



CHAPTER VIII

DISCUSSION

SOURCES

It is evident from several biomarkers characterized oil samples in this study that all the Sirikit oil samples are derived from same mixed organic source materials: algae, bacteria, and higher terrigenous plants.

The first biomarker examined to support this suggestion is the n-alkane distribution. Bimodal distribution was seen in most samples with no distinguishable difference among oils derived from different reservoir units. The predominant n-C₁₇ peak in the first region represents a direct input of hydrocarbons from algae and of the related acids (TISSOT and WELTE, 1978). The geological setting of the Phitsanulok Basin, a shallow, large lake of freshwater may determine the algae origin, probably the major organic source material in this depositional environment. A predominance of algal material might accumulate when the land surfaces were periodically submerged or when the lakes were deep enough for anoxic bottom conditions to develop and preserve organic material. The second maximum range in C₂₁ to C₂₉ infers a contribution of terrigenous higher plants to the sediments. A slight

predominance of odd-carbon numbered n-alkane is seen in this region even though the CPI values almost close to 1. The unity CPI value may indicate the effect of a dilution by hydrocarbons which originated from kerogen degradation (TISSOT and WELTE, 1978). The abundance of high molecular weight alkane suggests a derivation from cuticular waxes of higher plants which odd-carbon numbers may be either directly synthesized by the plant or derived through an early diagenesis (defunctionalization) of the even-numbered acids, alcohols or esters. Nevertheless, a large amount of a high molecular weight n-alkanes ($>C_{20}$) with a moderate odd predominance are probably derived from terrestrial organic matter reworked by bacteria and other microbes. Recently, there has been a report (MCKIRDY et al., 1986) suggesting an alternative source of high molecular alkane of C_{34} botryococanes which are derived from brown-green freshwater algae "*Botryococcus braunii*". It was suggested that these alkanes are organic precursors of high molecular weight alkanes now found in Australia waxy crude oils. Besides *B. braunii*, the other races of botryococane series has been suggested possibly to be an organic precursor of high molecular alkanes. This has been proposed by BRASSELL et al. (1988) by identifying the homologous series of C_{31} and C_{33} botryococanes in Maoming oil shales from China. Since the $\delta^{13}C$ isotopes of saturate and aromatic fractions in a Sofer type plot of the oil in this study did not refer terrestrial source, but

determining marine source oil which is contrary to their biomarker characteristics, a suggestion of different race of algae source that affected ^{13}C isotopic fractionation might be possible to describe the character of these oils.

The presence of bicyclic sesquiterpanes and diterpanes confirm that terrigenous higher plants were in part responsible for formation of the oils. By comparison to previous published studies (ALEXANDER et al., 1983; PHILP et al., 1981; ALEXANDER et al., 1984; BENDORATIS, 1973) and analysis by MID and daughter/parent ion mode of GC/MS, drimanes and eudesmanes were found to be the predominant sesquiterpanes. Drimane has been reported as a widely occurring constituent of crude oils and sediments and has been detected in all types of petroleum including marine and non-marine sourced oils. The origin of the drimanes is not dependent upon the presence of higher plant material but they are generally considered to most likely be derived from microbial sources (ALEXANDER et al., 1983, 1984). By contrast, the eudesmane distribution in most crude oils is indicative of terrigenous higher plants (PHILP et al., 1981; ALEXANDER et al., 1983) and hence the presence of eudesmanes in the oils can infer that higher plant materials were present in the source rocks. Variation in relative concentrations of the bicyclic compounds in the oils was probably a result of the different concentrations of the samples used in analysis. Besides

the sesquiterpanes, the distribution of the diterpanes distribution also indicated the presence of higher plant materials in the source rocks for these oils. Diterpanes are typically indicators of contributions from conifers and resins in sediments, coals and crude oils. In the case of organic rich source rocks which were deposited close to coal seams, their presence may be due to dissolution of the diterpanes present in the coal by dissolution by the oil during migration or in the reservoir (PHILP et al., 1983). Such a phenomenon may apply to the reservoir in the Sirikit oilfield since the geological setting of this oilfield has been ascribed to be a fluvio-lacustrine environment (FLINT et al., 1988), one in which the organic-rich clay source rocks were closely associated with coal in a facies assemblage mudstone-coal-oil shale (GIBLING, 1988). The diterpanes in the oils of the Sirikit field are probably derived directly from the terrigenous higher plant materials deposited directly in the source rocks or with a contribution of dissolved diterpanes from the associated and dispersed brown coal particles in the reservoir and during migration.

A possibility of a contribution of microbial organic matter to the source rocks is indicated by the presence of the extended tricyclic terpanes and 8,14-secohopanes as determined by MID analysis of m/z 191 and m/z 123. It has been suggested that the origin of the extended tricyclic terpanes is limited to marine sources

of organic material (PHILP, 1985 and ref. therein). However, in cases where terrigenous oils which have mixed with microbial and algal source materials, it is also possible to observe the tricyclic terpane existence (OUNG, 1987 thesis). It has been proposed that in some bacteria, the tricyclic terpanes play a role as membrane rigidifiers which are derived from cyclization reaction of regular polyprenol in such a bacterial membrane (OURISSON et al., 1982). The ratios of tricyclic terpanes/17 α (H)-hopanes have sometimes been suggested as a source correlation parameter of bacterial produced organic input in sediments and crude oils (MOLDOWAN and SEIFERT, 1983). This means an apparently diverse biogenetic precursor for the two series of compounds in archaebacteria, i.e. hopanes from squalene, and tricyclic terpanes from polyprenols. The ratio is significant in the oil samples examined in this study because of a very different intensity between both compounds. Hence, organic source of hopanes from archaebacteria might also be an another important source of the oil in this basin.

The presence of significant concentrations of 8,14-secohopanes in these oils suggest a widespread input of microbial source material into the sediments during diagenesis. (PHILP person. com.). The origin of 8,14-secohopanes is still uncertain, even though RULLKOTTER (1982) has proposed an origin via biodegradation. 8,14-Secohopane may also have a thermal origin, by derivation from the pentacyclic terpanes by ring C opening and

cleavage of the 8,14 bond which has the lowest bond energy (SCHMITTER et al., 1982). This suggestion concurs with the hypothesized tectonic setting, depositional environment and hydrocarbon potential of the lacustrine basin in Thailand (GIBLING, 1988). Hydrocarbon generation under rapid burial of the sediments with high heating rate might be possible for the oils in this basin. By such conditions, the 8,14-secohopanes from early diagenesis could be preserved in a burial sediments and then presents in the oils examined in this study.

By monitoring the ions at m/z 123 and m/z 191, tetracyclic terpanes were also detected in these oils. Usually, the tetracyclic terpanes are only revealed in the m/z 191 fragmentograms due to their relatively low concentration in most samples (OUNG, 1987). A homologous series with the side chain in the range from C_{24} to C_{27} are present these oils and are dominated by the C_{24} component. The tetracyclic terpanes has been reported to be derived from the thermal catalytic degradation of hopane precursors or microbial opening of ring E of hopanoids rather than cyclization of their precursor, squalene, stopping at ring D to produce tetracyclic precursors (TRENDEL et al., 1982). However, the possibility of a direct microbial origin (CONNAN et al., 1985) and invertebrate origin (SCHOLEFIELD and WHITEHURST, 1980) have also been proposed.

The pentacyclic hopanes are present in very high concentrations particularly when compared to other

biomarkers, such as the steranes. In general, the precursors of the pentacyclic hopanes are presented in the ubiquitous bacteria. Hence, their stereoisomer ratios are used to identify maturation change rather than the source variations. Plant triterpenoids such as, 18 (H)-oleanane, ursane, and lupane are used as indicators of an unambiguous source of terrigenous material derived from angiosperms even though they are usually present in relatively low concentrations. In this study only oleananes are presented in the oils, but insignificant concentrations. Its presence however suggests organic precursors are partly derived from terrigenous higher plant.

The ratios of hopanes and steranes measured in these oils show relatively high values (Table 13). Normally, this ratio can provide a method for quantifying the relative algal (sterane) input to the ubiquitous bacterial (hopane) input in a depositional environment (SEIFERT and MOLDOWAN, 1986). Nevertheless, the hopane/sterane ratios may be result either from the more widespread bacteria in the sediment compared to the algae or an anomalous slightly presence of the steranes resulted from the different type of algae source of the oils. An absence of sterane in the oils (MELLO et al., 1988 and ref. therein) has also be suggested to be resulted from a lack of steranes in organic sources in an oxic condition of a freshwater lacustrine environments due to the organisms living in such a habitat using

lipids rather than sterols as rigidifiers or/and as protectors of their cell wall materials.

Not only an anomalously very low concentration of the steranes relative to the hopanes, but a very low concentration of C_{29} steranes isomerization ratios has also shown in the Sirikit crude oils. GRANTHAM (1986) proposed that an anomalous presence of sterane stereoisomers in a very low concentration is affected by an insufficient time to complete the sterane isomerization reaction. This was referred to the MACKENZIE and MCKENZIE suggestion (1983) that under heating condition, time/temperature parameter constrains a completely sterane isomerization reaction. Stranahan et al. (1988, 1989) suggested the effects of sources and heating rates upon the reaction rate of the isomerization processes at the equilibrium. Since the original precursors of steranes in the nature are sterols, several complicated conversion processes during diagenesis of sterols to be derived steranes might either be affected by those constraints. If a sudden bury with high heating rate was happened during diagenesis, all such reactions probably had not been completed yet. By this assumption, thermal and burial histories might control stereoisomer configurations of the oil samples from this basin rather than the effect of their organic sources.

Even though a very low concentration of steranes relative to hopanes and anomalously low stereoisomer ratios of C_{29} steranes are seen in the oil samples in

this study, the predominance of C₂₉ steranes can be seen in the MID of m/z 217 chromatograms. The ratios of C₂₇:C₂₈:C₂₉ are repeatedly confirmed by the terrigenous higher plant derived source of these oils. An absence of C₃₀ steranes is consistent with non-marine depositional environment since only marine oils contain C₃₀ steranes (MOLDOWAN et al., 1985). The presence of C₂₈ steranes may probably also be derived from an algae origin (TISSOT and WELTE, 1978). In addition, a presence of 4-methylsteranes suggests a contribution of dinoflagellates in lacustrine sources of the Sirikit oils. The 4-methylsteranes are believed to be derived from the 4-methylsterols produced by dinoflagellates (DE LEEUW et al., 1983; ROBINSON et al., 1984). Most reports of their high concentrations appear to be associated with the lacustrine source rocks (BRASSELL et al., 1986; WOLFF et al., 1986). This suggestion would imply that dinoflagellates made a significant contribution to the organic matters of the source rocks of the Sirikit oils.

The carbon isotope ratios of saturate and aromatic fractions of the oils in this study are anomalous. The general isotopic relationship of Sofer-type plot (Sofer, 1984) which followed two equations of terrigenous and marine oils is not observed by the oil samples in this study (Figure 23), as well as the Canonical Variable (CV) values (Table 15). For the CV values, these oils have -0.5 to -2.2 range, where a value < 0.47 is used to refer marine or non-waxy oils. This is

unusual for crude oils that also derived from terrigenous higher plant source. Thus, on the basis of isotope data, one would expect that contribution from terrigenous higher plant material is a minor part of the organic source material of the Sirikit oils. However, some phenomena has been reported in crude oils derived from terrigenous source materials in Australia and Indonesia (SOFER, 1984; MCKIRDY et al., 1986). It was explained by SOFER that they were resulted from an uncommon occurrence of a contemporaneous group of marine organisms that synthesized those waxy crude oils. Nevertheless, this explanation was disconcerted for the oils in this study since a palynofacies of sediments in Phitsanulok Basin has been reported by FLINT et al. (1988). The detrital land-plant material, casts of freshwater algae with no marine indicators has been proposed. Recently, an anomaly in a Sofer-type plot of waxy crude oils from Australia has been explained by MCKIRDY et al. (1986) as suggesting another origin of non-marine source, such as brown-green algae, Botryococcus braunii. Botryococcus braunii can produce C₃₄ alkenes, botryococcenes, that have the same skeleton of an unusual high molecular weight C₃₄ acyclic isoprenoid, botryococcane. The C₃₄ botryococcane is presently used as an indicator of the different species of algae B. braunii in lacustrine environments of many studies of non-marine source oils (MCKIRDY et al., 1986; SEIFERT and MOLDOWAN, 1981). Waxy-oil character, CV values and Sofer-type plot of

carbon isotopes of the sirikit resembling to the Australian oils might propose an alternative source of the freshwater algae *B. braunii* being a possible precursors of the Sirikit oils. However, the C_{34} -botryococcane could not be seen in GC chromatogram of isoalkane fractions of the oils examined in this study and the ratios of $C_{27}:C_{28}:C_{29}$ steranes were not the same as shown in such group of Australian oils. So, the explanation of the Australian crude oils were probably suggested with precluding the derivation from mixed terrigenous source by consideration of their C_{27}/C_{29} sterane ratios. This probably suggested the different assumptions of Sirikit oils from those Australian oils since the biomarkers of the Sirikit oils indicated partly terrigenous higher plant precursors. Therefore, the typical characteristics of these oil samples may be explained by the mixed organic source materials or the other species of a freshwater algae origin. In addition, the analysis of lacustrine Maoming oil shale from China has also been reported by BRASSELL et al. (1988). The identified C_{31} and C_{33} botryococcanes in their studies suggested a different race of *B. braunii* or algae source in a lake deposition in China. According to the report of MCKIRDY et al. (1986), an abundance of botryococcane in a present oils was suggested by a preservation of the remains of *B. braunii* blooms in depositional sediments under anoxic to micro-oxic condition of the deep stratified lakes. The anomalously

low concentration of stereoisomers of steranes in many Tertiary crude oils could be resulted by their history of the deposition and migration (GRANTHAM, 1986). Also, time/temperature constraints of the geothermal gradient, heating rate, burial rate and the mineral matrix distributed in the source rocks can be the parameters controlling the completion of stereoisomerization reactions (GRANTHAM, 1986; STRACHAN et al., 1988; 1989). Then, the sources and burial history of the deposition of the sediments could be affect stereoisomer ratios of steranes of the Tertiary oils, and this will make it was anomalously low (GRANTHAM, 1986). Therefore, the typical characteristics of the Sirikit oils may better be understandable if the sources and maturity effects upon the stereoisomer ratios and stable carbon isotope values to the sediments and oils of the Phitsanulok Basin would be investigated due to their depositional events.

THE DEPOSITIONAL ENVIRONMENT

Given the diversity of variations of lacustrine environments which range from dominated freshwater to complete saline, the term freshwater lacustrine has been ascribed to the depositional environment of the Sirikit Oilfield (FLINT et al., 1988). A shallow, large lake with low wave energy into which highly variable rivers discharged was inferred to represent the construction of the lobate Sirikit deltas. Such an environmental interpretation is supported by the reported palynofacies

which indicated the absence of marine indicators in this oil reservoir.

In terms of geochemistry, the organic source materials described by their biomarker characteristics are non marine algae, bacteria and terrigenous higher plants. Pr/Ph ratio which is usually used to be an indicator of redox potential of sediment (DIDYK et al., 1978) also infers the lacustrine environment of this reservoir to be oxic. These values ranged from 2.7 to 4.0 (mean 3.3) (Table 11). Pristane and phytane have been described as originating from the cleavage of phytol side chains of chlorophyll. In an oxidizing environment, a decarboxylation reaction that produces pristane would follow after cleavage of phytol side chain, whereas reduction would produce phytane in reducing environment. This description suggests an oxic depositional environment of the Phitsanulok Basin in diagenesis. The preferential formation of phytanic acid by oxidation of phytol is then followed by the conversion of phytanic acid to pristane during the catagenesis.

However, the interpretation of the redox potential in the depositional environment by Pr/Ph ratio must be made with caution. Other organic precursors can source these two compounds. For example, bituminous coals and oils derived from higher plants are reported to have high Pr/Ph ratios (5-10) in comparison to marine oils and sediments (<1-3) (BROOKS, 1969, POWELL and MCKIRDY, 1973). Therefore, high Pr/Ph ratio (>3) may

result from either an oxic condition exposed before, or during, deposition or along with their terrigenous organic sources. In addition, an inappropriated using Pr/Ph ratio as a redox indicator in samples of low maturity without consideration of the precursors and maturity level has been mentioned by POWELL (1988). Nevertheless, it can be a reliable redox potential parameter for samples which have the same origin and maturity level as demonstrated from oil/source rock correlations (ten HAVEN and RULLKOTTER, 1988).

The concentration of low molecular weight steranes was not shown to be significant in all these samples. High concentrations have been reported to be associated with carbonate or hypersaline environments rather than a freshwater lacustrine environments (VOLKMAN, 1988). In addition, there is no indication of saline conditions by a high concentration of C₃₄ and C₃₅ in a homologous serie of hopanes. A presence of gammacerane in these samples is inconclusive in its environmental significance as it might be affected by an organic source precursor rather than the environment type: gammacerane has been reported to be originated from either terrigenous higher plants or from organic matter in hypersaline environments (VOLKMAN, 1988). Dinoflagellates which produce 4-methylsteranes of these oils can be present in both marine and non-marine aquatic environments (MOLDOWAN et al., 1985). Furthermore, an absence of C₃₀ steranes can confirm the non-marine

depositional environment since it has been suggested as a good exclusively marine biomarker (MOLDOWAN et al., 1985).

MATURITY

The method for determining maturity of crude oil samples in this study was based upon the comparison of general maturity parameters of the biomarker stereoisomers with recent reports. Specifically, the stereoisomer and epimer ratios of sterane, triterpanes and some aromatic compounds were determined. From the parameters shown in Table 12, 13 and 14 and compared to the specific information of the values, they suggest a relatively low maturity of the Sirikit oils. The ratios of $5\alpha(H), 14\alpha(H), 17\alpha(H) - 20S/20S+20R$ C_{29} steranes of the oil samples ranged from 0.23 to 0.31 (mean 0.27). At the thermodynamically equilibrium, this maturity parameter has been suggested to be value to 0.55 (PHILP and LEWIS, 1987; SEIFERT and MOLDOWAN, 1986, GRANTHAM, 1986). In addition, the other parameter from steranes were consistent with the $5\alpha(H), 14\beta(H), 17\beta(H) - 20R/5\alpha(H), 14\alpha(H), 17\alpha(H) - 20R$ epimer ratios ranged from 0.58 and 0.86 (mean 0.73) while mature values have been proposed ranging from 2.0 to 2.4 (SEIFERT and MOLDOWAN, 1986).

In addition, the maturity parameters from hopane epimer ratios of these oils were accordant to the sterane isomer ratios. Since the values of observed epimer ratios of $22S/22R - 17\alpha(H), 21\beta(H) - C_{31}$ hopanes ranged from

1.12 to 1.45 (mean 1.28) (Table 12), also meaning low maturity of the Sirikit oils. At thermal equilibrium, a mixture of 22S and 22R epimers of hopanes would yield approximately a ratio about 1.5 (60:40) (PHILP, 1985). There was also a report from SEIFERT and MOLDOVAN (1986) that in most crude oils the equilibrium ratio of 22S/22R $17\alpha(H), 21\beta(H)-C_{31}$ hopane usually range from 1.4 to 1.6. The nonequilibrium mixtures of a high moretanes to hopanes (0.18) and of low 22S/22R ratios (1.2) has been reported by GRANTHAM (1986) in many Tertiary crude oils. This phenomena has been explained that it was an effect of thermal stress upon the maturity (SEIFERT and MOLDOVAN, 1986). Besides an immaturity of the oil, extracted coal liquid by the oil was an alternative effect that might also be possible to the oils (SEIFERT and MOLDOVAN, 1986).

T_m [$17\alpha(H)-22,29,30$ -trisorhopane] and T_s [$18\alpha(H)-22,29,30$ -trisorhopane] ratios of these oils ranged from 0.41 to 0.67 (mean 0.56). This parameter is commonly used to compare maturity in correlation purposes since the relative concentration of T_m is affected by maturity changes whereas T_s is a source parameter and is not affected by maturity levels. There is no distinguishable variation of T_m/T_s values which can differentiate their different maturity levels among these oil samples.

Moretanes, the $17\beta(H), 21\alpha(H)$ stereoisomer, are also found in the same region of the chromatograms as the

hopanes. This compound series appear with increasing maturity or by the effect of the thermal stress (GRANTHAM, 1986). The ratios of C₃₀ moretane to C₃₀ hopane of the Sirikit oil samples range from 0.13 to 0.17 (mean 0.16), unusually high for Tertiary oils. The values of moretane/hopane ratios in general oils derived from Tertiary source rocks and terrigenous sources in several basins have been reported by GRANTHAM (1986), who suggested that they should be relatively low (< 0.1) in extracts of mature source rocks and in crude oils. The unusually high values in these Tertiary oils can be explained by their depositional environment with respect to time, the heating, the rate of burial and the geothermal gradient of these young basins. Unusually high thermal stress can affect the high conversion reaction of hopane to moretane isomers. This explanation is possible for the oils in this reservoir since general tectonism of Cenozoic lacustrine basins in South East Asia, especially in Thailand, has been proposed by GIBLING (1988). The strike-slip tectonism and hydrocarbon generation under condition of rapid burial and high heating rate might be a possible effects. The report of GIBLING of Cenozoic lacustrine basins in South East Asia with the tectonic setting, depositional environment and hydrocarbon potential will be discussed later.

The unusually low concentration of steranes in the crude oils has been previously described. Compared

to the hopanes in the same oils, an anomalous, yet comparatively low m/z 217 sterane chromatogram occurred in most of the oil samples. Nevertheless, this appearance probably depended upon the effect of a very low sterols in what specific type of the organic material in the sources and the maturity level of the oils. Furthermore, there is no correlation between maturity effect and anomalously low sterane/hopane ratios has been reported in any published papers exceptionally the effect of the depositional environment upon the sources.

Besides a very low sterane/hopane ratios, an anomalously low concentration of sterane isomer ratios have shown in these oil samples. The anomaly of low concentrations of sterane isomerization with an accompanying high ratio of moretane/hopane of crude oils which derived from Tertiary source rocks has been discussed by GRANTHAM (1986). He observed the sterane isomers of the 20S/20S+20R ratio of $5\alpha(H), 14\alpha(H), 17(H) C_{29}$ sterane and the ratio of $\alpha\alpha/\alpha\alpha + \beta\beta - C_{29}$ sterane and suggested that the values were due to an incomplete isomerization reactions. His explanation was proposed by the support of the hypothesis proposed by MACKENZIE and MCKENZIE (1983) that the available time for isomerization reaction of sterane in Tertiary sediments is generally insufficient despite the high temperatures for the oils generation. This can be described by an incomplete isomerization controlled by time/temperature constraints in kinetic reaction of conversion processes.

The second hypothesis has been proposed in this paper was that a low sterane isomer ratios was a result of the deltaic land-plant-containing source rocks generating crude oils under low heating conditions. Finally, the immature biomarkers of these oils that might reflect nonindigenous contributions of organic matter picked up during migration of the crude oils through or along immature source rocks has also been discussed in such paper. Since only oil samples have been analysed in this study without their source rock correlation, the obvious discussion therefore is limited to these proposed hypotheses.

Hydrocarbon generation of the oil in Phitsanulok Basin was reported to be taken at depth greater than 4000 m (KNOX and WAKEFIELD, 1983). The general aspect of depositional conditions under rapid burial and high heating rate associated with the active strike-slip tectonism of the lacustrine basins in Thailand has also been proposed by GIBLING (1988). Both descriptions may concern the rapid burial and thermal histories of the sediments generating oil of this basin. The effects of sources and heating rate upon the isomerization reactions of C_{29} steranes have been studied by STRACHAN et al. (1988, 1989). They described the constraints upon the use of epimer ratios of C_{29} sterane as a maturity parameter. Since the epimer ratios are affected by the type of mineral matrix in source rocks and the heating rate during their deposition, these could influence the

progressive rate of the sterane epimerization reaction. By kinetically modeling of the behavior of the epimerization process, they suggested that source rocks which contain coals as the dominant source (30% TOC), or in the form of dispersed coal particles, would produce petroleum with anomalously low sterane epimer ratios if they had experienced a high heating rate as a result of high geothermal gradients and high burial rates. The effects of different heating rates upon the epimerization process in two types of matrix between coal and shale were also studied. Hence, the effects to the maturity of the Sirikit oil samples based upon sterane isomer ratios probably must be conducted with such experiment since facies assemblages of mudstone-coal-oil shale in the Phitsanulok Basin has been reported by GIBLING (1988). Also, one of three facies which is particularly well developed in the basal section of the Lan Krabu Formation was reported to be made up of massive bituminous to coaly claystones (KNOX and WAKEFIELD, 1983). By such informations concerning to source rock and deposition of the Phitsanulok Basin, their typical biomarker characteristics might be influenced by these effects.

More recently, the possibility of oil generating-coals has been reported in many parts of the world such as in Nigeria, Australia and South East Asia, especially Indonesia (THOMPSON et al., 1987 and ref. therein). Those coals are reported to be deposited in Tertiary basins (in Indonesia) and Middle Jurassic basins

(in Australia). In Indonesia these most productive oil source rocks are dipt. coals with associated shales deposited within tidal dominated coastal plain environments during the Tertiary. Usually, the composition of oil generating-coals reportedly were liptinite-rich coals or hydrogen rich and oxygen poor coals. It is still doubtful that significant quantities of oil can be generated from vitrinite rich coals. However, it was suggested by BOUDOU et al. (1984) that when kerogens are rich in oxygen, carbon dioxide and water, such kerogens would be evolved in preference to hydrocarbon. The development of their origin and formation depend on deposition, accumulation and the geological setting. Oils derived from coals in Indonesia were reported to have a very high pristane content and a marked odd-over-even preference in the generally pronounced C₂₇ to C₃₃ waxy components at a relatively low thermal maturity level. The carbon isotope ratios of the C₁₅ fraction are around -30 ‰ which suggest a higher plant kerogen derivation (THOMPSON et al., 1987 and ref. therein). The mass spectra of biomarkers from GC/MS analysis would show a number of wax and resin-derived components which differ from general crude oil compounds (THOMPSON et al., 1985; GRANTHAM, 1983; PHILP et al., 1988). The presence of these compounds can be used to distinguish oils derived from coal or source rock in addition to their stratigraphic sequence of reservoir deposition. The oil generating-coal source rock is

discussed here because the local geological setting, depositional environment, and hydrocarbon potential of the lacustrine basins of South East Asia, especially Thailand, has been reported to be a peat swamp deposition of the fluviolacustrine environment (GIBLING, 1988). The kerogen was also proposed to be generally lipinitic type I kerogen in these lacustrine environments. Even though there was no evidence of biomarkers in these oils from the Phitsanulok Basin which specifically refer to resin products derived from coals as for the crude oils from Indonesia or Australia, some compounds which are not derived from steranes but are in the m/z 217 chromatogram can be distinguished.

ALTERATION REACTIONS

Biodegradation is often one of the first alteration reactions that will occur to crude oils since the composition of crude oils are hydrocarbons that can easily metabolized by bacteria. Biodegradation of crude oils will occur only under appropriate conditions. Consequently, the distribution of biomarkers, maturity and migration parameters can be affected by biodegradation. A summary of relative rate of degradation of certain components based upon their structural complexity has been illustrated by the Table 3. Usually, the components preferentially degraded in crude oil are the n-alkanes followed by the more structurally complex compounds.

The biomarker distribution of the oils in this study show that no biodegradation has occurred to the oils either in the reservoir or during migration. This lack of biodegradation helps further describe of the hydrocarbon generation within this basin. KNOX and WAKEFIELD (1983) reported that generation and expulsion of Sirikit hydrocarbons took place at depths exceeding 4,000m. At this estimated depth, bacterial activities should be absent and thus not effect crude oil. In addition, the high heating rate and rapid burial of sedimentation would be the additional limiting factors for bacterial activity. However, significant concentrations of 8,14-secohopanes in most samples may suggest the presence of bacterial contribution and their activities in this environment in the early stage of digenesis. The shallow, large lake depositional environment would be suitable for bacteria flourishing during the initial stage of lake expansion. Following the deposition of sediment during the diagenesis stage, rapid burial might be caused by the change of basinal tectonism. The 8,14-secohopanes derived from the hopane degradation then would be preserved in the sediments and observed in the analysis of the oils.

In addition, reaction that affected the Sirikit oil in the reservoir was catalytic reaction by clay mineral matrix. The presence of diasteranes, or rearranged steranes, in the oil samples implies an acid clay catalysed reaction to rearranged the regular

steranes to diasteranes. The lithologic sequence within the basin that probably encountered the oil during hydrocarbon generation and accumulation was suggested including claystone stratigraphy. Hence, the presence of diasteranes, but in a low concentration, may be explained by their relatively low concentration of regular steranes in these oils. The low concentration of regular steranes then also produced a low concentration of diasteranes even though the acid clay catalytic effect might be a possible reaction to be happened to the Sirikit oils.