CHAPTER V

PETROLEUM GEOLOGY OF THE FANG BASIN

It is the known fact that a sedimentary basin is an area of the earth's crust that is underlain by the thick sequence of sedimentary rock. Besides, petroleum commonly occurs in sedimentary basin and are absent from intervening areas of igneous and metamorphic rocks.

Petroleum, like other fossil fuel is wide spread but unevenly distributed. The kind of rocks that can be petroleum-bearing are very widespread, but the formation of oil pool is matter of delicate timing. The highest ratio of oil pools to volume of sediment is found in the petroleum-bearing sediment of Tertiary age. Furthermore, amongst various types of sedimentary basins, the intracratonic type covers approximately 18.2 per cent of the world's basin areas, and intracratonic basin-type shares about 1.5 per cent of the world proven and produced petroleum reserve.

The long-recognized critical elements for the formation of petroleum accumulations include a source, reservoir, trap, and seal. More recent recognition of the important dynamic aspects of oil and gas occurrence has added burial history including the evolution of temperture and pressure regimes and migration pathway to the original list. Depositional system analysis answers question about reservoir volume and distribution, and probable nature and extent of source and sealing facies. Trapping requires three-dimentional isolation of all or part of an element portion of the reservoir facies. Traps may be produced by structural flexures or discontinuities, by facies distribution pattern, or by a combination of both. Consequently, depositional systems analysis may also provide useful information about traping potential or style.

In this chapter, the discussion will be focussing upon the historical aspect of the petroleum exploration and production, characteristics of crude, sedimentary facies of source, reservoir and seal rocks, proposed model for petroleum generation and maturation, and lastly the petroleum potential of the Fang basin. It is, however, envisage that many of the solutions to the problem on petroleum potential of the Fang basin may remain unsolved, but at least a certain degree of attempt has been made to pave way for the final satisfactory answer in the future.

5.1 Petroleum Exploration and Production Records

The more systematic petroleum drilling exploration and production of the Fang basin began in 1955 through 1969 continuously in the areas of Chaiprakarn, Huai Bon, Mae Soon, and Pa Ngew. This period may be referred to as the first phase of drilling-exploration/production.

However, there was a 7-year period of no drilling-exploration in the Fang basin during 1970 to 1977. This is basically due to the involvement of the Defence Energy Department in the petroleum drilling-exploration in some other government reserved areas in northern Thailand. The second phase of petroleum drilling-exploration/production has begun again in 1978 till the present time. Altogether 201 exploration/production drill-holes of totally 105 kilometres has been conducted in the Fang basin since 1955 (Figure 5.1.a).

With respect to petroleum production in the Fang basin, the actual production began in 1959 in Chaiprakarn area. The production in this area has been declined and eventually stop in 1974 with the actual recovery of totally 204,099 barrels. For Mea Soon area, the production has begun since 1966 with the an increasing trend. Up to 1984, the cumulative production from this area is 1,559,336 barrels. Concerning the petroleum from Pong Nok area, the total recovery during 1979 and 1984 is 40,836 barrels. At present, Mae Soon and Pong Nok are the active petroleum production areas of the Fang basin. The cumulative petroleum recovery from these areas of the Fang basin between 1959 and 1984 is 1,764.271 barrels. The current petroleum production rate of the Fang basin in 1987 is espected to be about 350,000 barrels per annum (Figure 5.1.b). It is noted that no attempt has been made to undertake the secondary recovery programme.

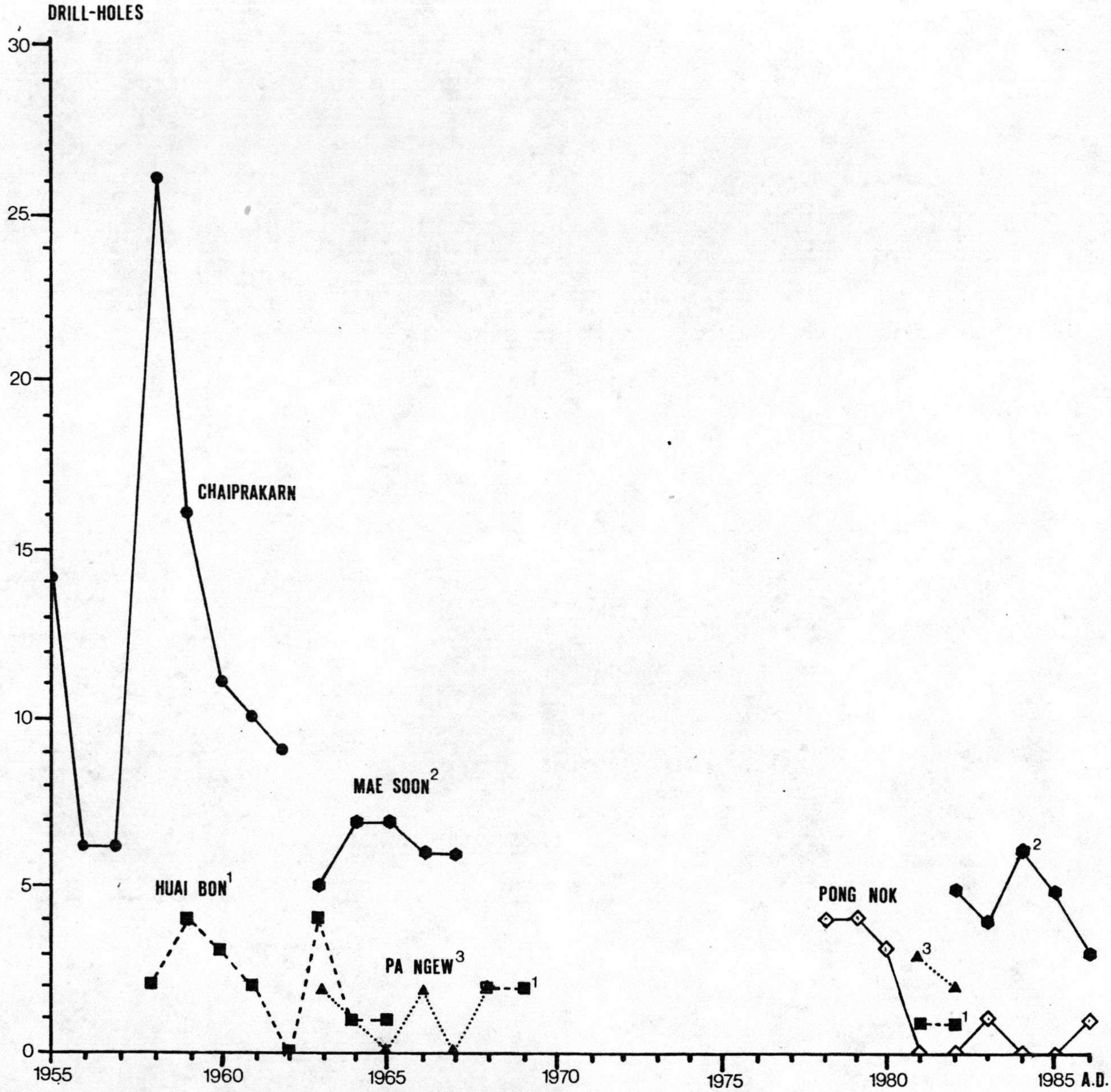

Figure 5.1.a Drilling exploration/production of the Fang basin up to 1986.

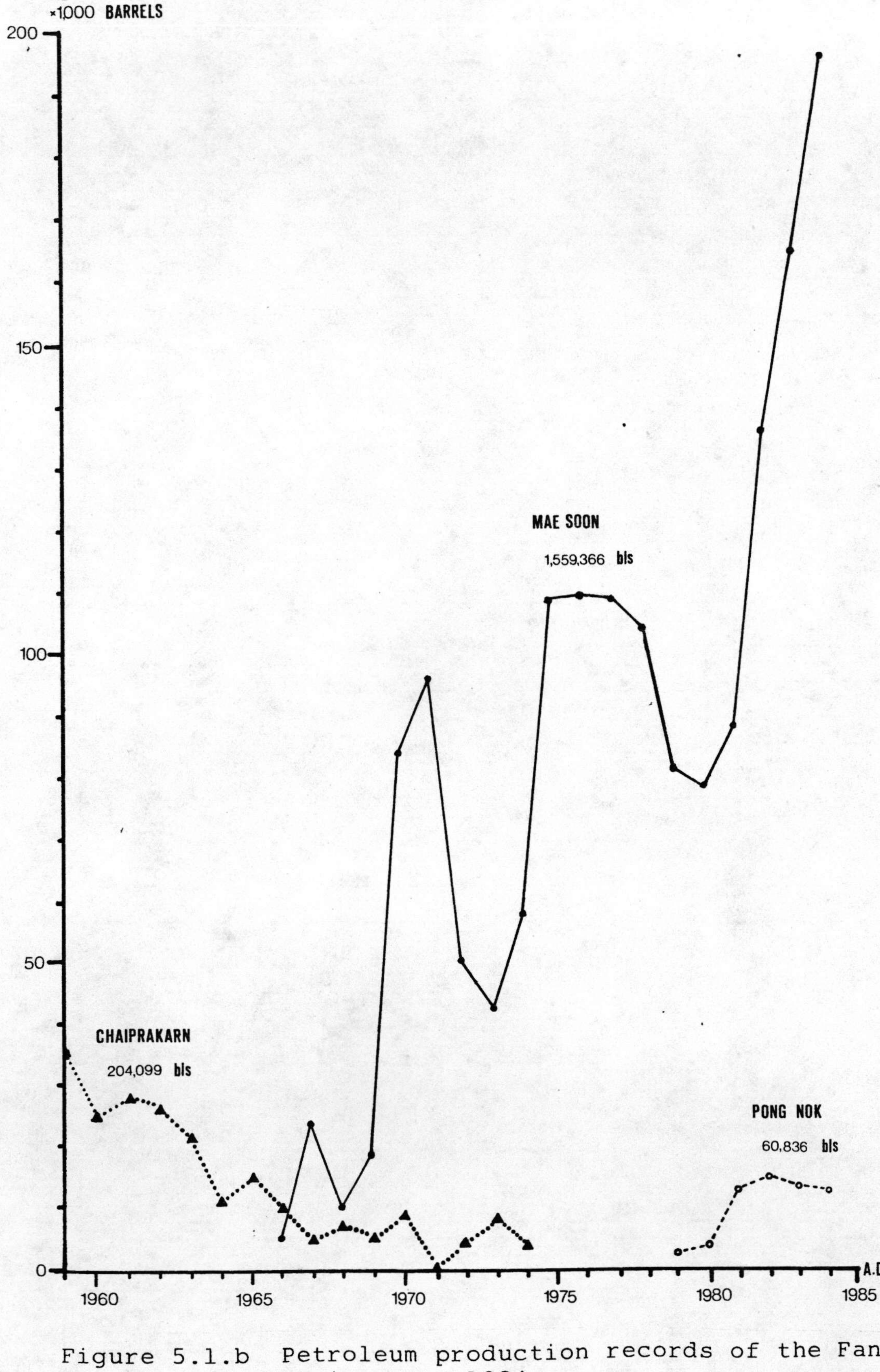

Figure 5.1.b Petroleum production records of the Fang basin up to 1984.

5.2 Fang Crude Oil Characteristics

Generally, crude oil is defined as a mixture of hydrocarbons that existed in the liquid phase in natural underground reservoirs and gas at atmospheric pressure after passing through surface separating facilities. In appearance, crude oils vary from straw yellow , green, and brown to dark brown or black in colour. For convenience, the compounds found in petroleum may be divided into two major groups: (a) the hydrocarbon, which contain three major subgroups, and (b) the heterocompounds, which contain other elements.

Hydrocarbon molecules occur in different structure forms with the following name : alkanes are open-chain molecules with single bonds between carbon atoms, cycloalkanes are alkane rings, allkenes contain one or more double bonds between carbon atoms, and arenes are hydrocarbons with one or more benzene rings. Most petroleum geologists and engineers are more familiar with the terms paraffins for alkanes, and naphthenes or cycloparaffins for cycloalkanes, olefins for alkanes, and aromatics for arenes. Consequently, these terms will be used in the following discussion.

It has been long known that the crude produced from Chaiprakarn, Mae Soon, and Pong Nok areas are different in base crude. The Chaiprakarn and upper pay zone of Pong Nok are of asphatic base crude, whereas Mae

Soon and lower zone of Pong Nok are of paraffinic base crude. Properties of crude oil from the Chaiprakarn, Mae Soon, and lower pay zone of Pong Nok areas are summarized and presented in Table 5.1.a.

With respect to the classification of crude oils, many schemes have been proposed to classify various type of crude oil. Generally, the classifications fall into 2 categories, namely, (a) those proposed by chemical engineers interested in refining crude oil, and (b) those devised by geologists and geochemists as an aid to understanding the source, maturation, history, or other geological parameters of crude oil occurrence. A more recent scheme by Tissot and Welte (1978) based on the ratio between paraffin, naphthenes, and aromatics including asphaltic compounds is being employed in the present study (Figure 5.2.a).

Considering the hypotheses on the origin of the Fang oil, many authors had proposeed how the Fang oil occurred . Lee (1923, 1927) believed that oil had generated from coal seams intercalated within Pleistocene sediments by distillation due to igneous contact. Brown et al. (1951) also supported Lee's hypothesis. Samattapand (1959) suggested that oil may have been derived from organic matter provided by plant remains and brackish water molluscs commonly found in the lower part or the sequence in the basin itself. Swai (1964) concluded that oil [Chaiprakarn oil] had originated from humic substance

Table 5.1.a Properties of the crude oil from the Chaiprakarn, Mae Soon, and lower pay zone of Pong Nok areas of the Fang basin.

Area / Parameters	Chaiprakarn Asphaltic Base Crude	Mae Soon Paraffinic Base Crude	Pong Nok Paraffinic Base Crude
Oil Properties			
Specific Gravity	0.957	0.872	0.837
A.P.I. Gravity	16.40	30.8 (60°F)	37.6 (140°F)
Colour	brownish black	brownish black	brownish black
Pour Point	65°F	95°F	92°F
Sulphur (%wt)	0.28	0.18	0.16
Viscosity (100 F)	7722 sec	195.8 sec	150.4 sec
Paraffin Wax (%wt)	-	16.0	18.628
Reid's Vapour	-	4.8 psi	4.3 psi
Oil Compound (%wt)			
Saturated HC	19.8	60.3	no data
Aromatic HC	45.0	22.1	no data
NOS Compounds	35.2	17.6	no data
Alkane Parameters			
Pristane/phytane	no data	4.91	no data
Pristane/n-C_{17}	no data	0.87	no data
Phytane/n-C_{18}	no data	0.18	no data
CPI	no data	1.08	no data

suppies from the land surrounding the Fang basin in the Tertiary period, highly asphaltic nature of the crude oil substantiates its young origin and precludes any possibility of long distance migration, the surprizingly low sulphur content of the crude suggests a non-marine environment for the Tertiary Fang basin. Hashimoto et al. (1968) belived that oil [Chaiprakarn oil] had originated from the Kanchanaburi Series which intercalates with graphtolite shale beds of Paleozoic Era. According to Buravas (1973), in 1968 Professor W. Gaines of Chiang Mai University, suggested that the thick viscous oil of Chaiprakarn and Mae Soon crude oil had been derived from coal beds of the Fang deposits through metamorphism of the coal. Piyasin (1979) believed that the petroleum of the Fang basin had generated from plant and animal remains which deposited in the Mae Sot Formation, naphthelene [asphaltic] base crude oil might generated from the mixture of coal and animal remains (mollusc and insect), whereas paraffinic base crude oil might generate from coal seams which interbedded with bituminous shale and siltstone. Dutescu and Enache (1980) proposed that the oil source rocks are shale of the Mae Sot Formation, the presence of the bituminous and carbonacous rocks are possible concidence and this should explain the fact that the abundance of fauna and flora was the possible origin of oil.

The detailed study in the present investigation of crude oil from the Fang basin particularly regarding the oil compounds, sulphur content, wax content, and principal fields of occurence of crude oils of Chaiprakarn and Mae Soon areas have been undertaken. The result of Chaiprakarn and Mae Soon crude oil characterization indicates that the Chaiprakarn crude oil is of aromatic-asphaltic (heavy degraded oil type), whereas the Mae Soon oil is of paraffinic oil type. Taking additional consideration of high wax content of Mae Soon crude, and low sulphur content of both crudes of the Fang basin into consideration, the final crude types are illustrated in the ternary diagramme in Figure 5.2.b.

It is, therefore, concluded that the Mae Soon crude oil represents the characteristics of probably original crude derived from the non-marine organic matter in the Fang basin. For the Chaiprakarn crude, it is believed that this crude have been migrated as well as degraded physico-chemically and biochemically from the original paraffinic type to the aromatic-asphaltic type of heavy degraded crude oil (Figure 5.2.c).

5.3 Source Rock and Reservoir Rock Facies

The prediction, recognition, and delineation of petroleum source rock facies are amongst one of the primary tasks in the basin evolution and subsequence exploration (Tissot & Welte, 1978; Hunt, 1979). By definition, the source is a unit of rock that has generated and expelled oil or gas in sufficient quantity

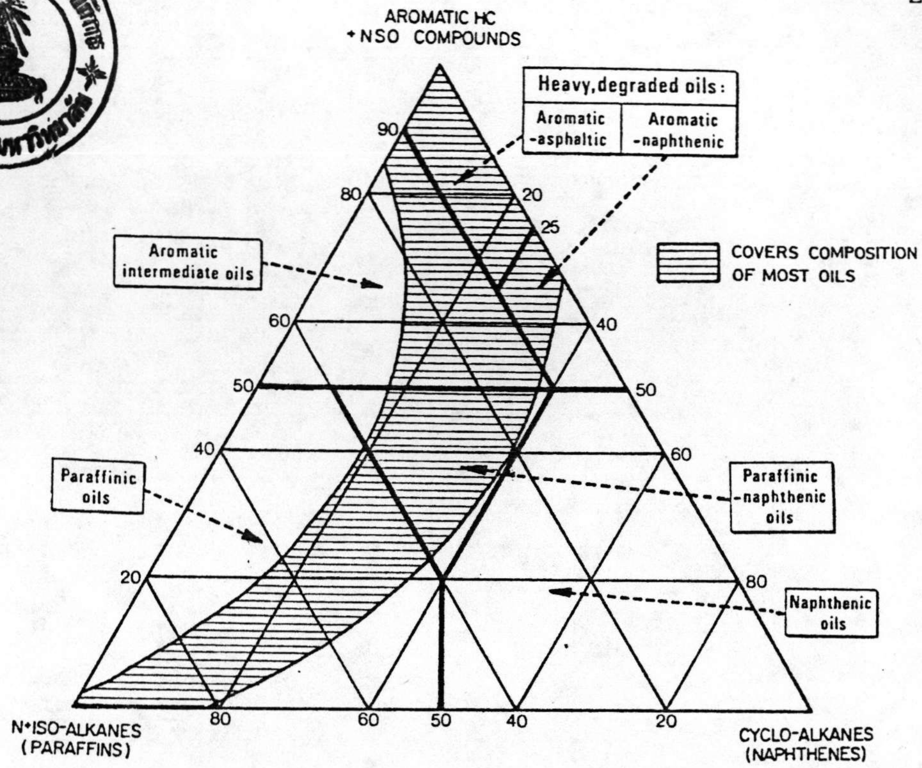

Figure 5.2.a Ternary diagram showing the classification of oils proposed by Tissot and Welte (1978).

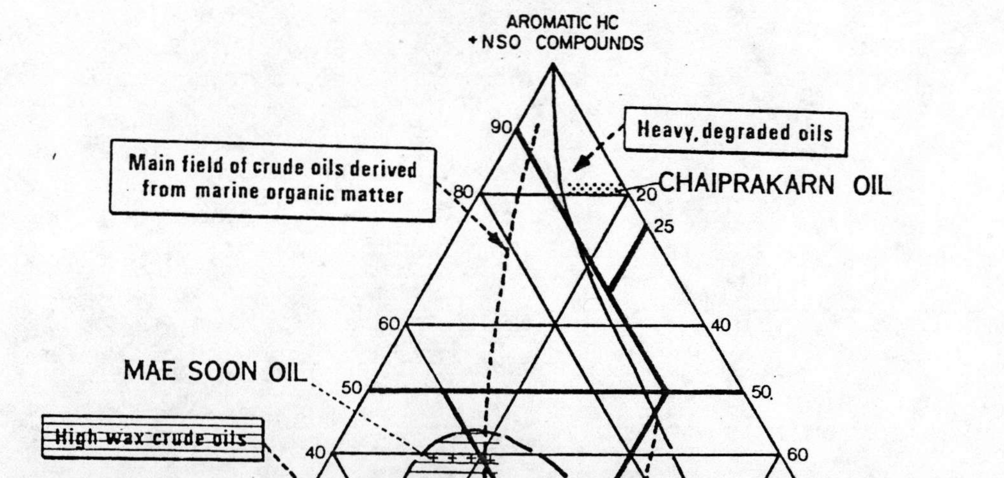

Figure 5.2.b Ternary diagram of the Fang crude oil composition, comparing with the principle field of occurrence of crude oil from marine and non-marine origin proposed by Tissot and Welte (1978).

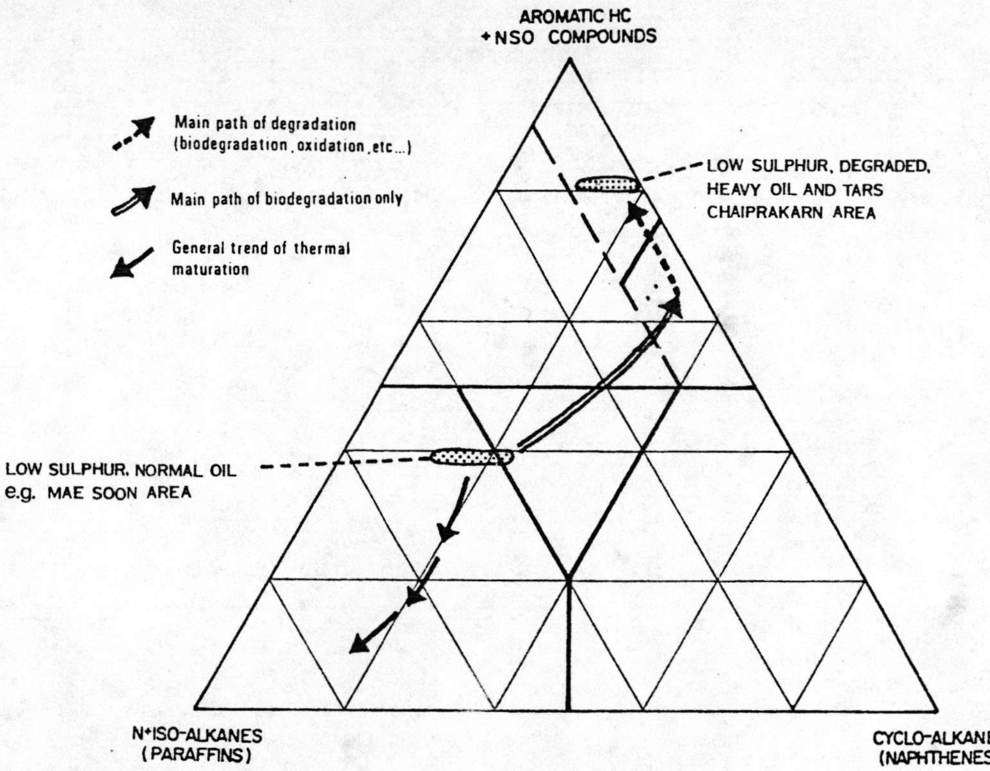

Figure 5.3.c Ternary diagramme showing the trends of alteration and thermal maturation of the Fang crude oils.

to form commercial accumulations. The term "commercial accumulations" is, however variable by definition.

Fundamentally, the evaluation of source-rock facies must provide answers to the following questions:

1) does the rock have sufficient organic matter ?

2) is the organic matter of the appropiate type ?

3) has this organic matter generated pretroleum ?

4) has the generated petroleum migrated out ?

Obviously, the presence of an adequate volume of functional source-rock facies is critical to the ultimate productivity of a sedimentary basin.

Empirical as well as experimental and theoretical considerations have led to the use of a variety of indices of source potential of a sediment or rock. A relatively simple measurement of total organic carbon content (TOC) is widely applied to screen for potential source rocks (Ronov, 1959; Dow, 1978). A commonly accepted minimal TOC content for the potential source rock is 0.4 per cent; values of one per cent or more are preferable. TOC is, however, only a crude index of source potential. Organic carbon may be recycled from older sediments, possesing little capacity for further release of liquids. Consequently, more sophiticated analytical procedures determine the content and composition of extractable hydrocarbons within rock matrix. Because expulsion of generated hydrocarbons from functional source rocks is an inefficient process, the effect of active generation and lose on measured extractable hydrocarbon values is considered by most geochemist to be negligible (Hunt, 1979). The organic matter content in sediment is a function of three variables: (a) the rate of organic productivity of the systems; (b) the rate of destruction by biological or inorganic processes; and (c) the rate of dilution by detrital sediments. Generally, for black shale, siliceous and carbonate sediments, the total organic matter content increases with sedimentation rate for slow rate of deposition, but decreases with sedimentation at high rate of deposition (Ibach, 1982). At slow sedimentation rate organic matter is oxidized, rapid deposition effectively dilute the organic matter content of the sediments. Therefore, for each lithology there appears to be an optimum rate for the preservation of organic matter. This rate is a balance between dilution and destruction of the organic matter. Besides, low depositional energy and minimal reworking favour preservation of organic materials.

Burial and diagenesis of depositional organic matter produces kerogen, the precusor of petroleum. Kerogen is classified on the basis of chemical composition into three types, commonly designated I, II,and III (Tissot et at., 1978). Type I is an oil-prone kerogen that consists of algal or amorphous organic material. Algal-rich varieties typically produce waxy, paraffic crude oils. Type II kerogen contains a mix of amorphous and herbaceous organic material and is also an oil-rich precursor. Type III kerogen consists of woody and coaly material; it yields largely gas upon thermal maturation. In addition, the sulphur content is lower in terrestial than in marine organic debris and their resultant oils.

In summary, interpretation of deposoitional systems and their component facies provide the basis for estimation of the probable distribution, richness, and oil- or gas-prone nature of hydrocarbon source rocks. However, the nature of the depositional basin, degree of bottom water restriction, or organic productivity can vary greatly in any depositional complex.

Prior to the analysis of the source-rock facies of the Cenozoic sedimentary sequence in the Fang basin, it is neccessary to define the terminology which will be used in following context (Table 5.3.a).

Table 5.3.a Definitions pertinent to source rocks (Barker, 1980).

Terminology	Definition
Latent Source Rock	A source bed that exist but is as yet concealed or undiscovered.
Potential Source Rock	A unit of rock that has the capacity to generate oil or gas in sufficient quantities to form commercial accumulations but has has not yet done so because of

	insufficient thermal maturation.
Active Source Rock	A source bed that is in the process of generating oil or gas.
Spent Source Rock	A source bed that has completed the process of oil or gas generation and expulsion.
Inactive Source Rock	A source bed that was once active but has temporarily stopped generating prior to becoming spent.
Limited Source Rock	A unit of rock that contains all the prerequisiites of a source bed except volume.

Considering the lithostratigraphy of the Fang basin (see Figures 4.1.3.b) with paticular emphasis on the Chaiprakarn, Mae Soon, and Pong Nok areas adjacent to the main sub-basin, Huai Ngu sub-basin, different type of source rock facies will be determined. For Chaiprakaren area, the fluviatile facies with some lacustrine facies intercalations of the "A-Formation" is considered to be the limited source-rock facies due to the fact that there are only thin fine-grained clastic layers of limited volume in the succession. With respect to the lacustrine facies of the "B-Formation", this unit is considered to be potential source rocks because there is sufficient organic matter content in the fine-grained clastic layers, but thermal maturation of the kerogen is not in the level to generate petroleum (see 5.4). The petroleum discovered and produced in this area is believed to be migrated from the deeper part of the Huai Ngu sub-basin in the west, and degraded physio-chemically and bio-chemically.

For the Mae Soon area, the lacustrine and/or fluvio-lacustrine facies in the middle and lower part of the "A Formation" (not penetrated by any exploration or production drill-hole at the present time) is certainly considered to be the active source-rock facies on the account of sufficient quantity and quality of organic matter and appropriate thermal maturation (see 5.4). However, the lacustrine facies in the uppermost part of the "A-Formation", the fluvio-lacustrine facies of the "B-Formation", and the fluvio-lacustrine facies of the "C-2 Member" of the "C-Formation" are altogether considered to be the potential source-rock facies due to the inadequate thermal maturation of the kerogen. The petroleum produced from the upper pay zones of this area must have been migrated from the lowest succession of "A-Formation" in the main Huai Ngu sub-basin.

With regard to the Pong Nok area, the meandering fluviatile facies of "A-1 Member" of "A-Formation" is considered to be the limited source-rock facies due to the only thin fine-grained clastic layers of limited volume as well as small amount of organic matter content present. For the lacustrine facies of the "A-2 Member" and "A-4 Member" of the "A-Formation" is considered to be the potential source-rock facies due to the inadequate thermal maturation of the kerogen. The coal swamp facies of the "A-3 Member" of the "A-Formation" is believed to be the limited source-rock facies because of unsuitable type of the organic matter of limnic coal and unappropriate thermal level. With respect to the fluvio-lacustrine and/or meandering fluviatile facies of the "A-4 Member" of the "A-Formation" and the mainly braided fluviatile of the "C-Formation" is also regarded as the limited source-rock facies on the accounts of thin fine-grained clastic layers of limited volume in the sequence and unappropriate thermal maturation. For the lacustrine facies of the "B-Formation" is considered to be the potential source-rock facies due to the sufficient organic matter content in the fine-grained clastic deposited sand preserved in the reducing condition but the thermal maturation of the kerogen is not in the level to generate oil (see 5.4). Therefore, the petroleum discovered and produced in this area is considered to be migrating from the deeper part of the Huai Ngu sub-basin in the northwest. Besides, the petroleum in the upper part of the fluvio-lacustrine facies of the "A-Formation" have been degraded both physico-chemically and bio-chemically.

With respect to the potential reservoir-rock facies, it is generally apparent that numerous sandstone layers in the Cenozoic sequence within the Fang basin are exclusively potential reservoir rock, these sandstone layers are either fluviatile channel sand or lacustrinedeltaic sand which have been only partially cemented. The two essential reservoir properties, notably, porosity and permeability are most preferable for the rock to act as a reservoir.

Considering the geometry of the reservoir-rock facies, the vertical and lateral facies change as well as the intrabasinal faults appear to be the only limiting factors. The general configuration of the reservoir bodies is characterized by relatively wide lateral distribution as compared with the vertical distribution. This type of reservoir can be categorized as bedded or stratiform reservoir.

The analytical data on the physical properties and fluid content in major oil unit of Mae Soon oil pool as obtained from the determination of core samples of "H-Sand unit" (classified by Kulsing, 1984) of drill holes BS-110-13 and IF-26-39 by Core Lab Inc., Singapore (1984) are summarized in Table 5.3.b.

Table 5.3.b Physical properties and fluid content of "H-Sand" by Core Lab Inc., Singapore (1984).

Drill-hole	Depth (ft.)	Permeability (mD.)	Porosity (abs.)	Fluid-saturation oil(%)	water(%)	Density
BS-110-13	2755	231	25.7	6.1	54.4	2.67
IF-26-39	2581	2390	25.4	17.5	30.0	2.65
	2587	3440	26.7	20.5	34.7	2.64

These porosity values are considered to be very good, and the permeability values are also very good according to classification of Hyne (1984). It is noted that the permeability of "H-Sand" of drill-hole IF-26-39 is extremely high because the core sample is very loose. The thickness of reservoir rocks of "H-Sand" unit is between 5 and 45 feet.

For the reservoir continuity, the lateral continuity is considered to be sheet shape with length:width ratio approaching 1:1 according to nomenclature of sand body geometry of Potter (1962). Considering vertically , the reservoir-rock facies is laterally stacked according to descriptive terms for sand body continuity by Harris and Hewitt (1977).

The reservoir-rock facies of Chaiprakarn area is confined in the upper part of the fluviatile facies of the "A-Formation", and the fluviatile facies of the "C-Formation". For Mae Soon area, the reservoir-rock facies are confined in the fluvio-lacutrine facies of "B-Formation". And the Pong Nok area, the reservoir-rock facies are confined in lower part of the fluvio-lacustrine facies of "A-5 Member" of the "A-Formation".

5.4 Petroleum Generation Potential of the Fang Basin

The prime rationale for the geological setting of a sedimentary basin being prospective for petroleum are:

(a) the sedimentary depositional environment suitable for quality and quantity of organic matter in the source-rock facies,

(b) the nature of sedimentary deposition with respects to the reservoir-rock facies and seals,

(c) sufficient burial and thermal history of the source rock to enable conversion of kerogen into hydrocarbons followed by the effective migrating, and

(d) primary sedimentary features to provide stratigraphic trap and/or tectonic event to provide structural trap timely for migrating hydrocarbons.

First, the geometry of sedimentary basin, its sedimentary fills, and its internal structural styles are the primary parameters which allow an initial assessment of the hydrocarbon prospect of a basin. The Fang basin with about 2.5 kilometers thick sediments covering 575 square kilometres area can generally be considered to be the petroleum-bearing potential.

In addition, the high heat flow nature of the basin coupled with the thermal activity in the form of hot springs provide additional favourable condition to the hydrocarbon generation potential. The heat flow data of the Fang basin particularly regarding Chaiprakarn, Mae Soon, and Pong Nok areas are summarized in Table 5.4.a. The location of the one hot spring of the Fang basin is earlier shown in Figure 2.4.a.

Table 5.4.a Heat flow and geothermal gradient of the Fang basin (Thienprasert et al. 1983, 1984).

Drill-Hole Number	Depth Range (m)	Rock Type	Heat Flow (mW/m)	Thermal conductivity (W/mK)	Geothermal Gradient (°C/km)
Chaiprakarn Area					
59[?]	90-180	cl,sd	97.02	1.34	72.0
F-4	90-160	sd,sh,gr	150.42	1.58	95.0
IF-13-28	50-120	sd,sh,gr	97.20	1.70	57.0
	130-190	sd,sh,gr	93.93	1.19	78.8
Mae Soon Area					
BS-64-7	40-200	cl,sd	125.16	1.34	93.0
Pong Nok Area					
IF-4-19	90-185	sd,cl,gr	68.21	1.70	40.0
	195-500	sd,cl,gr	104.37	1.19	87.5

cl=clay,sh=shale,sd=sand,gr=gravel

To answer the question that what kind of source rock exit and what kind of depositional environment of the source rock, it has been discussed earlied that the avialability of the source-rock facies in the sedimentary sequence of the Fang basin are lacustrine and/or fluvio-lacustrine facies. With respect to the type of source rock, it is considered that the kerogen, which is the organic constituent of the sedimentary source rock that is neither soluble in aqueous alkaline solvents nor in common organic solvents, is considered to be of mainly type II (Tissort and Welte, 1978). Type II kerogen (sapropelite) is the kerogen most commonly found in petroleum source rock and shale and is composed of autochthonous organic matter of usually marine or lacustrine origins which has been deposited in reducing environment. It consists of sapropelic organic matter as well as some algal particles and planktonic remains together with some terrestial material. However, there might be a wide mixture between types II and III. Type III (huminite) is derived from the allochthonous terrestial organic material containing high plant and coaly material with a high proportion of condensed polyaromatic nuclei and heteroatomic bonds, especially oxygen. It is essential to determine the type of kerogen because the hydrocarbon-generating potential of any kerogen will be related to its chemical composition.

From the paleontology and age indication of potential source-rock facies previously discussed, it is considered that the proposed active source-rock facies have been assigned to be of Oligocene and Miocene age. However, the state of maturity of proposed active source-rock facies has to be determined using the methods of Lopatin and Weples.

Lopatin's method has developed for taking both time and temperature into account as factors in thermal maturation of kerogen (Waples, 1980). The time-temperature index of maturity (TTI) values correlate with the thermal regimes corresponding to generation and preservation of hydrocarbons. The conceptual framework can be summarized as follows:

(a) The rate of the chemical reaction involved in thermal maturation of organic material appears to double with every 10 degree cencial rise in temperature.

(b) Thresshold values of Lopatin's time-temperature index of maturity (TTI) are:

15	Onset of oil generation
75	Peak oil generation
160	End of oil generation
~500	Upper TTI limit for occurrence of oil with API gravity <40
~1,000	Upper TTI limit for occurrence of oil with API gravity <50
~1,500	Upper TTI limit for occurrence of wet gas
65,000	Last known occurrence of dry gas

(c) TTI values calculated from Lopatin reconstruction consistently agree with other maturation parameters commonly used by petroleum geologists.

Basically, the drill-hole data regarding lithological characteristics, depth range, and heat flow value have been used together with thermal conductivity values of each rock type to calculate the geothermal gradient of the Fang basin.

For Chaiprakarn area, the drill-hole data from F-4 and B-33 are being selected for the calculation to represent the area. The drill-holes BS-64-7/IF-22-35, and IF-4-19/IF-1-16 have been selected to represent the Mae

Soon and Pong Nok areas, respectively.

Graphic representation between the subsurface temperature and depth of the three areas concerned have been accordingly prepared (Figure 5.4.a, Figure 5.4.b, and Figure 5.4.c). Afterthat, the geological model for every sedimentary facies of each area have been constructed using subsurface temperature, depth, and geological time as major parameters for consideration. It is noted that the tectonic episodes have also .been takening to consideration in the construction of the models. The three simplified geological models are presented in Figures 5.4.d, 5.4.e, and 5.4.f. The calculation of time-temperature index of maturity has been calculated from those three geological models and results are summarized in Tables 5.4.b, 5.4.c, 5.4.d.

Table 5.4.b. TTI valus of dill-hole B-33 of Chaiprakarn area.

Temperature interval (°C)	Time interval (my)	Temperature factor	Interval TTI	Total TTI
20- 30	3.9	0.003906	0.015233	
30- 40	3.1	0.007813	0.024220	0.394533
40- 50	3.4	0.015625	0.053125	0.447765
50- 60	3.4+0.9	0.03125	0.134375	0.582033
60- 70	3.4+1+7.3	0.0625	0.73125	1.313284
70- 80	1.7	0.125	0.2125	1.525783

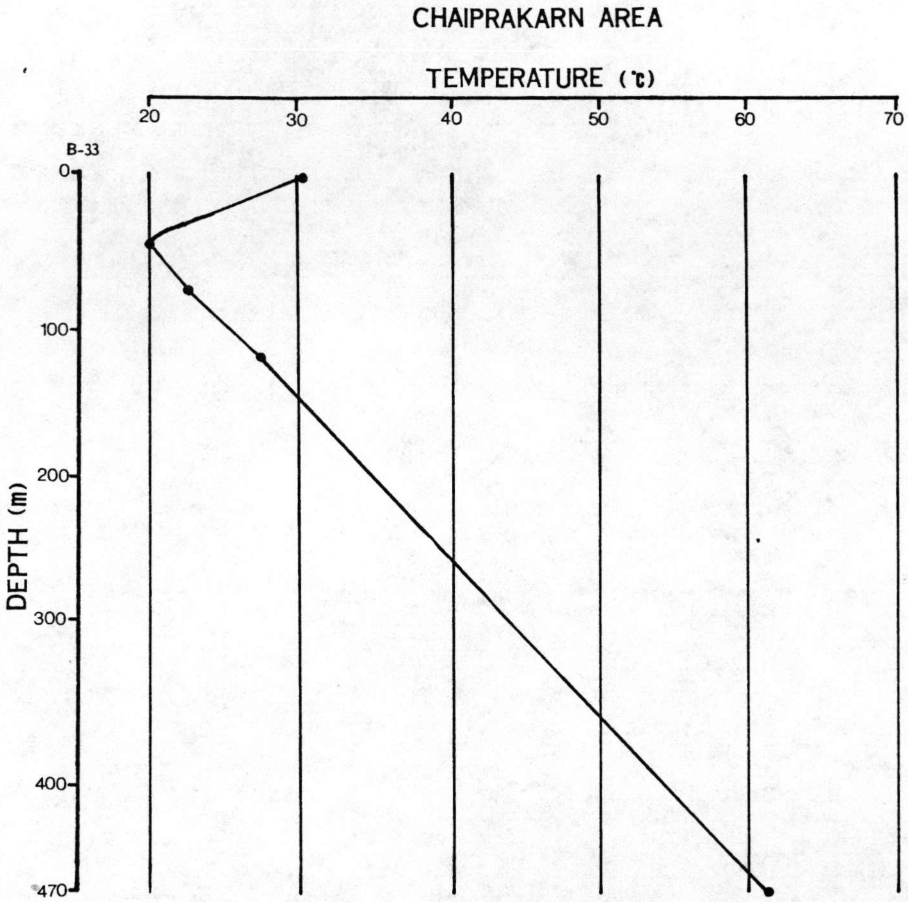

Figure 5.4.a Relationships between the subsurface temperature and depth of the drill-hole B-33 of the Chaiprakarn area.

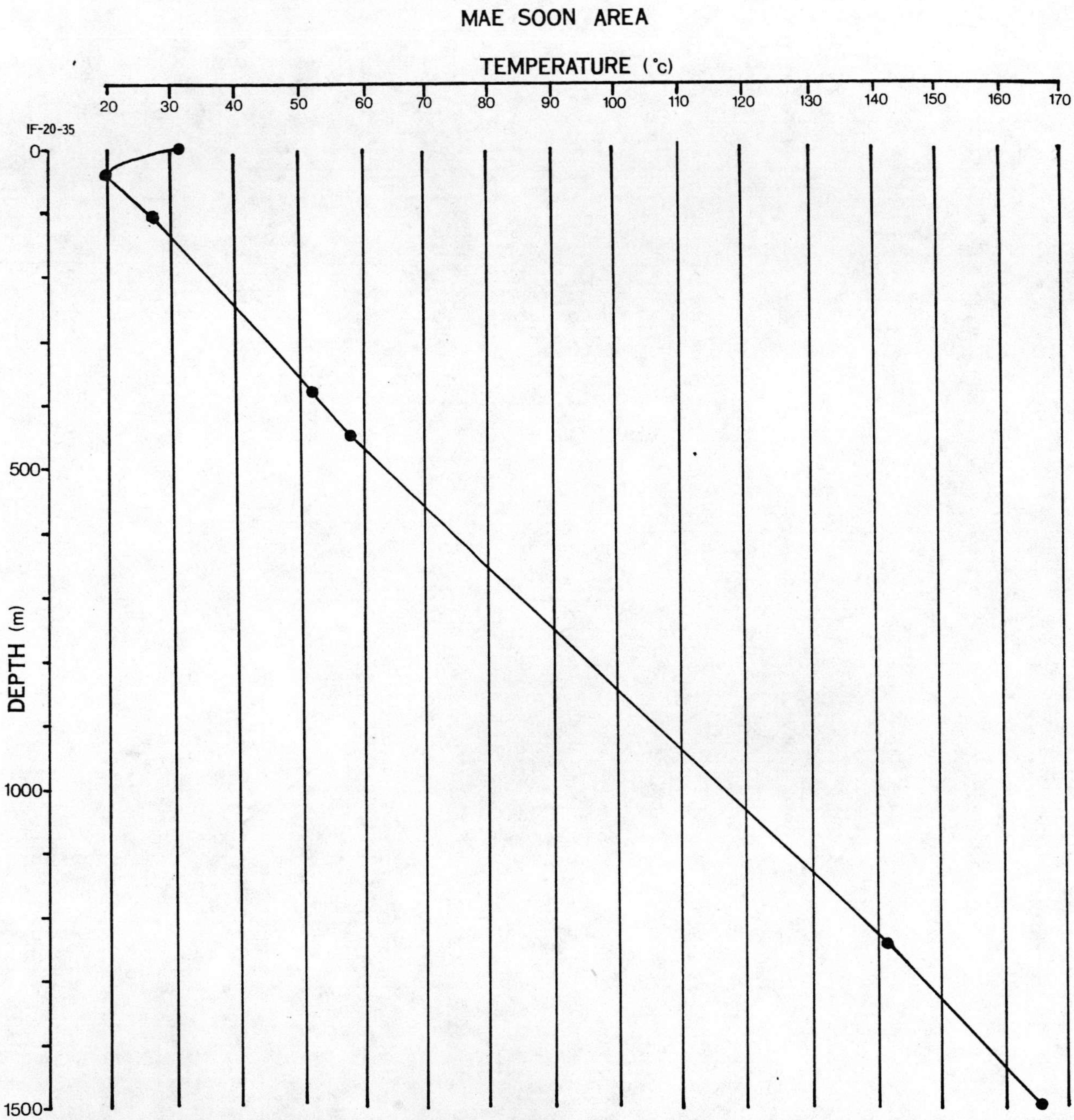

Figure 5.4.b Relationships between the subsurface temperature and depth of the drill-hole IF-20-35 of the Mae Soon area.

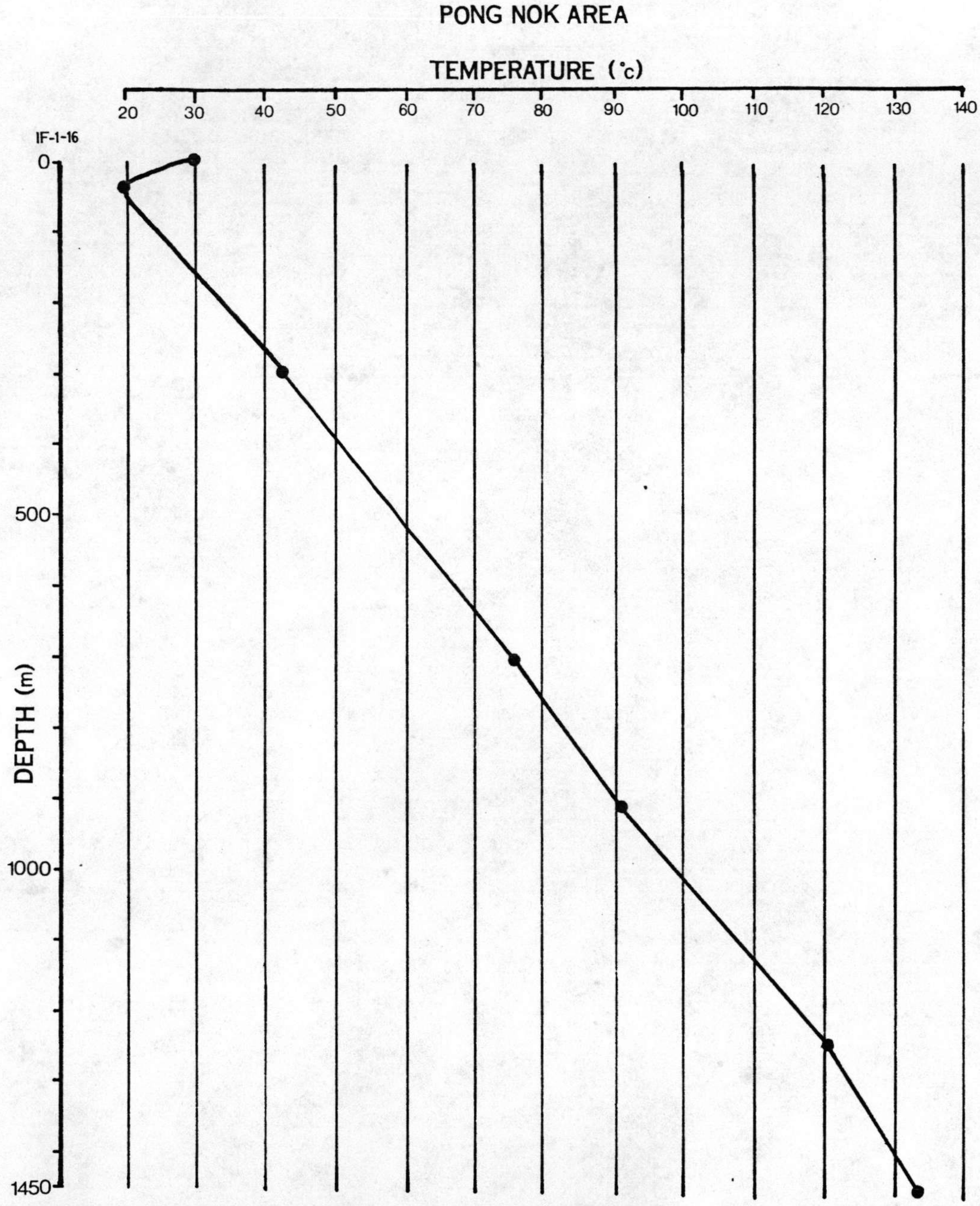

Figure 5.4.c Relationships between the subsurface temperature and depth of the drill-hole IF-1-16 of the Pong Nok area.

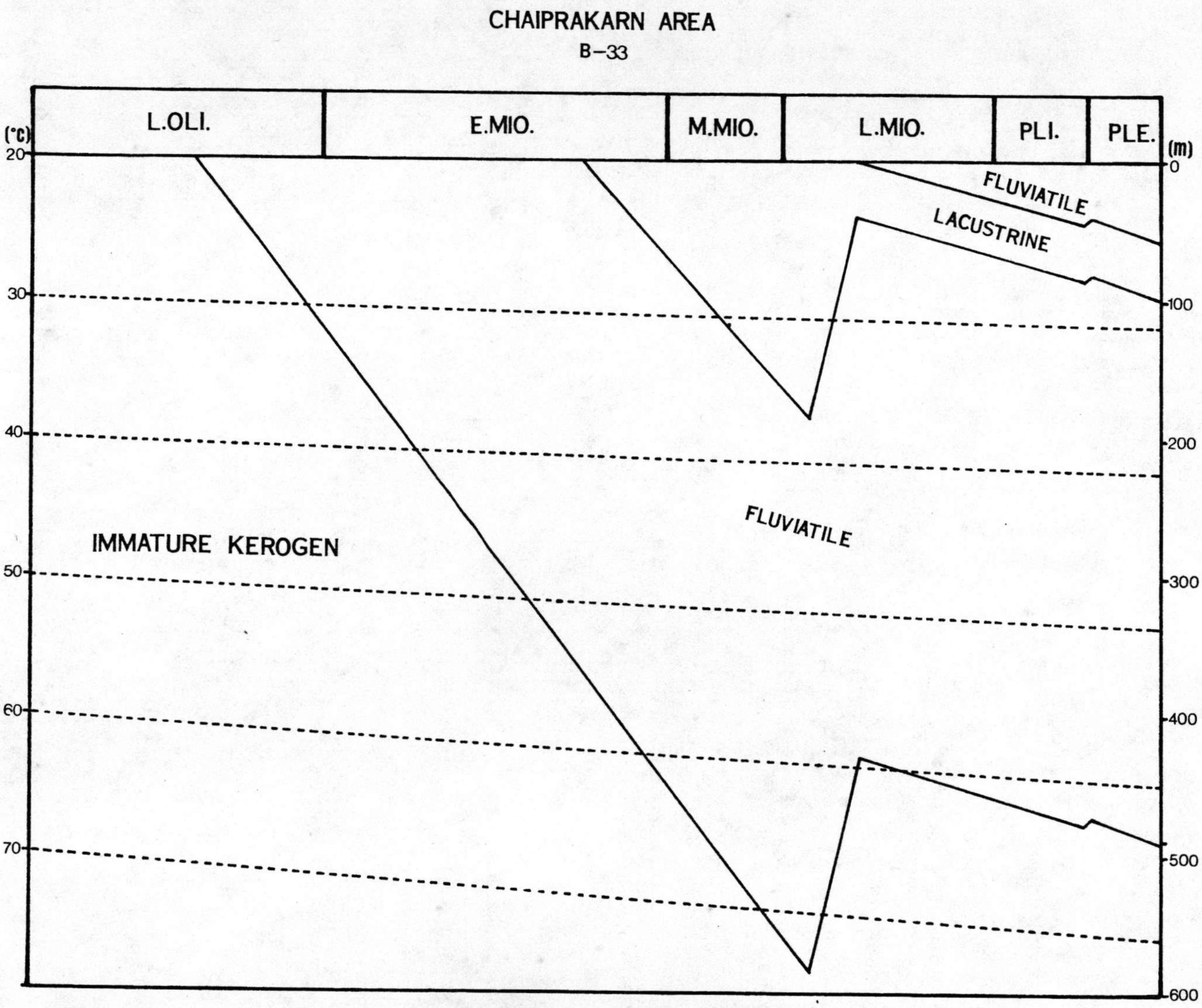

Figure 5.4.d Geological model of drill-hole B-33 of the Chaiprakarn area.

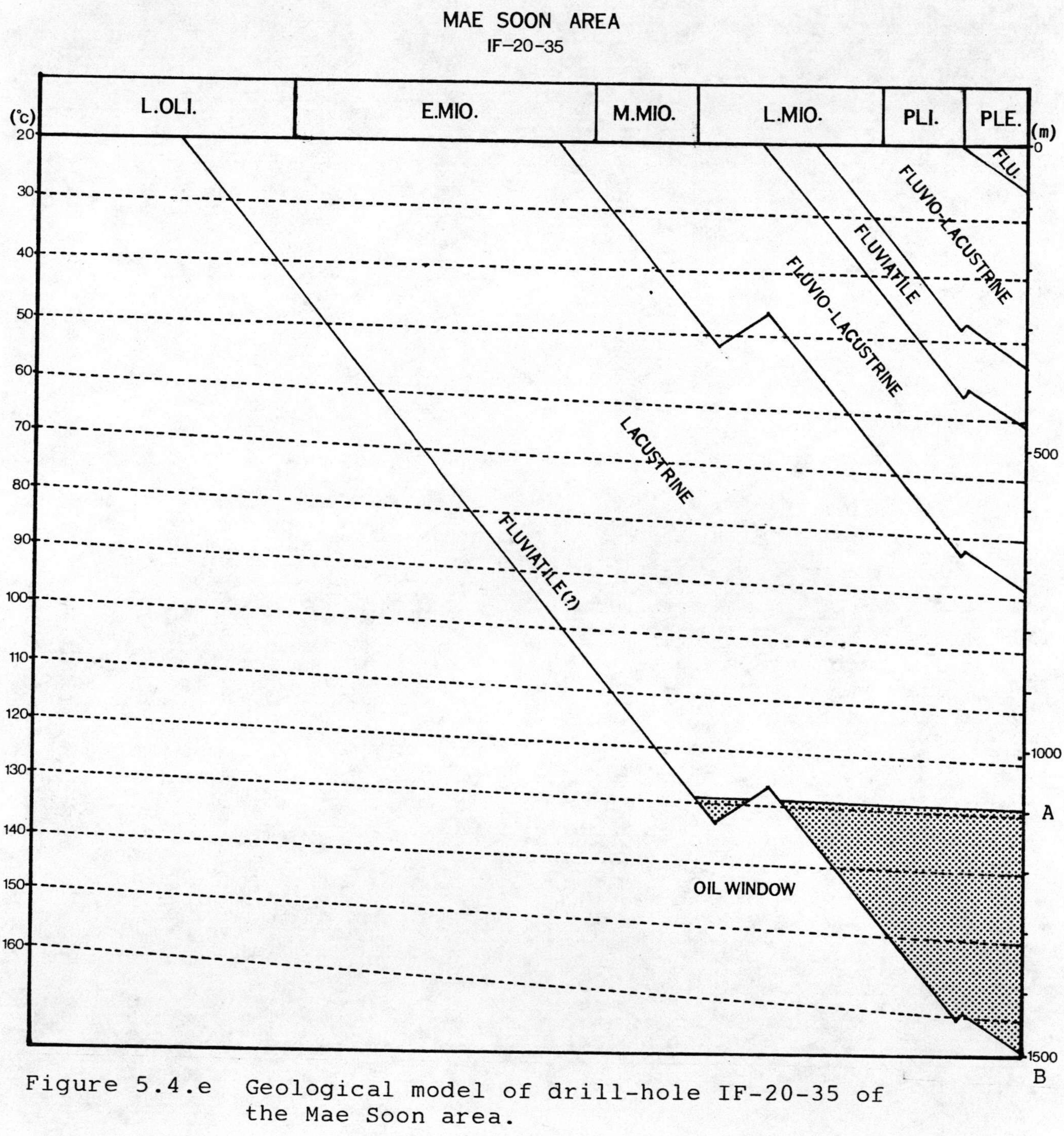

Figure 5.4.e Geological model of drill-hole IF-20-35 of the Mae Soon area.

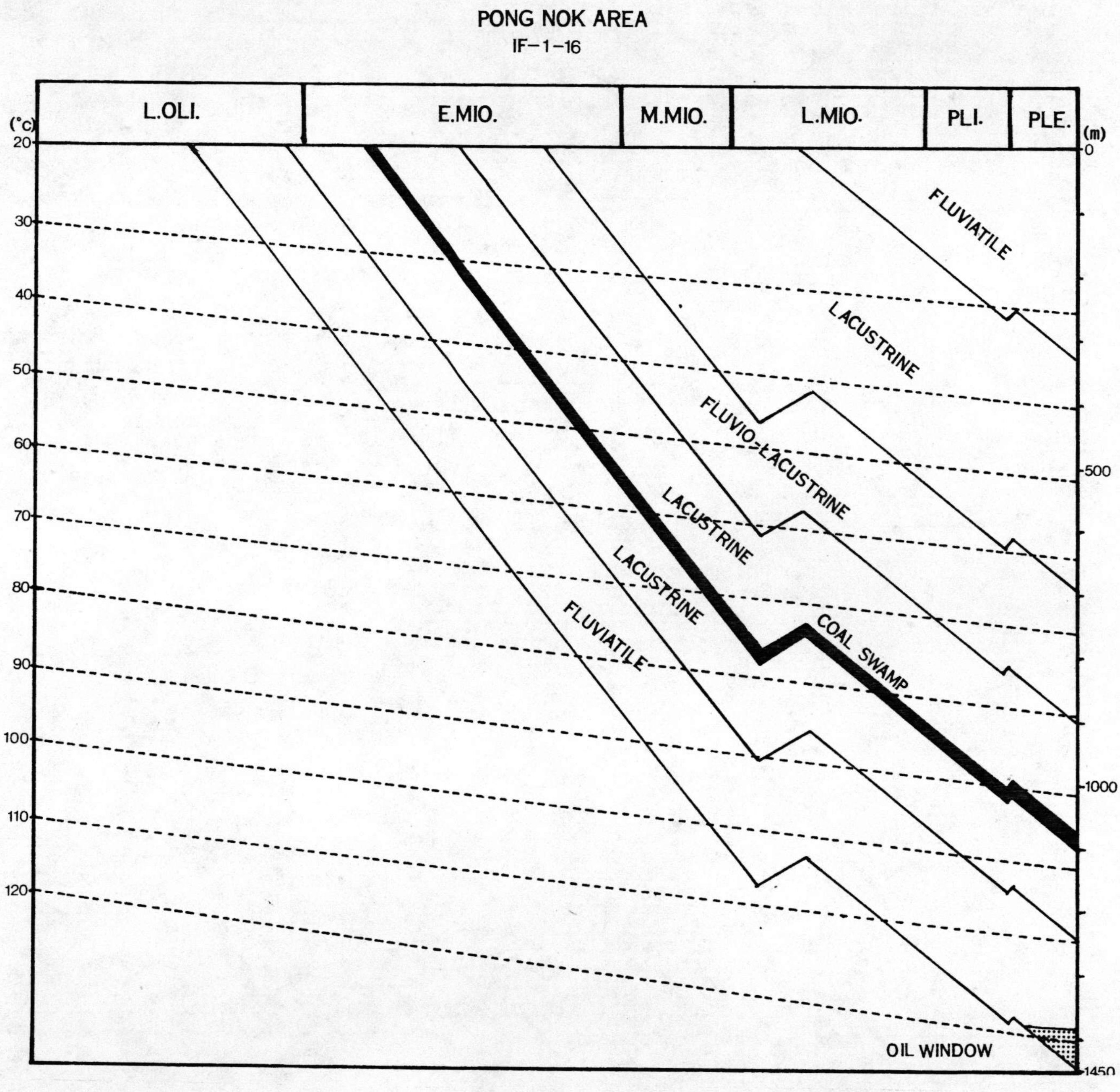

Figure 5.4.f Geological model of drill-hole IF-1-16 of the Pong Nok area.

Table 5.4.c. TTI values of drill-hole IF-22-35 of Mae Soon area.

Temperature interval (°C)	Time interval (my)	Temperartue factor	Interval TTI	Total TTI
A-horizon				
20- 30	1.71	0.003906	0.0066953	
30- 40	1.71	0.007813	0.013390	0.020085
40- 50	1.71	0.015625	0.0267812	0.046867
50- 60	1.71	0.03125	0.0535626	0.100429
60- 70	1.71	0.0625	0.107125	0.207554
70- 80	1.71	0.125	0.21425	0.421804
80- 90	4.3	0.25	1.075	1.496804
90-100	2	0.5	1	2.496804
100-110	1.6	0	1.6	4.096804
110-120	1.2	1	2.4	6.496804
120-130	2.4	2	9.6	16.096804
B-horizon				
20- 30	1.62	0.003906	0.0063203	
30- 40	1.62	0.007813	0.0126406	0.018960
40- 50	1.62	0.015625	0.0252812	0.044242
50- 60	1.62	0.03125	0.0505625	0.094804
60- 70	1.62	0.0625	0.101125	0.195929
70- 80	1.62	0.125	0.20225	0.398176
80- 90	1.62	0.25	0.4045	0.802676
90-100	1.62	0.5	0.809	1.611676
100-110	1.62	1	1.618	3.229676
110-120	1.62	2	3.296	6.465676

120-130	1.62+1.4	4	12.072	18.537676
130-140	1.4+1.8	8	25.6	44.137676
140-150	2	16	32	76.137676
150-160	2	32	64	104.137676
160-170	2	64	128	232.137676

Table 5.4.d. TTI values of drill-hole IF-1-16 of Pong Nok area.

Temperature interval (°C)	Time interval (my)	Temperature factor	Interval TTI	Total TTI
20- 30	2.3	0.003906	0.00894375	
30- 40	2.2	0.007813	0.0171875	0.026131
40- 50	2.2	0.015625	0.034375	0.060506
50- 60	2.2	0.03125	0.06875	0.129256
60- 70	2.2	0.0625	0.1375	0.266756
70- 80	2.2	0.135	0.275	0.541756
80- 90	2.2	0.25	0.55	1.091756
90-100	2.2	0.5	1.1	2.191756
100-110	5.3	1	5.3	8.491756
110-120	4.1	2	8.2	16.691756
120-130	1.0	2	4	20.691762

For Chaiprakarn area, the TTI indicates that the oil can not be generated in situ due to the immature value of TTI. Therefore, the presence of petroleun in this area suggests that it must have been generated in the lower sequence of Tertiary sediments somewhere, may be in the deepper part of the Huai Ngu sub-basin and migrated presumably along the intrabasinal fault planes to be trapped in the upper part of the Chaiprakarn area, asphaltic base crude indicates that it has been physico-chemically and bio-chemically degraded from the originally generated paraffinic base crude.

With respect to the Mae Soon area, the oil can be generated from the middle Miocene onward below the depth of approximately 1,100 metres if the favourable source-rock facies of lacustrine and or fluvio-lacustrine is available below this depth. However, many lines of evidence indicate that the favourable source-rock facies is likely to be present in the lower part of the sequence in the area. Besides, the seismic evidence indicates that the Cenozoic sequence of this area is approximately 2,500 metres thick. Therefore, the potential oil window of this area would be about 400 metres thick. It is significant to conclude that the petroleum generation potential of the Mae Soon area is very high.

Regarding the Pong Nok area, the TTI value indicates that the petroleun can be generated below the depth of about 1,380 metres. However, due to the shallow basement in this area of about 1,450 metres depth and the presence of unfavourable source-rock facies in the oil window zone lead to the conclusion that the petroleum generation petential in the area is low. The presence of petroleum in the upper part of the sedimentary sequence in this area is believed to be mainly generated from the lower sequence of the Huai Ngu sub-basin. However, the combination of both paraffinic and asphaltic base crudes in different pay zones of the area suggests that the migrated paraffinic petroleum has been partially degraded physico-chemically and bio-chemically to the upper pay zone of the asphaltic base one.

In the assessment of source rock, maturation, and generation potential of the petroleum in the Fang basin using the Lopatin's method earlier described, additional attempt has been made to use the coalification to determine the maturity level. The presence of coal seam in the drill-hole data and the coal quality in terms of proximate analysis have been used to determine the coal rank according to the ASTM Coal Rank Classification (1981).

The data regarding this matter is summarized and presented in Table 5.4.e. The study by Vassoevich (1969, 1974) on the main stage of evolution of organic matter and the level of maturity (LOM) scale of Hood et al. (1975) indicate that the oil can be generated when coal rank is higher than subbituminous B (Figure 5.4.d). The coal rank of Huai Bon area of Huai Ngu sub-basin, and Pa Ngew area of Pa Ngew sub-basin suggest that the level of maturity of the kerogen is sufficient to generate oil if there is adequate of source rock facies of the favourable type of organic matter.

Table 5.4.e. Coal rank of some coal seams of the Fang basin according to ASTM Coal Rank Classification (1981).

Drill-Hole Number	Depth Range (m.)	Heat Value* (BTU/lb.)	Coal Rank (ASTM,1981)
Huai Bon Area			
BS-92-35	464- 502	9,184.550	Subbituminous C
	737- 745	12,314.066	High Volatile C Bituminous
BS-94-37	719- 740	12,019.818	High Volatile C Bituminous
	840- 855	12,470.273	High Volatile C Bituminous
BS-95-38	68- 69	9,039.164	Subbituminous C
	190- 193	10,798.384	Subbituminous A
BS-60-3	471- 476	8,280.008	Lignite A or Subbituminous C
Pa Ngew Area			
BS-59-2	668- 698	10,371.574	Subbituminous B
	1109-1115	11,811.072	High Volatile C Bituminous
BAN HANG TUM	1- 2	1,612.802	Peat

*Moist and Mineral Free.

In addition, the carbon prefered index (CPI) of the Mae Soon crude oil of 1.08 (Table 5.1.a) indicates the petroleum maturation zone according to Demaison (1976). Besides, the isoprenoids of the Mae Soon oil, moderately abundant and dominant by pristane, indicate the precursor of the oil is of continental organic matter. The high pristane:phytane ratio about 4.91 (Table 5.1.a, ang Figure 5.4.h) also indicates the progressive gerneration of pristane by decarboxylation of phytanic acid during the first stage of catagenesis according to Powell and Mckirdy (1975). Therefore, these evidences suggest that the degree of maturation of organic matter in the sedimentary sequence of the Huai Ngu sub-basin is promissing for the petroleum generation.

5.5 The Petroleum Potential of the Fang Basin

Upon evaluating the subsurface geology of the Cenozoic Fang intermontane basin, it can be concluded that the geometry of the Huai Ngu, the Pa Ngew, and the Huai Pa sang sub-basins are favourable to be the petroleum-bearing in decreasing order, respectively.

Considering the sedimentary facies and sedimentary volume of the Tertiary sediment in these three sub-basins particularly regarding the poitential source-rock facies, it looks promissing from the view point of availability and quality of source rock in decreasing order from Huai Ngu, Pa Ngew, and Huai Pa Sang sub-basins, respectively. Emphasis on the potential source-rock facies in this case is given to the lacustrine and fluvio-lacustrine facies only.

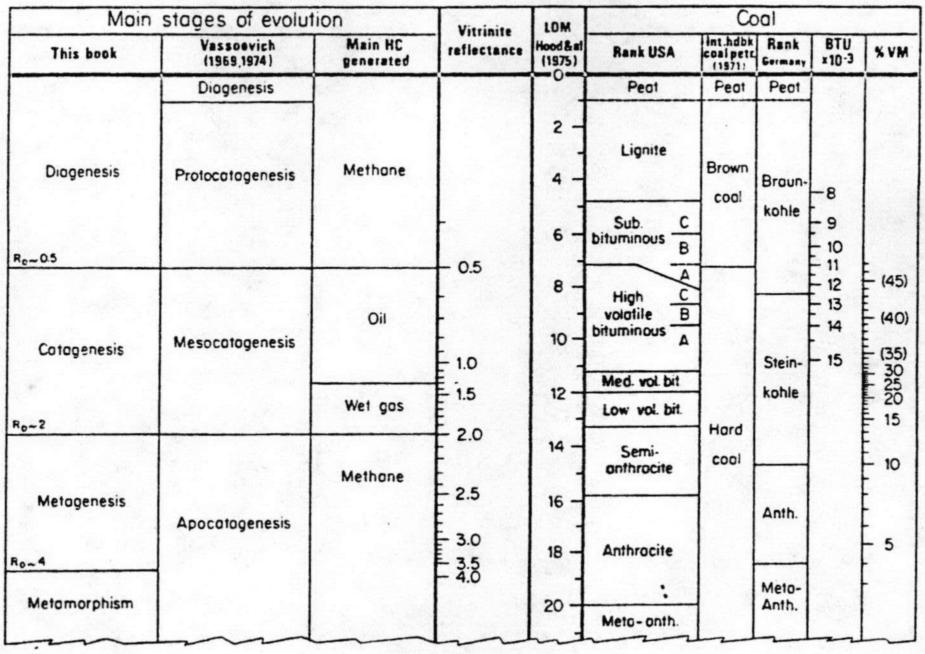

Figure 5.4.g Main stage of evolution of the organic matter. The stage used by Vassoevich (1969, 1974) and the Lom scale of Hood et al.(1975) are shown for comparison, and also the equivalent coal ranks (after Tissot & Welte, 1978).

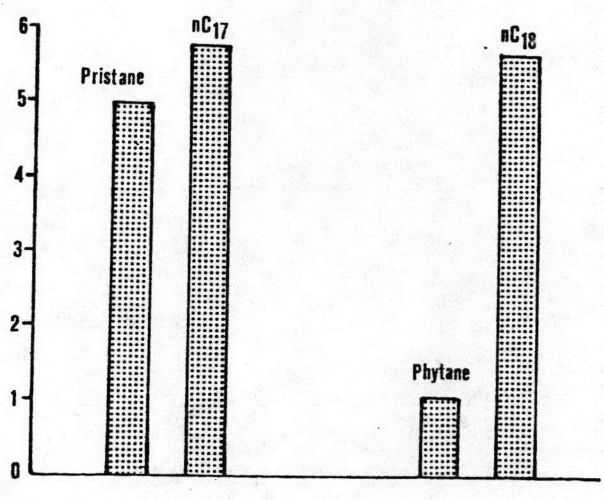

Figure 5.4.h Comparing isoprenoids with n-C17 and n-C18 alkanes of the Mae Soon crude oil. Pristane is taken as unit for comparisom of pristane/n-C17, phytane/n-C18, and pristane /phytane ratios.

From previous analysis of geothermal gradient in the Fang basin of approximately 95° C/1,000 metres can generally be judged for the oil window below the depth of 1,100 to 1,400 metres beneath the ground surface. Seismic survey data indicate that the depth to the basement rocks in the Huai Pa Sang, Huai Ngu, and Pa Ngew sub-basins are approximately +2,000, 2,500 to less than 3,600, and +2,200 metres, respectively. Therefore, the lower part of these three sub-basins can be considered as kitchen areas.

The petroleum so far produced from the Fang basin is almost entirely recovered from the migrated pay zones at the relatively shallower depth. Therefore, the possibility to recover the petroleum from greater depth not penetrated by any drill-holes is very high particularly regarding those generated and trapped in situ if favourable source-rock facies are present.

To sum up, the petroleum prospecting in the Fang basin particularly in the deeper central part and marginal areas of these three sub-basins, namely, Huai Ngu, Pa Ngew, Huai Pa Sang is considered to be proliferous. The petroleum trap is either stratigraphic and/or structural types.