CHAPTER III

OIL SHALE

Oil shale is one of the largest underdeveloped natural resources formed through the decomposition of plants and micro-organisms, which made it different from coal, in the oxygen starved, flat, poorly ventilated still water basin of past geological ages. It is a rock like substance, rich in hydrocarbons and of slaty stratification, also called "kerogen". Oil shale is found in strata which are sometimes only a few centimeters, but at times also hundreds of meters thick[9].

3.1 Definition and Origin[10,11]

Oil shale is a fine-grained, usually dark-colored sedimentary rock containing mineralized organics of varied compositions. On heating, it is decomposed to yield oil. No real minimum oil yield or content of organic matter can be established to distinguish oil shale from other sedimentary rocks. One of the many oil shale definitions is that it is an organic rich shale that can yield substantial quantities of oil when subjected to destructive distillation (heating in the absence of oxygen) by low confining pressure in a closed retort system. The quality of oil shale can be graded as lean or rich depending on the oil yield. Other definitions of oil shale are based on sources, uses, physical and chemical properties of the shale. One such definition is to further limit the minimum ash content to 33 % of the oil-yielding shale.

Oil shale is lithefied from lacustrine or marine sediments relatively rich in organic matter. Each shale represents the slow accumulation of inorganic sediment together with the organic debris contributed by aquatic flora and fauna. A major contribution to organic constituents consists of pollen and plant fragments carried into the sedimentary basin by wind or streams. Specific geochemical conditions are required to accumulate and preserve organic matter, and these were present in the lake and oceans whose sediments beçame oil shale. Organic matter accumulates under the strongly reducing conditions and neutral or basic pH present in euxinic marine environments and organic-rich saline waters. The organic-rich sediments which became oil shale accumulated slowly in water isolated from the atmosphere, a condition relatively rare in natural waters. This isolation was achieved by stagnation or stratification of water body and the accompanying protection of its sediments.

As the organic sediments become fossilized through biostratinomy and tophonomy process, the environment of deposition may be important in influencing the composition and structure of a particular decomposition. The principal environments in which oil shale is formed are large lake basins, shallow seas on continental platforms and shelves, and small lakes, logs, lagoons, associated with coal-forming swamps. The prevailing climate during deposition was similar to that favorable for coal formation.

Most investigators agree that kerogen and bitumen are of biological origin and are largely derived from the lipid fraction of algae. During taphonomy and biostratinomy further conversion is possible for the fossilized material.

3.2 Classification[12]

The most significant factors in oil shale classification were found to be color, lamination, fracture and toughness, and grain size. Rocks rich in organic material are classified as oil shale A, B, C, and D. Rocks poor in organic material are classified as marlstone, laminated siltstone and sandstone. Table 3.1 represents the said classification scheme.

Color types of oil shales, referenced to Table 3.1, are coded by using the Munsell Soil Color Chart. Freshly broken surfaces of hand specimens are needed because the shales tend to blacken on exposure, and areas adjacent to weathered surfaces, joints and fissures are commonly darker than the center of the samples. This change of color is probably due to oxidation of organic matter.

Lamination in these rocks is caused by alternation of organic-rich and organic-poor laminae. Oil shale A shows very weak lamination, without noticable change of color in adjacent laminae. Irregular wavy partings may occurs. Polished slabs and thin sections show alternation of paler and darker organic-rich laminae. Oil shale B is distinctly laminated (moderate to poor), but adjacent laminae show only slight change in color. Oil shale C shows moderate to good lamination, with distinct

Table 3.1

Field Classification of Rock Type, Ban Huai Kalok, Mae Sot basin[12]

ROCK TYPE	COLOUR	GRAIN SIZE	LAMINATION	FRACTURE AND TOUGHNESS
Organic-rich rocks				
OIL SHALE A	Dark gray-dark reddish brown	Clay	Poor; minor colour change	Conchoidal-subplanar; tough
OIL SHALE B	Dark grayish brown	Clay	Moderate-poor; minor colour change	Subplanar-planar; tough
OIL SHALE C	Gray-grayish brown-olive gray	Clay (-silt)	Good-moderate; pale laminae in dark rock	Planar; soft-tough
OIL SHALE D	Gray-olive gray-pale yellow	Clay (-silt)	Good-moderate; dark laminae in pale rock	Planar-conchoidal ; soft-tough
Organic-poor rocks				
MARLSTONE	Light gray-light olive gray-pale yellow	Clay -silt	Moderate-absent	Subplanar-conchoidal; soft-tough
LAMINATED SILTSTONE	Grayish-brown	Silt-very fine sand	Good (parallel-cross lam.) in thin beds	Conchoidal; tough
SANDSTONE	Pale yellow-gray	Very fine-very coarse sand, minor granules	Good-moderate (parallel -cross lam.) in thin beds	Conchoidal; tough

color change between laminae; dark material predominates and the paler laminae stand out clearly. In some sample, dark and pale layers are interbanded on a scale of several millimeters, with dark material more abundant. Oil shale D shows moderate to good lamination, pale material predominates, and darker laminae stand out clearly.

Toughness (resistance to fracture) is related to organic and silicate contents. Oil shale A-B (organic rich) are tougher than oil shale C-D.

Style of fracture is related to the presence or absence of lamination. Oil shale A and some oil shale D show conchoidal fracture. Oil shale B-D split along planar surfaces.

3.3 Reserves and Properties

The world oil shale deposits by itself represents a vast store of fossil energy as shown, some huge resources, in Table 3.2. The size of the existing shale-oil reserves are equivalent to more than 3 trillion barrels of oil[14], which is staggering when compared to the world's crude oil reserves which have been estimated to be 500-600 billion tons. Table 3.3 shows the shale-oil reserves as evaluated from the world's oil shale deposits[10].

The main oil shale reserve in Thailand was found in the Mae Sot basin, Tak province where surface outcrops can be easily observed. The location is shown in Figure 3.1. Thai oil shale reserves are estimated at 18,668

Table 3.2

World Oil Shale Reserves (Billion Barrels)[14]

DEVELOPED MARKET ECONOMIES	
AUSTRALIA	0.25
AUSTRIA	0.01
BELGIUM	0.69
CANADA	44.00
FRANCE	0.44
GERMANY, FR	2.00
ISRAEL	0.02
ITALY	—
NEW ZEALAND	0.25
SOUTH AFRICA	0.13
SWEDEN	2.50
UNITED KINGDOM	1.00
U.S.A.	2,166.20
SUBTOTAL	2,217.49
CENTRALLY PLANNED ECONOMIES	
BULGARIA	0.13
CHINA	27.90
POLAND	0.05
USSR	112.60
SUBTOTAL	140.68

DEVELOPING COUNTRIES	
NET OIL EXPORTERS	
BURMA	2.01
ZAIRE	100.64
SUBTOTAL	102.65
NET OIL IMPORTERS	
ARGENTINA	0.38
BRAZIL	800.84
CHILE	0.02
JORDAN	0.04
MADAGASCAR	0.03
MOROCCO	0.59
THAILAND	0.82
TURKEY	0.02
YUGOSLAVIA	0.19
SUBTOTAL	802.93
SUBTOTAL DEVELOPING COUNTRIES	905.58
WORLD TOTAL	3,263.75

Table 3.3

World Reserves of Oil Shale[10]

Country	Basin	Oil Yield (gal/ton)	HV (Btu/lb)	Ash (%)	Oil Equivalent (10^6 ton)
Thailand	Mae Sot	25-70	6,630	56	18,000
China	Fushun	15	1,460	83	24,500
Brazil	Paraibo	15-18	3,520	-	-
Great Britain	Scottland	16-40	2,540	78	90
Spain	Cuidad Real	15	5,380	63	40
Sweden	Norke	15	3,870	72	600
U.S.S.R.	Estonia	40	5,780	53	2,900

where HV = heating value

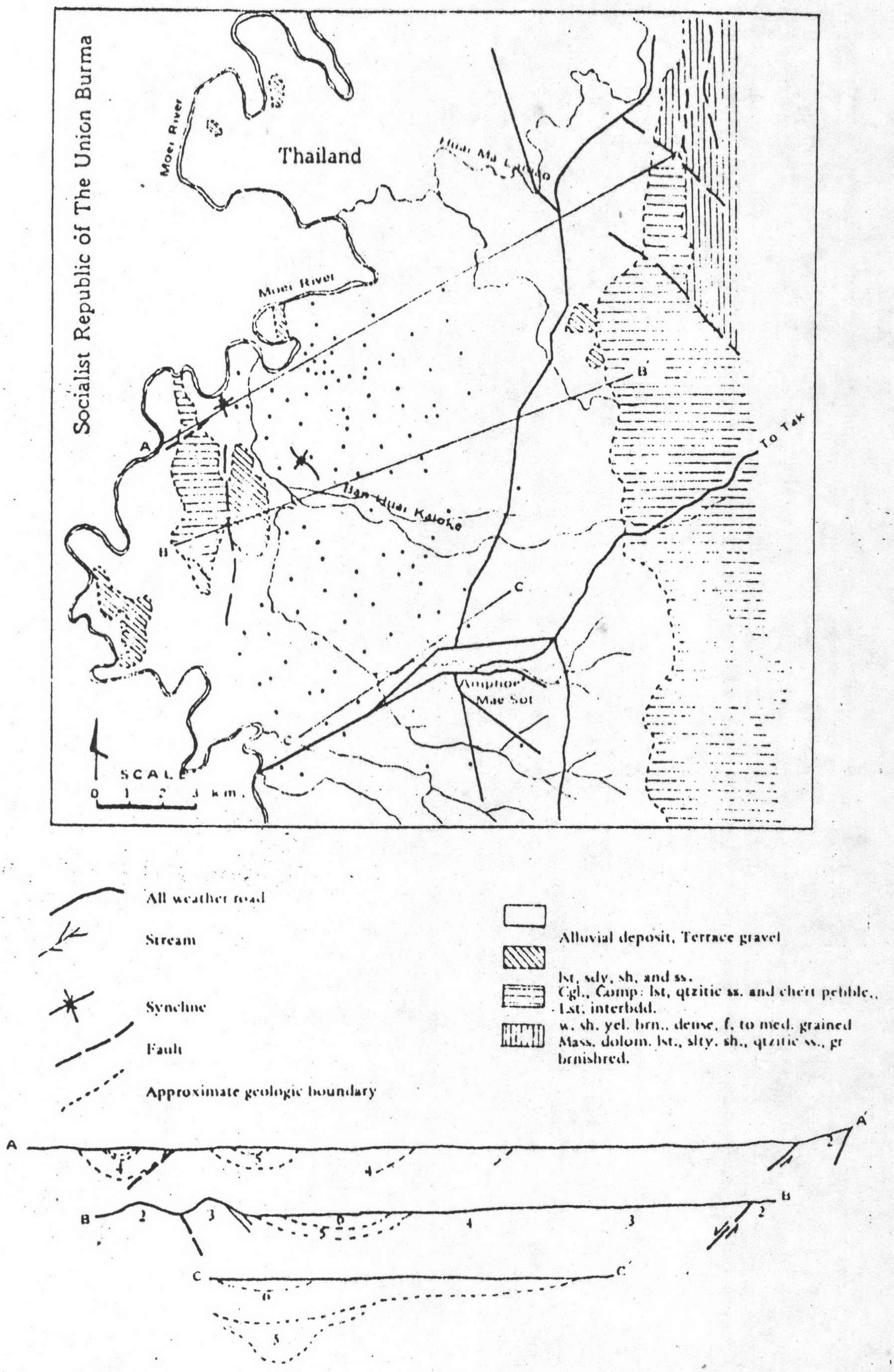

Figure 3.1

Geological Map of Mae Sot District [12]

million metric tons, of which 2,500 million metric tons are already confirmed, and with an average of 5 % oil yield by weight or 12 gallons per ton. The total oil yield is approximately 5,996 million barrels[9].

Another oil shale resource was discovered at Li, Lampoon province. The estimate of this reserve is 15 million tons with oil content ranging from 12 to 41 gallons per ton[10] which gives a total oil yield of about 9.66 million barrels.

The properties of oil shale of the Mae Sot basin have been extensively studied. Table 3.4 summarizes the results of the analyses of the shale by various analysts. The results of all the tests cannot be taken as the representative results of the reserve. Certain properties do, however, agree with one another e.g. the percentage of ash content and volatile matter.

Table 3.5 summarizes the ash analysis of Mae Sot oil shale. The results show the same order of magnitude of major inorganic components in the shales. The ultimate analysis of the same shale is shown in table 3.6.

3.4 Utilization

The three main catagories of oil shale utilization are:

1. Direct use as solid fuel for low grade shales.

2. Shale oil production by retorting oil shale. There are many commercial retorting processes available such as TOSCO-2[25] and Petrosix. The oil obtained from

TABLE 3.4

Analysis of some Mae Sot Oil Shale[10]

Reference / Properties	EGAT [1]	ICSITEEMR [2]	Polzomov [3]	Lurgi [4]	Sangbangpla [5]	Thanomas [6]	Bunyakiat & Premyothin [7]
Heating value , kcal/kg	287 - 2700	686-1374	1400-3700	2160	350-2700	1533	1992
Moisture , %	0.9 - 13.5	7	1.15-3.60	1.6	5 - 8	n.d.	4.5
Ash , %	51 - 70	61 - 70	55-78	77.2	66 - 76	n.d.	78.0
Volatile matter , %	n.d.	90	90-96	n.d.	n.d.	n.d.	n.d.
Oil Content , %	-	6 - 12	-	14.8	3 - 17	15.53	14.2
Number of test samples	34 [1]	8 [2]	10 [3]	1 [4]	7 [5]	218 [6]	30 [7]

(1) Samples were taken from a number of beds at various depths .

(2) Samples were taken from a number of beds , total weight of samples sent for analysis is 200 kg .

(3) It is reported that the samples recieved did not meet the regulation for selecting and storing fuel samples

(4) 6 kg of sample believed to be upgraded samples .

(5) Samples were from three different locations with different colours .

(6) 218 samples from 6 boreholes , values given are average value .

(7) No details of the locatons and depths of samples were given . Random sample were drawn from the lots received .

TABLE 3.5

Ash Analysis of Mae Sot Oil Shale (%)[10]

Reference \ Component	SiO_2	CaO	Al_2O_3	MgO	Fe_2O_3	No_2O+K_2O	Li_2O
EGAT[1]	41 - 65	6 - 23	0.1 - 10	1.4 - 10	7 - 19	n.d.	n.d.
ICSITEEMR[1]	41 - 52	14 - 24	14 - 17	7 - 10	5 - 6	n.d.	n.d.
Polzonov[1]	44 - 53	11 - 16	13.8-16.8	4 - 8	4.7 - 6.8	7	0.1
Lurgi						n.d.	
Sangbangpla[2]	50	16	17.6	7.57	5.45	n.d.	n.d.
Bunyakiat and Premyothin[3]	47.64	18.1	25.3	5.2	4	3.3	n.d.

(1) See footnotes of Table 3.4

(2) Analysis was done by Portlandzementwerk Dotternhausur

(3) Results were the average of the results from three samples .

TABLE 3.6

Ultimate Analysis of Some Mae Sot Oil Shales[10]

Analysis \ Reference	ICSITEEMR	Polzonov	Lurgi
Carbon , %	10 - 17	13 - 31	19.6
Hydrogen , %	1.28 - 2.28	1.86 - 4.58	2.92
Combined sulphur , %	0.049-0.065	n.d.	n.d.
Total sulphur , %	0.59 -1.131	1	0.88 (+Cl)
Nitrogen+Oxygen, %	10.43 -15.37	n.d.	n.d.

Table 3.7

Comparative Costs of Energy from Different Sources for Developing Countries[14]

Source of Energy	Cost ($/barrel)
Diesel fuel from coal	40 to 60
Ethanol from sugar cane	25 to 45
Methanol from natural gas	25 to 45
Gasoline from methanol	40 to 60
Shale oil	22 to 35

these processes are shown to be among the lower costs of non- conventional fuels (see Table 3.7).

3. Utilization of spent shale in producing cement, cement products, and building materials etc.

Hitherto, there have not been any commercial applications of Thai oil shale, however, research activities on potential utilizations are being undertaken.