3.1.3 Geology

(1) Stratigraphy

Stratigraphy of the Phrae Basin is subdivided as shown in Table 3.1- 4.

Table 3.1- 4 Stratigraphy of the Phrae Basin

Geologic age	Deposits	Exploration
Quaternary	Alluvium	Thin fluvial deposits along the Recent rivers.
	Residual deposits	Unconsolidated gravel, thin residue of the weathered Phrae Formation.
	Diluvium	Unconsolidated gravel, NW area : terrace deposits, central and southern areas: thick gravel bed
	~~Unconformity~~~~~~~~~~~~~~~~~~~~	
Tertiary (Miocene or younger)	Phrae Formation	Alternations of fan and lacustrine lithofacies. Fan lithofacies consist of weathered breccia of argillaceous rocks and thin conglomerate. Lacustrine lithofacies consist of sandstone, mudstone, carbonaceous mudstone, and lignite with fossil beds
	~~Unconformity~~~~~~~~~~~~~~~~~~~~	
Triassic ~ Silurian	Lan Pang, Ratburi, Mae Tha and Donchai Group	Mainly consist of argillaceou rock, chert, quartzite, limestone and tuff. Basement for the Phrae Formation.

1) Ratburi, Mae Tha and Donchai Groups

The Phrae Basin is surrounded by the mountain ranges of basement rock ranging from Silurian to Triassic time. According to the geological map scale 1:250,000, basement rock comprises mainly of argillaceous rock such shale and phyllite with a minor amount of sandstone, chert, limestone, quartzite and tuff. Basement rock was eroded and deposited in the Phrae Basin forming the Phrae Formation. Most of coarse clastics in the Phrae Formation are slate or phyllite with a minor amount of chert, quartzite and limestone.

2) Phrae Formation

The Tertiary formation in the Phrae Basin is denominated to the Phrae Formation during the Study due to its difference in lithofacies to the Mae Moh Basin, which represents the standard stratigraphy of the intermontane lacustrine coal basins in northern Thailand. The difference in lithofacies is as follows:

Mae Moh Basin	Phrae Basin
Quaternary	Quaternary
~~ Unconformity	~~~~~~~~~~~~ Unconformity
Huai Luang Red mudstone (C)	Phrae Formation
Form. Thin conglomerate (w)	Alternations of fan lithofacies (w)
~~ Disconformity	and lacustrine lignite - bearing
Na Khaem Form. Lignite - bearing (B)	Lithofacies
Hui King Form. Coarse clastics (A)	~~~~~~~~~~~~ Unconformity
~~ Unconformity	Silurian ~ Triassic basement
Perm -Triassic basement	

(A): conglomerate facies

(B): lignite- bearing facies

(C) : lacustrine argillaceous facies

(w) : Ftg, gritty mudstone, weathered breccia of argillaceous rock including thin conglomerate.

a) Fan lithofacies

Many outcrops of Ftg, gritty mudstone, with thinly intercalated conglomerate were observed throughout the northern area and periphery of the Phrae Basin. A typical one is in the well-known national park, namely Phae Mueng Phi, as shown in Ph.3.1-1. Ftg consists mainly of buff mudstone with a little amount of granule of chart and quartzite. Steeply dipping laminae of granule were found in an outcrop of Ftg at the national park. Geologically incompatible components of mud and glanule in Ftg were not believable at first. Mud is basically transported by suspension and settled under the low energy regime. On the contrary, granule is transported by bed load under the high energy regime. This contradiction was solved by observation of borehole cores. It was revealed that Ftg at shallow depth gradually changed to deeper to weathered breccia of argillaceous rock as shown in Ph. 3.1-2 and 3.1-3. Finally it changed to slightly weathered phyllite breccia just above the basement as shown in Ph. 3.1-4. Therefore the origin of Ftg was concluded that basement rock which consists mainly of argillaceous rocks was derived from the uplifting hinterland and settled in the basin transported by streams. Same accumulation of breccia of fresh argillaceous rock forms detritus at the foot hills of surrounding mountain ranges.

Ftg occasionally intercalates thin conglomerate as shown in Ph.3.1-5. It consists of poorly sorted angular or subangular chert and quartzite gravel and sand. Its fluvial origin is identified by cross bedding in it. The same weathered breccia bed was observed at the base of the Huai Luang Formation at Mae Moh mine. Where weathered breccia bed, which could be identified from white brown color in the reddish brown matrix, rests disconformably on the Na Khaem Formation as shown Ph.3.1-6. Furthermore a few pieces of well rounded quartzite pebble were found in the breccia bed.

b) Lacustrine Lithofacies

Though fan lithofacies dominate the basin, a few outcrops of lacustrine lithofacies were identified during field mapping. They are as follows:

Outcrop No.5082102: an outcrop, located along the road No.103 in the northern area, consists of massive bioturbated sandstone dipping steeply toward WWN. This sandstone is unconformably overlain by the unconsolidated gravel bed (Ph.3.1-7 and 3.1-8).

Outcrop No.5080192: an outcrop located along the stream, 4,500m NE of Phae Mueng Phi, consists of mudstone with coaly matter of more than 3 m thick.

Outcrop No.5082101: an outcrop in Phae Mueng Phi consists of fine-grained sandstone with planar laminae. This sandstone is overlain by Ftg (Fig. 3.1-6).

Outcrop No.5073101: an outcrop at the intersection of CP94-110 and CP94-80. Poorly sorted and cross bedded sandstone (Ph.3.1-9).

Drilling exploration has revealed several intervals of massive (Ph.3.1-10) or fining upward sandstone, laminated mudstone, fossil bed (Ph.3.1-11), carbonaceous mudstone and lignite (Ph.3.1-11) with diatomite, calcareous bed, and thin Ftg.

These intervals are attributed to lacustrine deposits from their lithofacies, though some of them can be subdivided into fluvial deposits. The intervals identified to be lacustrine deposits occur from LA to LD in the ascending order (Plate 3.1-2 and Fig.3.1-4). And they are correlated to the seismic reflectors as follows:

LD: Upper triple reflector in the eastern area.

LC: Upper triple reflector in the western area and week reflector in the eastern area.

LB: Strong triple reflector all over the area.

LA: a part of double reflector

The seismic reflector below LA are interpreted to be lacustrine intervals i.e. L-1 and L-2 in descending order as shown in Fig.3.1-4. Then homogeneous zone without significant reflector on the seismic profiles were interpreted to be the fan lithofacies. However steep reflectors in the northern area indicate bedding planes of fan lithofacies.

3) Diluvium

The Diluvium in the Phrae Basin was identified at Outcrop No.5082102 and the western side of the Yom River in the northern subbasin. At the former outcrop, Gc, thick well rounded cobble bed, is unconformably underlain by steeply dipping bioturbated sandstone of the Phrae Formation as shown in Ph.3.1-7. Cobble is mainly sandstone of older rock. The latter forms terrace as shown in Ph.3.1-12 and Ph.3.1-13. The geologic age of these outcrops of Gc is concluded to be Diluvium due to its occurrences as terrace deposits unconformably overlying the Phrae Formation.

In the southwestern and central areas, borehole exploration revealed Gc, unconsolidated cobble bed approximately 200 m thick at maximum, by non-core drilling under paddy field. This cobble bed is correlated to the terrace deposits of the northern area due to its consistency of unconsolidated cobble, though several finning upward sequences were traceable in the geophysical logs.

4) Residual deposits

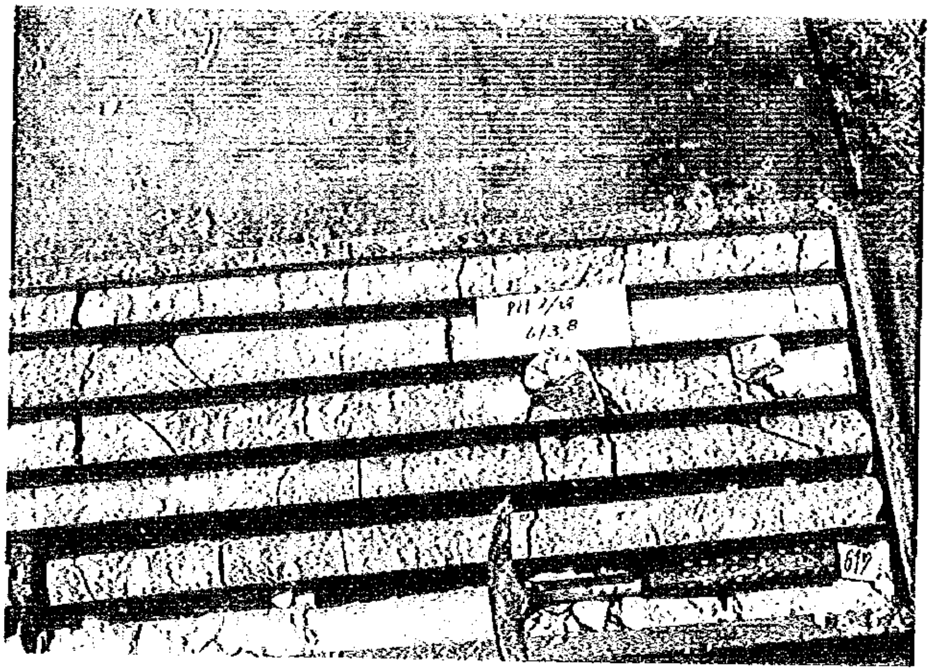
Many outcrops of loose and poorly sorted gravel of angular chert and quartzite were observed unconformably overlying the Phrae Formation especially in the northeastern hilly area. The gravel bed does not have sedimentary structure in general except for a few outcrops, where vague trough type bedding was observed as shown in Ph.3.1-14. The origin of gravel is concluded to be residue formed through weathering of fan deposits, especially fluvial conglomerate. Weathering washed away mud portion of fan deposits remaining only gravel of highly resistant rocks for weathering. Trough type bedding in some outcrops of residual deposits means slight transportation during heavy rain. However most of them look like in-place deposits. Residual deposits, being the weathered bed rock, are eliminated in geological map as usual.

5) Alluvium

Due to intrenching nature of the Recent rivers and streams, the significant Alluvium deposits were not observed except for small detritus along the foothills of the surrounding mountain ranges and thin deposits of paddy field. Probably the river system in the basin formed thin meandering natural levee sand deposits along the existing or abandoned channels. On which the old housing sites in paddy field might be chosen.

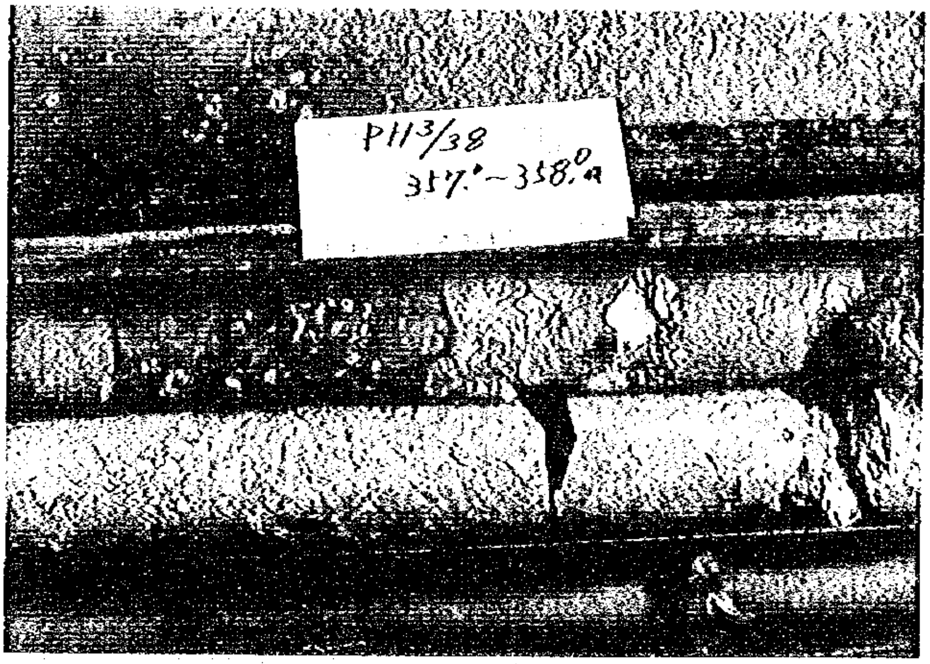
Ph.3.1.1 Outcrop of the Phrae Formation, gritty mudstone with intercalated thin conglomerate in the national park.

Ph.3.1.2 Weathered breccia of argillaceous rock. PH 5/38, 257.5m

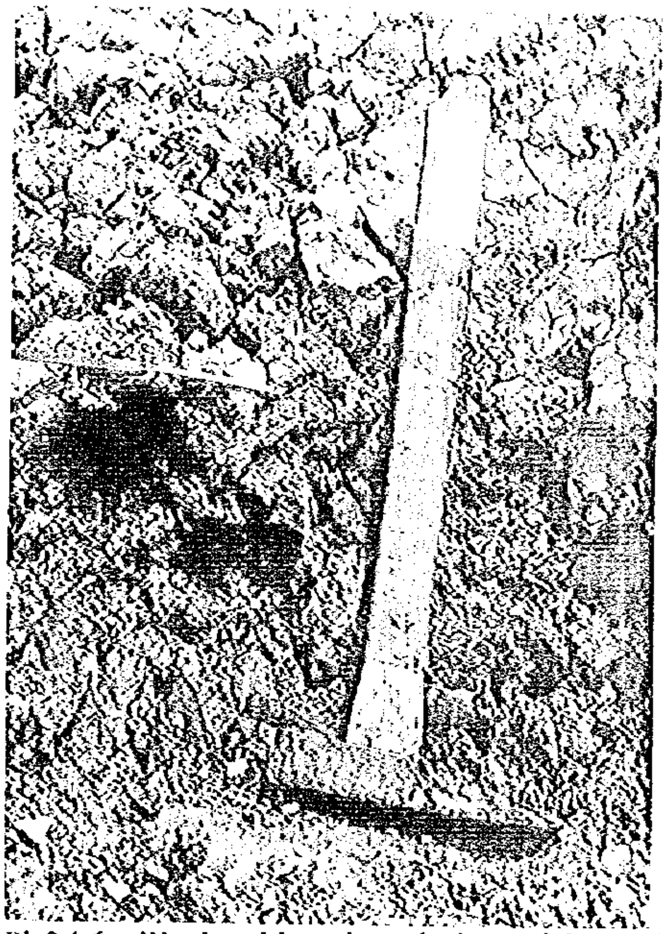


Ph.3.1.3 Weathered breccia of argillaceous rock. PH 2/38, 613.8m

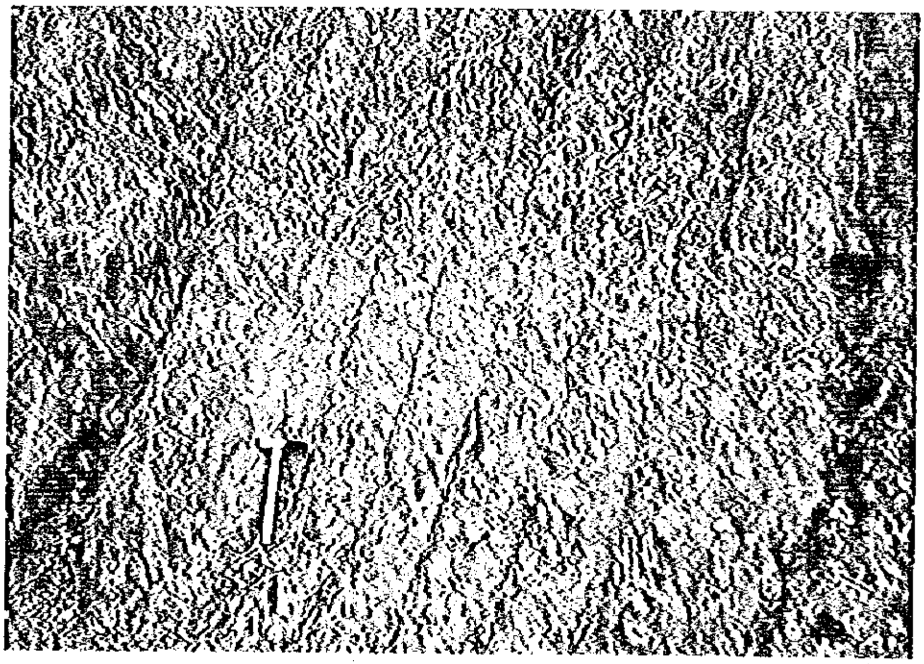
Ph.3.1.4 Phyllite, basement of the Phrae Formation. PH 2/38, 685.3m



Ph.3.1.5 Fluvial gravel bed in fan lithofacies. PH 3/38, 357m

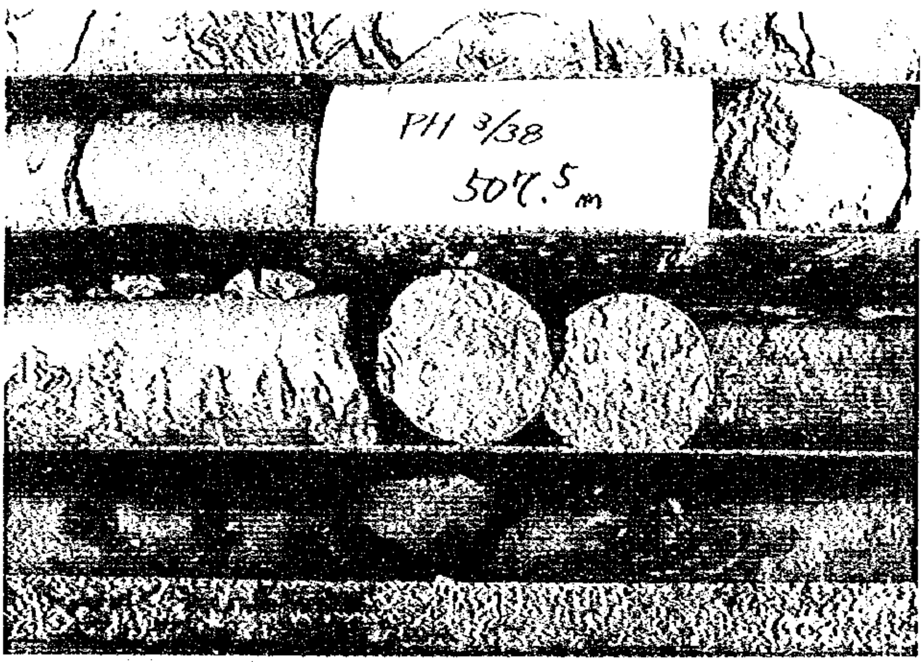

Ph.3.1.6 Weathered breccia at the base of the Huai Luang Formation at the Mae Moh Mine.

Ph.3.1.7

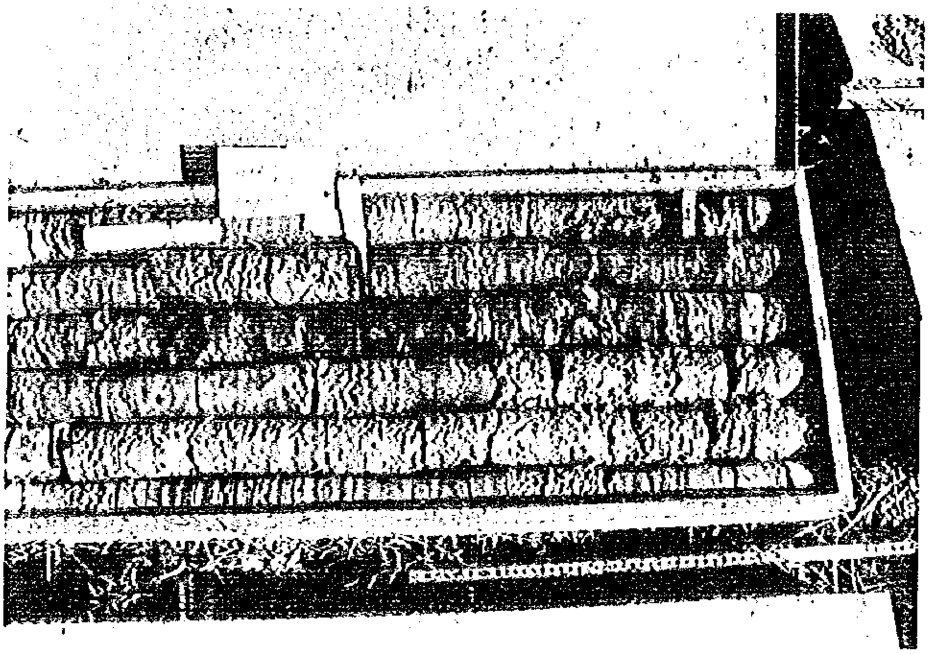


Ph.3.1.8 Outcrop of Diluvium which unconformably rests on the steeply dipping Phrae Formation at outcrop No.5082102 in the northern area.

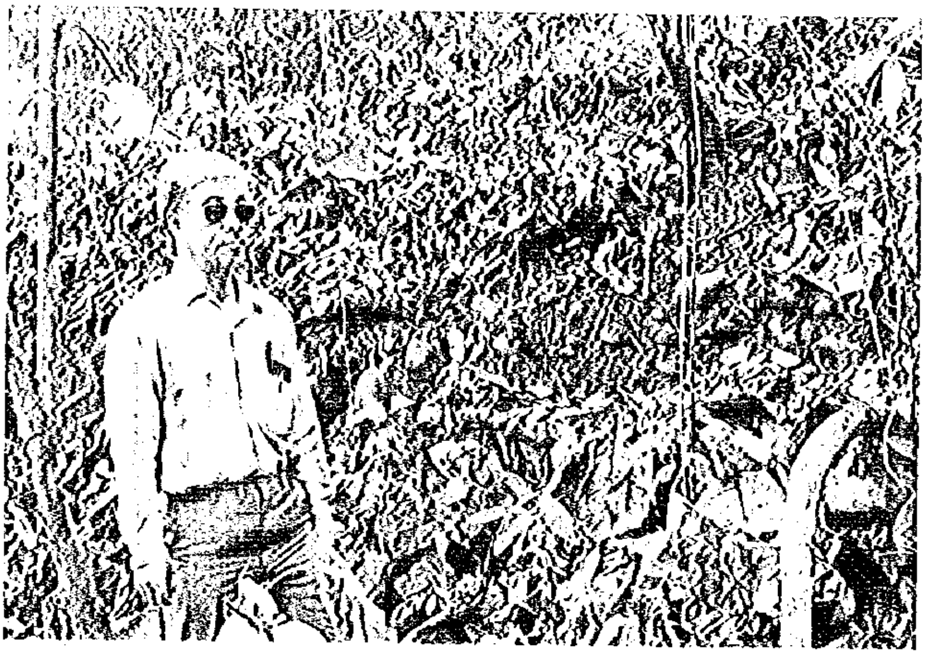
Ph.3.1.9 Outcrop of the Phrae Formation at outcrop No.5073101 in the centre of the basin.



Ph.3.1.10 Sapropelic massive fine-grained sandstone in lacustrine lithofacies of the Phrae Formation. PH 3/38,507.3m

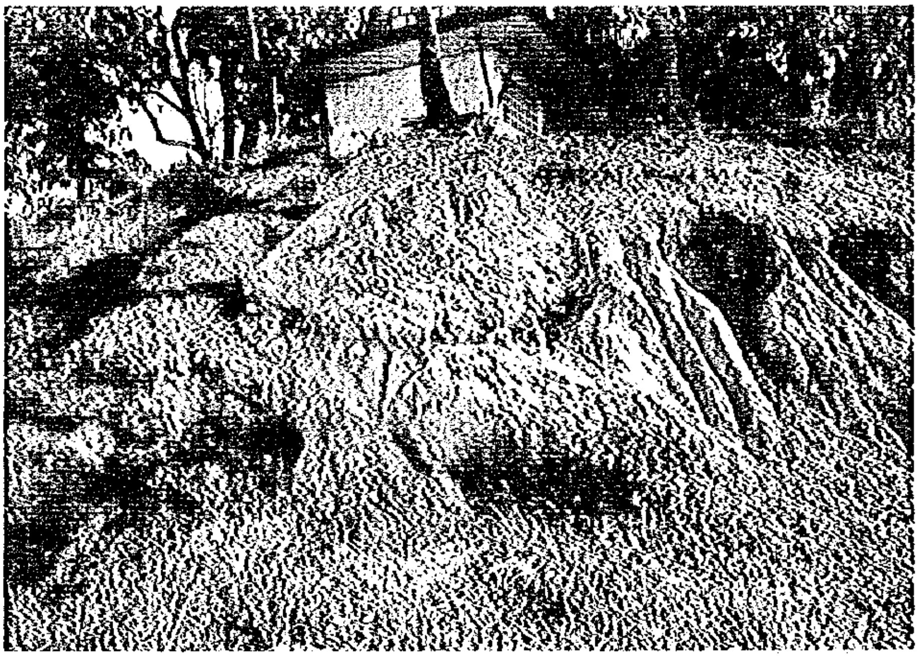


Ph.3.1.11 Lignite bed C-3, 301.60-303.20m. Fossil bed of the floor.

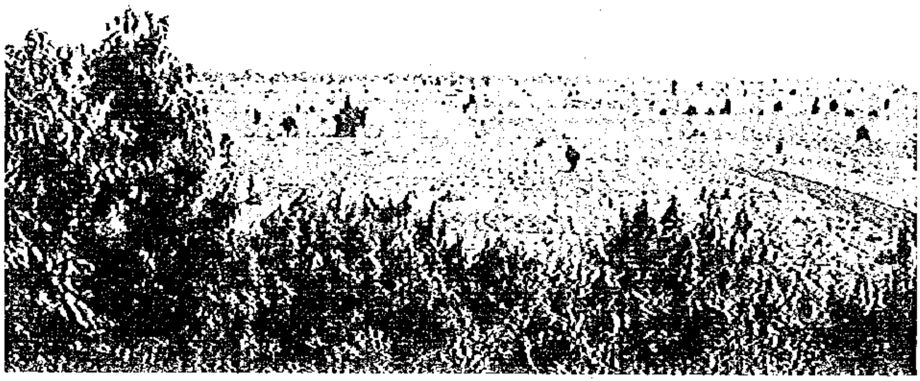


Ph.3.1.12 Terrace deposits in the western part of the northern subbasin.

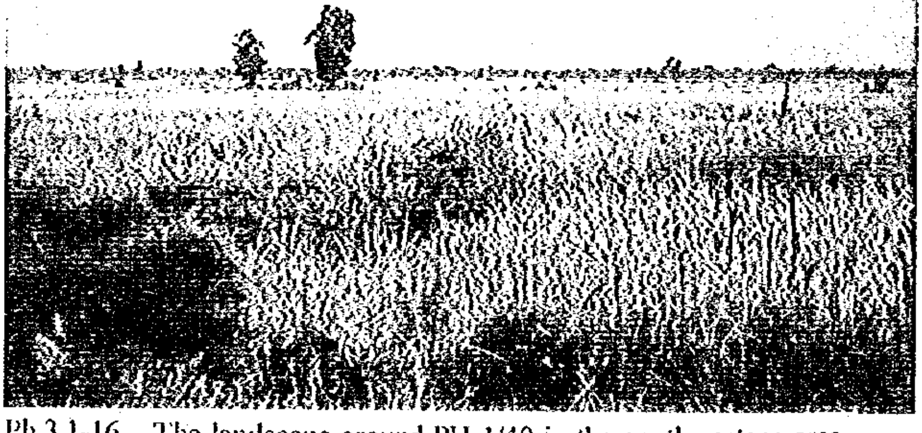
Ph.3.1.13 Terrace, western side of the northern subbasin.



Ph.3.1.14 Outcrop of the residual deposits which suggests slight transportation of gravel at outcrop No.5080201 in the southeastern area.



Ph.3.1-15 The view of the southwestern area looking toward northeast from southwest.



Ph.3.1-16 The landscape around PH 1/40 in the southwestern area.

(2) Coal bed

1) Coal occurrence

The coal bed in the Phrae Basin are relatively thin and their thickness are variable. Four coal beds including carbonaceous mudstone have been found by borehole exploration. They have been denominated C-1, C-2, C-3, and C-4 in ascending order which were deposited in each lacustrine unit of LA, LB, LC, and LD respectively.

Relatively thick coal bed of less than 2 m in thickness occur in LB and LC in the southwestern part of the basin. The summary of coal beds identified by borehole exploration is shown in Table 3.1-5, and coal bed profiles of C2 and C3 are shown in Fig.3.1-2 and 3.1-3. Lithofacies investigation of each borehole reveals the deposition of coal beds as follows:

- Coal beds were deposited in lacustrine lithofacies, which is occasionally intercalated in fan lithofacies.
- In the northern and eastern parts of the basin, fan lithofacies dominates the Phrae Formation, and lacustrine lithofacies is concluded thin and not stable to intercalate any coal bed except for thin carbonaceous bands. This view is also supported by the results of EGAT's boreholes in which no coal bed has been found.
- In the southern part of the basin, the western side (between W.M. Fault and A Fault) is concluded to intercalate the relatively thick coal beds owing to stable depositional condition of lacustrine lithofacies. On the contrary, the eastern side of A Fault is concluded that the coal beds were deposited not thick enough or too deep to estimate the resources.

2) Coal quality

The half of cores which were collected from the relatively thick coal bed were analyzed in Japan. Based on the analytical results, the general coal quality of the Phrae Basin seems to be high ash, high sulfur and low heating value as shown in Table 3.1-6.

Table 3.1-5 Summary of Coal Beds in Boreholes

		1/38	2/38	3/38	4/38	5/38	1/39	2/39	3/39	1/40	2/40	3A/40	4/40	5/40
Elevation(m)		158.807	195.787	167.651	152.203	149.503	155.700	148.563	157.157	151.683	154.718	158.817	164.541	169.646
Total depth(m)		622.0	691.0	738.0	650.0	850.0	575.0	554.0	650.0	650.0	445.5	650.0	597.5	611.0
C3U	Thickness	0.00/1.75	0.00/0.90	0.00/1.20	0.40/2.10	?	thinning out	eroded	*0.80/1.70	eroded	*0.30/1.60	0.00/0.70	0.00/0.80	0.33/3.00
	Roof	118.75	204.10	361.20	295.20				297.80		301.60	225.50	173.45	238.60
	Floor	120.50	205.00	362.40	297.30				299.50		303.20	226.20	174.25	241.60
C3	Thickness	1.10/1.65	0.00/1.30	0.00/0.30	*1.30/1.50	1.30/1.90	thinning out	0.00/0.10	0.00/1.40	*0.25/1.10	*0.68/2.30	0.00/1.30	thinning out	thinning out
	Roof	197.85	294.00	433.80	407.20	458.40		109.70	393.40	130.90	402.70	310.60		
	Floor	199.50	295.30	434.10	408.70	460.30		109.80	394.80	132.00	405.00	311.90		
C2U	Thickness	0.47/0.61	thinning out	thinning out	?	?		0.00/1.85	0.80/1.00	0.00/1.10		0.00/0.70	0.00/1.95	0.00/0.25
	Roof	333.09						245.15	566.00	262.95		465.20	406.00	576.00
	Floor	333.70						247.00	567.00	264.05		465.90	407.95	576.25
C2	Thickness	1.54/1.95	0.40/1.40	0.00/0.30	?	?		*0.80/1.20	*0.81/1.20	*1.52/2.15		1.50/1.70	0.00/1.20	0.00/1.00
	Roof	346.65	496.00	593.80				257.60	590.80	274.10		484.00	416.30	591.75
	Floor	348.60	497.40	594.10				258.80	592.00	276.25		485.70	417.50	592.75
C1	Thickness	0.00/0.30	thinning out	thinning out				0.00/0.10		0.00/0.10			thinning out	
	Roof	533.25						443.40		476.60				
	Floor	533.55						443.50		476.70				

*:These coal beds were analyzed in Japan.

It should be noted, however, that some non-coal partings are included in the samples, because sampling section were determined in consideration of the possible mining thickness. The sampling intervals are indicated in Fig.3.1-7. The remaining half of the cores were analyzed in DMR laboratory. The details of the analytical results are shown in Appendix 1.

Table 3.1-6 Analytical Results of Sampled Coal Beds

DH	sample	analytical sample			as received		as analysed basis								
No.	No.	from	to	thick	TM	SM	M	ASH	VM	FC	(FR)	HV	TS	S ash	S comb
4 /38	1	407.20	408.70	1.50	16.5	6.8	10.4	56.1	23.3	10.2	0.44	1640	4.94	0.77	4.17
2 /39	2	257.80	258.60	0.80	27.5	14.4	15.3	25.6	38.2	20.9	0.55	3360	6.62		
3 /39	3	298.50	299.30	0.80	33.4	23.9	12.5	45.4	29.5	12.6	0.43	2370	7.82		
3 /39	4	590.80	591.40	0.60	23.4	13.6	11.3	43.9	27.8	17.0	0.61	2800	6.81	0.67	6.14
3 /39	5	591.70	592.00	0.30	27.7	16.1	13.8	26.8	33.7	25.7	0.76	4090	5.52	1.18	4.34
1 /40	6	130.90	131.35	0.45	35.3	28.3	9.8	61.1	19.5	9.6	0.49	1460	3.67		
1 /40	7	131.70	132.00	0.30	32.1	25.1	9.3	49.7	25.4	15.6	0.61	2210	8.94		
1 /40	8	274.50	275.90	1.40	15.2	4.0	11.7	32.5	33.2	22.6	0.68	3540	5.80		
2 /40	9	301.60	303.20	1.60	27.7	18.6	11.2	59.0	20.4	9.4	0.46	1570	4.47		
2 /40	10	403.70	405.00	1.30	18.7	8.5	11.1	51.2	25.6	12.1	0.47	2310	6.08		

DH	sample	dry basis											
No.	No.	ASH	VM	HV	TS	Ssulf	Spy	Sorg	C	H	O	N	S
4 /38	1	62.6	26.0	1830	5.51	1.69	2.54	1.28	19.0	2.02	11.17	0.54	4.65
2 /39	2	30.2	45.1	3967	7.82								
3 /39	3	51.9	33.7	2709	8.94								
3 /39	4	49.5	31.3	3157	7.68	0.89	4.73	2.06	30.3	2.45	9.84	1.00	6.92
3 /39	5	31.1	39.1	4745	6.40	0.80	3.94	1.66	47.0	3.55	11.78	1.54	5.03
1 /40	6	67.7	21.6	1619	4.07								
1 /40	7	54.8	28.0	2437	9.86								
1 /40	8	36.8	37.6	4009	6.57								
2 /40	9	66.4	23.0	1768	5.03								
2 /40	10	57.6	28.8	2598	6.84								

DH	sample	dry ash free basis						atomic ratio				HGI	ash fusion temp C		
No.	No.	CV	C	H	O	N	S	HC	OC	NC	SC		DT	ST	FT
4 /38	1	4896	50.8	5.40	29.89	1.44	12.45	128	44	2	9	100	1085	1230	1255
2 /39	2	5685													
3 /39	3	5629													
3 /39	4	6250	60.0	4.85	19.47	1.98	13.71	97	24	3	9	81	1070	1130	1155
3 /39	5	6886	68.2	5.15	17.10	2.23	7.31	91	19	3	4	58	1060	1080	1090
1 /40	6	5017													
1 /40	7	5390													
1 /40	8	6344													
2 /40	9	5268													
2 /40	10	6127													

DH	sample	ash analysis as oxide												ASTM class	
No.	No.	Si	Al	Fe	Ca	Mg	Na	K	S	P	Ti	Mn	Ig loss	Btu lb	Class
4 /38	1	46.7	26.60	13.02	2.84	1.52	0.75	3.10	3.05	0.08	0.48	0.04	1.82	6148	ligB
2 /39	2													6684	ligA
3 /39	3													4965	ligB
3 /39	4	43.6	22.98	19.73	3.49	1.52	0.95	2.66	3.41	0.20	0.40	0.02	1.04	7270	ligA
3 /39	5	34.4	14.18	27.03	8.36	1.66	1.55	1.64	9.61	0.81	0.41	0.03	0.32	8122	ligA
1 /40	6													3423	ligB
1 /40	7													4709	ligB
1 /40	8													9238	subC
2 /40	9													4595	ligB
2 /40	10													7600	ligA

In addition to the above core samples, some core samples were collected and analyzed by DMR. The results of the analysis are shown in Appendix 1.

Ash analysis indicates that the Fe_2O_3 and CaO contents are relatively high, probably due to the sedimentary environments of high temperature and precipitation of Fe^{3+} and Ca^{2+}. Also high ash and sulfur contents in coal mean their concentration from the result of strong decomposition of original peat under the environments of high temperature and dry climate.

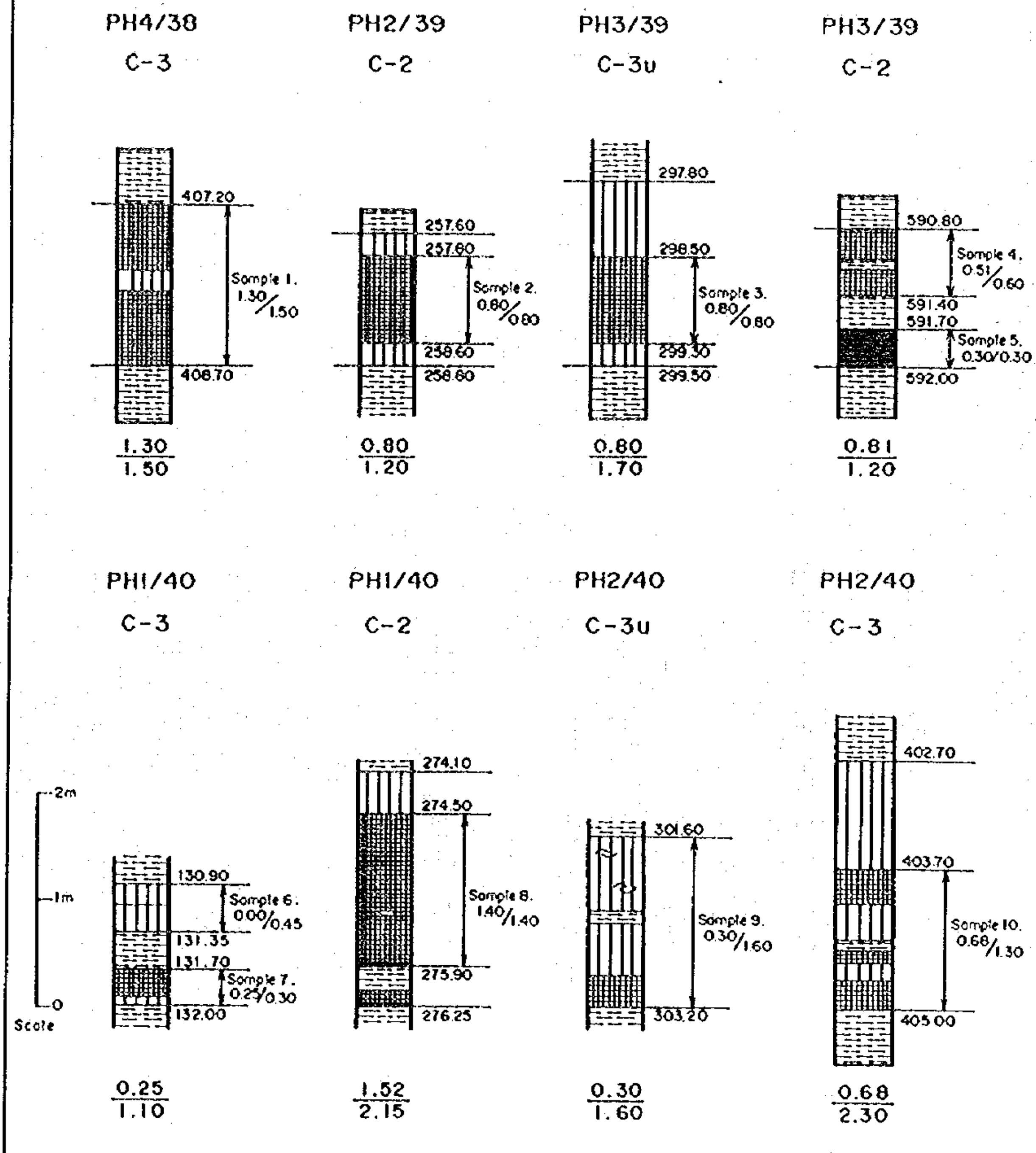
(3) Geologic structure

Main geologic structure is mostly presumed by interpretation of the previous seismic profiles by PTT. The western margin is delineated by W.M Fault (Western Margin Fault), and at the eastern margin Tertiary deposits are gradually thinning, steeply dipping and abutting against the basement.

Three main faults are present in the basin, i.e. Fault A, B, and C as shown in Fig. 3.1-4. All of these faults are NNE-trending normal faults dipping east. Maximum displacement is approximately 200 m in Fault A. A few conjugated faults which dip to west are also revealed in the seismic profiles.

In the southwestern part of the basin, a gentle syncline of NNE-SSW axis occurs. It extends toward north to NE-SW direction. The general structure indicates relatively gentle with dipping angle of between 5 to 8 degrees.

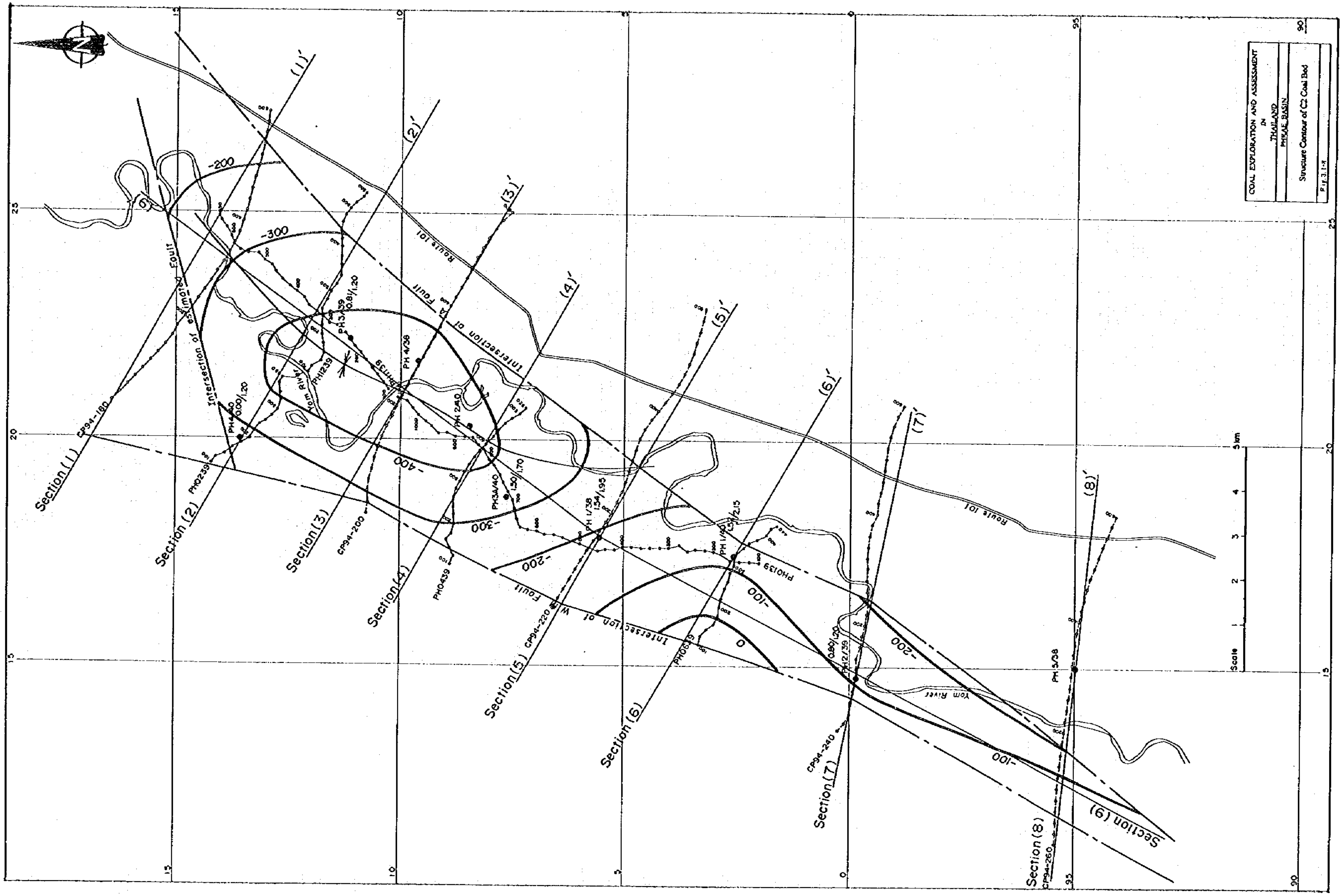
The structure contour of C2 coal bed and geological cross sections in the southwestern area are shown in Fig.3.1- 8, and Fig.3.1-9 respectively.



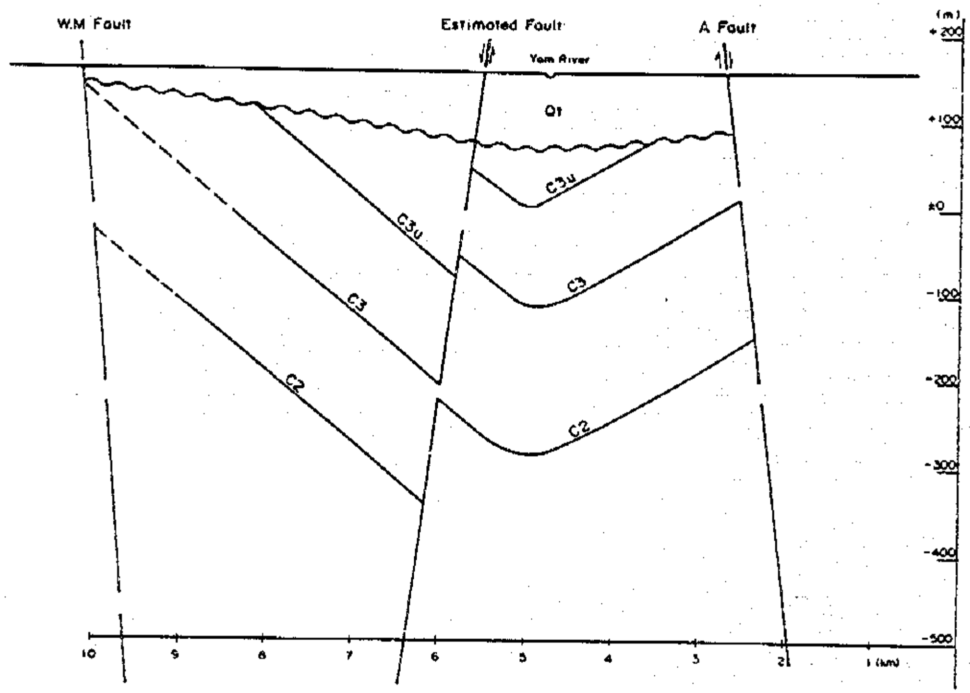
COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
PHRAE BASIN

Section of Sampled Coal Beds

Fig. 3.1-7


COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
PHRAE BASIN
Structure Contour of C2 Coal Bed
Route 101
Yom River
Intersection of estimated Fault
Intersection of Fault
Intersection of W Fault
Section (1)
Section (2)
Section (3)
Section (4)
Section (5)
Section (6)
Section (7)
Section (8)
Section (9)
(1)'
(2)'
(3)'
(4)'
(5)'
(6)'
(7)'
(8)'
CP94-180
CP94-200
CP94-220
CP94-240
CP94-260
PH0239
PH0439
PH0139
PH1239
PH 4/38
PH 1/38
PH 5/38
PH 2/40
PH3A/40
-200
-300
-400
-100
0
Scale
5 km

Profile (1) : CP94-180

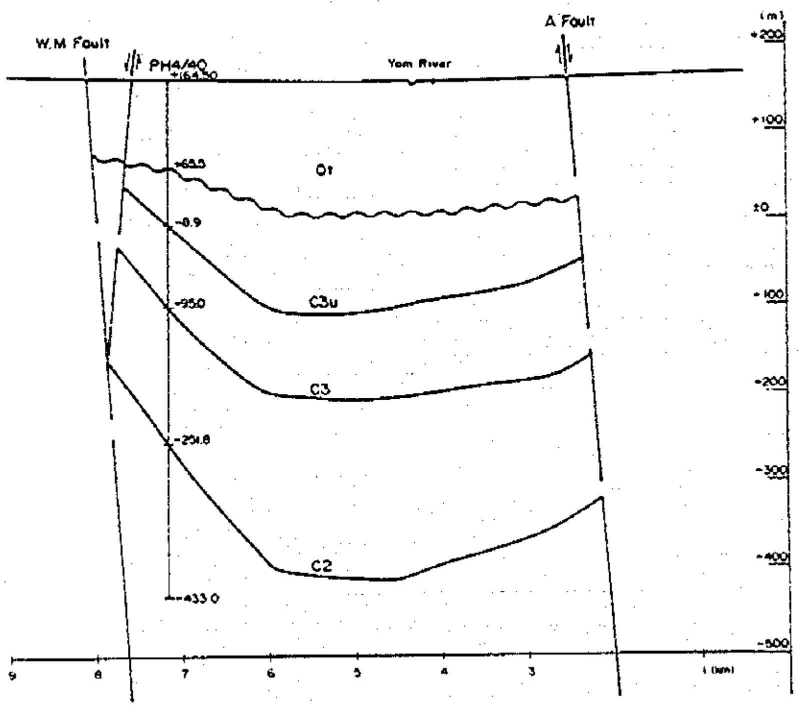


COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
PHRAE BASIN

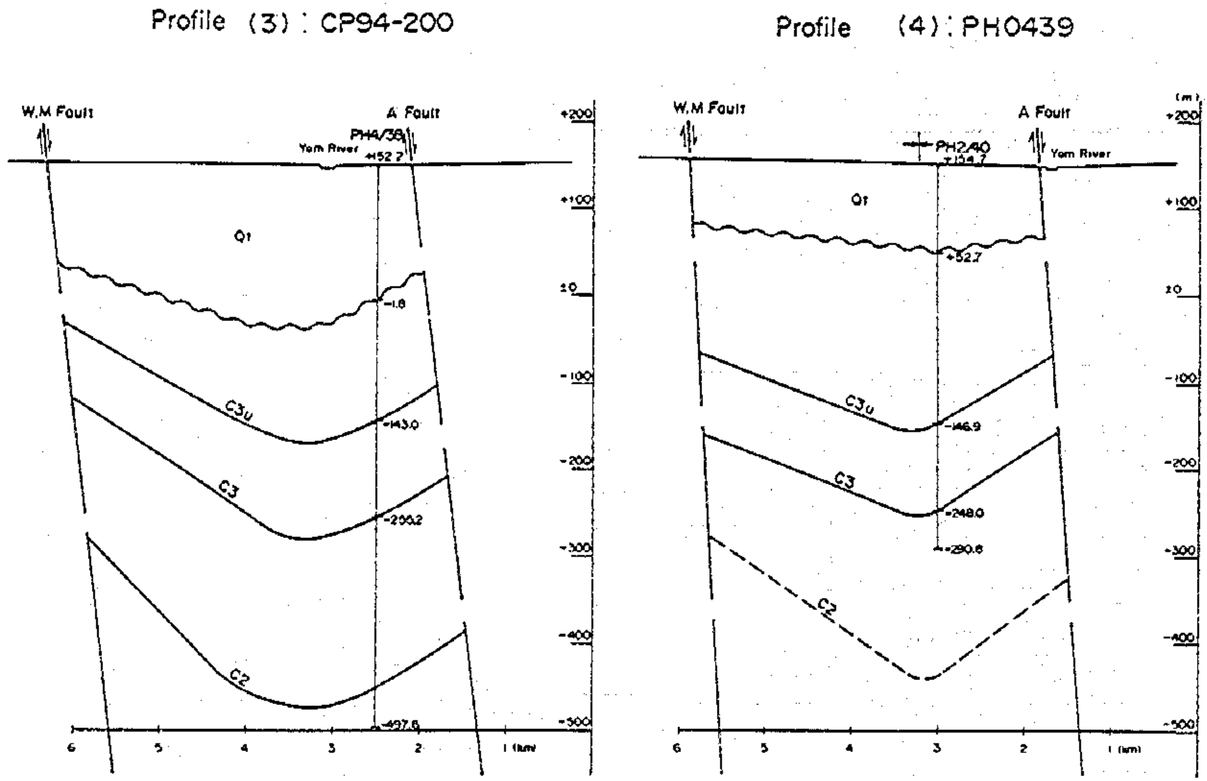
Geological Profile (1)

Fig. 3.1-9-1

Profile (2) : PH0239, I239



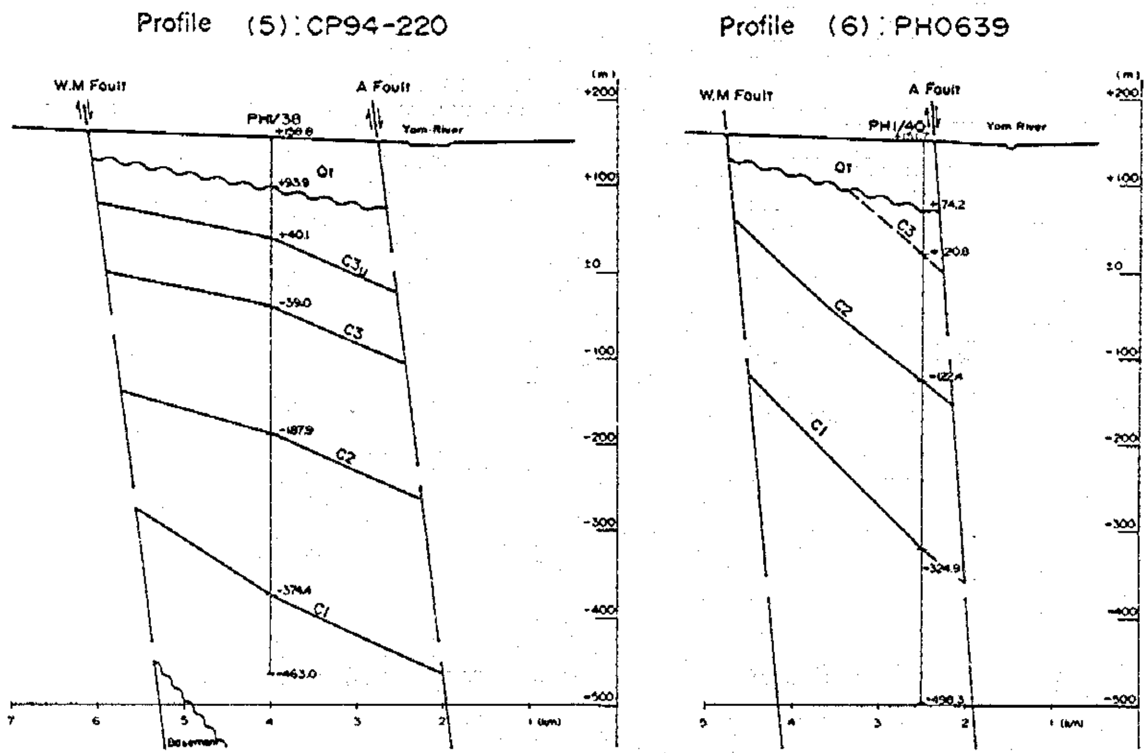
COAL EXPLORATION AND ASSESSMENT IN THAILAND
PHRAE BASIN
Geological Profile (2)
Fig. 3.1-9-2



COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
PHRAE BASIN

Geological Profile (3)

Fig. 3.1.4-3

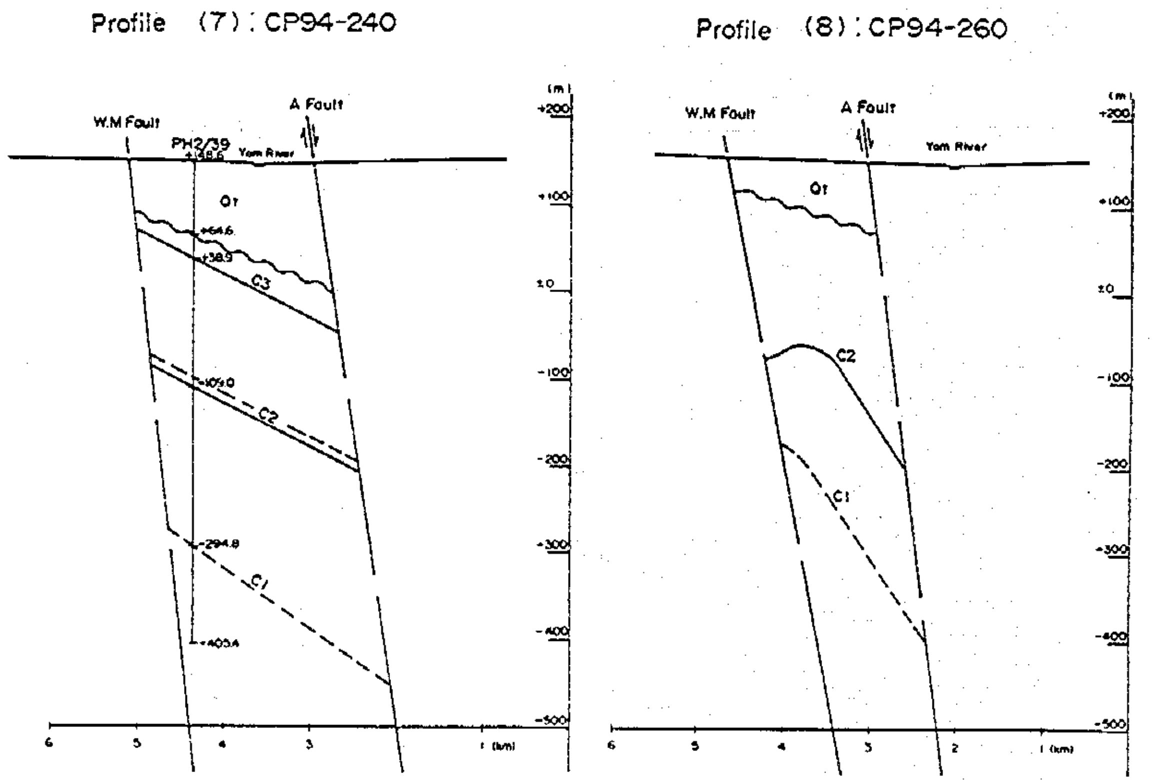


COAL EXPLORATION AND ASSESSMENT IN THAILAND

PHRAE BASIN

Geological Profile (4)

Fig. 3.1-9-4

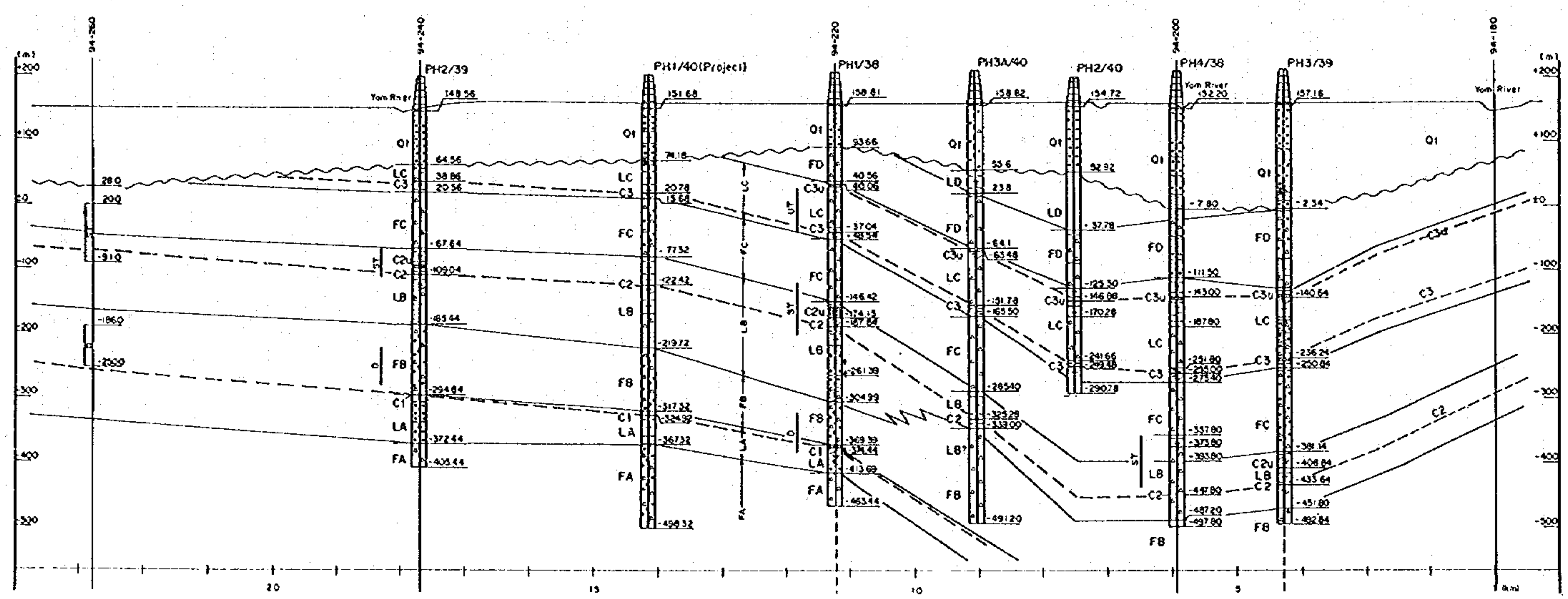


COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
PHRAE BASIN

Geological Profile (5)

Fig. 3.1-9-5

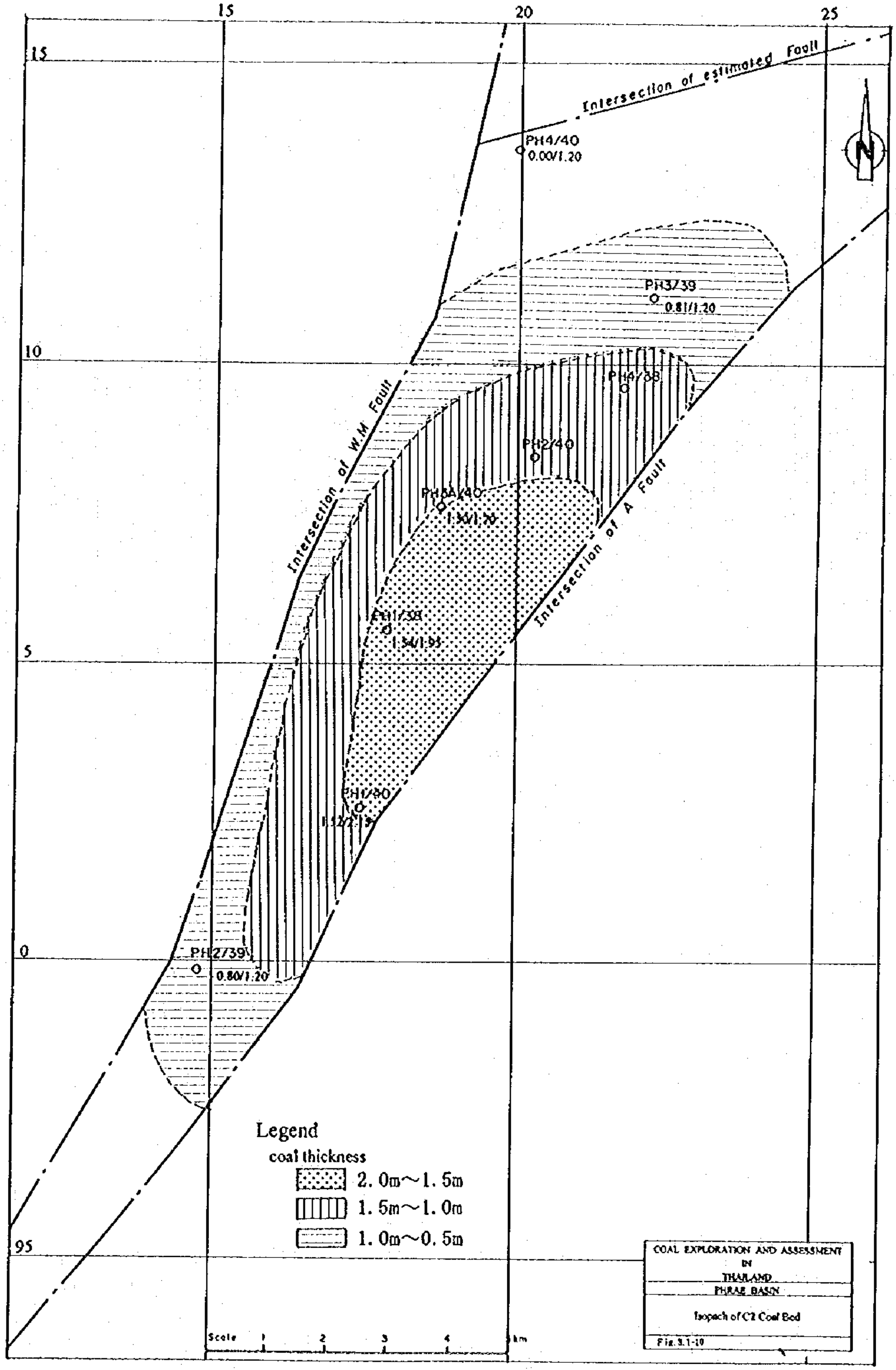
Profile (9)

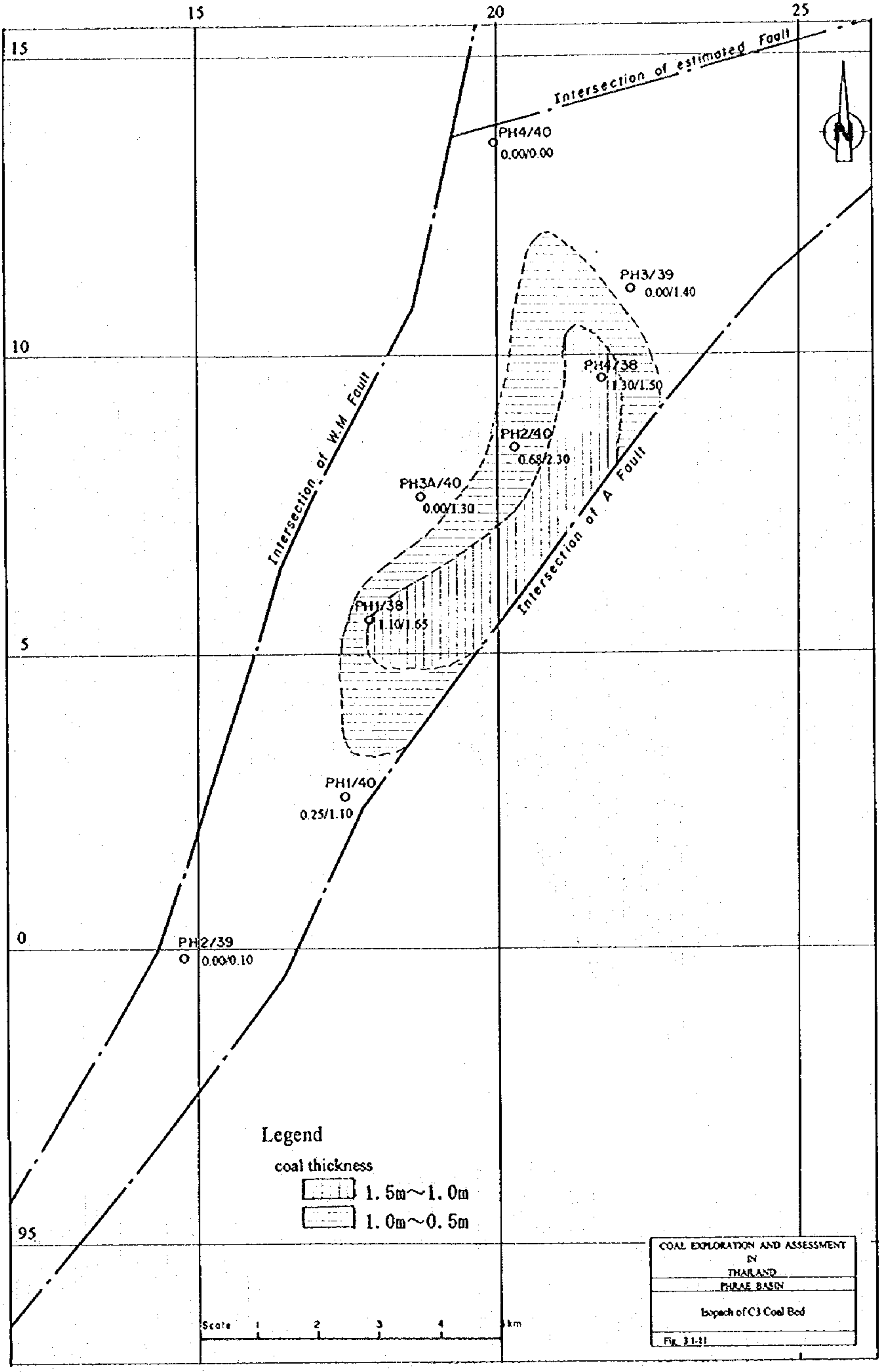


COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
PHRAE BASIN

Geological Profile (6)

Fig. 3.1-94


15
20
25
15
10
5
0
95
Intersection of estimated Fault
PH4/40
0.00/1.20
PH3/39
0.81/1.20
PH4/38
PH2/40
Intersection of W.M Fault
Intersection of A Fault
PH1/38
PH1/40
PH2/39
0.80/1.20
Legend
coal thickness
2. 0m～1. 5m
1. 5m～1. 0m
1. 0m～0. 5m
Scale
1
2
3
4
km
COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
PHRAE BASIN
Isopach of C2 Coal Bed


15
20
25
15
10
5
0
95
Intersection of estimated Fault
PH4/40
0.00/0.00
PH3/39
0.00/1.40
PH4/38
1.30/1.50
PH2/40
0.68/2.30
PH3A/40
0.00/1.30
PH1/38
1.10/1.65
PH1/40
0.25/1.10
PH2/39
0.00/0.10
Intersection of W.M Fault
Intersection of A Fault
N
Legend
coal thickness
1.5m～1.0m
1.0m～0.5m
Scale 1 2 3 4 5km
COAL EXPLORATION AND ASSESSMENT IN THAILAND
PHRAE BASIN
Isopach of C3 Coal Bed
Fig. 3.1-11

(4) Sedimentary environment of lignite

1) Lignite-bearing lacustrine lithofacies

Stratigraphy of the Phrae Basin is characterized of its alternations of fan and lacustrine lithofacies compared to the standard stratigraphy of the Tertiary intermontane coal basins in northern Thailand. Peat, the precursor of lignite or coal, is believed to be deposited as peat swamp in shallow lacustrine or deltatic environment which lasts for long period under calm condition with least inflow of clastics in general. Fan lithofacies, consisting of coares clastics transported under the high energy regime, might not provide the suitable environment for peat swamp. On the other hand, lacustrine lithofacies might provide the environment of peat swamp, so far calm condition and least inflow of clastics are maintained for long period.

The strong reflectors of steeply dipping fan lithofacies and the results of borehole exploration by EGAT in the northern area suggest that the coarse clastics were mainly supplied from north and east, though small amount of coarse clastics might be supplied from every surrounding mountain ranges as observable at the southern periphery of the basin. Lacustrine environment, therefore, might prevail when and where the supply of coarse clastics was lessened. Investigation of the seismic profiles and outcrops concluded that the lacustrine environment mainly developed in the central and southern areas in the basin, where the progradation of fan was less than the northern area. Therefore borehole exploration was conducted at first in the central and southern areas in the basin. Then recognizing the superiority of the southwestern area in geologic structure and deposition of the lignite beds to the rest, further exploration was concentrated there.

In the central and southeastern area, borehole exploration revealed that the main lignite-bearing lacustrine facies, i.e. LC and LB are too deep in addition to thin thickness of the lignite beds.

2) Sedimentary environment of the lignite beds

Recent progress in coal geology has revealed the following facts:

- Transformation of peat deposits of geologic age into present coal or lignite through coalification process.
- Domed and planar types of peat as shown in Table 3.1-7.
- Relatively low ash and sulfur contents in domed peat. Its higher surface than water level prevents invasion of clay into peat. And clay particles, being coagulated by strong acidity, settle beneath peat deposits.
- High ash and sulfur contents in planar peat. Topogeneous water enhances degradation of peat by microbial activity and oxidation resulting accumulation of ash and sulfur as residue of degraded plant materials. Furthermore suspended clay in topogenous water can invade and settle in peat due to its same surface level.
- The relationship between peat-forming environment and coal quality established in the Appalachian Basin can be applied to most of the coal basins including those in northern Thailand. In addition to high ash and sulfur contents of the lignite beds in the Phrae Basin, concentration of molluscan fossils in the roof, parting and floor of the lignite beds evidently exhibits that so much oxygen was supplied to hinder growth of peat.

Sedimentary environments of the lignite beds in the Phrae Basin are interpreted from the above mentioned geological facts are as follows:

- Incessant inflow of coarse clastics from the uplifting mountain range around the Phrae Basin formed fan deposits all over the basin.
- While the supply of coarse clastics was lessened, lacustrine environment was maintained where fan did not prograde.
- Lacustrine environment enabled growth of peat swamp. But its short period and topogenous water prevented peat swamp to change to domed peat from planar peat.
- The reactivated inflow of coarse clastics formed fan deposits overlying the lacustrine deposits.

Table 3.1-7 Characteristics of generalized types of peat-forming environments

Characteristic	Domed peat	Planar peat
climate	over - wet tropical	seasonal tropical
water source	ombrogenous (rain fall)	topogenous (surface water)
nutrient content	oligotrophic (poor)	mesotrophic to eutrophic
pH	<4	4 to 7
floral communities	low diversity	high diversity
microbial activity	low (cellulose preserved)	high (cellulose degraded)
mechanism of degradation	primary chemical	primary microbial
ash content	low, uniform	high, variable
sulfur content	low, uniform	high, variable
nitrogen content	low, uniform	high, variable
fiber content	fiberic	hemic to sapric
biogenic sulfide	low	high
biogenic methane	low	high

Cecil, C.B., Stanton, R.W., Neuzil, S.G., Dulong, F.T., Ruppert, L.F. and Pierce, B.S., (1985); Paleoclimate controls on Late Paleozoic sedimentation and peat formation in the Central Appalachian Basin. Inter .J. of Coal Geology, 5:195-230.

(5) Coal resources

1) Standard of estimation

a) Resources

Resources are the tonnage of coal in the ground which will be mined or utilized in the future. The standards are as follows:

- Estimation for each coal bed and for each block divided by major geologic structures. The block means an area which will be developed continuously.

- Geologic assurance

  Due to the characteristic morphologically variable nature of the coal bed, intrinsic to the origin in the intermontane coal basins, the geologic assurance is defined to the smaller area than the U.S. standard, as well as the current DMR standard.

  The resources are subdivided by geologic assurance as follows.

  Measured: Tonnage of coal in an area of a radius of 200 m from a control point. Control point means where the thickness of coal bed was measured by a borehole, geophysical logs and an excavated outcrop.

  Indicated: Tonnage of coal in an area between the radius of 400m and 200m from a control point.

  Inferred: tonnage of coal in an area between the radius of 800m and 400m from a control point.

- Thickness of a coal bed ≧0.5m

  A coal bed thinner than 0.5m is believed very difficult to be mined even by open pit mining due to contamination of the coal with spoils.

- Ash content≦45% a.d.

  The coal beds which contain ash between 35-45% are characteristic in Thailand.

- Depth ≦ 1000m

The formula for estimation is shown in the Table 3.1-8.

b) Reserves (Reserve base of the U.S. standard)

Reserves are tonnage of coal in the ground, a part of the resources, which are esteemed to be possibly mineable by contemporary technology.

- Estimation for each mineable coal bed and mineable block.
  The small or structurally disturbed areas are excluded.

- Thickness of the coal bed
  Underground mining ≧ 1.0m
  Thickness of partings ≦ 1/2 of the thickness of coal
  Open pit mining ≧ 0.5m

- Geologic assurance: measured + indicated + inferred
  Inferred area is contained, if it is relatively partial to the block.

- Ash content ≦ 45% a.d.

- Specific gravity: 1.3 for coal

- Depth
  Underground mining ≦ 500m
  Open pit mining ≦ 100m (Variable depending on the stripping ratio)

c) Mineable Reserves (Reserves of the U.S. standard, sum of mineable coal)

Mineable reserves are tonnage of product estimated by mining plan.

Run of mine coal (t) = Mining area (m^2, mining panels + mine roads)
× mining thickness (m) × specific gravity (average including partings)
× mining recovery (%)

Contamination of roof and floor rocks is estimated.

d) Salable Coal (t) = Run of mine coal (t) × benecifiation yield (%)

Table 3.1-8 Resources and Reserves Estimation Standards

		DMR	This Study	U.S. (U.S.Geol.Survey)
Geologic Assurance	Measured area	Radius≦ 200m	Radius≦200m	Radius≦400m
	Indicated area	Between the radius of 400 and 200m	Between the radius of 400 and 200m	Between the radius of 1200 to 400m
	Inferred area	None	Between the radius of 800 and 400m	Between the radius of 4800 and 1200m
Resources	Thickness (m)	≧0.2	≧0.5	≧0.75 (lignite and sub-bituminous)
	Ash Content (%)	≦40	≦45	≦33
	Depth (m)	0-50, 50-100,100-150, 150 - 200, >200	≦1000	≦1800
	Estimation method	Σ Total coal thickness within the depth criteria ×area ×specific gravity	Each coal bed and block. *1) Σ area*2)×average coal thickness*3)×1.3	Each coal bed and block Σ area ×average coal thickness ×SG*4)
Reserves	Thickness (m)	None	Open pit≧ 0.5	[Reserve Base] ≧ 1.5
	Depth (m)	None	Open pit≦100*6) Underground≦500	Sub-bituminous ≦ 300 Lignite≦150
	Estimation	None	Same as the resources	Same as the resources
Mineable Reserves	Estimation	None	Each coal bed and block Σ Planned mining area× mineable thickness×S.G. *5) ×recovery	[Reserves] Each coal bed and block Reserve base ×recovery×yield
Salable Reserves		None	Run of mine coal × benecification yield	

*1) Block means the area delineated by the major geologic structures.

*2) Area is subdivided on the coal bed map by geologic assurance, isopach lines of an appropriate interval of coal thickness and contour lines of elevation.

*3) Coal thickness is the average thickness between the two neighboring isopach lines.

*4) Average value is estimated.

*5) S.G. is estimated including partings.

*6) If the coal bed is thick enough, 150m or 200m can be used in relation to stripping ratio.

2) Coal resources

In situ coal resources of the Phrae Basin were calculated for the limited area between W.M Fault and A Fault on the basis of coal occurrence. The resources of C2 and C3 coal beds are estimated, because they are relatively stable in thickness and other coal beds are mostly composed of carbonaceous mudstone in quality. The estimation is performed according to the standard described in the previous section. Other criteria used for the estimation are as follows;

Thickness : determined from isopach map as shown in Fig.3.1-10 and 3.1-11.
minimum thickness : 0.5m

Area by geologic assurance
measured + indicated + inferred : 800m from a control point

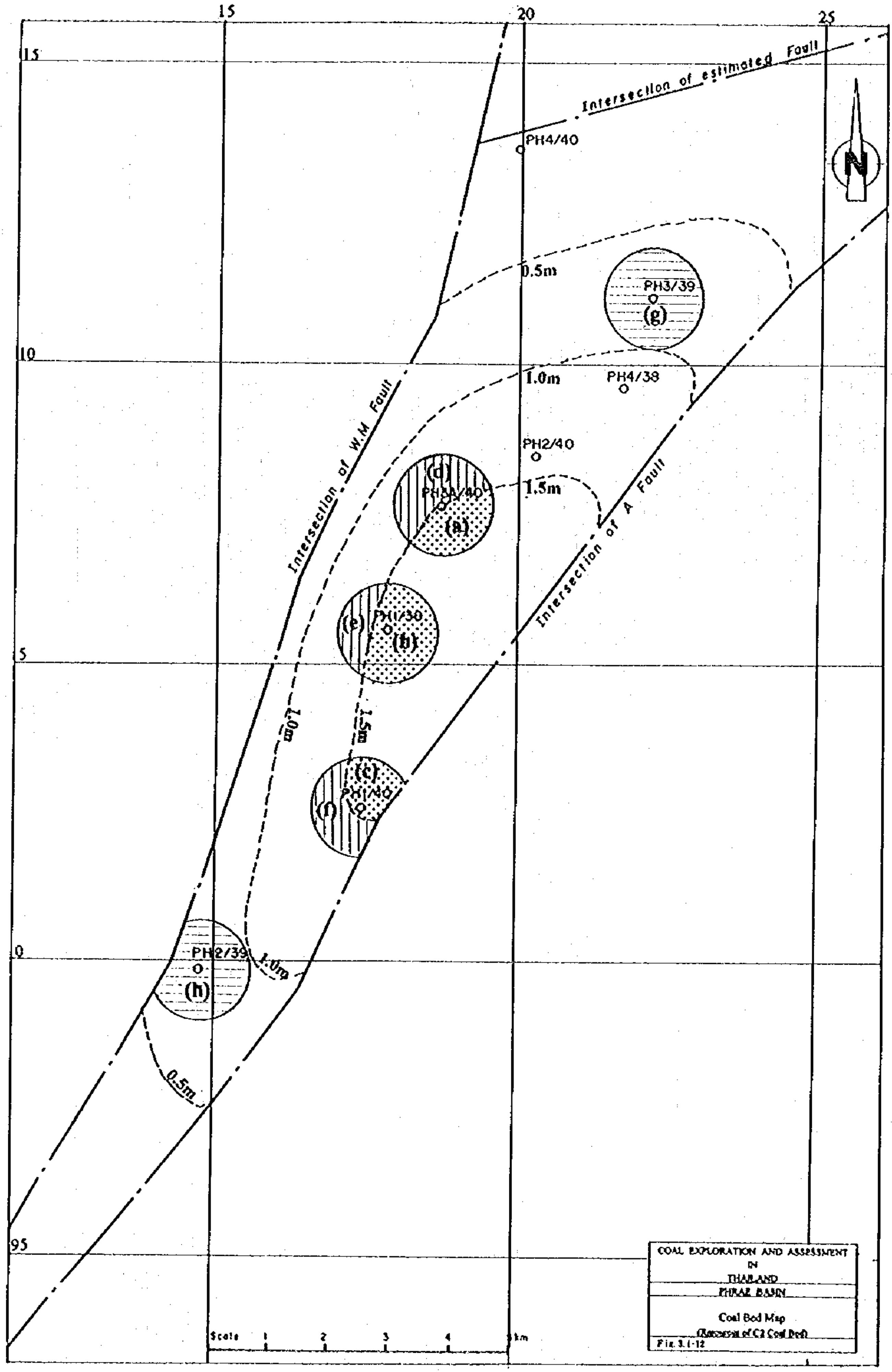
Specific gravity : 1.3

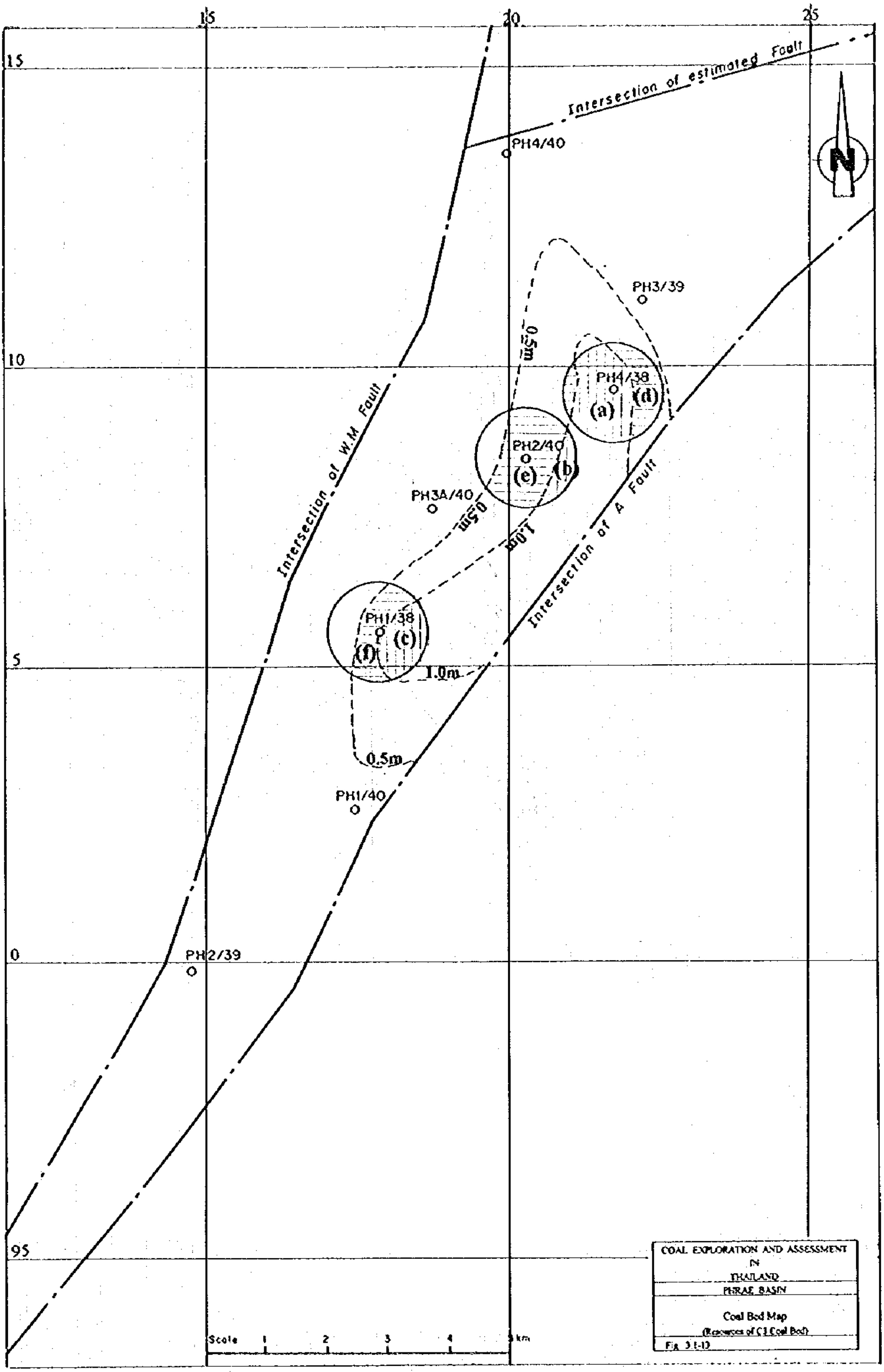
The total coal resources have been estimated at 20,909,000 t as summarized in Table 3.1-9 and illustrated in Fig.3.1-12 and 3.1-13.

Table 3.1-9 Coal Resources of C2 and C3 Coal beds

Block	Thickness (m)	Plan (1,000m2)	Resources (1,000t)
C2 Coal Bed Measured+indicated+inferred			
(a)+(b)+(c)	1.50	3,070	5,987
(d)+(e)+(f)	1.25	2,660	4,323
(g)+(h)	0.75	3,810	3,715
Total	1.13	9,540	14,024
C3 Coal Bed Measured+indicated+inferred			
(a)+(b)+(c)	1.25	2,430	3,949
(d)+(e)+(f)	0.75	3,010	2,935
Total	0.97	5,440	6,884
Grand total	1.07	14,980	20,907

Specific gravity: 1.30


15
20
25
15
10
5
0
95
Intersection of estimated Fault
PH4/40
N
0.5m
PH3/39
(g)
1.0m
PH4/38
PH2/40
Intersection of W.M Fault
(d)
1.5m
(a)
Intersection of A Fault
PH1/30
(e)
(b)
1.0m
1.5m
(c)
PH1/40
(f)
PH2/39
1.0m
(h)
0.5m
Scale 1 2 3 4 5 km
COAL EXPLORATION AND ASSESSMENT IN THAILAND
PHRAE BASIN
Coal Bed Map


15
20
25
15
10
5
0
95
Intersection of estimated Fault
Intersection of W.M Fault
Intersection of A Fault
N
PH4/40
PH3/39
PH4/38
PH2/40
PH3A/40
PH1/38
PH1/40
PH2/39
0.5m
1.0m
(a)
(b)
(c)
(d)
(e)
(f)
Scale 1 2 3 4 5 km
COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
PHRAE BASIN
Coal Bed Map

3.1.4 Mining plan

Exploration in the Phrae Basin is in the reconnaissance stage with borehole spacing of 2 km or more. The existing geological information is insufficient for preparation of a mining plan. It should be noted, therefore, that the following plan explains only a basic idea of underground mine development from the technical point of view.

(1) Mining area

According to the borehole exploration, only the C2 Coal Bed is determined to have mineable thickness for underground mining to some extent. The possible mining area is between W.M and A faults and an area with coal thickness of over 1 m in the isopach map.

(2) Mine access

The location of pit mouth is to be selected at relatively higher place near the shallowest part of the C2 Coal Bed to prevent the damage by flooding and to minimize the length of rock slopes.

Two rock slopes are to be driven from the southwestern area toward northeast in order to reach the coal bed at zero meter in elevation. The slopes are 15 degrees in inclination and about 580 m each in length. Blasting is used for the slope construction. Broken rock is loaded into mine cars with a side-dump loader and winded up to the surface.

(3) Mine development

From the bottom of the slopes, main entries are developed in the coal bed toward northeast. Then, to the both sides of the main entries, inseam roads are driven to prepare mining panels. Owing to the very gentle dip of coal bed, a combination of a continuous miner and a shuttle car can be applied for road development. A set of four parallel roadways are planned both in main entries and in-seam road in order to reduce ventilation resistance.

(4) Room and Pillar mining

The surface of the mining plan area is intensively cultivated and irrigated for paddy field. In order to minimize the impact on the surface, room and pillar mining is suitable as the mining method in this area. However the mining recovery will be reduced to much less than longwall mining. The continuous miner and shuttle car system is also applicable for the room and pillar mining operation.

(5) Transportation and coal handling

Mined coal is loaded in a shuttle car, then unloaded on and transported by belt conveyor to the surface. The coal is discharged into a coal bin on the surface, then moved to a sizing screen through a feeder. Oversize non-coal materials are removed by hand-picking.

3.2 Nong Plab Basin

3.2.1 Geography

The Nong Plab Basin is located to the boundary of Petchaburi and Prachuab Khirikhan Provinces, and accessible from Hua Hin at 54 km via Provincial Highway No.3301. The basin is elongated in shape with 12 km long in N-S and 5 km wide in E-W, covering an area of approximately 47 km^2 as shown in Fig.3.2-1. The surface of the basin is mostly flat land with gentle hills ranging from 100 m to 190 m in altitude. The Pranburi River flows from north to south in the center of the basin. The land is utilized mainly for corn and pineapple field and stock farming.

The weather statistics for the past ten years at Phetchaburi station are as follows;

Temperature (°C) : mean 27.8
mean maximum 31.9
mean minimum 24.1

Rainfall (mm) : mean annual 945.7
monthly 0.9 (February) - 287.6 (October)

3.2.2 Exploration and geological investigation

(1) Exploration

The following exploration was carried out by DMR in the Nong Plab Basin.

Table 3.2-1 Exploration in the Nong Plab Basin

		1993	1994	1995	Total
Drilling	(holes)	18	42	5	65
Total depth	(m)	2,803.5	5,015	745.5	8,564
Geophysical Logging	(holes)	4	28	5	37
Seismic Survey	(lines)	15	-	19	34
Total length	(km)	23	-	33	56
Coal Analysis	(samples)	13	41	-	54

The location of boreholes and seismic lines are shown in Fig.3.2-2. The summary of boreholes is shown in Table 3.2-2, 3.2-3 and 3.2-4.

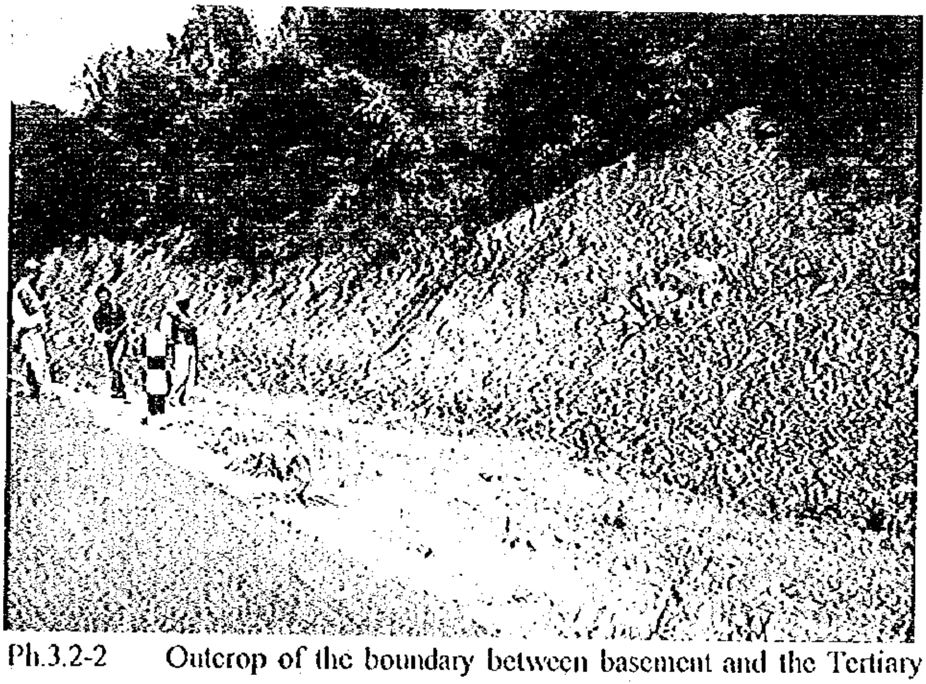
(2) Geological investigation

All the geological data obtained from the above exploration were investigated by the following procedures;

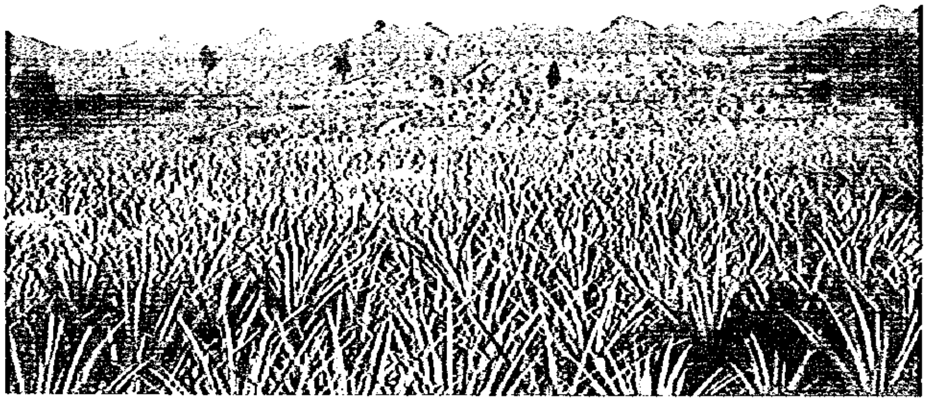
- Cores of five boreholes drilled in 1995 were logged by the Study Team (Ph.3.2-1) using lithofacies coding method and lithofacies logs were drafted at a scale of 1:500.
- All lithologic logs of a scale of 1:400 were correlated each other by taking the Upper Coal Bed as a stratigraphic marker.
- Coal bed sections on a scale of 1:100 were produced from core logs and adjusted to geophysical logs, when available. Each coal bed section was correlated on a ply by ply basis.
- Geologic structure was interpreted from seismic and borehole data, but the use of seismic profiles were only utilized to determine the general trend of dipping direction because of their poor quality.
- Based on the above investigation, various kinds of coal bed maps, such as an isopach map, a structure contour map, were produced.
- Coal resources and reserves of the Upper Coal Bed were estimated in accordance with the standard introduced in the Study.

All the analytical data were examined. However, many assumptions were required for estimation of product coal quality, due to inadequate sampling method and records.

Ph.3.2-1 Core logging of the borehole NPG 3/38.

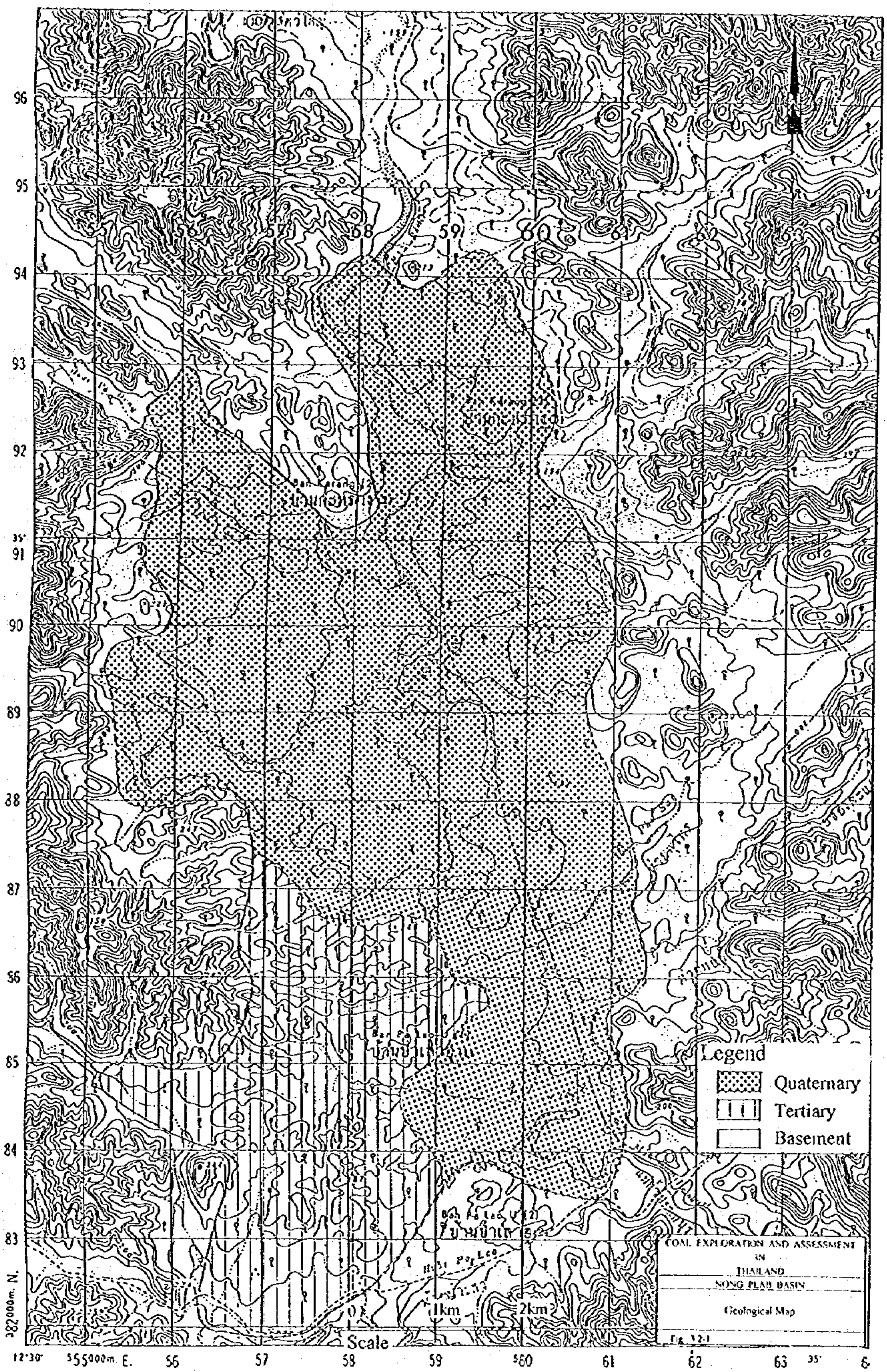


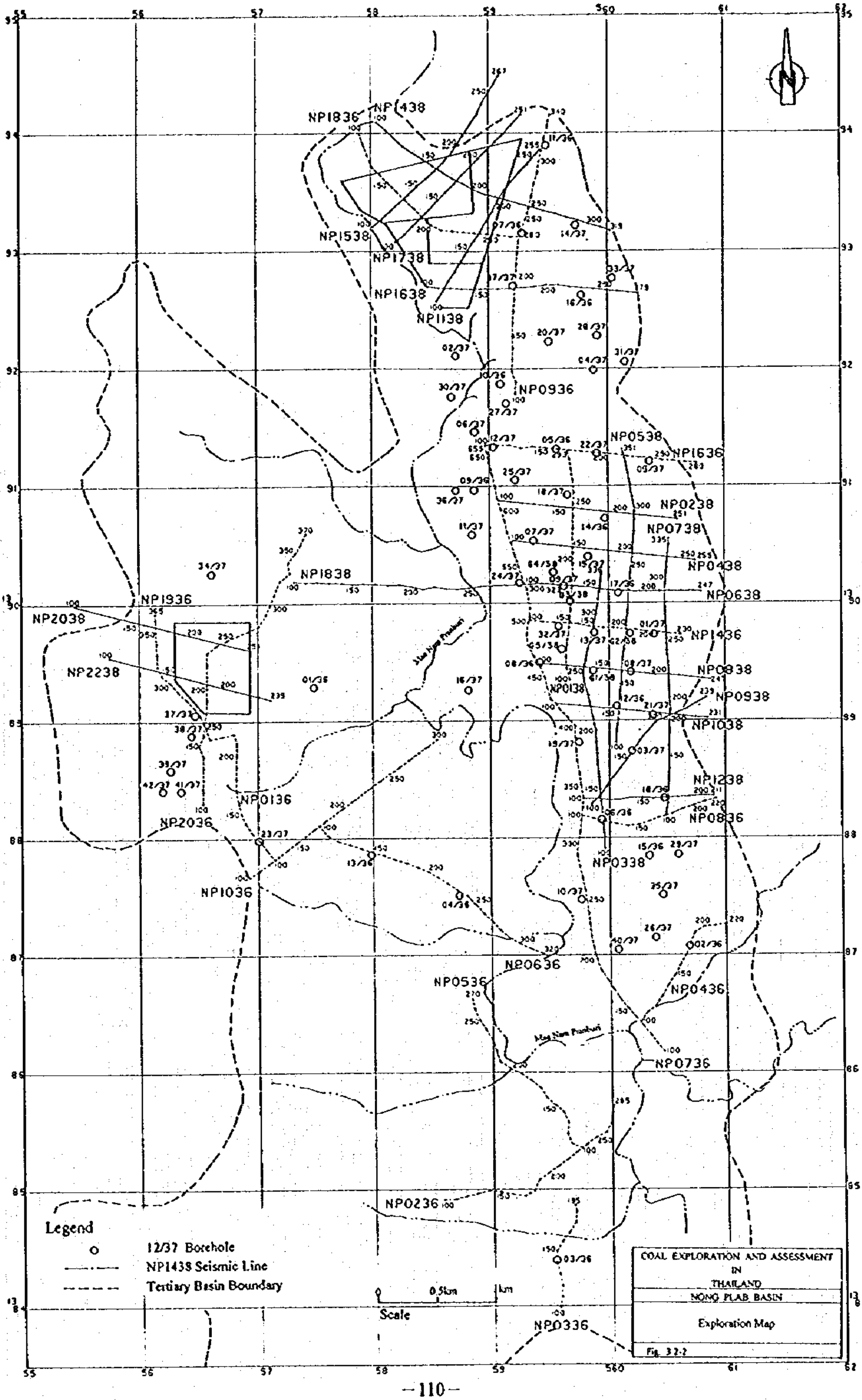
Ph.3.2-2 Outcrop of the boundary between basement and the Tertiary deposits.



Ph.3.2-3 The view of the mine planning area.

Ph.3.2-4 Site investigation of proposed mine mouth in the northeastern area.


Legend
Quaternary
Tertiary
Basement
0
1km
2km
Scale
COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
NONG PLAB BASIN
Geological Map
Fig. V2-1


COAL EXPLORATION AND ASSESSMENT IN THAILAND
NONG PLAB BASIN
Exploration Map
Fig. 3.2-2
Legend
12/37 Borehole
NP1438 Seismic Line
Tertiary Basin Boundary
0.5km
1km
Scale
NP1836
NP1438
NP1538
NP1738
NP1638
NP1138
NP0936
NP0538
NP1636
NP0238
NP0738
NP0438
NP1838
NP0638
NP1936
NP2038
NP1436
NP2238
NP0838
NP0138
NP0938
NP1038
NP1238
NP0136
NP0836
NP2036
NP0338
NP1036
NP0636
NP0536
NP0436
NP0736
NP0236
NP0336

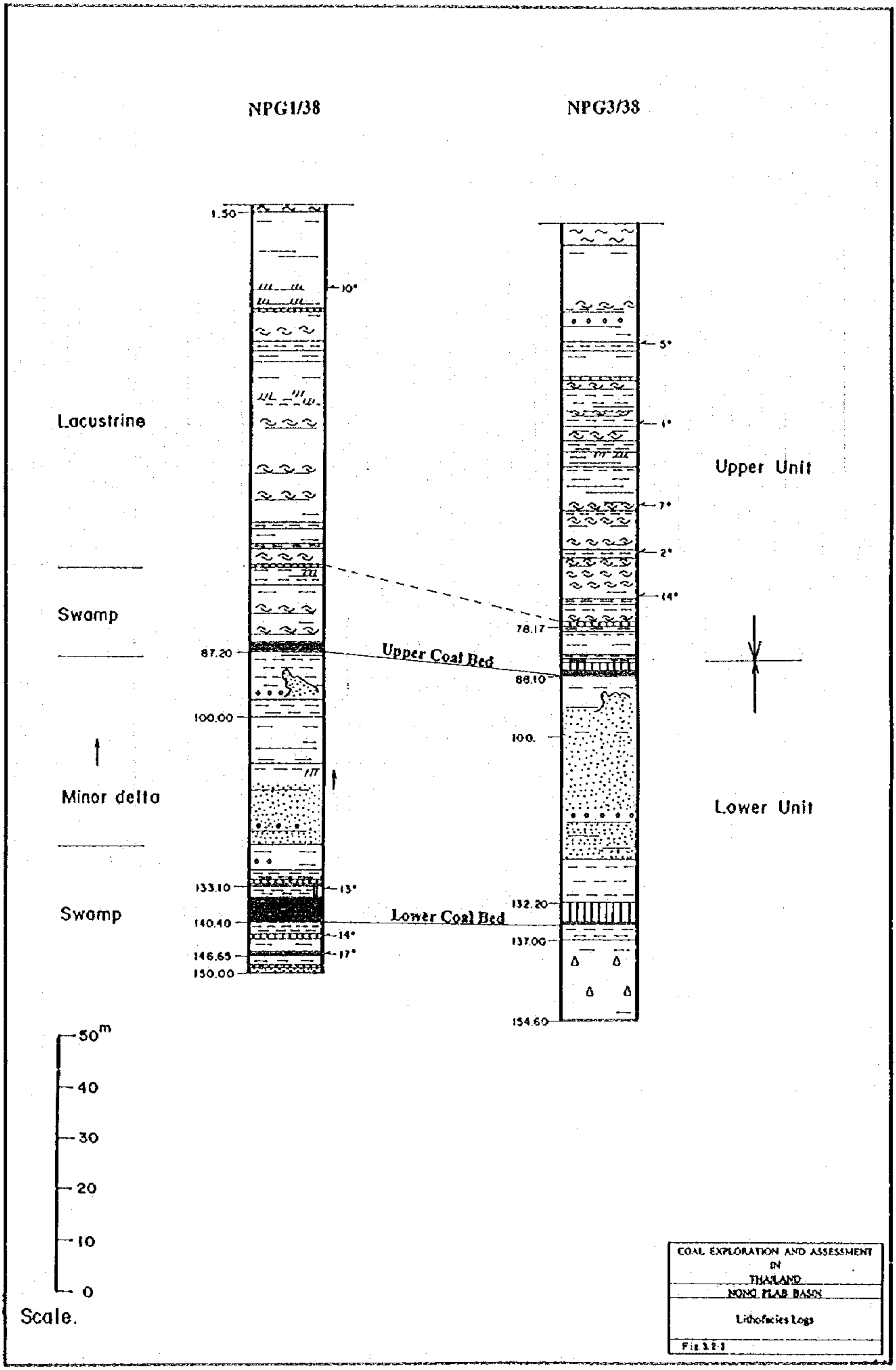

NPG1/38
NPG3/38
Lacustrine
Swamp
Minor delta
Swamp
Upper Unit
Lower Unit
Upper Coal Bed
Lower Coal Bed
1.50
87.20
100.00
133.10
140.40
146.65
150.00
10°
13°
14°
17°
78.17
88.10
100.
132.20
137.00
154.60
5°
1°
7°
2°
14°
50m
40
30
20
10
0
Scale.
COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
NONG PLAB BASIN
Lithofacies Logs

Table 3.2-2 Summary of Boreholes in the Nong Plab Basin (1)

Hole No.	Elevation	T.Depth	Basement		Upper Coal Bed				Lower Coal Bed				Remarks
			Drill depth	Sea level	Coal thick	Seam thick	Depth of Roof(m)		Coal thick	Seam thick	Depth of Roof(m)		
	(m)	(m)	(m)	(m)	(m)	(m)	Drill depth	Sea level	(m)	(m)	Drill depth	Sea level	
NT 01 / 36	156.6	212.0			-	-							thinning out
NT 02 / 36	152.1	88.5			-	-							not deep enough
NT 03 / 36	132.5	111.0			-	-							thinning out
NT 04 / 36	138.2	430.0	409.0	-270.8	C 1.16	1.55	371.4	-233.2					
NT 05 / 36	161.1	179.0	170.5	-9.4	C 1.10	1.50	105.8	55.3					
NT 06 / 36	141.7	129.0	117.9	23.8	G 0.95	1.20	115.7	26.0					
NT 07 / 36	161.2	144.0	140.3	20.9	G 2.69	3.43	120.6	40.6					
NT 08 / 36	151.4	133.0	120.9	30.5	C 2.58	2.58	99.6	51.8					
NT 09 / 36	156.0	138.0	130.0	26.0	C 2.62	2.62	121.1	34.9					
NT 10 / 36	153.6	113.1			C 3.51	3.55	68.4	85.2					
NT 11 / 36	175.9	93.0	92.7	83.2	C 2.86	2.90	59.8	116.1					
NT 12 / 36	155.9	171.0	164.9	-9.0	C 0.72	1.43	109.6	46.3	6.31	6.31	150.6	5.3	
NT 13 / 36	149.6	210.0			-	-							thinning out
NT 14 / 36	166.7	77.9			-	-							fault
NT 15 / 36	148.8	138.0			C 1.63	2.31	40.1	108.7					
NT 16 / 36	161.8	105.0	97.0	64.8	C 1.50	1.90	78.0	83.8					
NT 17 / 36	170.8	124.0			C 0.08	0.08	90.9	79.9					
NT 18 / 36	152.6	207.0	204.0	-51.4	C 0.30	0.30	125.6	27.0	-	-			L coal bed split

Thickness, G : from geophysical logging C : from core logging

Table 3.2-3 Summary of Boreholes in the Nong Plab Basin (2)

Hole No.	Elevation (m)	T. Depth (m)	Basement: Drill depth (m)	Basement: Sea level (m)	Upper Coal Bed: Coal thick (m)	Upper Coal Bed: Seam thick (m)	Upper Coal Bed: Depth of Roof (m) Drill depth	Upper Coal Bed: Depth of Roof (m) Sea level	Lower Coal Bed: Coal thick (m)	Lower Coal Bed: Seam thick (m)	Lower Coal Bed: Depth of Roof (m) Drill depth	Lower Coal Bed: Depth of Roof (m) Sea level	Remarks
NT 01 / 3'	173.9	181.0			C 0.13	0.13	101.5	72.4	-	-			L coal bed split
NT 02 / 3'	149.2	124.5	105.0	44.2	C 0.63	0.91	89.2	60.0					
NT 03 / 3'	162.9	125.0	88.0	74.9	-	-							basement
NT 04 / 3'	157.0	88.5			C 0.14	0.41	56.6	100.4					
NT 05 / 3'	174.7	59.0			-	-							below outcrop
NT 06 / 3'	151.5	61.0			-	-							not deep enough
NT 07 / 3'	150.9	171.0			C 0.94	1.61	84.4	66.5	1.99	2.84	158.2	-7.3	
NT 08 / 3'	168.5	170.0	159.0	9.5	C 0.41	0.66	112.8	55.7	2.66	3.23	150.5	18.0	
NT 09 / 3'	156.8	197.0	182.1	-25.3	G 0.40	1.20	97.6	59.2	1.80	2.70	158.3	-1.5	L coal bed split
									3.60	5.00	175.9	-19.1	
NT 10 / 3'	139.0	252.0			G 0.50	0.50	162.0	-23.0					
NT 11 / 3'	149.6	136.5	121.1	28.5	G 1.50	2.00	102.2	47.4					
NT 12 / 3'	152.8	66.0			G 1.15	1.15	43.0	109.8					
NT 13 / 3'	169.4	159.0	142.5	26.9	G 0.75	2.45	73.8	95.6	-	-			L coal bed split
NT 14 / 3'	168.2	70.0			G 1.70	2.65	56.0	112.2					
NT 15 / 3'	150.9	114.0			-	-							fault
NT 16 / 3'	141.4	270.0			G 1.40	2.20	180.6	-39.2					
NT 17 / 3'	152.4	137.5			G 1.85	2.40	118.1	34.3					
NT 18 / 3'	163.9	73.0			G 0.80	1.10	35.4	128.5					
NT 19 / 3'	151.1	134.5	130.0	21.1	G 0.90	1.20	129.9	21.2					
NT 20 / 3'	156.6	91.0			G 1.65	2.75	75.3	81.3					
NT 21 / 3'	158.7	126.0	113.8	44.9	C 0.20	0.20	104.7	54.0					
NT 22 / 3'	165.9	85.0			C 0.12	1.53	45.2	120.7					
NT 23 / 3'	171.5	162.0			0.00	0.64	92.9	78.6					

Thickness, G : from geophysical logging C : from core logging

Table 3.2-4 Summary of Boreholes in the Nong Plab Basin (3)

Hole No.	Elevation	T. Depth	Basement		Upper Coal Bed				Lower Coal Bed				Remarks
			Drill depth	Sea level	Coal thick	Seam thick	Depth of Roof(m)		Coal thick	Seam thick	Depth of Roof(m)		
	(m)	(m)	(m)	(m)	(m)	(m)	Drill depth	Sea level	(m)	(m)	Drill depth	Sea level	
NP 24 / 37	146.8	114.0	104.0	42.8	G 1.25	1.60	76.0	70.8					
NP 25 / 37	161.1	92.0			G 1.10	1.50	74.4	86.7					
NP 26 / 37	138.5	72.0			G 1.30	2.05	24.6	113.9					
NP 27 / 37	151.5	78.0			G 1.90	1.90	55.4	96.1					
NP 28 / 37	158.4	92.0			G 1.45	2.55	86.6	71.8					
NP 29 / 37	154.2	126.0			G 1.80	2.45	64.2	90.0					
NP 30 / 37	147.2	40.0			-	-							not deep enough
NP 31 / 37	166.2	79.0			G 0.60	0.60	71.0	95.2					
NP 32 / 37	153.8	90.0			-	-							fault
NP 33 / 37	167.8	75.0			-	-							not deep enough
NP 34 / 37	174.0	43.5			-	-							below outcrop
NP 35 / 37	139.5	231.0			C 0.98	0.98	189.5	-50.0					
NP 36 / 37	149.6	112.0	108.2	41.4	G 1.50	1.80	81.2	68.4					
NP 37 / 37	172.2	97.0			G 1.45	1.85	48.6	123.6					
NP 38 / 37	172.3	99.0			G 1.75	2.00	61.7	110.6					
NP 39 / 37	174.0	102.0			G 1.70	2.20	75.0	99.0					
NP 40 / 37	138.0	218.0			C 0.77	0.77	170.2	-32.2					
NP 41 / 37	171.0	101.0			G 2.45	2.75	78.7	92.3					
NP 42 / 37	174.6	100.0			C 0.76	1.46	86.7	87.9					
PC 01 / 38	164.3	150.0			C 0.59	2.25	85.0	79.3	5.06	5.10	135.3	29.0	
PC 02 / 38	187.5	174.0			C 0.05	0.17	129.2	58.3					
PC 03 / 38	158.4	154.6			C 0.10	2.60	85.5	72.9	0.00	4.20	132.8	25.6	
PC 04 / 38	153.5	153.4	148.0	5.5	C 0.50	1.30	83.3	70.2	0.85	1.53	137.0	16.5	
PC 05 / 38	155.9	113.5			C 0.00	0.20	90.3	65.6					

Thickness, G : from geophysical logging C : from core logging

3.2.3 Geology

(1) Stratigraphy

Tertiary formation in the Nong Plab Basin is divided into two units. The upper unit mainly consists of lacustrine mudstone and claystone with minor sandstone bands. Gastropod fossils are common and a few thin carbonaceous mudstone beds are present in this unit. The lower unit is characterized in lithology by increase of coarse clastics, such as sandstone and conglomerate, which indicates deltaic lithofacies. No molluscan fossil is observed in this unit. The unit is unconformably underlain by Paleozoic basement rocks. (Ph.3.2-2) The maximum thickness of Tertiary formation observed in a borehole is 409 m in NP04/36. Lithofacies logs of two boreholes and correlation of all lithologic logs are shown in Fig.3.2-3 and Fig.3.2-4 respectively.

(2) Coal bed

There are two coal beds in the lower unit of the Tertiary formation, namely the Upper and the Lower Coal Beds.

The Upper Coal Bed was deposited extensively in the basin and observed at 52 boreholes, although its thickness varies widely. Maximum thickness is 3.55 m at NP10/36, but it tends to thin toward east and south as shown in Fig.3.2-7. The coal bed of more than 1.5m thick appears in the northern part and in a limited area of the western part of the basin. The Upper Coal Bed sections of the all boreholes are shown in Fig. 3.2-5.

The Lower Coal Bed occurs about 50 m below the Upper Coal Bed. It was deposited only in the several restricted areas divided by protruded basement as illustrated in Fig. 3.2-10. The maximum thickness is more than 6 m in NP12/36, but it splits and thins rapidly. The sections of the Lower Coal Bed are shown in Fig.3.2-6.

(3) Geologic structure

Geologic structure of the Nong Plab Basin is fairly complex as shown in Fig.3.2-8. In the eastern part of the basin, the area is divided into several blocks by faults, which are assumed to be normal faults and denominated as from C to K faults. A synclinal structure exists in the middle of the area. The coal bed dips at 2 to 5 degrees eastward on the northwestern side and westward on the southeastern side of the syncline axis. Probably, the coal beds abut against the basement at the eastern margin of the basin.

Though the geologic structure of the central part of the basin is uncertain, a graven structure seems to be formed by two NNW-SSE trending normal faults as shown in the cross section b-b' (Fig.3.2-9). Geologic structure of the western part appears to be comparatively simple and the Upper Coal Bed may crop out to some extent. Due to a limited number of boreholes, however, interpretation can be made only for a limited area.

(4) Sedimentary environment

Stratigraphy of this basin is similar to the typical coal basins in Thailand with slight difference in A: coarse clastics member and B: coal-bearing member. As shown in Fig. 3.2-3, the Lower Coal Bed was deposited in a confined small area overlying the subsided basement.

Borehole exploration discloses that a thick coal bed occurs overly between the protruded basement and it chips on the protruded basement accompanying wash-out of the coal bed. Also the coal bed indicates splitting toward north. These data mean that tectonic subsidence started in a small confined area, where paleotopography was characterized by many islands or small scale peninsulas with inlets between them. Peat was mainly deposited in inlets and split toward north due to tilting of the basement.

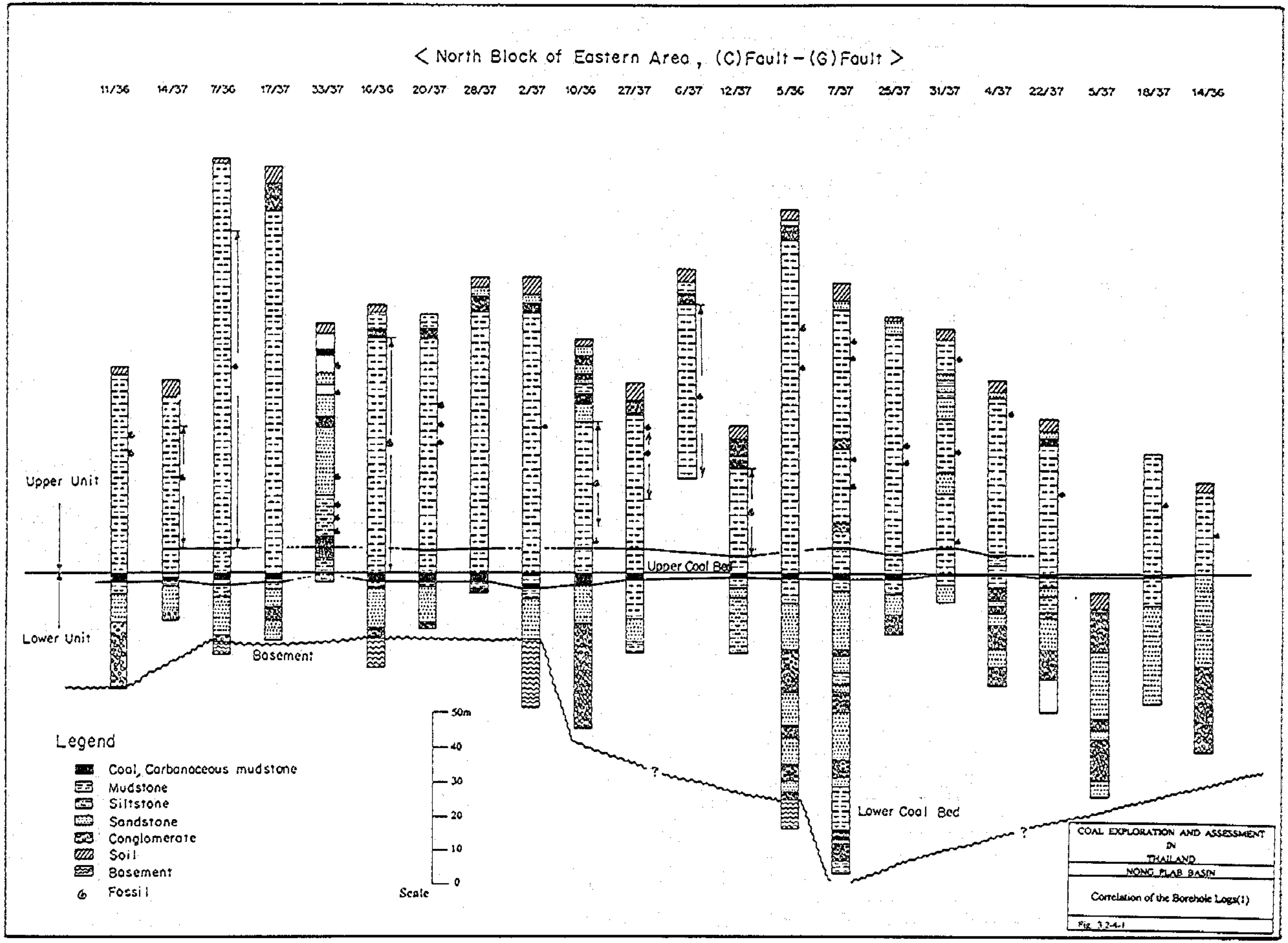
The Lower Bed is overlain by relatively thick coarse clastics which were deposited probably in the enlarged subsided area forming fan and fluvial deposits. The basin extended to the north where thin coarse clastics were deposited overlying the eroded basement.

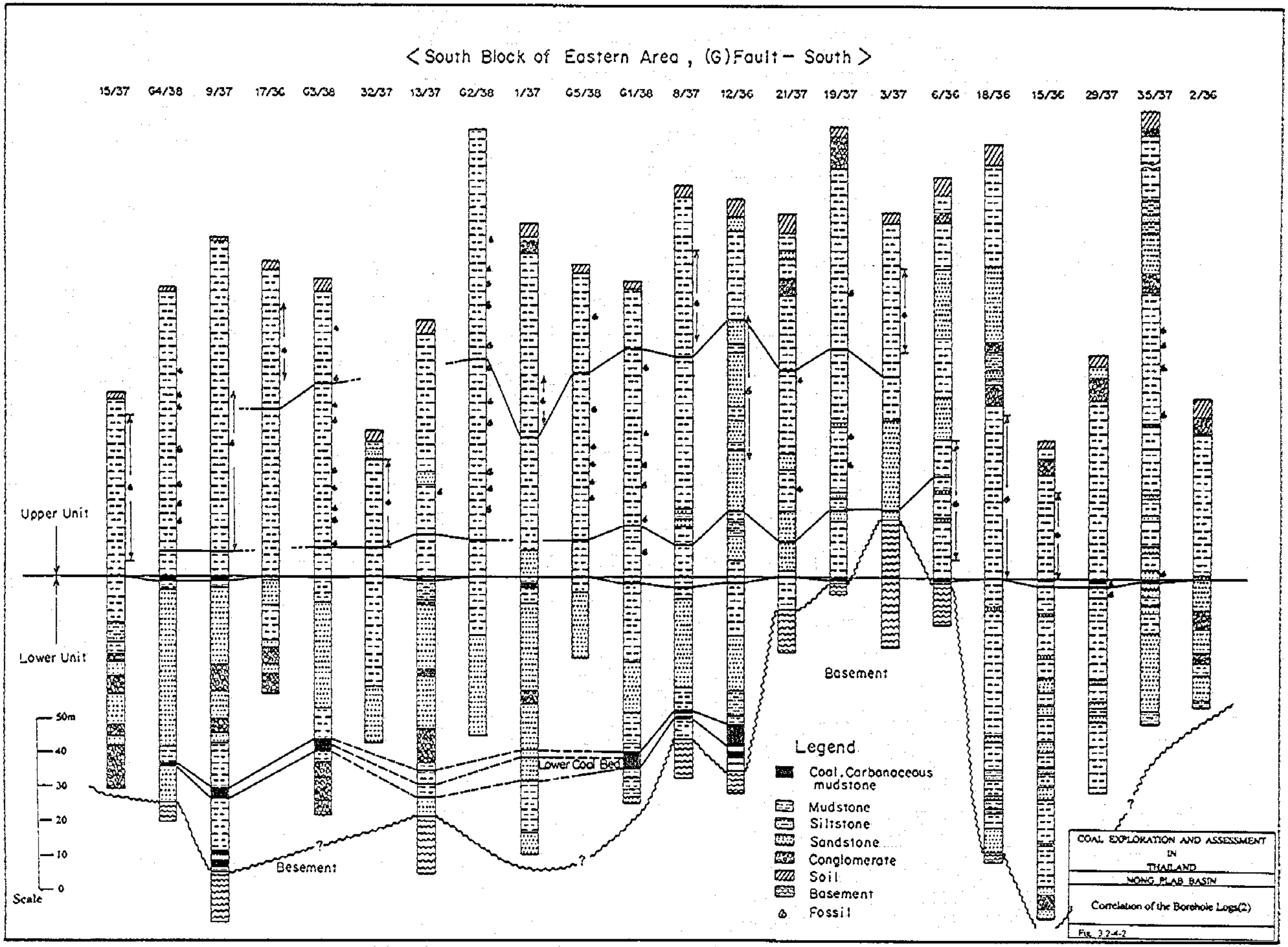
The Upper Coal Bed which rests on the coarse clastics is thicker in the northern area where the basin extended, and underlain by thin coarse clastics were deposited. But it splits in the area where the Lower Coal Bed and thicker coarse clastics were deposited.

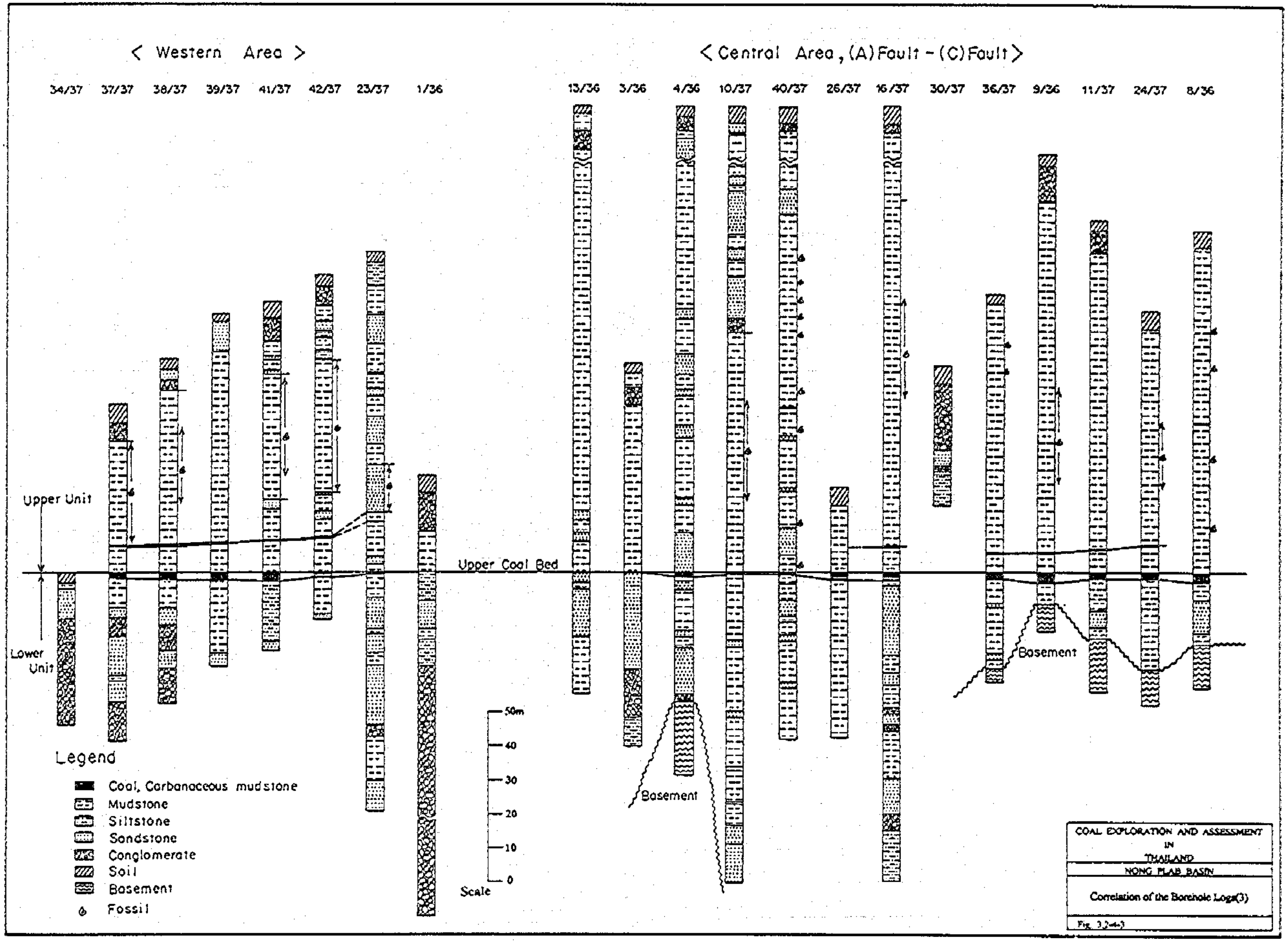
Probably, their diagenesis and compaction caused deeper water depth compared to the northern area.

At NP03/37, coal-bearing member was not deposited and lacustrine fine clastics member directly covers the basement, indicating the existence of barrier during deposition of the coal-bearing member.

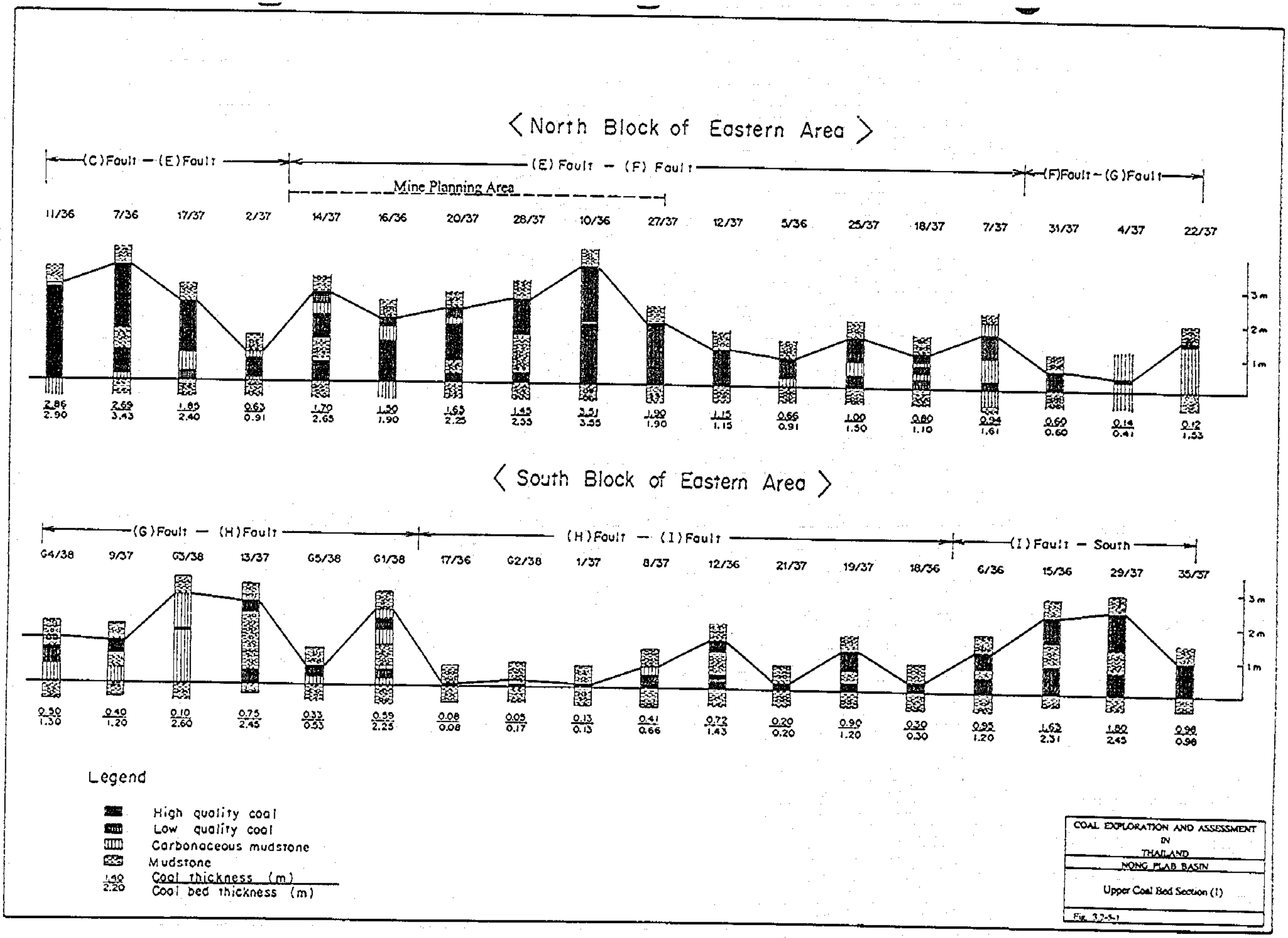
The southern side of the barrier indicates fining of coarse clastics toward north. This evidence suggests the existence of a fault at the southern side of the barrier and blockwise tilting of this area.

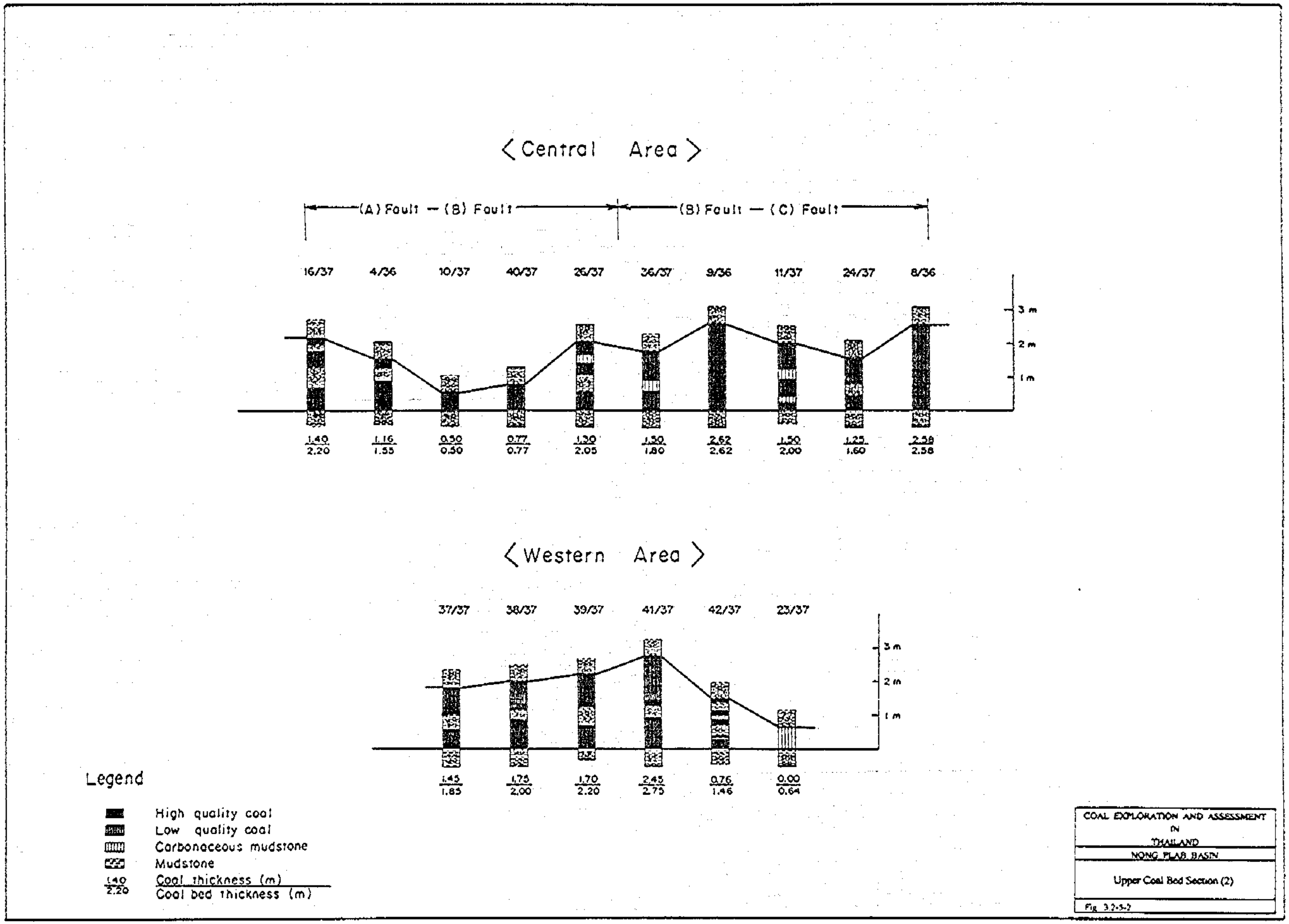

< North Block of Eastern Area , (C) Fault – (G) Fault >
11/36 14/37 7/36 17/37 33/37 16/36 20/37 28/37 2/37 10/36 27/37 6/37 12/37 5/36 7/37 25/37 31/37 4/37 22/37 5/37 18/37 14/36
Upper Unit
Lower Unit
Upper Coal Bed
Lower Coal Bed
Basement
?
?
Legend
Coal, Carbonaceous mudstone
Mudstone
Siltstone
Sandstone
Conglomerate
Soil
Basement
Fossil
50m
40
30
20
10
0
Scale
COAL EXPLORATION AND ASSESSMENT IN THAILAND
NONG PLAB BASIN
Correlation of the Borehole Logs(1)
Fig. 3.2-4-1


<South Block of Eastern Area, (G)Fault – South>
15/37
G4/38
9/37
17/36
G3/38
32/37
13/37
G2/38
1/37
G5/38
G1/38
8/37
12/36
21/37
19/37
3/37
6/36
18/36
15/36
29/37
35/37
2/36
Upper Unit
Lower Unit
Basement
Besement
Lower Coal Bed
Legend
Coal, Carbonaceous mudstone
Mudstone
Siltstone
Sandstone
Conglomerate
Soil
Basement
Fossil
50m
40
30
20
10
0
Scale
COAL EXPLORATION AND ASSESSMENT IN THAILAND
NONG PLAB BASIN
Correlation of the Borehole Logs(2)
Fig. 3.2-4-2

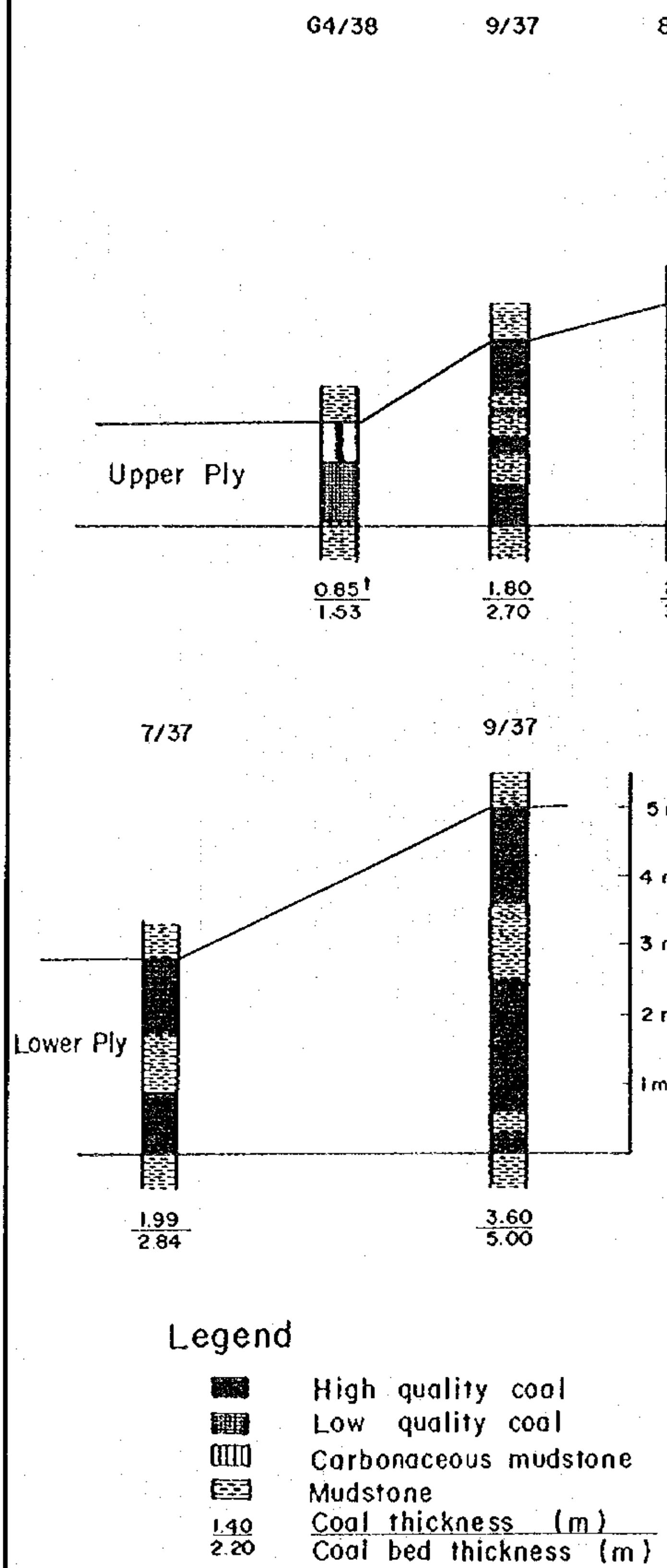


< Western Area >
< Central Area, (A) Fault - (C) Fault >
34/37
37/37
38/37
39/37
41/37
42/37
23/37
1/36
13/36
3/36
4/36
10/37
40/37
26/37
16/37
30/37
36/37
9/36
11/37
24/37
8/36
Upper Unit
Lower Unit
Upper Coal Bed
Basement
Basement
Legend
Coal, Carbonaceous mudstone
Mudstone
Siltstone
Sandstone
Conglomerate
Soil
Basement
Fossil
50m
40
30
20
10
0
Scale
COAL EXPLORATION AND ASSESSMENT IN THAILAND
NONG PLAB BASIN
Correlation of the Borehole Logs(3)


〈 North Block of Eastern Area 〉
(C) Fault — (E) Fault
(E) Fault — (F) Fault
(F) Fault — (G) Fault
Mine Planning Area
11/36 7/36 17/37 2/37 14/37 16/36 20/37 28/37 10/36 27/37 12/37 5/36 25/37 18/37 7/37 31/37 4/37 22/37
2.86/2.90 2.69/3.43 1.85/2.40 0.63/0.91 1.70/2.65 1.50/1.90 1.65/2.25 1.45/2.35 3.51/3.55 1.90/1.90 1.15/1.15 0.66/0.91 1.00/1.50 0.80/1.10 0.94/1.61 0.60/0.60 0.14/0.41 0.12/1.53
3 m
2 m
1 m
〈 South Block of Eastern Area 〉
(G) Fault — (H) Fault
(H) Fault — (I) Fault
(I) Fault — South
G4/38 9/37 G3/38 13/37 G5/38 G1/38 17/36 G2/38 1/37 8/37 12/36 21/37 19/37 18/36 6/36 15/36 29/37 35/37
0.30/1.30 0.40/1.20 0.10/2.60 0.75/2.45 0.33/0.53 0.59/2.25 0.08/0.08 0.05/0.17 0.13/0.13 0.41/0.66 0.72/1.43 0.20/0.20 0.90/1.20 0.30/0.30 0.95/1.20 1.63/2.31 1.80/2.45 0.96/0.96
Legend
High quality coal
Low quality coal
Carbonaceous mudstone
Mudstone
1.40/2.20 Coal thickness (m) / Coal bed thickness (m)
COAL EXPLORATION AND ASSESSMENT IN THAILAND
NONG PLAB BASIN
Upper Coal Bed Section (1)
Fig. 3.2-5-1



〈Central Area〉
(A) Fault — (B) Fault
(B) Fault — (C) Fault
16/37
4/36
10/37
40/37
26/37
36/37
9/36
11/37
24/37
8/36
3 m
2 m
1 m
1.40 / 2.20
1.16 / 1.55
0.50 / 0.50
0.77 / 0.77
1.30 / 2.05
1.30 / 1.80
2.62 / 2.62
1.50 / 2.00
1.25 / 1.60
2.58 / 2.58
〈Western Area〉
37/37
38/37
39/37
41/37
42/37
23/37
3 m
2 m
1 m
1.45 / 1.85
1.75 / 2.00
1.70 / 2.20
2.45 / 2.75
0.76 / 1.46
0.00 / 0.64
Legend
High quality coal
Low quality coal
Carbonaceous mudstone
Mudstone
1.40 / 2.20
Coal thickness (m)
Coal bed thickness (m)
COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
NONG PLAB BASIN
Upper Coal Bed Section (2)
Fig. 3.2-5-2

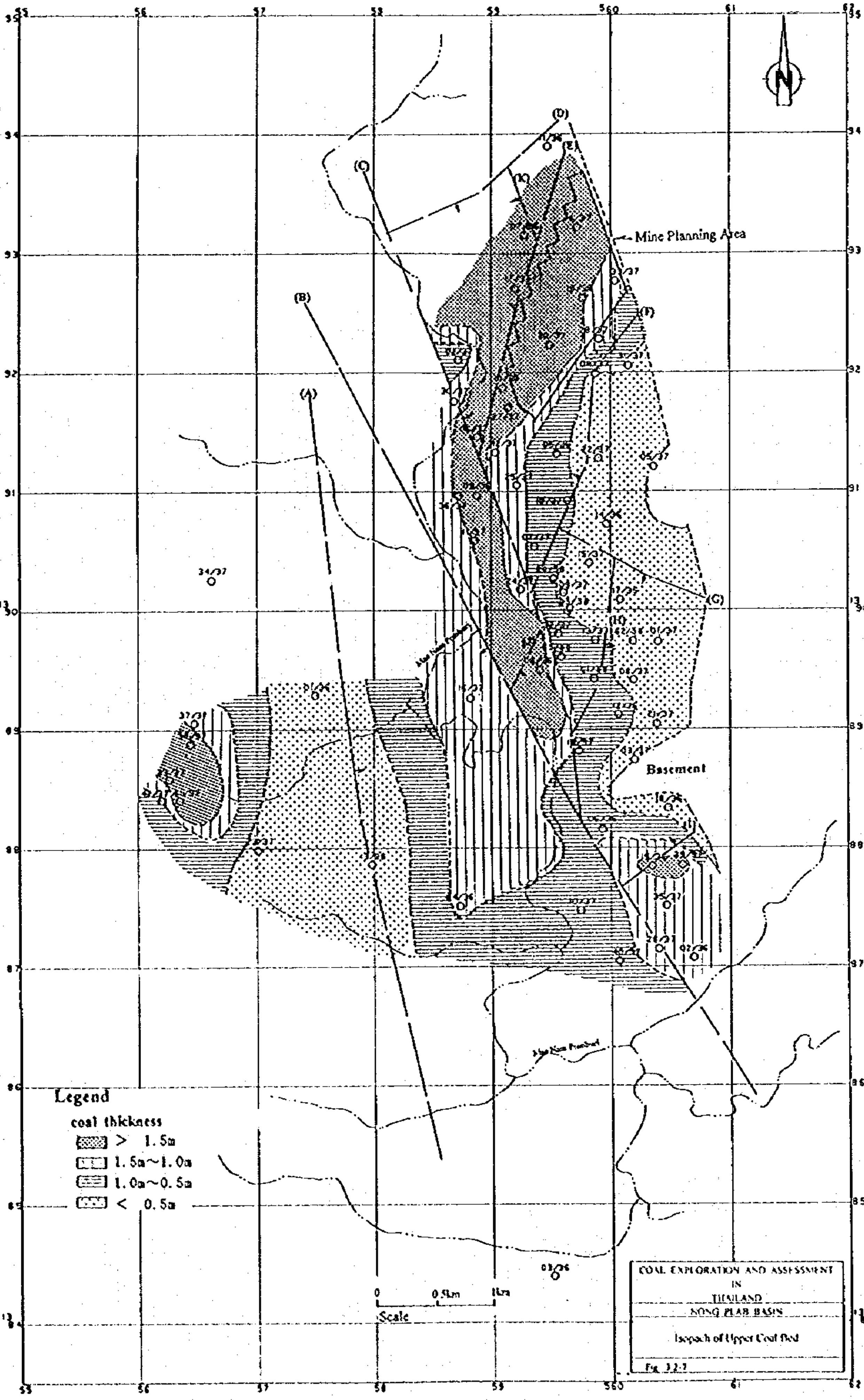


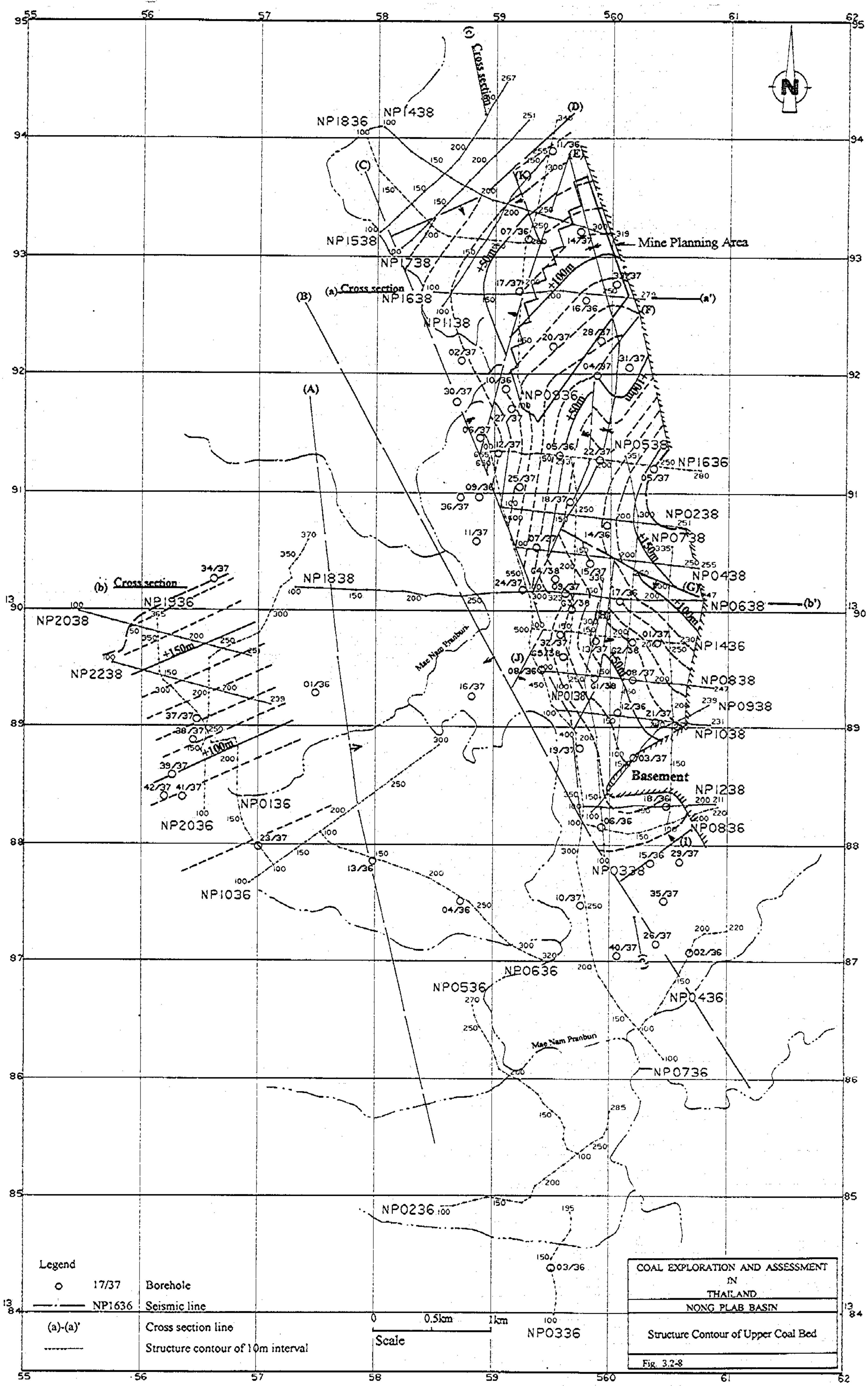
COAL EXPLORATION AND ASSESSMENT IN THAILAND

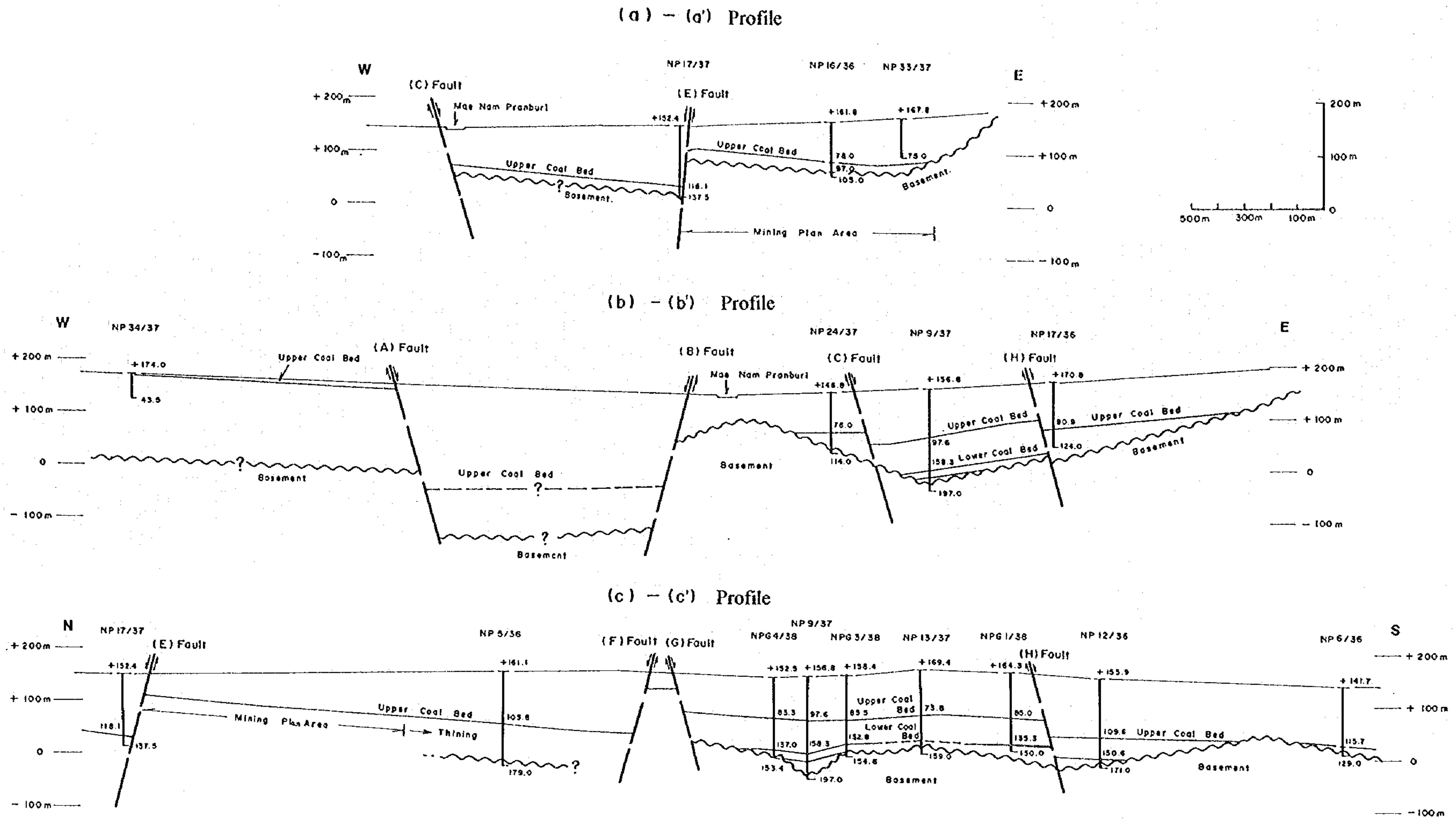
NONG PLAB BASIN

Lower Coal Bed Section

Fig. 3.2-6


N
Mine Planning Area
Basement
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(K)
Legend
coal thickness
> 1.5m
1.5m~1.0m
1.0m~0.5m
< 0.5m
0
0.5km
1km
Scale
COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
NONG PLAB BASIN
Isopach of Upper Coal Bed
Fig. 3.2-7


COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
NONG PLAB BASIN
Structure Contour of Upper Coal Bed
Fig. 3.2-8
Legend
17/37 Borehole
NP1636 Seismic line
(a)-(a)' Cross section line
Structure contour of 10m interval
Scale
0
0.5km
1km
Mine Planning Area
Basement
(a) Cross section
(b) Cross section
(c) Cross section
Mae Nam Pranbun
NP1836
NP1438
NP1538
NP1738
NP1638
NP1138
NP0936
NP0538
NP1636
NP0238
NP0738
NP0438
NP0638
NP1436
NP0838
NP0938
NP1038
NP1238
NP0836
NP0338
NP1838
NP1936
NP2038
NP2238
NP2036
NP0136
NP1036
NP0636
NP0536
NP0436
NP0736
NP0236
NP0336

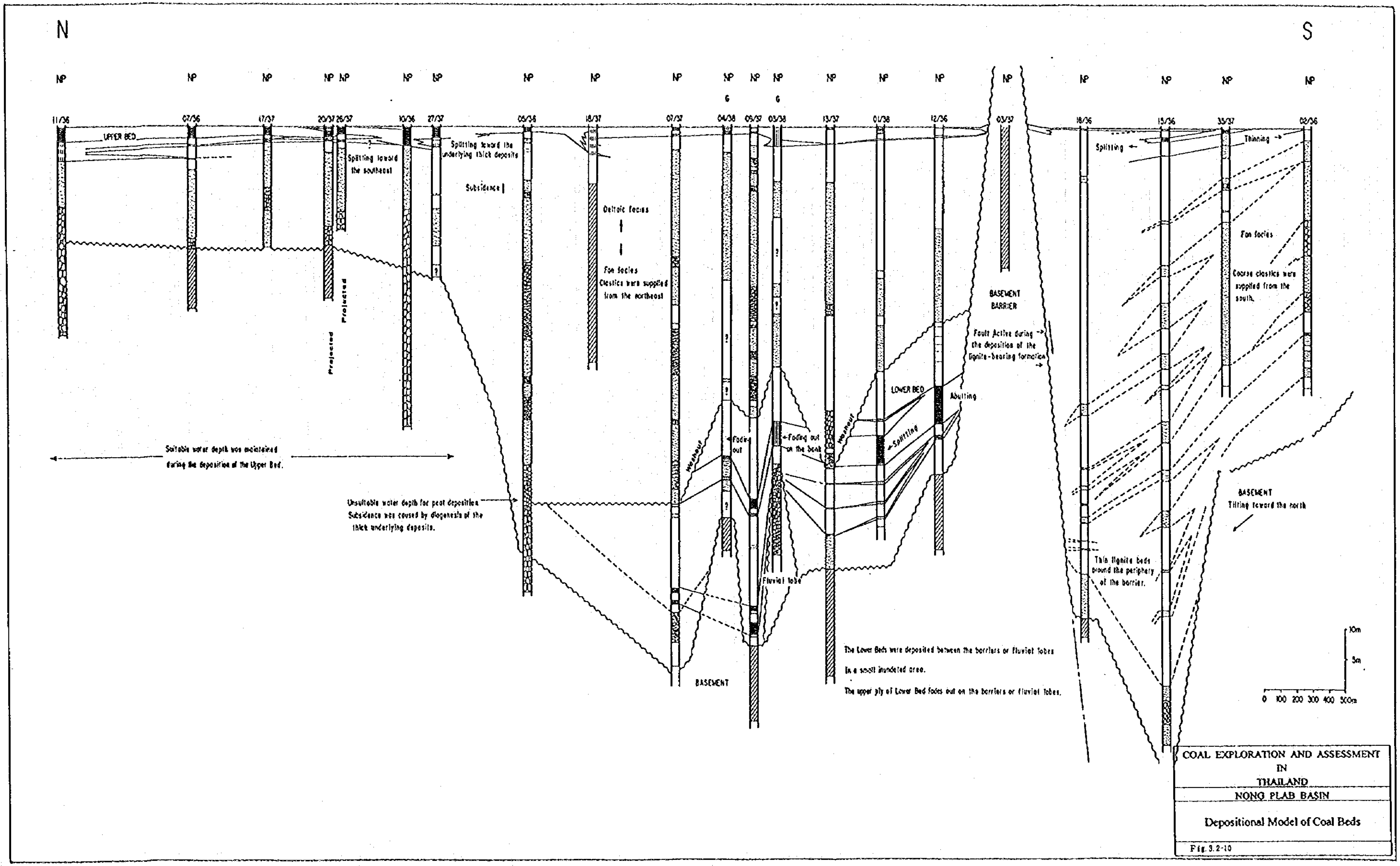


COAL EXPLORATION AND ASSESSMENT
IN
THAILAND

NONG PLAB BASIN

Geological Profile

Fig. 3.2-9



COAL EXPLORATION AND ASSESSMENT IN THAILAND

NONG PLAB BASIN

Depositional Model of Coal Beds

Fig. 3.2-10

(5) Coal resources and reserves

Coal resources of the Upper Coal Bed, as well as coal reserves, are estimated. Those of the Lower Coal Bed are excluded due to its restricted area of deposition. The estimation is performed according to the standard described in 3.1.3 (5).

1) Resources

In situ coal resources of the Upper Coal Bed are calculated for each block divided by major faults and on the basis of coal thickness excluding partings. The criteria used for the estimation are as follows;

Thickness : determined from isopach map

minimum thickness : 0.5 m

Area by geologic assurance

measured + indicated : 400 m from a control point

inferred : 400 m to 800 m from a control point

Specific gravity : 1.3

Coal bed map of the Upper Coal Bed is shown in Fig.3.2-11. The total coal resources of the Upper Coal Bed is estimated at 27,257,000 t, of which measured and indicated resources are 8,356,000 t as summarized in Table 3.2-5.

2) Reserves

Coal reserves are defined to be such a part of coal resources as esteemed to be possibly mineable by present technology. In the Nong Plab Basin, only the resources in a block bounded by E and F faults in the northern part is considered to be applicable to the above definition.

The standard for reserve estimation is same as that for resources except for minimum coal thickness of 1.0 m compared with 0.5 m for coal resources.

Consequently, the coal reserves in the Nong Plab Basin is estimated at 4,353,000 t, which is equivalent to the tonnage of (d) and (e) blocks in Table 3.2-6.

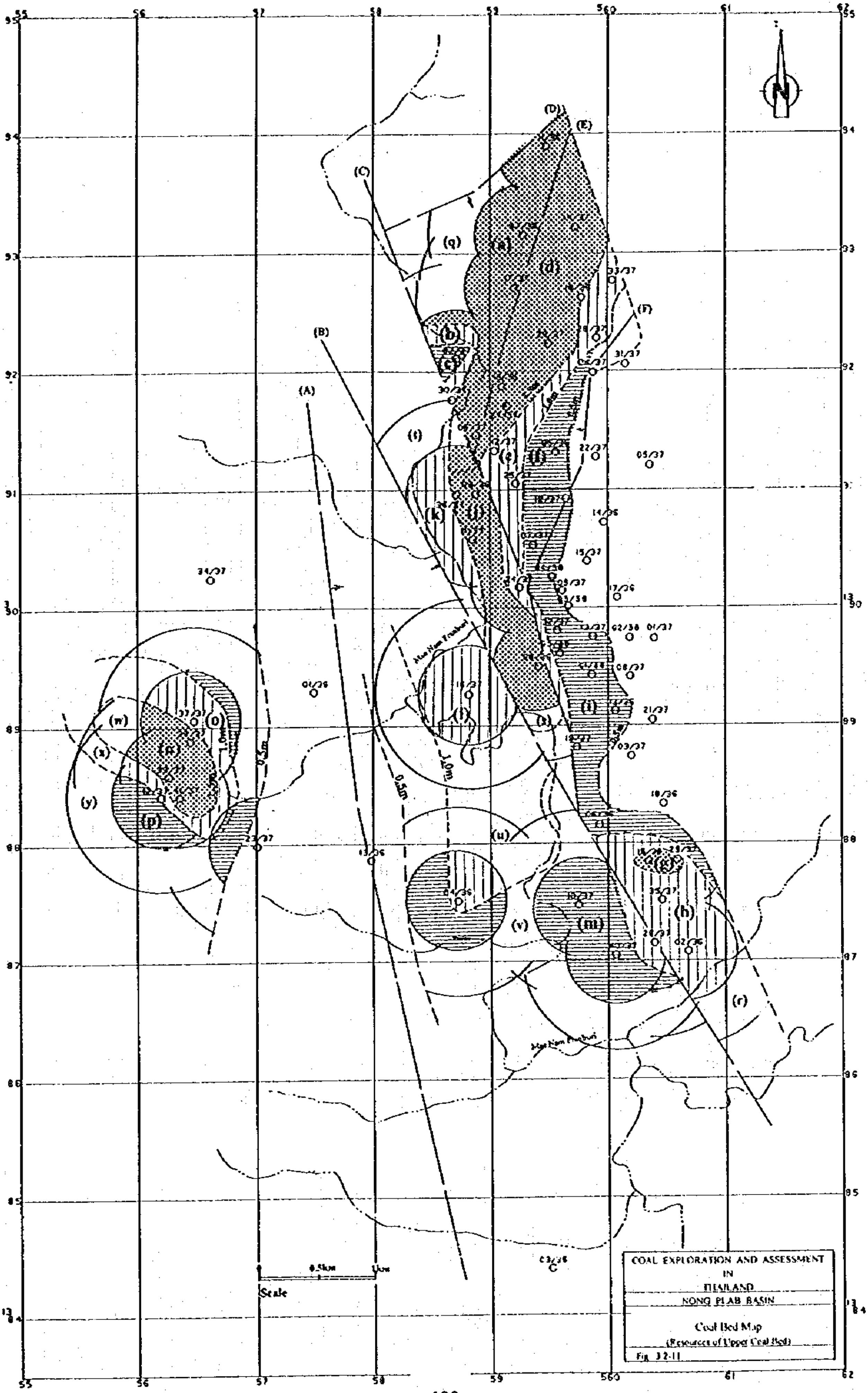

COAL EXPLORATION AND ASSESSMENT
IN
THAILAND
NONG PLAB BASIN
Coal Bed Map
(Resources of Upper Coal Bed)
Fig. 3.2-11
Scale
0.5km
1km
Mae Nam Prasae
Mae Nam Prasae
1.0m
0.5m
0.5m
1.0m
0.5m
(A)
(B)
(C)
(D)
(E)
(F)

Table 3.2-5 Coal Resources of Upper Coal Bed

Area	Block	Thickness (m)	Plan area (1,000m2)	Resources (1,000t)
Measured+Indicated				
(C)-(E)Fault	(a)	2.47	1,002	3,217
	(b)	1.25	153	249
	(c)	0.75	54	53
	Subtotal		1,209	3,519
(E)-(F)Fault	(d)	2.05	1,220	3,251
	(e)	1.25	678	1,102
	(f)	0.75	464	452
	Subtotal		2,362	4,805
South of (F)Fault	(g)	1.72	70	157
	(h)	1.25	805	1,308
	(i)	0.75	998	973
	Subtotal		1,873	2,438
(B)-(C)Fault	(j)	2.05	767	2,044
	(k)	1.25	488	793
	Subtotal		1,255	2,837
(A)-(B)Fault	(l)	1.25	794	1,290
	(m)	0.75	1,180	1,151
	Subtotal		1,974	2,441
West of (A)Fault	(n)	1.97	425	1,088
	(o)	1.25	454	738
	(p)	0.75	503	490
	Subtotal		1,382	2,316
Total		1.40	10,055	18,356
Inferred				
East of (C)Fault	(q)	2.47	478	1,535
	(r)	1.25	300	488
	Subtotal		778	2,023
(B)-(C)Fault	(s)	2.05	84	224
	(t)	1.75	353	803
	Subtotal		437	1,027
(A)-(B)Fault	(u)	1.25	1,100	1,788
	(v)	0.75	1,973	1,924
	Subtotal		3,073	3,712
West of (A)Fault	(w)	1.97	146	374
	(x)	1.25	252	410
	(y)	0.75	1,390	1,355
	Subtotal		1,788	2,139
Total		1.13	6,076	8,901
Grand total		1.30	16,131	27,257