from the multivariate statistics. Correlation and source geochemistry evaluation conclude that the shales and coals of Talang Akar are the main source rocks of oils in the Jabung area.

INTRODUCTION

Jabung area is located in Jambi Sub-Basin, South Sumatra Basin. This basin covers area of approximately 1642.8 km2. Oil production in the area has been started since 1995 from North Geragai dan Makmur fields. Recently, six oil fields are still producing in Jabung area.

Formation that has been believed as source rock is Talang Akar Formation and the productive reservoir rocks are Talangakar, Gumai and Air Benakat Formations.

Generally, oil fields in Jambi exist in the NW-SE anticline line and have been identified being formed during Plio-Pleistocene tectonic period.

This research intends to establish oil family found in the basin based on GC and GC-MS data and to correlate the crude oils to their source rocks.

GEOLOGIC SETTING

There are two fault patterns that typify Jambi Sub-Basin, namely fault pattern that is oriented NE-SW and that of NW-SE direction. The first fault pattern is assumed to form in tectonic period of Late Cretaceous until Early Tertiary, whereas the second pattern is assumed to form in the last tectonic period (Plio-Pleistocene). Both faults have been responsible as the configuration control of the present basement.

The first fault period was in Late Cretaceous-Early Tertiary. During this period, the oceanic plate Indian-Australian colided the continental plate of micro Sunda resulting the formation of Sumatra fault. This fault caused fracture pattern along the Sumatra fault as response toward its fault movement. In Early Oligocene, vertical movement was occurred as an impact of deceleration of belt. This process formed horsts and grabens and then followed by deposition of Lahat Formation (LAF) in graben area.

In Late Oligocene-Mid-Miocene (second period), an anticlockwise rotation movement happened in micro Sunda forming rifting and local subsidence and followed by erosion process and fast deposition of sediment. This period was ended by transgressive phase, followed by the deposition of Talang Akar (TAF), Baturaja (BRF) and Gumai Formations (GUF). In Jambi Sub-Basin, Baturaja Formation is not quite well developed.

The third period happened in Late Miocene-present. During this time, the movement of Indian-Australian plate increased forming a direction of N65OE. Compression shown by direction of plate caused basin uplift and then regression occurred indicated by the deposition of Air Benakat (ABF), Muara Enim and Kasai Formations (KAF). This compression culminated in Plio-Pleistocene that caused tertiary sediments folded and faulted.

Faulted pattern in Plio-Pleistocene period formed anticline stripes with NW-SE direction that controls oil fields in Jambi Sub-Basin at the present. Stratigraphy of Jabung area is shown in Figure 1.

Oils in Jabung area have been generated in Early Miocene until Late Miocene and migrated through old structures position. Activities in Plio-Pleistocene period, marked by the formation of trap structures have caused accumulated oils up to present time. Hidrocarbon system of Jabung area can be seen in Figure 2.

OIL GEOCHEMISTRY

Database and Interpretation Methods

Geochemical data of the seventeen oil samples and some rock samples have been used during this study. The available data include bulk properties (API), carbon isotope-13, GC (gas chromatography), and GC-MS (gas chromatography-mass spectrometry) of saturate terpane and sterane. Interpretation of oil properties, oil grouping, maturation, and characteristics of source rocks were based on geochemical cross plots. A method of "geochemical inversion" is used to predict source rock from oil properties as outlined by Bissada et al. (1992). Hierarchical Clustering Analysis (HCA) that resulted in dendogram is used to establish the oil family.

Oil Occurrences

The crude oils have been interpreted to come from two different areas, so are their reservoirs. Oils taken from Geragai and Betara areas are commonly reservoired in Talang Akar and Gumai Formations (Figure 3). Geragai area includes North Geragai, Makmur and Berkah fields. Geragai and Makmur were the first area in Jabung that produced oils. Generally, reservoir in this area is the Gumai Formation. Betara area comprises North Betara, NE Betara, Gemah and Ripah. Sandstones of Talang Akar Formation are the most common reservoir in this area.

Analyses of Oil Properties

Oil samples collected from both areas show API of 25.5-62.3 with average of 44.79. The variation seen in the API values may be due to the effect of degree of maturation and biodegradation or water washing. Based on the work done by BP Research (1991), plot between API and Pr/Ph ratio shows that the crude oils belong to class D and E or could be interpreted as a non-marine derived (Figure 4). All pristane/phytane (Pr/Ph) values are higher than 3.0 with average of 7.55 indicating terrestrial derived with oxic environment (Figure 5). According to Robinson (1987), Pr/Ph value up to 3.0 shows source rock derived from fluvio-deltaic environment.

Figure 6 indicates a plot of carbon isotope data for saturate and aromatic fractions. The average of carbon isotope values of saturate and aromatic are 29.51 o/oo and 27.52 o/oo respectively. This figure suggests that the crude oils were derived from a mixture between terrestrial and algal organic facies, but the terrestrial materials seem to be more predominant.

GC data relatively vary, but commonly there are two maximum peaks before and after C20 indicating a mix input between higher plants and algae, a very common in the fluvio-deltaic deposits. General type of Jabung oils is relatively similar with that of other oils found in Indonesia being derived from shales and coals of fluvio-deltaic environment containing minor algal.

GC-MS data used in this study comprising triterpane (m/z 191) and sterane (m/z 217). They consistently show fluvio-deltaic deposit. The minor biomarker differences among the oil samples may reflect variation in the oil source rocks. The biomarker composition of the oils suggests that the origin of the oil samples is dominantly terrestrial with minor algae. Generally, the samples contain 18a-oleanane in relatively high concentration indicating contribution of angiosperms. Domination of C29 steranes in this area delineates a great higher plant contribution. Hopane/sterane ratio also indicates that the oil source was derived from suboxic-oxic. Figure 7 shows ternary C27-C28-C29 diagram of Huang & Meinschein (1979). It is apparent that Jabung oils were most likely derived from terrestrial environment.

Oil Family

Cluster analyses has been used to establish the oil family. Seventeen samples were characterized by using thirteen parameters to define the family. The parameters used did not include those affected by maturation. The parameters used are C_{27}-C_{29} steranes, Pr/Ph, Pr/nC_{17}, Phy/nC_{18}, oleanane/hopane, opanes/steranes, gammacerane/C_{30} hopane, C_{29}/C_{30} hopanes, Tm/Ts, and carbon isotope-13 (Table 1).

The results indicate that there is no significant difference among the oil facies. The families obtaind during this study are significantly reflect the contribution of terrestrial deposit. However, this study could define two oil families. According to BP Research (1991) classification, Jabung oils can be classified as non-marine type (class D). This class has been characterized by the appearance of oleananes and resins as terrestrial-derived materials. Then, on the basis of the dendogram (Figure 8), the crude oils are grouped into two classes, namely D_I (Betara) and D_{II} (Geragai). The two families are differed based on their biomarker distributions. In general, D_{II} family is more terrestrial, more oxic, more oleanane content, and higher hopane/sterane ratio compared with the D_I family (Figure 9). Plot of Pr/Ph ratio versus hopane/sterane (Figure 10) shows that Betara area is oxic-terrestrial whereas Geragai area is suboxic-oxic terrestrial.

Source Identification

Geochemical inversion method (Bissada et al., 1992) was used for source identification because the absence of source data in deeper area. Source rocks information in the deeper areas is frequently absent because exploratory drilling focuses on structural highs. By using the inversion technique, it is intended to interpret the depositional environment, age, and location of the hydrocarbon kitchen(s).

The oils of Jabung are typically derived from non-marine source rocks associated with kerogen from terrestrial. Based on bulk properties, and biomarker analyses, it is apparent that all oil samples are relatively similar, being generated from fluvio-deltaic shales and coals predominated by terrestrial organic matter and minor algal. Referring to the stratigraphy of Jabung area, the most appropriate formation having such characters is the Talang Akar shales and coals of Late Oligocene to Early Miocene.

The ratio of oleanane/(oleanane+hopane) of the oil samples can be used to define the age of source rocks (Peters et al., 1999). Oleanane is a biomarker derived from flowering plants (angiosperms) originated in the Cretaceous and more abundant in Tertiary age. As a consequence of this statement, oils from early Tertiary should contain less oleanane than those of Miocene. The D_I family has olenane/hopane ratio of 0.2-0.61, with average of 0.37, whereas the D_{II} family has such a ratio of 0.12 – 1.12, with average of 0.66. It is considered that the D_{II} family was generated from younger source rocks than the D_I family. Such a phenomenon can be seen Figure 11 for well BTR-01 (D_I) and GRG-07 (D_{II}).

SOURCE ROCK GEOCHEMISTRY

Source Rock Facies

Source rock samples taken from some wells are generally from Late Oligocene of Lower Talang Akar Formation, Early Miocene of Upper Talang Akar Formation and Early Miocene-Mid Miocene of Gumai Formation.

Shales of Lower Talang Akar Formation (LTAF) has fair-excellent source rock potential with TOC 0.51-10.99 and coals 21.58-64.18. Shales that are organically rich Type III kerogen tend to generate gas and few oils upon maturity. Shales of Lower Talang Akar Formation are believed as a potential source rock in Jambi Sub-Basin. Shales of Upper Talang Akar Formation (UTAF) has TOC 0.31-7.16 and coals 59.75-78.52. This formation was a fluvio-deltaic strives to marine area due to transgression effect. Type II and III kerogens are very common in this formation. Such kerogens tend to generate oil and gas. Oil was derived from type II kerogen that is usually marine. Gumai Formation has poor-excellent rock potential with TOC 0.18-8.00 and no coal found in this formation. This formation is marine deposit containing relatively high abundance of marine algae, although the occurrence of some terrestrial deposits is also observed. Organic content based on plot of TOC versus HI and Tmax versus HI for each formation can be seen in Figure 12.

Oil Generation, Maturity and Migration

Maturity and oil generation modelling were constructed using data such as stratigraphy, lithology, formation age, geochemical data (TOC, Rock-Eval pirolysis, and vitrinite reflectance), and geothermal gradient. The results obtained from the modelling indicate that the oil generation in the area was started in Early Miocene and then migrated toward old structures in Betara area. In Geragai area, oils were generated in Mid-Miocene and migrated toward younger structures formed during Plio-Pleistocene (Figure 13).

Migration pathway in Jabung area seems to follow the kitchen and high patterns with the most common trend directing relatively NW-SE (Figure 14). Probability of the charging prospect for the high areas can be evaluated using detailed modelling along the migration pathways.

CONCLUSIONS

- Based on the geochemical study, oils of Jabung area were commonly derived from terrestrial source rock, having suboxic-oxic environment (fluvio-deltaic) predominated by marine algae.
- Oils of this area could be divided into two families: DI and DII. DII family contains more higher plant material input (C29 sterane), higher Pr/Ph, higher concentration of oleanane, and higher hopane/sterane ratios than the DI family.
- Based on the oleanane content, oils belong to the DII family have been estimated that their source rock is relatively younger than that of the DI family.
- Source rocks of Talang Akar Formation were generally constructed by type II and III kerogens with type III being more predominant. The occurrence of algal-material input in Talang Akar Formation indicates that the study area was transition of a fluvio-deltaic environment. Shales of Gumai Formation were marine deposited, being rich of marine algae, although some inputs of terrestrial organic materials were recognised.
- The oil generation was started in Early Miocene and migrated toward old structures in Betara area. In Geragai area, oils were generated in Mid-Miocene and migrated toward young structures that were formed during Plio-Pleistocene.

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OIL SAMPLE	C_{27}	C_{28}	C_{29}	Pr/Ph	Pr/nC_{17}	Phy/nC_{18}	Ol/Hop	Hop/ster	GMx100 / C_{30} Hop	C_{29} Hop / C_{30} Hop	Tm/Ts	$\delta^{13}C$ sat	$\delta^{13}C$ aro
BTR-01	20.79	32.38	46.83	8.07	2.59	0.35	0.27	6.97	4.08	0.65	2.14		
BTR-02	19.52	37.73	42.75	8.16	2.20	0.28	0.33	5.89	4.14	0.72	2.06		
BTR-03	22.77	28.18	49.06	5.76	2.34	0.39	0.29	5.96	3.99	0.72	2.04	-30.14	-27.62
BTR-04	18.48	26.67	54.86	6.70	4.44	0.81	0.20	11.46	4.08	0.73	4.00	-30.41	-27.62
BTR-05	19.30	28.27	52.44	6.47	7.20	0.8	0.21	7.49	3.47	0.77	3.61	-30.20	-27.50
BTR-06	45.00	25.00	30.00	10.57	2.20	0.27	0.55	6.71	0.00	0.80	0.59	-28.40	-27.06
BTR-07	42.50	25.00	32.50	10.36	2.20	0.26	0.61	4.12	0.00	0.81	0.46	-28.37	-27.03
BTR-08	37.50	29.20	33.30	11.16	2.10	0.29	0.52	5.09	0.00	0.91	1.01	-28.58	-26.65
GRG-01	23.00	26.00	51.00	9.81	1.60	0.31	0.87	3.97	0.00	0.88	1.21	-29.40	-27.40
GRG-02	22.00	27.00	51.00	8.60	1.55	0.25	1.10	3.94	0.00	0.87		-29.70	-28.40
GRG-03	23.00	25.00	52.00	5.72	1.33	0.29	0.59	2.21	0.00	0.63	1.89	-28.50	-28.90
GRG-04	16.00	16.00	69.00	8.34	1.73	0.28	0.57	3.42	0.00	0.46	1.59	-30.30	-27.50
GRG-05	14.00	11.00	75.00	6.94	2.35	0.33	0.68	2.72	0.00	0.45	1.74	-29.90	-27.30
GRG-06	9.00	18.00	72.00	7.16	2.25	0.3	0.44	2.60	0.00	0.46	2.11	-30.20	-27.20
GRG-07	43.87	14.19	41.97	7.22	1.97	0.27	0.49	2.47	2.01	0.16	1.72		
GRG-08	31.21	26.63	42.16	3.83	1.95	0.26	0.12	6.61	8.51	0.94	0.79		
GRG-09	27.41	24.12	48.46	3.45	0.16	0.29	1.12	2.77	3.10	0.49	4.63		

TABLE 1: 17 samples and 13 parameters from oil data that used in oil family / grouping

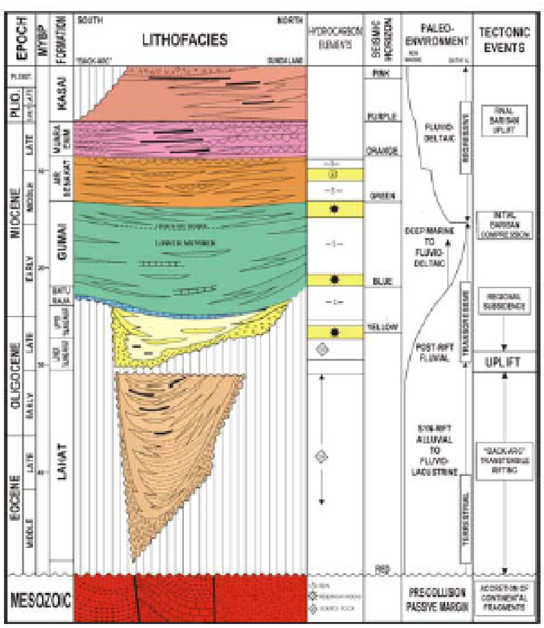

FIGURE 1: Stratigraphy of Jabung area

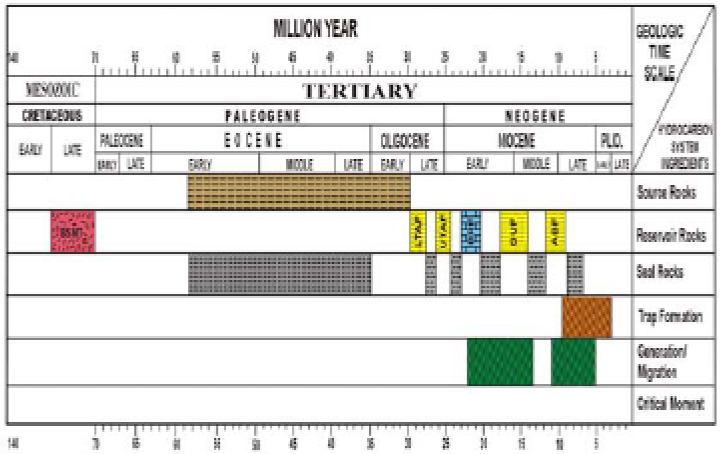

FIGURE 2: Hydrocarbon system of Jabung area

FIGURE 3: Location map of Jabung study area (non-marine oil)

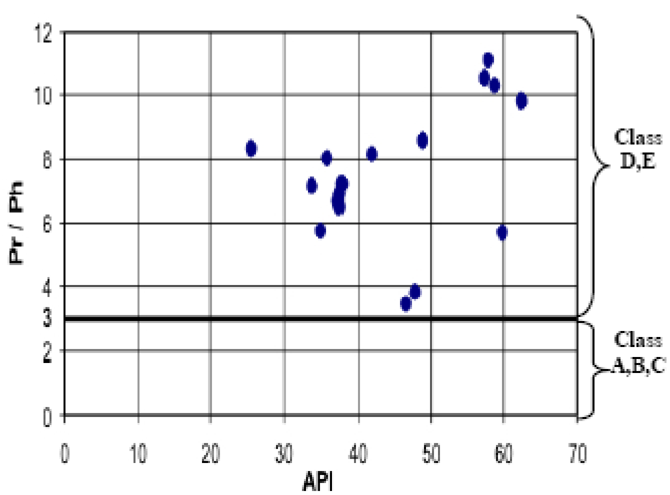

FIGURE 4: All oils include in class "D" or "E"

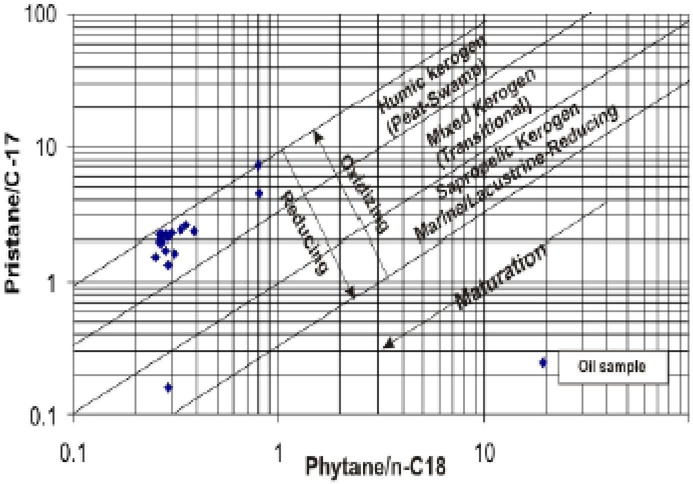

FIGURE 5: Cross plot of pristane and phytane to normal alkane showing oxic condition with terrestrial characteristic

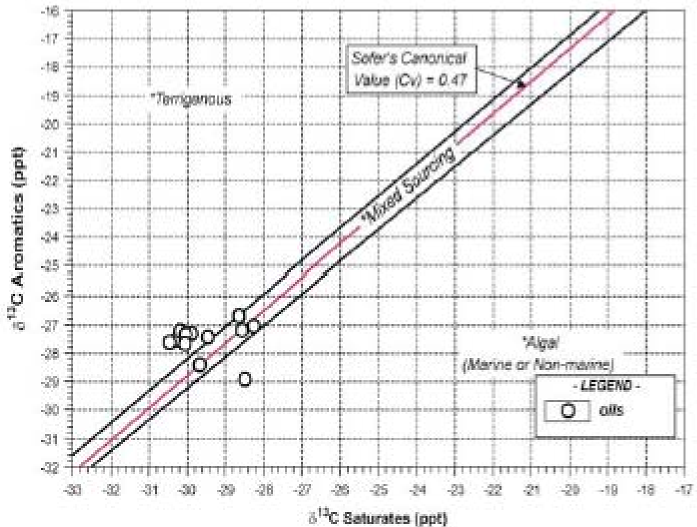

FIGURE 6: Cross plot of aromatic and saturate carbon-13 isotopes showing mixtures between terrestrial material and algal

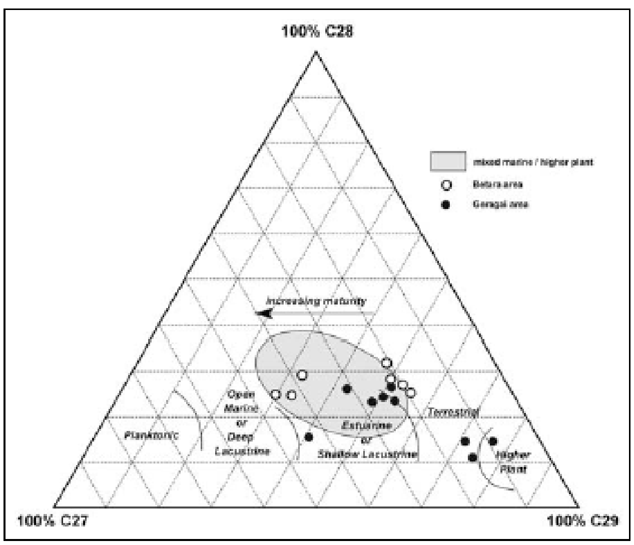

FIGURE 7: Ternary diagram of m/z 217 C_{27}- C_{28}-C_{29} showing depositional environments, non-marine and fluvio-deltaic source rock

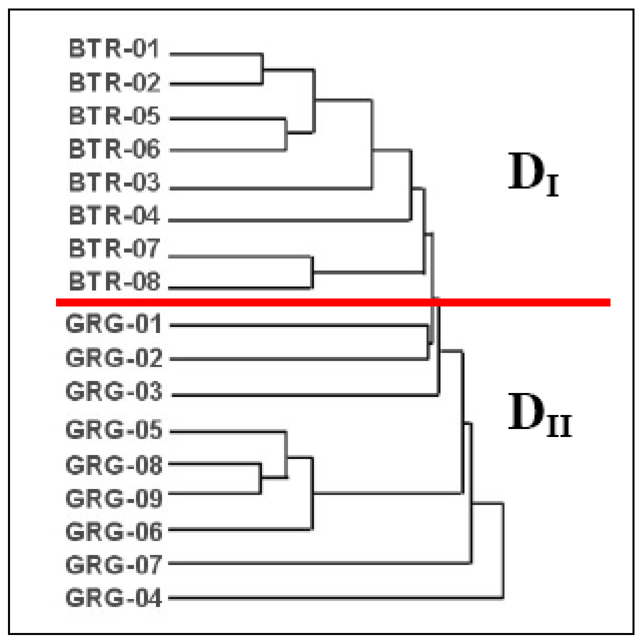

FIGURE 8: Dendogram as a result of cluster analysis divided into two family oils D_I and D_{II}

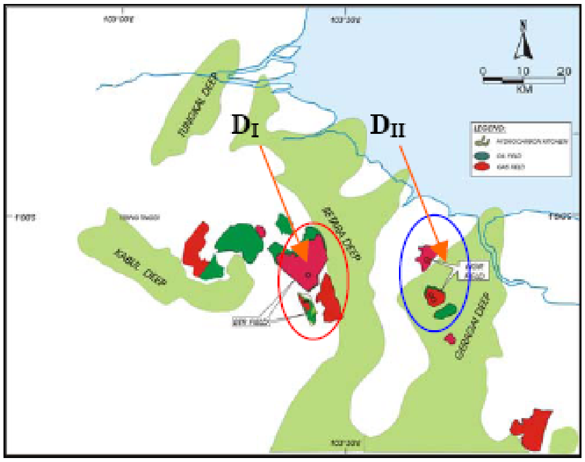

FIGURE 9: Location of oil family

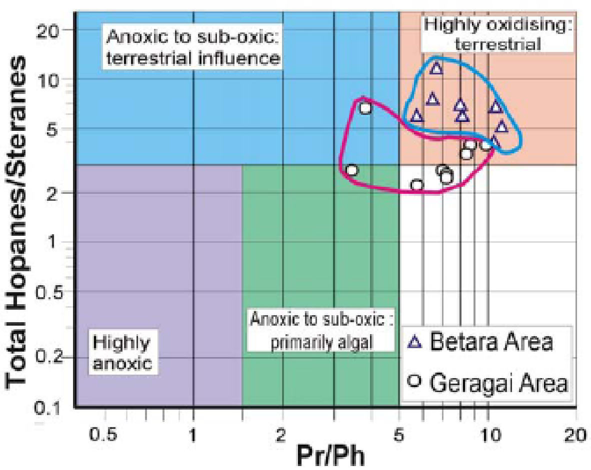

FIGURE 10: Source rock facies based on hopane/sterane and pristane/phytane showing suboxic – oxic terrestrial

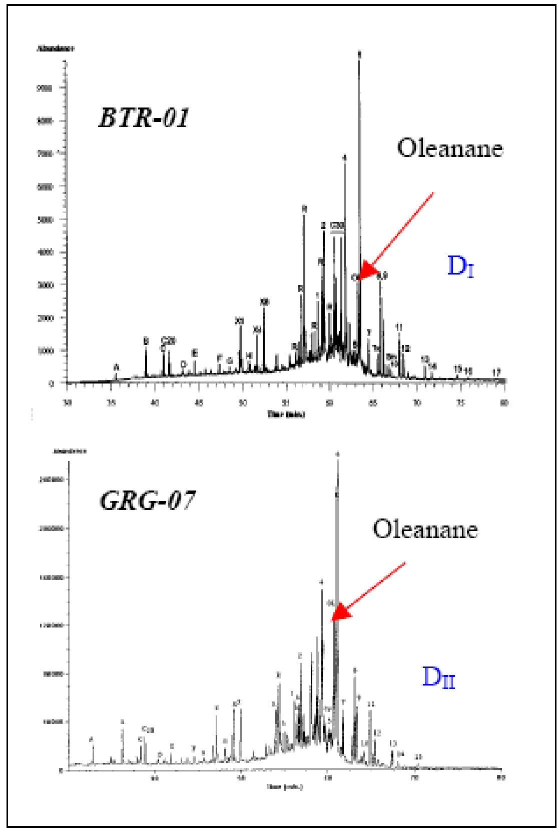

FIGURE 11: m/z 191 triterpane showing oleanane content, D$_I$ that representatived by BTR-01has less oleanane than oleanane content in D$_{II}$ that representatived by GRG-07

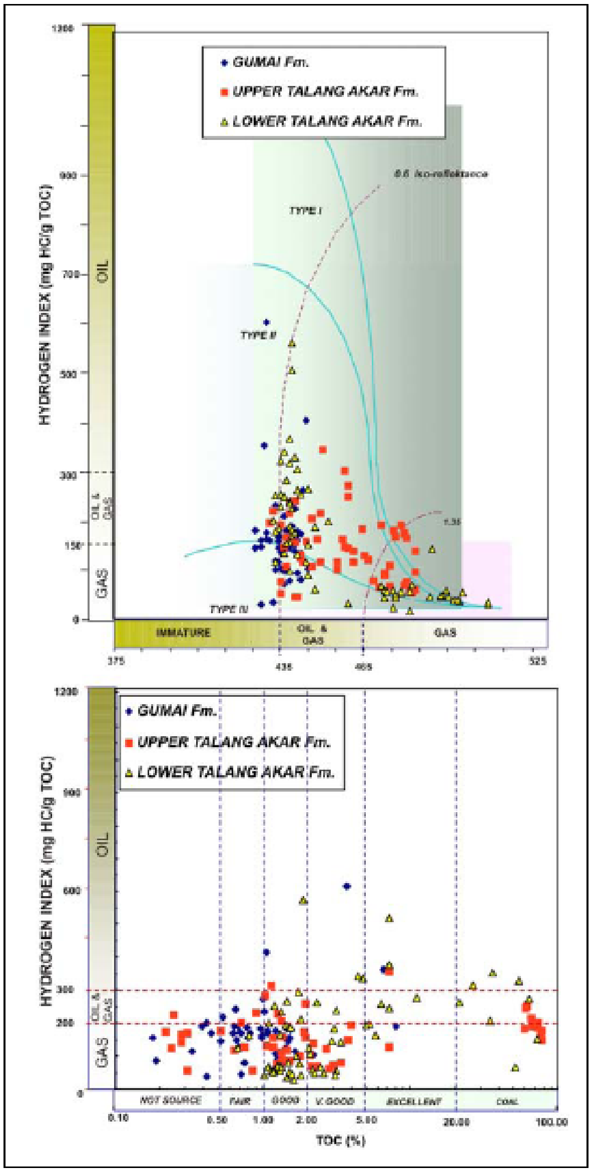

FIGURE 12: Cross plot TOC vs HI for organic richness and Tmax vs HI for kerogen type and maturity

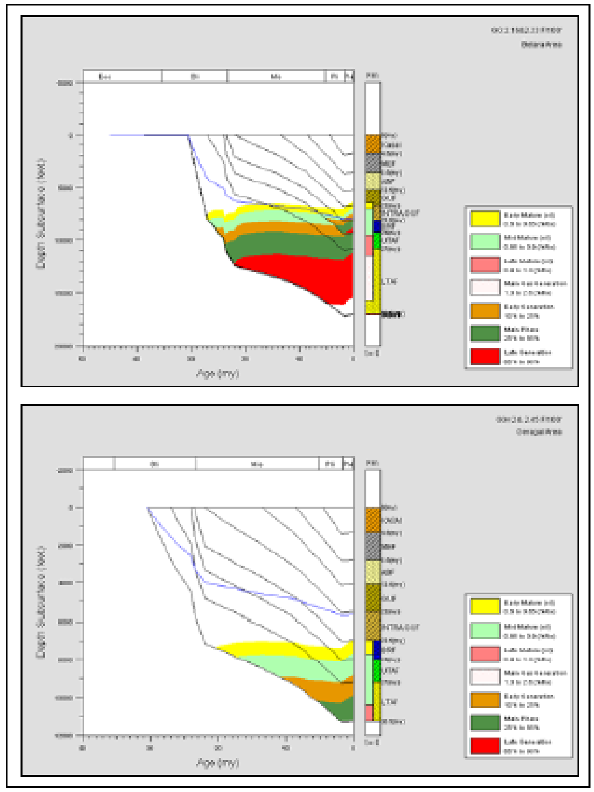

FIGURE 13: 1-D modelling from Betara area and Geragai area

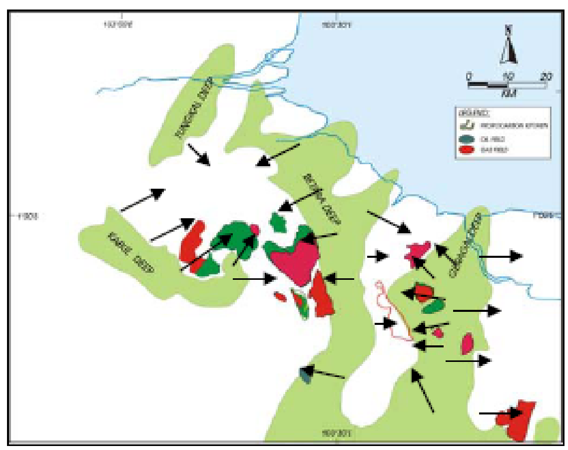

FIGURE 14: Migration pathway from mature kitchen to high area