No. 4

GEOLOGICAL EXPLORATION REPORT
ON
THE SURVEY FOR THE REHABILITATION
OF
OMBILIN COAL MINE

NOVEMBER 1979

Japan International Cooperation Agency

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PREFACE

The Government of Japan, in response to a request made by the Government of the Republic of Indonesia, decided to conduct a survey for the rehabilitation of the Ombilin Coal Mine in West Sumatra, Indonesia, and commissioned its implementation to the Japan International Cooperation Agency.

The survey was commenced in January 1978 and the geological exploration work of the survey which corresponds to CTA-79 of BAPENAS's project code was completed in June 1979.

The work was carried out jointly by the Japanese team and its counterpart from the Geological Survey of Indonesia and PN. Tambang Batubara appointed by the Indonesian Government.

The report submitted herewith summarizes the result of geological exploration.

I wish to express my sincere appreciation for the officials concerned of the Government of Indonesia for their close co-operation extended to the survey team.

October 1979

Shinsaku HOGEN
President
Japan International Cooperation Agency

ACKNOWLEDGEMENTS

The Government of Japan, in response to the request extended by the Government of Republic of Indonesia, decided to execute a survey for the rehabilitation of Ombilin Coal Mine in West Sumatra, Indonesia, and commissioned its implementation to the Japan International Cooperation Agency.

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This report submitted hereby summarizes the results of geological exploration.

We wish to take this opportunity to express our gratitude to all members concerned with the survey execution.

October 1979

Prof. Dr. J.A. KATILI
Director General,
Ministry of Mines and Energy
Republic of Indonesia

LETTER OF TRANSMITTAL

Mr. Shinsaku Hogen, President

Japan International Cooperation Agency

Dear Sir:

I have a great pleasure of submitting herewith the report in consequence of the completion of geological exploration as the first stage of the survey in the technical cooperation which aims at a rehabilitation of the Ombilin Coal Mine, West Sumatra, Republic of Indonesia.

The geological exploration work, commenced in January 1978 was completed in June 1979 on schedule, in accordance with the Minutes which was concluded on 27th July, 1979 between the Ministry of Mines, Indonesia and Japan International Cooperation Agency at the request of the Government of Republic of Indonesia.

The survey team, headed by Eiichi Kawai, Sumitomo Coal Mining Co., Ltd., was organized by specialized engineers in geology, mining and drilling, among whom one geologist and four drilling engineers stayed at the site throughout the survey period.

The survey was conducted mainly on drilling work comprising 8 holes with total length of 4,100 meters.

The report describes the analytical results with regard to the geological conditions, conditions of coal seam development, coal quality and coal reserves, etc. mainly in the Waringin area of the Ombilin Coal Mine, on the basis of the drilling results, various analysis on coal and rock core samples taken by drillings as well as previous survey data.

In view of the strong hope on the part of Ministry of Mines and Energy and authorities concerned in Indonesia toward some additional exploration of a part of the Mines and a comprehensive study on feasibility, the survey team eagerly expects that the report would be of good service to them for promoting future coal exploration.

On submitting the report, I would like to express our sincere gratitude to all those personnel in the Government of Indonesia, Embassy of JAPAN in Indonesia, the Ministry of Foreign Affairs, the Ministry of International Trade and Industry and Japan International Cooperation Agency, who gave the survey team generous cooperations for the execution of survey.

November 1979

Eiichi Kawai
Survey team leader for the rehabilitation of Ombilin Coal Mine

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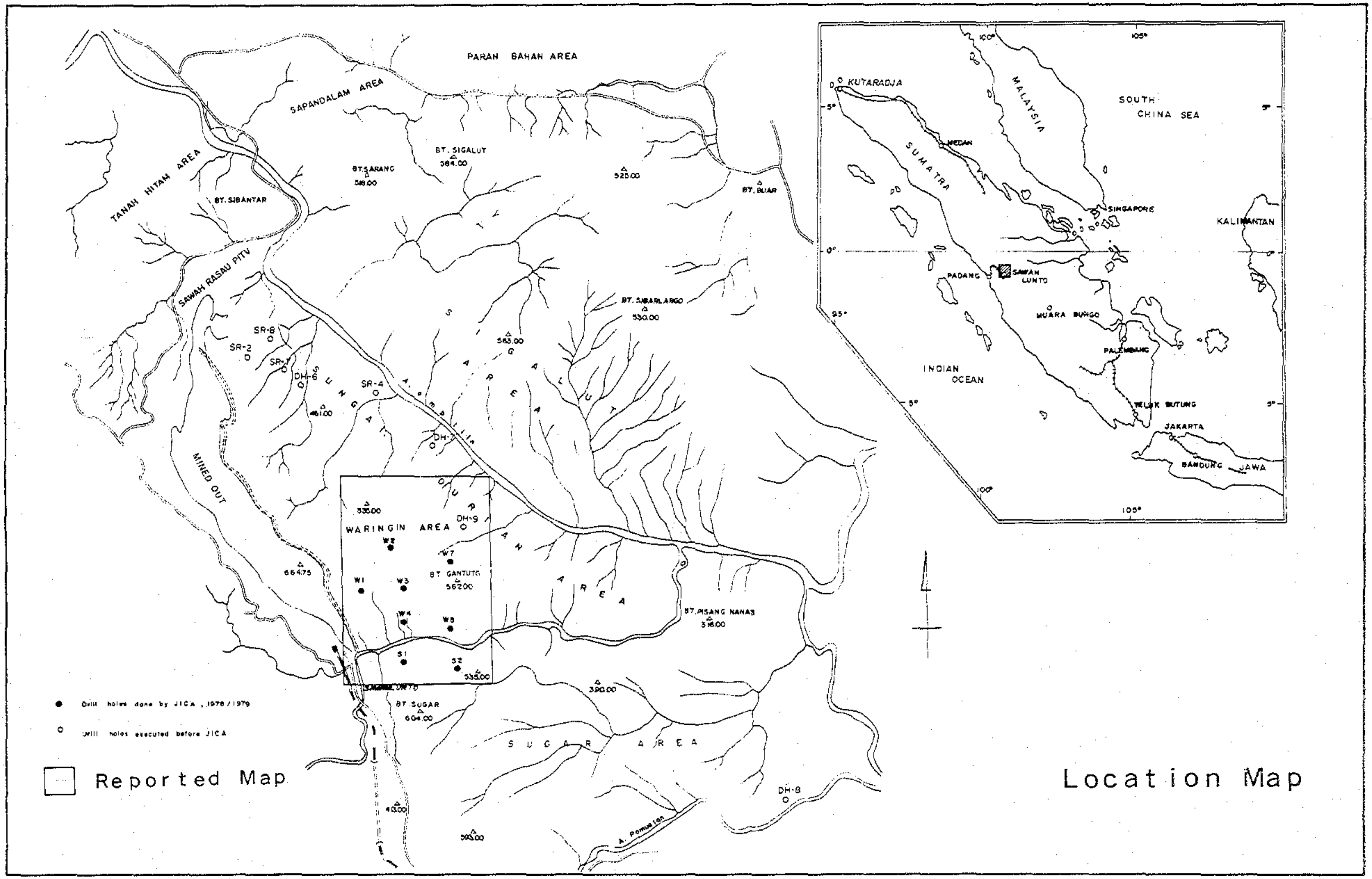

Location Map

SUMMARY

SUMMARY

A. Introduction

The Government of the Republic of Indonesia intends in its energy policy to promote development and utilization of domestic coal as well as those of water power and geothermal in order to reduce its dependance on petroleum for domestic energy consumption and set out to the rehabilitation of, first of all, Bukit Asam and Ombilin Coal Mines which are in operation at present.

At the end of 1976 the Indonesian Government asked the Japanese Government for technical assistance of confirming the coal seam developing condition and coal reserves in Waringin Area of Ombilin Coal Mine and also the execution of a feasibility study on the basis of the above survey results. The Japanese Government complied with the request and the "Minutes" concerning the execution of the survey was officially concluded on July 27, 1977 between Ministry of Mines, the Republic of Indonesia and Japan International Cooperation Agency (JICA).

The exploration work consisted mainly of a drillings, geological mapping, topographical mapping and laboratory testing. The field work was started in January 1978 and ended in June 1979 with few difficulties.

Each survey items are follows:

Exploration drilling	:	Eight holes (total 4,104.65 m)
Geological mapping	:	Necessary area for the geological study.
Topographical mapping	:	About 10 Km^2 (1 to 2,000)
Period of field work	:	January 24, 1978 to June 4, 1979

In order to perform the exploration work effectively 1 geologist and 4 drilling engineers were sent from Japan and stationed continuously. A set of drilling equipment for the survey was brought with them.

On the Indonesian side, a project director, one or two counterpart geologists, 6 drillers, etc. took part in the survey in collaboration with the Japanese team.

B. Results

The outline of results which became clear in the current exploration work have been explained in the followings.

Samples taken from drilling cores were analyzed for the examination of coal quality and depositional conditions of coal seam by means of the conventional way for chemical, physical and petrographical properties of coal, the palynological analysis for pollen and spore contained in coal and coaly shale, the electron microscopic and X-ray diffraction analyses for clay and other sedimentary minerals, etc.

B.1 Geological age of coal bearing formation

Many reports have been presented on the geological age of the Tertiary coal bearing formation in the exploration area. The palynological analysis executed first in the present work showed the possibility of somewhat older geological age than considered previously. Sawahlunto coal bearing formation whose geological age was considered to be Oligocene ∿ Eocene is now considered Eocene ∿ Pre-Eocene and the geological age of Sangkarewang formation lying below Sawahlunto formation is thought Palaeocene.

B.2 Sedimentary environments

Taking lithofacies, mineral assemblages, palynological analysis, etc. into consideration as a whole, the sedimentary environments in the area are considered as follows:

The Tertiary formations beginning with Sangkarewang formation were fluvial or lacustrine environments deposited in the basin developed in the continental area of Barisan mountains and in due time the marine transgression gradually started in the deposition of Ombilin formation, which was formed first in marine environments in the area. The coal is also considered to be deposited in fluvial or lacustrine environments. For A and B seam the autochtonous origin can be postulated, but C seam, especially the lower part of it, is considered to be an allochtonous one, in which source materials for coal might be drifted not from the different area but from the general area of their growth. (So-called "hypautochthonous" origin,)

B.3 Coal seams

Three minable coal seams, A, B and C seam, exist in the exploration area. A seam distributes widely almost all over the area (its workable coal thickness is about 1.6 ∿ 2.3 m) except some partial deteriorated zone. Large area for mining is expected. Although B seam is not so thick, it distributes continuously and in some areas, the workable coal thickness is over 1 m, therefore, it can also be expected for mining in the limited area. C seam is developed thick in the southren Waringin and northern Sugar area. Around the drilling hole

S-1 the workable thickness of C seam shows over 19 m. As it deteriorats rapidly towards the northern and southeastern parts, the deteriorated zone of C seam previously supposed in the deeper part of the goaf extends more widely than expected. The minable area of C seam is thought to be limited in the south part of Waringin area.

Some previous survey report concluded a possibility of the existence of burried hill, and the cause of the deterioration of C seam was consequently considered by a burried hill. Nevertheless the current exploration work suggests that no thick coal seam was deposited originally, but poor coal seam was deposited owing to the inadequate depositional condition. Moreover, in some parts the coal seam seems to be eroded (by contemporaneous erosion).

In the southern area of drilling hole S-1 and S-2, A seam is supposed to exist stably. On the other hand B seam can not be expected minable in the same area. Thick C seam at drilling hole S-1 will be deteriorated towards south and only the upper part is considered to continue to drilling hole DH-8. Much will not be expected on C seam as minable. Such is still matter of conjecture, and detail exploration is wanted in future.

B.4 Coal quality

The 3 seams of A, B and C have almost the same coal quality and it is classified as high volatile A bituminous on the ASTM classification. The coal has the characteristics of low ash content and high calorific value, and is suitable for thermal coal and blending coal in coke making.

Average qualities of the raw coal is as follows:

I.M. (%)	3 ∿ 4
Ash (%)	4 ∿ 6
V.M. (%)	38 ∿ 41
F.C. (%)	51 ∿ 53
Total sulfur (%)	0.5 ∿ 1.5
C.S.N.	3 ∿ 4 $\frac{1}{2}$
C.V. (Kcal/Kg)	7,400 ∿ 7,500
H.G.I.	43 ∿ 48
Melting point of ash (C°)	1,340 ∿ 1,370

Moreover the tendency that the rank of coalification becomes slightly higher in the southern area than in the current mining area (the northern area) is seen.

B.5 Coal reserves

The theoretical recoverable coal reserves and recoverable coal reserves in and around Waringin area as follows:

	Theoretical recoverable coal reserves (1,000 t)	Recoverable coal reserves (1,000 t)
A seam	15,610	10,316
B seam	1,606	1,092
C seam	18,238	11,912
Total	35,454	23,420

Note: The recoverable coal reserves are what the theoretical recoverable coal reserves are multiplied by the safety factor (70 ∿ 85%) and the recoverable factor (85%).

The depth of coal seam here is down to -200 m below the sea level.

Taking into consideration the area of high coal reserve density (reserves/unit area), pit-mouth location expected in future, coal seams developing depthes etc., the expected recoverable coal reserves in the area at the initial development stage is 4,126,000 t for A seam, 879,000 t for B seam and 5,687,000 t for C seam and 10,728,000 t in total. Consequently, the recoverable coal reserves corresponding to the operation in the scale of the yealy production of 500,000 t for more than 20 years is duly confirmed in the current survey.

Above mining scale seems to be enough to delineate the economical mining scheme for the rehabilitation of Ombilin Coal Mine.

C. Conclusion and Recommendation

Over 10,000,000 tons of estimated coal reserves consisting of A, B, and C seam in the area around drilling holes W-4, W-8 and S-1 is recommended for the initial mine development in the rehabilitation program for the Ombilin Coal Mine.

To support the effective feasibility study as scheduled in the MINUTES signed in july 1977, exploration work comprising two drillings, geological mapping and laboratory testing in the southern extension of the current reported area is highly recommended for the comprehensive rehabilitation scheme.

CHAPTER 1

INTRODUCTION

CHAPTER 1. INTRODUCTION

1.1 Purpose

The Government of the Republic of Indonesia intends in its energy policy to promote development and utilization of domestic coal as well as those of water and geothermal power in order to reduce its dependance on petroleum for domestic energy consumption and set out to the rehabilitation of, first of all, Bukit Asam and Ombilin Coal Mines which are in operation at present.

Out of the above, Ombilin Coal Mine is a historied one which has been continuously operated since 1892. The yearly production recorded 600,000 tons ealier in this century, but since after World War II the production has reduced in accordance with diminished demand of coal and has been in the level of 80,000 to 90,000 tons in recent years.

In Ombilin Concession geological surveys have so far been made by Polish, Japanese and Indonesian team itself (P.N. Tambang Batubara and GSI), however, any suitable place and sufficient coal reserves for the present rehabilitation have not yet been found.

The Indonesian Government, then, recommended Waringin Area, which is located at the center of Ombilin Coal Mine and near the railway terminal, as the place to be urgently developed.

Since the shallow part of coal seams adjacent to the surface has already been mined out, it was the deeper part considered as the object for early development.

At the end of 1976 the Indonesian Government asked the Japanese Government for technical assistance of confirming the coal seam developing condition and coal reserves in Waringin Area including the execution of a feasibility study on the basis of the above survey results. The Japanese Government complied with the request and the "Minutes" concerning the execution of the survey was officially concluded on July 27, 1977 between Ministry of Mines, the Republic of Indonesia and Japan International Cooperation Agency (JICA).

1.2 Method, Period and Organization of Exploration Work

The exploration work consisted mainly of 8 drillings. Adding to it, geological mapping and topographical mapping were carried out in Waringin Area. The work was started in January 1978 and proceeded with few difficulties.
But upon the discovery of some discrepancies in the development condition of coal seams from the expected one as a result of interim reviewing in November 1978, remaining drilling locations were changed to the southern part of the area.

As a result of this change, six drillings (No. W series) were carried out in Waringin Area and two (No. S series) in Sugar Area. A topographical mapping was performed under the auspice of the Geological Survey of Indonesia.

Exploration drilling	:	Eight holes with total depth of 4,104.65 m
Geological mapping	:	Carried out at places deemed necessary during the drilling survey
Topographical mapping	:	About 10 Km^2 (1 to 2,000 topographic map was made)
Period of field work	:	From January 24, 1978 to June 4, 1979

In order to perform the exploration work 1 geologist and 4 drilling engineers were sent from Japan and a set of drilling equipment for the survey was brought with them.

On the Indonesian side, a project director, one to two counterpart geologists, 6 drillers, etc. took part in the survey in collaboration with the Japanese team. Furthermore, the Indonesian authorities extended such conveniences for the execution of the survey as road construction, transportation of equipment and staffs, procurement of materials available in the country, custom formalities for spare parts, and lodgings, together with immigration and emigration procedures for the Japanese engineers.

The summary of the survey process and staffs are shown in Fig. 1 and the Table 1 show, in detail, the affiliation of the Japanese engineers.

Fig. 1. General view of exploration work

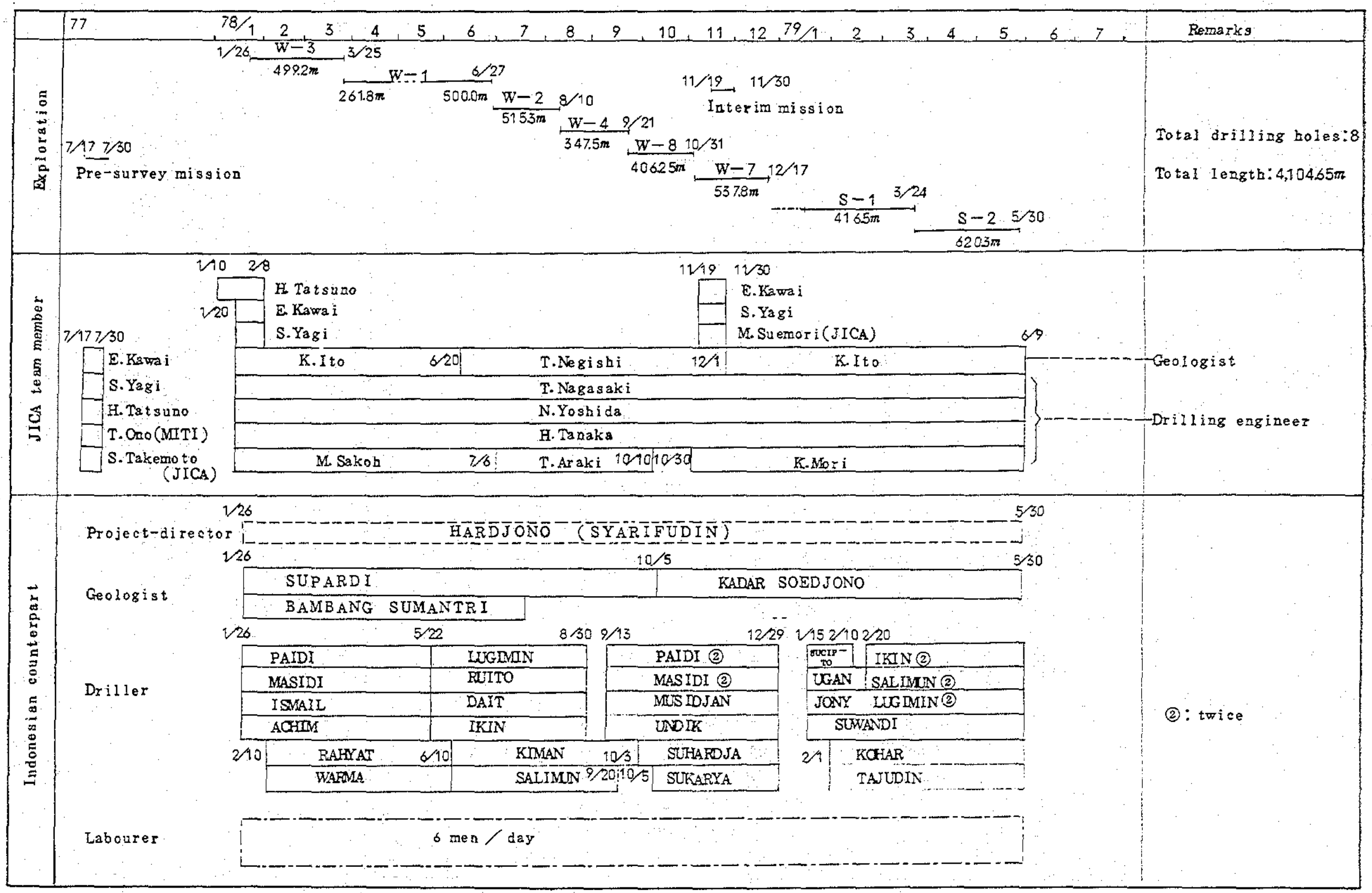

Table 1. Engineers sent from Japan

Name	Charge	Position	Working period
Eiichi Kawai	Leader	Director & Manager of Overseas Coal Development Department, Sumitomo Coal Mining Co., Ltd.	A, B, D, E
Shozo Yagi	Geology	Manager of Geology Section, Survey Department, Japan Overseas Coal Development Co., Ltd.	A, B, D, E
Kimihiko Ito	Geology	Geologist, Mining Dept. SCM	C
Hiroaki Tatsuno	Mining	Mining engineer, Overseas Coal Development Dept. SCM	A, B, E
Toshio Negishi	Geology	Geologist, Mining Dept. SCM	C
Takeyuki Nagasaki	Drilling	Drilling engineer, Mining Dept. SCM	C
Masashi Sako	Drilling	Drilling engineer, Mining Dept. SCM	C
Nagao Yoshida	Drilling	Drilling engineer, Mining Dept. SCM	C
Tadashi Araki	Drilling	Drilling engineer, Mining Dept. SCM	C
Kunio Mori	Drilling	Drilling engineer, Mining Dept. SCM	C
Hiroshi Tanaka	Drilling	Drilling engineer, Mining Dept. SCM	C
Takashi Ono		Ministry of International Trade and Industry	A
Setsuo Takemoto		Japan International Cooperation Agency	A
Mitsuru Suemori		Japan International Cooperation Agency	D
Isao Asai		Japan International Cooperation Agency	E

* SCM, Sumitomo Coal Mining Co., Ltd.

Note :

A : Preliminary survey ; July 17, 1977 to July 30, 1977
B : Preparation ; January 10, 1978 to February 8, 1978
C : Main field work ; January 20, 1978 to June 9, 1979
D : Interim reviewing ; November 19, 1978 to November 30, 1978
E : Report explanation ; September 25, 1979 to October 7, 1979

CHAPTER 2

GENERAL DESCRIPTIONS OF OMBILIN COAL MINE

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2.1 Location and Communication

Ombilin Coal Mine, about 55 Km apart in the northwest direction from Padang, the capital city of West Sumatra, and at about 0° 40' S. Lat. and 100° 45' E. Long. is located in Sawahlunto City which is at the north end of Sawahlunto / Sihunjun District, West Sumatra (Fig. 2).

There are road and railway transportations available from Padang as shown in Fig. 3. Travel on roads occupies about 3 hours' driving on about 90 Km pavemant going through passes of about 1,100 m elevation. On the other hand the railway makes a detour towards the north in order to pass the Barisan mountains and the total distance extends about 155 Km. It is rarely utilized at present except for the transporation of coal.

2.2 Concession and Topography of Area

Ombilin basin has a ellipsoidal form with a long axis of about 50 Km in the northwest-southeast direction and a short axis of about 20 Km, occupying an area of about 800 Km^2 in the center of West Sumatra. The concession (No. 19/DDP/1967) is located in the northwest part of this basin and has the area of

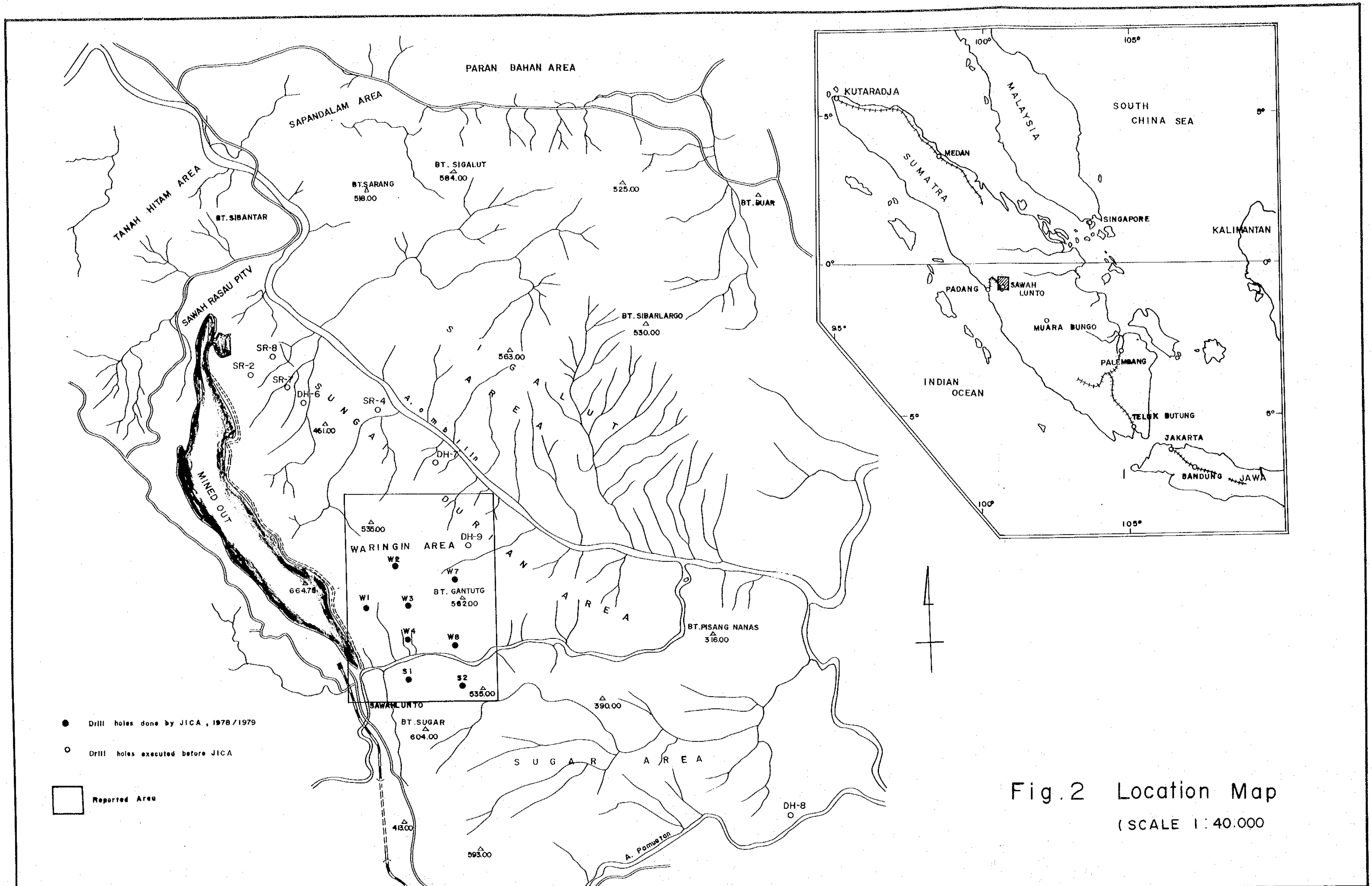
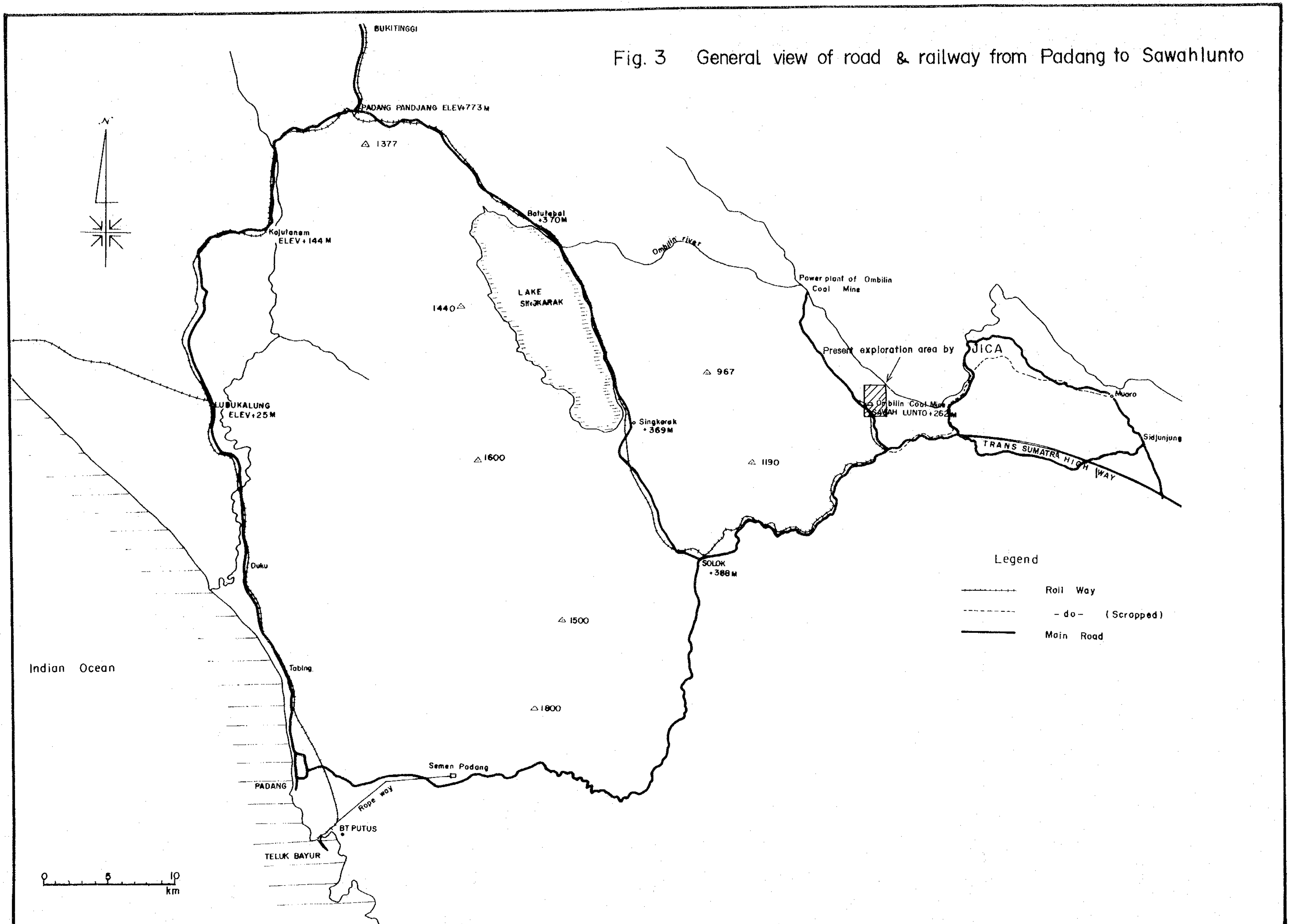


Fig.2 Location Map
(SCALE 1:40.000)

Fig. 3 General view of road & railway from Padang to Sawahlunto



about 210 Km^2. In the western and northern parts of the concession, basement rocks form a highland having the elevation of over 500 m. Eastward from Sigalut Fault which can be observed in the eastern part of the concession is formed a lowland of the Neogene with the elevation of under 300 m.

Ombilin River (the elevation is about 190 m above the sea level) flow from the northwestern part of the concession towards the southeast through the center, and some branch streams including Lunto River flow into Ombilin River. The coal seam existence area is considered somewhere in the center of this concession and the outcrops of coal seams can be observed mainly in the semicircular area ranging from the northern part to the western part of the concession. The area expected for the existence of coal seams can be divided into the following 6 areas according to the geographical features and faults; Parambaham, Sapandalam, Sigalut, Tanah Hitam, Sungai Durian and Sugar.

2.3 Exploration and Production States

Long history as it has in the production, exploration work with full-scale drillings has just begun in the 1960's in Ombilin Coal Mine. Since then about 140 holes with the length of 17,000 m in total have been drilled up to the end of 1978. Tha past exploration drillings, for the most part, as a part of general survey in Sapandalam, Parambaham, Sungai Durian and Tanah Hitam area. Very few exploration drillings have been performed up to now in both Sigalut and Sugar area. It is observed that the strip mining is adopted in the northern part of Sungai Durian area and a part of Tanah Hitam area, but it is the underground mining in Sungai Durian area that accounts for the most part of the past production.

The mining as a whole took the form of operation mainly in upper level of the main transport gallery. The activities were then gradually progressed from Sawahlunto side where railway terminal is located towards the north. Currently in operation is Sawah Rawaw Pit-V in the northern end of Sungai Durian area.

The yearly production had been rapidly increased since 1882 when the production was started with the annual level of several hundred thousand tons continued in the period from the beginning of 1900's to 1942. With the diminished demand of coal, however, the production amount has been on the decrease since then and moving somewhere between 80,000 and 90,000 tons per year in these days.

Main consumers of Ombilin coal are cement manufacture in Pandang, the railways and private power plant. Ombilin Coal Mine is, however, expected to revive active operation now that those cement works have come up with an expansion plan, and what's more, in view of the recent trend to reevaluate coal as an alternative energy resource.

CHAPTER 3

EXPLORATION DRILLING WORK

CHAPTER 3. EXPLORATION DRILLING WORK

3.1 Outline of Drilling Work

The drilling work was conducted using the drilling machine Koken EP-W1 (max. drilling depth 1,0000 m) and the mud pump MG-15H (capacity 220 l/min.) by means of the wireline coring method. 8 holes with the total length of 4,104.65 m were drilled. The outline of working process is shown in Fig. 4 and that of individual drilling in Table 2.

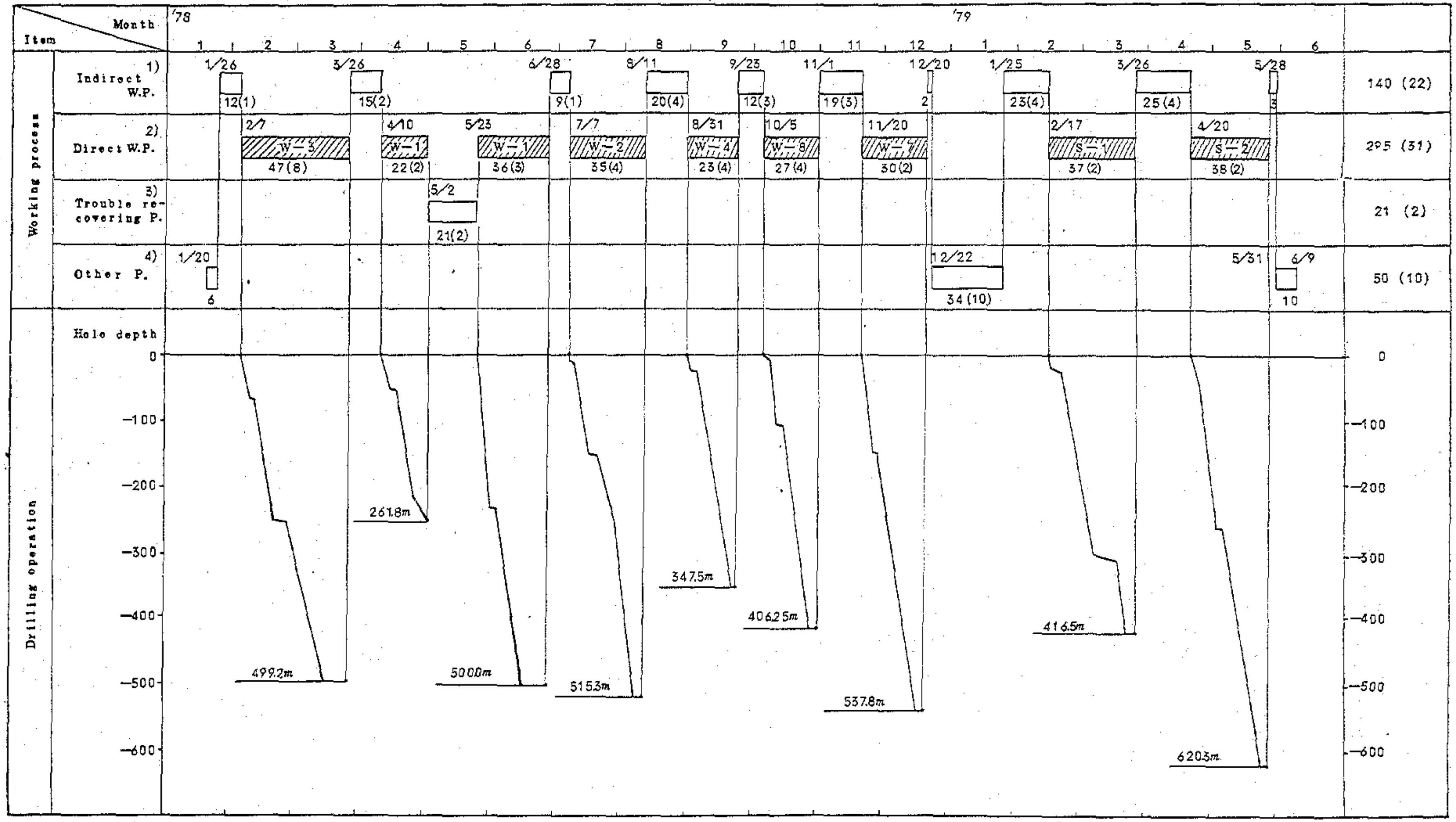
The proposed and performed bit and casing plan is shown in Fig. 5.

Phase I : From the surface to around 5 m's depth.
After drilling with the 180 mm metal crown bit, 165 mm casing pipes were set.

Phase II : Upto 50 - 100 m's depth (mid part of Upper Sawah Tambang formation)
After drilling with 5 $\frac{5}{8}$ inch tricone bit (non-core) or HQ wireline bit (coring) with reaming, 127 mm casing pipes were set.

Phase III : UPto 150 - 250 m's depth (upper part of Lower Sawah Tambang formation)
After drilling with HQ wireline bit (coring), 97 mm casing pipes were set.

Fig. 4. Execution process of drilling operation



Notes. & Legend

1) Indirect working period: machine disassembling, transporting & setting

2) Direct working period: Drilling, core barel pulling up & setting, casing setting & pulling up, mud conditioning & circulation, hole deviation survey.

3) Trouble recovering period: Jamming trouble, machine breaking, etc

4) Other period: Preparation, waiting, releasing & leaving, etc.

Commencing date
Drilling No.
Total days (Non working days)

Table 2. Drilling record

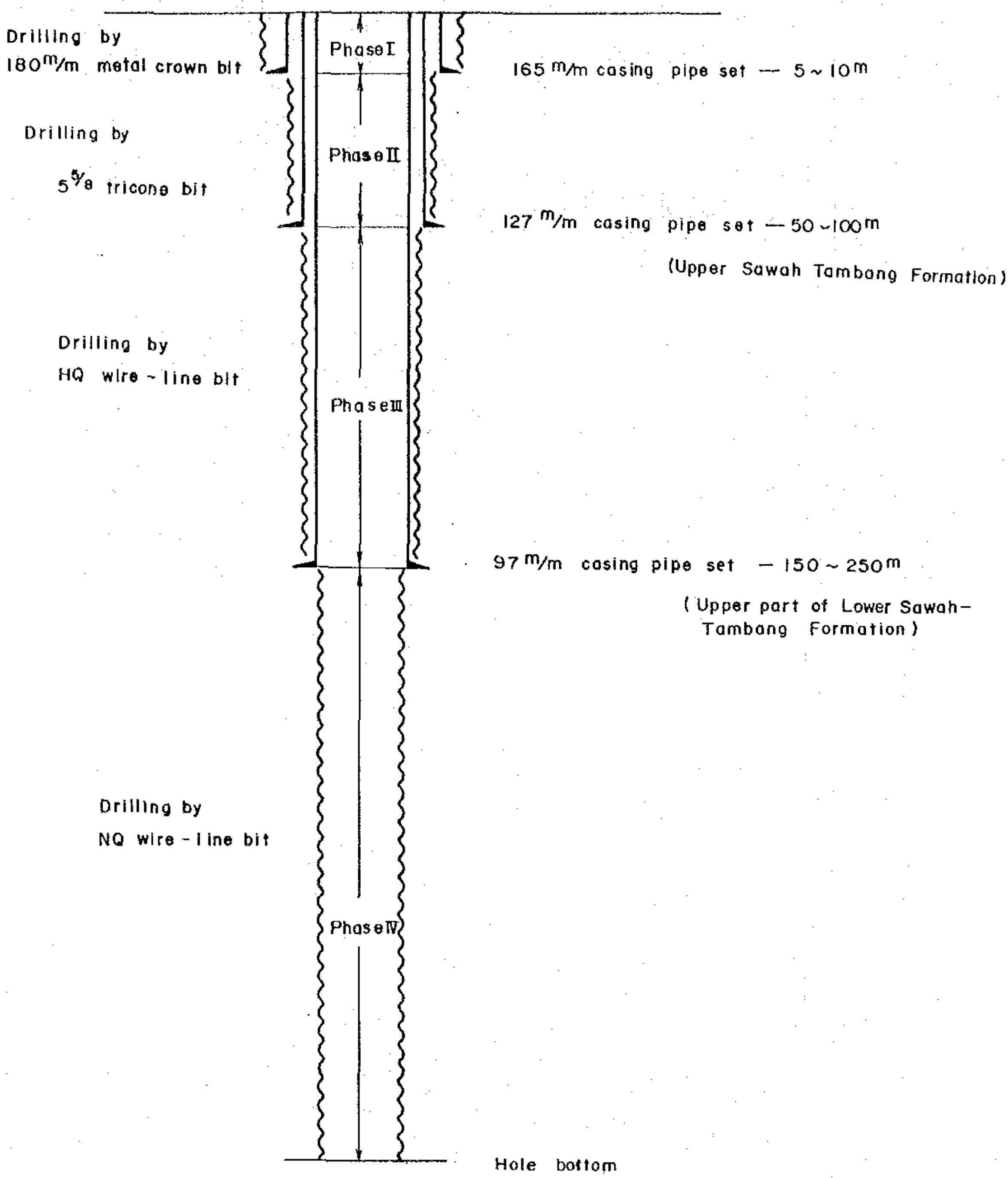
			W−3	W−1	W−1 (Redrilling)	W−2	W−4	W−8	W−7	S−1	S−2
Operation	Transportation & Setting		1978. 1/26~2/6	1978. 3/26~4/9		1978. 6/28~7/6	1978. 8/16~8/30	1978. 9/24~10/4	1978. 11/8~11/19	1979. 1/25~2/16	1979. 3/26~4/19
	Drilling		2/7~3/14	4/10~5/1	1978. 5/23~6/15	7/7~8/6	8/31~9/21	10/5~10/27	11/20~12/17	2/17~3/21	4/20~5/24
	Casing pulling up & Disassembling		3/15~3/25		6/16~6/27	8/7~8/15	9/22~9/23	10/28~11/7	12/18~12/21	3/22~3/25	5/24~5/30
	Operating days		59	37	36	49	39	45	44	60	66
Location	Coordinate	X	−18,880.988	−18,699.020	−18,699.020	−18,225.184	−19,506.899	−19,731.923	−18,670.917	−20,034.670	−20,166.155
		Y	− 9,585.830	−10,239.975	−10,239.975	− 9,594.421	− 9,528.179	− 9,100.838	− 9,104.947	− 9,399.066	− 9,027.277
	Elevation (m)		+ 482.660	+ 570.000	+ 570.000	+ 483.326	+ 513.998	+ 237.620	+ 353.266	+ 340.489	+ 385.697
Final Drilling Depth (m)			449.20	261.80	500.00	515.30	347.50	406.25	537.80	416.50	620.30
Casing bottom	165% at (m)		15.00	15.00	5.00	15.00	10.05	7.05	10.20	15.00	6.00
	127% 〃		50.00	50.00	80.00	52.00	37.60	12.00	49.90	73.00	100.00
	97% 〃		250.00	170.00	230.00	154.10	124.00	108.00	147.00	157.00	268.45
Drilling	180% MCB (m)		0~15.00	0~15.00	0~5.10	0~15.00	0~10.05	0~7.05	0~10.20	0~15.00	0~6.00
	5 5/8 TCB (m)		15.00~50.00	15.00~50.00	5.10~80.00	15.00~52.00	10.05~37.60	7.05~12.00	10.20~49.90	15.00~73.00	6.00~100.00
	HQ DMB (m)		50.00~250.00	50.00~170.10	80.00~230.00*	52.00~154.10	37.60~124.00	12.00~108.00	49.90~147.00	73.00~157.50	100.00~268.45
	NQ DMB (m)		250.00~449.20	170.10~261.80	230.00~500.00	154.10~515.30	124.00~347.50	108.00~406.25	147.00~537.80	157.50~416.50	268.45~620.30
	Coring interval (m)		50.00~449.20	50.00~261.80	126.65~500.00	52.00~515.30	37.60~347.50	12.00~406.25	49.90~537.80	73.00~416.50	100.00~620.30
	Core recovery (%)		97	94	94	99	99	97	100	97	99
Major drilling difficulties & troubles				Lost circulation Pipe stucked by jamming trouble.		Lost circulation		Lost circulation D.P.breaking		Lost circulation	
Remarks				1978. 5/2 ~ 5/22 trouble recovering & machine resetting	*80.00~126.65m drilled by 4 1/8 TCB (non−coring)					12/22~1979. 1/24 waiting for buldozer for road construction & transportation	

* T.B.O. coordinate system was used.

Note 1) Drilling machine and equipment arrived in Padang (Teluk Bayur) on Jan. 23, 1978 and arrived at Ombilin (Kayugadan storage site) Jan. 24

2) Survey team (geologist & drilling engineers) arrived at Ombilin on Jan. 24, 1978 and left on Jun. 4, 1979 after the completion of the drilling work.

Fig. 5. Bit & casing programme



Phase IV : UPto the target depth

Drilling with NQ wireline bit (coring)

Namely, the casing progamme was composed of 3 stages including 165 mm guide pipes at the surface. It was planned to set 127 mm casing pipes roughly in the upper part of Upper Sawah Tambang formation and 97 mm ones in the upper part of Lower Sawah Tambang formation. Casing pipes were set approximately in the depth as planned, but in some holes change occurred in accordance with geological conditions and hole depth.

The non-core part was drilled with the tricone bit and the coring part with HQ and NQ wireline bit (diamond).
The average bit life was 106.4 m/piece for HQ-DMB and 113.4 m/piece for NQ-DMB as summarized in Table 3. As such a good result was obtained.

The core recovery ratio was over 94 % both in rock and coal seam, and cores obtained by so doing were found utilizable enough for observing the geology and coal seam states as well as taking coal samples for analysis.

The drilling mud was adjusted to the optimum condition by adding lignite, C.M.C. and caustic soda to the base material of bentinite mud. In the case of drilling of mudstone interval oil emulsion and water prepared by adding heavy oil was used in order to prevent the drilling pipes from sticking.

The drilling mud water has the specific gravity of about

1.05 - 1.15 and the viscosity of about 30 - 35 sec./500 ml. An appropriate means was taken to remove sand, by installing three mud water bags and extending the ditch as long as possible.

3.2 Drilling Records

The drilling operation was started on February 7, 1978 and finished on May 24, 1979 as shown in Fig. 4. During this period 8 exploratory drillings with the total length of 4,104.65 m were performed. Particulars of each drilling are summarized in Table 2. The whole operation process proceeded relatively smoothly except for the jamming trouble in W-1 which attributed to the complete lost circulation at the depth of 261.80 m and the operation delay in S-1, waiting for a bulldozer's arrival. Table 3 gives details of operation records. With net drilling rate being 1.34 m/hour a fair result was obtained. Operating times of machines and consuming conditions of major tools and materials are summarized in Table 4 and 5, the results of which, both below the expected levels, show a fair picture of how satisfactorily the operation went through.

3.3 Major Drilling Troubles and Countermeasures

The drilling operation proceeded smoothly as a whole except for the redrilling in W-2 owing to a complete lost circulation

Table 3. Working time and efficiency

Item		Hole No.	W-3	W-1 Before Jamming	W-1 Redrilling	W-2	W-4	W-8	W-7	S-1	S-2	Total	Drilling Rate
Total drilling length (m)			499.2	261.8	500.0	515.3	347.5	406.25	537.8	416.5	620.3	4,104.65	
Total working time [1] (hr)												5,677° 30′	0.72 m/hr
Direct working time [2] (hr)			590° 45′	323° 15′	498° 15′	567° 45′	364° 20′	452° 30′	586° 55′	506° 00′	715° 45′	4,605° 30′	0.89 m/hr
Actual drilling time [3] (hr)			377° 30′	197° 45′	356° 30′	306° 15′	251° 10′	269° 05′	437° 20′	329° 05′	543° 40′	3,068° 20′	1.34 m/hr
Bit used	180 ϕ MCB	Dr. length (m)	15.0	15.0	5.0	15.0	10.05	7.05	10.2	15.0	6.0	98.3	1.90 m/hr
		Act. D.T. (hr)	2° 55′	10° 20′	2° 00′	5° 30′	8° 45′	8° 40′	5° 05′	4° 15′	4° 25′	51° 45′	
	5 5/8″ TCB	Dr. length (m)	35.0	35.0	121.65	37.0	27.55	4.95	39.8	58.0	94.0	440.95	1.77 m/hr
		Act. D.T. (hr)	18° 40′	24° 40′	61° 05′	18° 45′	17° 30′	5° 10′	20° 35′	38° 30′	43° 45′	248° 40′	
	HQ DMB	Dr. length (m)	200.0	120.0	103.35	102.1	86.4	96.0	97.0	84.5	168.45	1057.8	1.50 m/hr
		Act. D.T. (hr)	113° 40′	71° 35′	65° 25′	40° 40′	60° 15′	47° 35′	62° 55′	81° 25′	160° 15′	703° 45′	
	NQ DMB	Dr. length (m)	249.2	91.8	270.0	361.3	223.5	298.25	390.8	259.0	351.85	2,495.7	1.21 m/hr
		Act. D.T. (hr)	242° 15′	91° 10′	228° 10′	241° 20′	164° 40′	207° 40′	348° 45′	204° 55′	335° 15′	2,064° 10′	
Casing depth		165 ϕ CP	15.0	15.0	5.0	15.0	10.05	7.05	10.2	15.0	6.0	98.3	
		127 ϕ CP	50.0	50.0	80.0	52	37.6	12.0	50.0	73.0	100.0	504.6	
		97 ϕ CP	250.0	170.0	230.0	154.10	124.0	108.0	147.0	157.5	268.45	1609.05	
Coring		Length (m)	449.2	211.80	373.35	463.3	309.9	394.25	487.9	343.5	520.3	3553.50	
		Recovery (%)	97	94		99	99	97	100	97	99	98	

Notes 1) Total working time : Direct, indirect & trouble recovering time (indirect : refer to the note in Fig. 4)
2) Direct working time: (Refer to the note in Fig. 4)
3) Actual drilling time : Drilling itself.

Table 4. Operating time of drilling machines

	W−3	W−1	W−2	W−4	W−8	W−7	S−1	S−2	Total
Drilling machine	495° 50′	884° 50′	465° 40′	322° 10′	372° 05′	513° 10′	586° 45′	639° 25′	4,279° 55′
Drilling mud pump	439° 30′	831° 50′	420° 15′	296° 15′	318° 45′	576° 25′	413° 30′	592° 40′	3,889° 10′
Water pump	44° 10′	95° 10′	89° 30′	20° 25′	20° 20′	70° 35′	59° 15′	21° 50′	421° 15′
Mud mixer	80° 20′	174° 05′	230° 05′	54° 05′	52° 50′	53° 20′	66° 55′	55° 05′	766° 45′
Generator	266° 00′	437° 35′	259° 10′	170° 15′	215° 05′	35° 30′	61° 55′	131° 25′	1,576° 55′
Welder	—	34° 00′	3° 30′	2° 05′	1° 20′	1° 55′	8° 10′	6° 45′	57° 45′

Table 5. Material consumption

		W−3	W−1 Before Jamming	W−1 Redrilling	W−2	W−4	W−8	W−7	S−1	S−2	Total	Consumption Rate	Remarks
Total drilling length (m)		499.2	261.8	500.0	515.3	347.5	406.25	537.8	416.5	620.3	4,104.65		
Bit	180φMCB (Pc)	1	1	1	—	1	—	—	1	—	5	19.7 m/piece	D.L. 98.3 m
	5 5/8" TCB (Pc)	1	—	2	2	1	1	1	1	2	11	40.6 〃	〃 446.95
	HQ−DMB (Pc)	2	1	1	1	—	1	1	1	2	10	106.4 〃	〃 1,063.7
	NQ−DMB (Pc)	3	1	2	3	3	2	3	2	3	22	113.4 〃	〃 2,495.7
Casing pipe (Desertion in hole)	165mmφ (m)	—	—	—	—	—	—	—	15.0	—	15.0	15 %	C.L. 98.3 m
	127mmφ (m)	—	—	49.5	—	—	—	—	21.0	30.0	100.5	20 〃	〃 498.6
	97mmφ (m)	126.0	48.0	129.65	12.1	3.0	12.0	24.0	40.5	144.0	539.25	34 〃	〃 1,608.95
Mud & Cement	Bentonite (kg)	2,483	5,770	1,845	9,837	3,105	2,725	2,245	3,030	2,587	33,627	8.19 kg/m	
	Ribonite (kg)	450	55	330	731	265	220	197	108	235	2,591	0.63 〃	
	CMC (kg)	14.5	43.0	26.5	77.5	12.0	33.0	7.5	11.7	5.5	231.2	0.06 〃	
	Caustic soda (kg)	18.0	—	11.5	14.0	8.0	—	—	13.0	15.3	79.8	0.02 〃	
	Heavy oil (ℓ)	—	—	—	1,070	378	361	708	1,840	638	4,995	1.22 ℓ/m	
	Cement (kg)	280	880	40	800	40	40	40	675	160	2,955	0.72 kg/m	
Fuel & oil	Gasoline (ℓ)	185	215	311	307	132	171	42	99	341	1,803	0.44 ℓ/m	
	Light oil (ℓ)	1,014	959	1,151	1,080	798	848	1,167	1,293	1,730	10,040	2.45 〃	
	Lub. oil (ℓ)	200	30	30	50	30	25.5	60.5	30	65	521	0.13 〃	

caving and jamming accident. The major troubles were a) lost circulation, b) cavings, c) sticking, d) drilling rod breakage. In spite of these troubles the operation could be carried out without causing big accidents by taking effective countermeasures.

a) Complete lost circulation

This trouble frequently occurred in coarse sandstones of the *Upper Sawah Tambang formation.* Equally *it* sometimes occurred in mudstones in Lower Sawah Tambang or, a cause for which was considered cracks in mudstone. Except for few cases where the circulation was recovered by reducing the mud density it failed in most places even with fresh water. It was then considered that the formation state in such places was so-called a "subnormal pressure" zone. While in some cases the circulation was recovered by filling the porosity with dense mud, with sawdust and rice skin, so that the operation could be continued. On the other hand, there were those where cementing or setting casing had to be applied.

b) Caving

The caving took place mainly in mudstones in Lower Sawah Tambang formation. This mudstone develops many slickensides in it so that it may easily lead to cavings. Except for W-2 the cavings could be overcome without causing big accidents by the mud control, however, in W-2 drilling was repeated by jamming accident owing to caving together complete lost circulation.

c) Sticking

Red-brown mudstones in Lower Sawah Tambang formation and grey mudstones in Sawahlunto formation had relatively high viscosity to cause for sticking. It was overcome without causing big accidents by minimizing the pause of mud water circulation by means of shortening the recorvery time of core barrels and holding the adequate mud viscosity with oil emulsion mud.

d) Breakage

In the mid course of the operation in W-8 the drilling pipe breakage accident took place frequently. The breakage occurred at exhausted joint parts and the reasons of which were considered to be the unequal wear caused by the rotation of drilling pipes and the wear caused by remaining sand in circulating mud. The bit load was adjusted and the removal of sand from drilling mud was taken into consideration.
After then there occurred no breakage trouble.

3.4 Hole Deviation Survey

Hole deviation survey executed at every 50 m of depth to measure the deviated distances of drilled holes. The survey was conducted with a Murata type measureing unit (plotting type), running twice at every 50 m of depth before inserting casing pipes or before abandoning the hole in the case of the range of non-cased hole (NQ).

Surveyed results are summarized in Dwg. 15. The following data show deviated distances of the top and the bottom:

Drilling number	Deviated distance (m)	Direction	Mean inclination of borehole
W-1	2.9	N 65° E	0.4°
W-2	21.2	S 21° W	2.4°
W-3	13.1	S 4° E	1.7°
W-4	7.2	S 17° E	2.0°
W-7	10.6	N 36° W	1.2°
W-8	6.8	N 3° E	1.0°
S-1	17.1	S 80° W	2.4°
S-2	14.3	S 68° W	1.4°

W-1 had the least deviation of hole averaged 0.4° each, and W-2 and S-1 had maximum deviation of 2.4°, whereby leaving the deviation of all other holes below this value. Directions of deviations were seen distributed irregularly, seemingly with no relation with geological structures.

Although some holes (W-8 and S-1), especially in deeper ranges, had the deviation of 5° - 6°, those as a whole were measured below 2.4°, which was not big enough to cause serious problems in terms of drilling as well as geological data study.

CHAPTER 4

GEOLOGY

CHAPTER 4. GEOLOGY

4.1 General Description

This survey was executed mainly with Waringin Area as its object, therefore, the geological particulars described below are concerned in Ombilin Coal Mining concession since the years under Dutch rule up to 1975, those surveying data were taken into due consideration as much as possible. Also with an eye on the future development plan, references were made to the northern part of Waringin Area and a part of Sugar area.

For the geological studies the following data were taken into consideration, together with the current survey results.

Topograhical map : ° 1/5,000 topographical map submitted by T.B.O.

Geological map : ° 1/5,000 geological map preapred by Marubeni-Kaiser

° 1/250,000 geological map preapred by G.S.I.

° 1/2,000 geological map prepared by G.S.I. (only for the northern part of the concession)

° 1/10,000 geological map prepared by R.P. Koesoemadinata and Th. Matasak

Drilling data and others : ° Ombilin Coalfield, Technical Report of Invesigation and Exploration (September 1971) prepared by Marubeni-Kaiser

° The Geologiy and Coal Resources of the Sawah Rasau Area (January 1976) prepared by P.T. Petrosea International (Indonesia)

The locations and elevations of the drilling hole shown on the attached drawing are based on the Ombilin Mine Grid System. The coodinates and elevations of individual exploratory drilling are shown in Table 6.

4.2 General Geology and Stratigraphy

The coal bearing formation which includes coal seams mined by Ombilin Coal Mine diestributes within the elliptical intramontane basin developed on the east slope of the Barisan mountains of Sumatra with its long axis of 50 Km and short axis of 20 Km. In this sedimentary basin its basemant rocks are of Carboniferous to Triassic in age and the relation with the Teriary strata on them is unconformities and faults. Ombilin Coal Mine is located at the west margin of the sedimentary basin. No detailed geological surveys have been executed except for the Teriary strata around Ombilin Coal Mine, however, the geological map and its explanation published by G.S.I. (Solok 5/VII, 1/250,000) makes it possible to have access to the outline of the geology.

Table 6. Coordinate and elevation of drilling holes

Ombilin grid system

(by P.N.Tambang Batubara Ombilin)

	X	Y	Elevation
SR－2	－15,846.626	－11,576.111	＋344,28
4	－16,668,725	－ 9,931,825	＋240,840
7	－16,159,17	－11,104,93	＋260,76
8	－15,781,490	－11,349,464	＋310,364
DH－6	－16,460,274	－10,811,878	＋312,340
7	－17,588,839	－10,774,373	＋398,127
7′	－17,150,070	－ 9,352,233	＋349,614
8	－22,493,934	－ 6,494,908	＋209,310
9	－18,327,007	－ 8,817,808	＋307,479
W －1	－18,699,020	－10,239,975	＋570,000
2	－18,225,184	－ 9,594,421	＋483,326
3	－18,880,988	－ 9,585,830	＋482,660
4	－19,506,899	－ 9,528,179	＋313,998
7	－18,670,917	－ 9,104,947	＋353,266
8	－19,731,923	－ 9,100,838	＋237,620
S －1	－20,034,670	－ 9,399,066	＋340,489
2	－20,166.155	－ 9,027,277	＋385,697

G. S. I. grid system

(by Geological Survey of Indonesia)

	X	Y	Elevation
W－1	14,880,904	－18,548,455	568,716
2	15,521,371	－18,103,973	482,546
3	15,511,456	－18,726.242	483,471
4	15,586.509	－19,344,008	325,217
7	16.010,573	－18,540,306	355,158
8	16.004,560	－19,586.486	249,557
S－1	15,708,432	－19,886.792	341,157
2	16,079,231	－20,016.285	387,556

4.2.1 Basement rocks (Pre-Teriary)

The basement rocks distributed mainly in the west of Ombilin Coal Mine are as follows:

1) Kuantan formation

The upper part of this formation consists mainly of phylite shale and strata of limestone interbedded with the layer of phylite and shale (lateral interfinger), and its lower part is strata of quartzite and quartzose sandstone with phylite and shale, with igneous rock, tuff, conglomerate, partially observed. A.Mayer found the following fusulina of Middle Permian from limestone in the east of Danau Singkarak (December 1971)

Neoschwagerina aff
Neoschwagerina (SCHWAGER)
Verbeekina sp.
Chusenella sp.
Climacammina sp.

Also found the following fossils diagnistic of Lower Carboniferous or lower part of Upper Carboniferous from limestone in Sungai Kuantan. (Musper, 1930)

Syringogora
Endothyra
Bigenerina

It can be concerned from the above facts that these strata are of Lower Carboniferous to Middle Permian in age and their thickness over 5,000 m.

2) Silungkang formation

This formation distributes in the west of Sawahlunto and is divided into the upper part composed of hard massive limestone interbedded with thin strata of shale, sandstone, and conglomerate and the lower part composed mainly of volcanic rock (andesite).

The following fossils were found in limestone in the upper part of the formation, estimated to be of Permian in age. (Katili, 1969)

Doliolina lepida SCHWAGER
Pseudofusulina padangensis
Neoschwagerina multiseptata DEPART
Fusulinella lantenoisi DEPART

The lower part is mainly composed of andesite in which thin strata of shale, sandstone, conglomerate, etc. are interbedded. These rocks show clear green color in general and suffer chloritization strongly. From this fact, these volcanic rocks are considered to have been formed by a lava flow generated from a submarine eruption or flow into the sea. The entire thickness of Silungkang formation is approx. 150 m.

3) Tuhur formation

This formation can be divided into the following two facies:

Shale and clayslate; Chert and radiolarite partially included.

Limestone; Psammitic and rudaceous limestone.

The relation between these two is that of interfinger. It can be oberved contact metamorphism by intrusive rocks and limestone suffered by recrystallization at Gunung Besi, Gunung Sibumbum Jantan and Gunung Subumbum Batio in the east of Danau Singkarak.

The formation was identified of Trias in age by Musper (1930)

The sedimentation from Kuantan formation to Tuhur formation is serial with each relation between the upper and lower formation considered as formable one. But further investigation are called for, since some of the facies show a possibility of continental deposit or the affection of igneous activity.

4) Igneous rocks

Occurences of granite, granodiorite, quartz diorite and quartz porphry are known around the surveyed areas, besided volcanic rocks in Silungkang formation. These granitic rocks are considered to be interrelated each other. In some places pegmatitic or gneissose ones exist.

The absolute age determination of granite around Danau Singkarak showed 112 ± 24 m.y. (Katili, 1962) and 206.5 ± 2.5 m.y. (Obradovich, 1972) which correspond respecrively with Cretaceous perios and Triassic period. similar granitic rocks distribute in the westnorth of Sawahlunto, however, they gave no thermal influence on Tertiary coal seams, the main subject of this survey, in terms of the geology of igneous activity chronologically.

4.2.2 Tertiary formation

The surveyed area is located in the center part of Barisan range where large continental formation develops up to around Pliocene in age. Therefore, the Tertiary formation developed in this area are considered to be of non-marine deposit.

Not a few surveys have been made on the Tertiary formations including coal seams at which the current operation aimed. Accordingly formations have been named as variously as the number of surveys, which are summarized in Table 7. The formation names adopted in this report apply those of Koesoemadinata/Hardjono (1978) and Koesoemadinata/Matasak (1978).

1) Sangkarewang formation

This formation is of dark brown marlaceous shale and partially interbedded with arkose sandstone. It contains abundant fossils of fresh-water fishes (Musperia radiata, Scleropages sp, etc.) Sanders considered that this formation would be of Eocene series and Musper of Oligocene series. (van Bemmelen, 1949). Its thickness is about 500 m. According to the

Table 7. Stratigraphy of Ombilin coal basin

<table>
<tr><th colspan="2">Marubeni/Kaiser (1970)</th><th colspan="2">Silitonga/Kastowo (1975)</th><th colspan="2">Koesoemadinata/Hardjono (1978)</th><th colspan="2">Koesoemadinata/ Th.Matasak (1978)</th><th colspan="2">Present study (JICA) (1979)</th></tr>
<tr><th>Formation</th><th>Geological age</th><th>Formation</th><th>Geological age</th><th>Formation</th><th>Geological age</th><th>Formation</th><th>Geological age</th><th>Formation</th><th>Geological age</th></tr>
<tr><td>E_1</td><td rowspan="5">Eocene</td><td>Anggota Atas Formasi Ombilin</td><td rowspan="4">Miocene</td><td>Neogene Marl -limestone formation</td><td>Early Miocene</td><td>Formasi Ombilin</td><td>Early Miocene</td><td>Ombilin formation</td><td>Early Miocene</td></tr>
<tr><td>E_2</td><td rowspan="3">Anggota Bawah Formasi Ombilin</td><td rowspan="3">Ombilin Coal Measure</td><td rowspan="3">Oligocene</td><td rowspan="2">Formasi Sawah Tambang</td><td rowspan="3">Oligocene</td><td>Uppen Sawah Tambang formation</td><td rowspan="2">Oligocene</td></tr>
<tr><td>E_3</td><td>Lower Sawah Tambang formation</td></tr>
<tr><td>E_4</td><td>Formasi Sawahlunto</td><td>Sawahlunto formation</td><td>Eocene ~pre-Eocene</td></tr>
<tr><td>E_5</td><td>Formasi Brani/Sang-karewang</td><td>Oigocene</td><td>Sangkarewang formation</td><td>Eo-Oligocene</td><td>Formasi Sangkarewang</td><td>Eo-Oligocene</td><td>Sangkarewang formation</td><td>pre-Eocene (palaeocene)</td></tr>
<tr><td colspan="10">Triassic~Carboniferous
(Tuhur formation, etc)</td></tr>
</table>

results of palynological analysis made in the current survey, the geological age of the formation is considered to be Pre-Eocene (Palaeocene ?).

Brani formation, which is composed mainly of conglomerate, is considered the contemporaneous heterrotopic facies of Sangkarewang formation. Brani formation is contained gravel of granite and limestone and the thickness is about 600 m. Since strata developed in the surveyed area are composed mainly of shale, it is considered correlatable to Sangkarewang formation from the viewpoint of lithofacies.

The relation with the lower strata is unconformable.

2) Sawahlunto formation (Ombilin coal measure)

This formation refers only to the coal bearing formation which was called Lower Ombilin formation or Ombilin coal measure in the geological map of G.S.I. and by Koesoemadinata and Hardjono. It is composed of dark grey shale, medium to fine sandstone and coal. 3 coal seams of A, B, and C in descending order exist, however, noticeable are changes of coal seams as a result of splitting, deterioration or development.

The palynological analysis shows that the geological age of the formation would be Eocene to Pre-Eocene. The current drillings and the geological mapping brought about no evidence of unconformity with lower formation. On the other hand drilling in DH-7 showed the formation was thinner than ordinary one and its lithofacies were sandy, suggesting marginal facies. There may be a possibility that a weak upheaval of Sangkarewang formation (burried hill) may exist and local unconformity and overlapping may have been caused.

3) Sawah Tambang formation

This formation includes the upper part of what is usually called Lower Ombilin formation or Ombilin coal measure and is classified into Upper Sawah Tambang formation and Lower Sawah Tambang formation by lithofacies.

Lower Sawah Tambang formation is alternated beds of red-brown mudstone and coarse or congloneratic sandstone, having conglomerate in parts. the thickness of the formation is about 180 - 200 m and has the tendency of being thicker towards the south.

Upper Sawah Tambang formation is composed mainly of coarse sandstone and conglomerate, and shale is interbedded partially. The formation composed of sandstone and conglomerate has the resistance against erosion, forming high cliffs over the surveyed area. Futhermore, the formation distributes in entire ground surface of the surveyed area and material for sand packing is taken from the weathered area of this sandstone. The thickness of the formation is about 600 m. The relation between Lower Sawah Tambang formation and Sawahlunto formation is conformable. The geological age of these formations seems to be Oligocene, considering the age of the upper and lower formations.

4) Ombilin formation

This formation is composed mainly of blue-grey or green-grey mudstone and sandstone interbedded with conglomerate and tuff. Tinged with green color and having calcareous feature, they contain the following fossils (Silitonga, 1975):

Globigerinoides ruber (D'ORBIGNY)
Globigerinoides trilobus (REUSS)
Globigerinoides sacculifer (BRADY)
Globigerinoides sicanus DE STEFANI
Miogypsina excentrica TAN SINHOK

From these fossils the formation is conceivable as that of upper horizon of Lower Miocene (N-8 by Blow, 1969) the relation with Upper Sawah Tambang formation which lies below the formation is conformable. This formation is distributed to the east of the surveyed area and cannot be found within the surveyed area.

4.2.3 Later formed volcanic rocks

Such later volcanic rocks as andesite lava, welded tuff, tuff breccia and mudflow generated from volcanic activities of such as Mt. Marapi, Mt. Talang, etc. are distributed in the area. These eruptions are considered to have taken place in the period from Pliocene to Quarternary. Their distribution is limitted in the north of the sedimentary basin and no direct influence on the Tertiary coal is traceable.

4.3 Detailed Description of Tertiary Formations

Followings are the description of each Tertiary formation based mainly on the drilling data of the current survey.

4.3.1 Sangkarewang formation

The upper boundary of the formation could be confirmed by drilling except for W-2, however, it was only a restricted upper part that was actually drilled, the respective depth being as follows:

W-1	12.8 m	W-2	5.95 m	W-3	17.50 m
W-7	20.06 m	W-8	10.80 m	S-1	19.30 m
S-2	2.85 m				

The formaiton mainly consists of grey, red-brown, yellow, (blue-) grey, or spottedly mixed colored mudstone and silt-stone interbedded with thin sandstone beds about 1 m thick. Both mudstone and sandstone are calcareous in general, and the former containing calcareous concretions in some cases (S-1).

There are also some cases (W-1, W-4 and W-7), where thin coaly shale and mudstone with carboceous materials are interbedded and sandstone has stripes of carbonaceous materials.

Drilling DH-7 penetrated into this formation over 215 m. The about upper 60 m consists mainly of sandstone with minor mudstone, the middle 55 m mudstone and the lower 100 m sandstone. The conglomerate and sandstone zone of the lower part seems to correspond to Brani formation which is said to be in the relation of contemporaneous heteropic facies of Sangkarewang formation, and the latter seems to overlie the former conformably.

The boundary to Sawahlunto formation is noticed through the color change of mudstone from miscellaneous to grey colors and, as far as oberving cores, there is no evidence to suggest unconformity such as basal conglomerate and denudation of the uppermost part of Sangkarewang formation. Only at S-2, sandstone occurrs in the lowest part of Sawahlunto formation, but in all other cases, contact is between mudstone or siltstones among themselves. Since coaly shale occurrs also in Sangkarewang formation and calcareous sandstone occurrs also in the lower part of Sawahlunto formation, it is generally considered that both formations would be serial conformable sedimetns, even though supplied materials are varied.

Fresh-water fishe fossils were aboundantly found from this formation around this area. (Musperia rediḍta, Scleropages sp., etc.) It is considered from the above lithofacies and included fossils that the sedimentary environments of Sangkarewang formation may have undertaken a gradual change with the increase of water affection from basal conglomerate in the lower part to mudstone and silitstone in the upper part of fresh-water environments. Such environments would be those of fluvial or lacustrine. At places where the formation assumes contemporaneous heteropic facies with Brani formation, it is considered to have been deposited in somewhat deeper environments around alluvial fans or deltas (Brani formation).

4.3.2 Sawahlunto formaiton

This formation is penetrated over entire successions in all drillings. Its thickness is almost constant between 106 m and 130 m as shown in Table 8, but it is understood an overall tendency of going thicker towards the north and south from DH-7.

The thickness between top of the formation and A-seam increase rapidly from 22 m to 42 m around S-1 and S-2 which are located in the southern verge of the surveyed area. Consequently Sawahlunto formation develops thick in the area.

Table 8. Formation boundary, sand ratio and composit thickness of coal

	Total depth	top Lower Sawah Tambang	top Sawahlunto	top Sangkarewang	Lower Sawah Tambang fm. True thickness	Lower Sawah Tambang fm. Sand ratio	Sawahlunto fm True thickness	Sawahlunto fm Composit thickness of coal	Sawahlunto fm Sand ratio	Remarks
W−1	500.00	159.00 m	378.75 m	487.20 m	216.4 m	28.6 %	105.5 m	3.38 m	10.7 %	
W−2	515.30	176.40	392.37		192.4	41.9	108	7.39	44.2	
W−3	499.20	157.40	340.90	493.25	165.8	35.4	132.5	4.98	7.3	
W−4	347.50		203.26	333.00	248 (?)*		121.5	16.38	16.4	*supposition
W−7	537.80	106.92	389.59	518.74	265.4	34.2	122.5	7.89	20.5	
W−8	406.25		274.63	395.45	250 (?)*		106.5	14.75	21.6	*supposition
S−1	416.50		277.83	397.20	261 (?)*		112.5	27.41	18.2	*supposition
S−2	620.30	172.50	456.80	617.45	266.7	33.5	129.5	6.75	18.9	
DH−5	469.00	115.30	355.60	435.00	228.3	34.6				
DH−6	357.45		151 (?)	296.85			138.6(?)	3.31	45.9	
DH−7	463.05	0.00	181.25	249.60	172.7	47.5	64.9	1.69	70.5	
DH−7′	512.00	148.58	372.70	494.14	212.9	34.8	115.4	3.28	30.8	
DH−8	862.30	571.75	787.83		205.3	53.6				
DH−9	618.65	172 (?)	439.29	555.04	254 (?)*		110.0	7.28	17.5	*supposition
SR−5	349.01	127 (?)	349.5(?)		116 (?)	27.2(?)				Lithology is doubtful
SR−6	301.25	130 (?)	302 (?)		163 (?)					for noncore drilling

True thickness: Apparent thickness × 0.95 in DH & SR drilling series

True thickness: revised by the calculation using the actual average dipping in W & S drilling series.

The thickness of same interval at W-8 is reduced to about 12 m, which suggestes a possibility of weak denudation in the uppermost part owing to partial disconformity.

The formation consists mainly of dark grey mudstone interbedded with fine or medium sandstone and contains many thin coal seams (coaly shale) besides A, B and C seams. Sandstone shows generally lens shape with lateral extent of 500 - 1,000m. Each coal seam occurrs at almost constant stratigraphic horizon and coal seams themseleves form good key beds. The interval from the uppermost to the roof of A seam is 20 - 25 m thick except of W-8 and S-2. That from the roof of A seam to the roof of C seam is 40 - 50 m thick (distance between A and B, B and C seam are fluctuated considerably). That from the roof of C seam to the floor of lower C seam is 20 - 30 m thick.

The interval between the uppermost to A seam consists of grey or dark grey mudstone interbedded with several thin layers of fine sandstone less than 1 m thick and 2 or 3 coaly shale beds (more in splitted A seam zone at W-4 and W-8). Some mudstone contain calcareous (sideritic) concretions. The interval between A and B seam has the highest sand ratio in the formation (exceptionally at W-3, only mudstone) and is interbedded with characteristic rhythmical fine alternated beds of very fine sandstone and mudstone or very fine sandstone with stripes of mudstone (remarkable at W-2 : 5.5 m, S-1 : 6.5 M and S-2 : 5.5 m) or fine sandstone interbedded irregularuly with mudstone (remarkable at W-4 : 8.5 m and W-8 : 8 m)

The interval between B and C seam is composed almost of mudstone and siltstone except of sandstone beds of 1 - 3 m thick, however, at W-3 fine alternated beds of 9 m composed of mudstone and very fine sandstone similar to the above mentioned occur. At W-1 coarse sandstone bed of 3.5 m thick occurrs at the horizon where C seam should have occurred, which suggests a possible substitution of the coal seam.

The horizon between C and lower C seam is the richest in carbonaceous matter in the formation. Many coaly shale or carbonaceous mudstone are interbedded in the interval or the entire interval is composed of carbonaceous (silty) mudstone in some cases (at W-7 about 30 m). This interval consists mainly of irregularly alternated or mixtured beds of mudstone or silststone with very fine sandstone and carbonaceous matters showing disturbed deposition.

The part below lower C seam consists mainly of mudstone and siltstone interbedded with coaly shale and calcareous sandstone. In some cases mudstone contains calcareous concretions.

Dwg. 10 a shows the sand rario (the ratio of sandstone and silty sandstone to the overall formation thickness) and overall formation thickness. The sand ratio is decreasing from the maximum 70 % at DH-7 towards the southeast, and over the whole surveyed area it is between 10 - 20 %.

The thinnest formation is observed in the area of DH-7, measured about 70 m. From there towards outskirts it goes on a gradual increase. The current survey area was measured about 110 - 130 m.

The developing conditions of individual coal seam are described in chapter 4.5 in detail. C seam is the thickest developed coal seam, but the varience from its maximum thickness of 19.34 m at S-1 to deteriorated area around DH-6, DH-7, and W-1 is too remarkable, with a noticable varience to coaly shale in the lower part. B seam develops to about 0.5 to 1.0 m thick, thought it is deteriorated at W-1 and DH-7 and has the tendency of splitting towards the east. A seam develops to about 2 m thick as a whole except deterioration at DH-7 and thinning out caused by splitting at W-4 and W-8.

The roof of coal seam consists of mudstone or siltstone in all cases and floor consists mainly of mudstone except for sandy siltstone in some cases of C seam. Coal seams have sharp boundaries with roof and floor. Underclay (seat earth) or the like are not found. Dwg. 11 shows the composite thickness of coal seams in Sawahlunto formation. There is a tendency to increase towards the southeast from about 2 m at the area of DH-7 to 25 - 15 m at W-4, W-8 and S-1.

The tendency of the developing condition of coal seams corresponds relatively to those of the variation of the formation thickness and sandratio, and at areas where thick coal seams are developed the formation has the thickness of 105 - 125 m and the sand ratio of 15 - 20 %.

Allochthonous coal, generally speaking, has the following features, 1) Remarkable change of seam thickness or coal quality, especially change to coaly shale in the horizontal and vertical directions, 2) No development of underclay, 3) Low sulfur and high ash contents, 4) Lack of flora remains in roof or interbedded shale in coal seams. The condition of C seam in this area is fairly conformable to these characteristics. However, in the case of well development of the seam, C-coal has rather low ash content, which indicates hypautochonous origin explained later. As a matter of fact similar tendency between the developing conditions of coal seams and those of the formation gives an influential indication that coal was also allochthonous. Since thicknesses of B and A seams does not change like that of C seam, those coals are considered to be of autochthonous originating from peat in marsh in a relatively stable period of later Sawahlunto formation. Especially, splitted seams found in A seam is considered to have been formed by diffusion of clastic rocks from surrounding areas owing to flooding to coal seams, since change of its seam thickness is not so remarkable in spite of its seam splitting.

From the features of this basin described in chapter 4.2 Sawahlunto formation may possibly deposit in fluvial or lacustrine environments. Since the development of the formation and sandstone are not zonal but rather plane (Dwg. 10a), the formation would have deposited probably not in fluvial environments but in lacustrine ones. In addition to that, the area of around DH-7 is considered to a relatively higher area at that time. Taking into consideration these and the developing condition of C seam, C seam is considered of "hypautochthonous origin". That is to say, it is not wide of the mark to consider that C seam is formed with drifted peat from closely nearby marsh in the same basin.

4.3.3 Lower Sawah Tambang formation

This formation is entirely penetrated at W-1, W-2, W-3, W-7 and S-2 except at W-4, W-8 and S-1 where a part the uppermost is lacked. The thickness of the formation is varied as shown in Table 8 from 166 m to 267 m and has the tendency to go thicker towards the south. However, the upper boundary of this formation was assumed arbitrarily to be at the bottom face of thick massive coarse sandstone and conglomerate with rare intercalation of mudstone and siltstone in Upper Sawah Tambang formation. In the southern area mudstone and siltstone interfingered with the sandstone exists below the thick sandstone. Since this part is comprised into Lower Sawah Tambang formation lithologically, there is a possibility that it became apparently thicker in the southern area compare to northern area.

The formation consists of mudstone / siltstone of miscellaneous colors and grey or grey-white sandstone, whereas the former is predominant. The thickness of individual unit beds range from several to scores meters, changing considerrably in the horizontal direction, which, therefore, makes it difficult to correlate unit beds each other. The maximum thickness of unit bed each drilling is 25 - 65 m in mudstone and siltstone and 10 - 25 m in sandstone. Mudstone and siltstone are massive, compact and frequently accompanied by slickensided feature, the color of which are varied from red-violet / red-brown (mainly), yellow, blue-grey, grey to complicated mixture of the above. In general both in the upper and lower parts of each mudstone bed blue-grey color comes predominant while approching to sandstone. Sandstone is composed mainly of quartz-rich coarse sandstone and contains granuels or pebbles composed of quartz and Pre-Tertiary rock fragments, which become finer towards the upper part in many cases. In this formation and Upper Sawah Tambang formation there are following distinct phenomena and structures caused by slumping, underwater streaming and others which took place during the period of immediately after deposition.

Contemporanceous mudstone breccia in sandstone (slump ball)

Irregularly alternated beds of sandstone and mudstone

Complete mixture of gravel, sand and mud (pebbly mudstone)

Diastem

Small scaled decollement type faults

Cross bedding

Autobrecciated mudstone

Small scaled clastic dike

Dwg. 10b shows the thickness of the formation and sand ratio. The thickness of the formation is thinnest in the area linking DH-7 and W-3, which is about 170 - 180 m. It goes gradually thicker towards the southeast and reachs 260 - 270 m around W-7, S-1 and S-2. The tendency of sand ratio falls in line with that of thickness of the formation. The maximum sand ratio of 45 % at DH-7 are declining towards the southeast and outskirts of DH-7 and it runs to about 30 % in the current surveyed area. This depositional condition is similar to that in Sawahlunto formation and it shows that the area of DH-7 was still higher than surrounding area even during the sedimentation period of this formation. The sedimentary environment of the formation is considered, judging from its lithofacies and above distinct structures, to be an intermediate or transtional one of "subarerial environment" and "fluvial-lacustrine environment" and to have more element of trestrial environment than in the sedimentary environment of Sawahlunto formation.

4.3.4 Upper Sawah Tambang formation

The drilling at W-1, W-2, W-3, A-7 and S-2 penetrated the lower part of this formation, with the maximum drilled length being 176 m at W-2. The formation consists of dark blue to green grey (grey-white in the lower part of 7 - 50 m) medium-coarse sandstone and conglomerate, interbedded at rarely with mudstone and siltstone of less than 1 m thickness. Thought the details of the upper part at W-2 and S-2 (corresponding to the middle part of the formation) remain unclear because of non-coring, it seems that many mudstone layers are inter-bedded. Sandstone is massive and porous, containing little matrix. It becomes very loose by weathering. 1 cm or so thick stripes of mudstone are interbedded in some places. Conglomerate consists of subangular granules and, on rare occasions, pebbles composed mainly of quartz. The formation is considered to have deposited in a fluvial-lacustrine environment, which assumes an aspect of more terrestrial environment than Lower Sawah Tambang formation.

4.3.5 Ombilin formation

The formation extends widely in the east of Ombilin River, but it could not be directly observed in the currently surveyed area where the formation is not distributed. Main components are blue-grey to green grey mudstone, with partial interbedding of sandstone, conglomerate and tuff. Being calcareous, it contains forminifera. These facts may give a positive evidence that it was of shallow marine and that the first transgression took place during this period.

4.4 Geological Structure

The Ombilin Mining concession area can be divided into the following 6 areas according to major faults and topography. (Refer to Fig. 6)

Tanah-Hitam : Northward of Lurah Gadang fault and westward of Ombilin River.

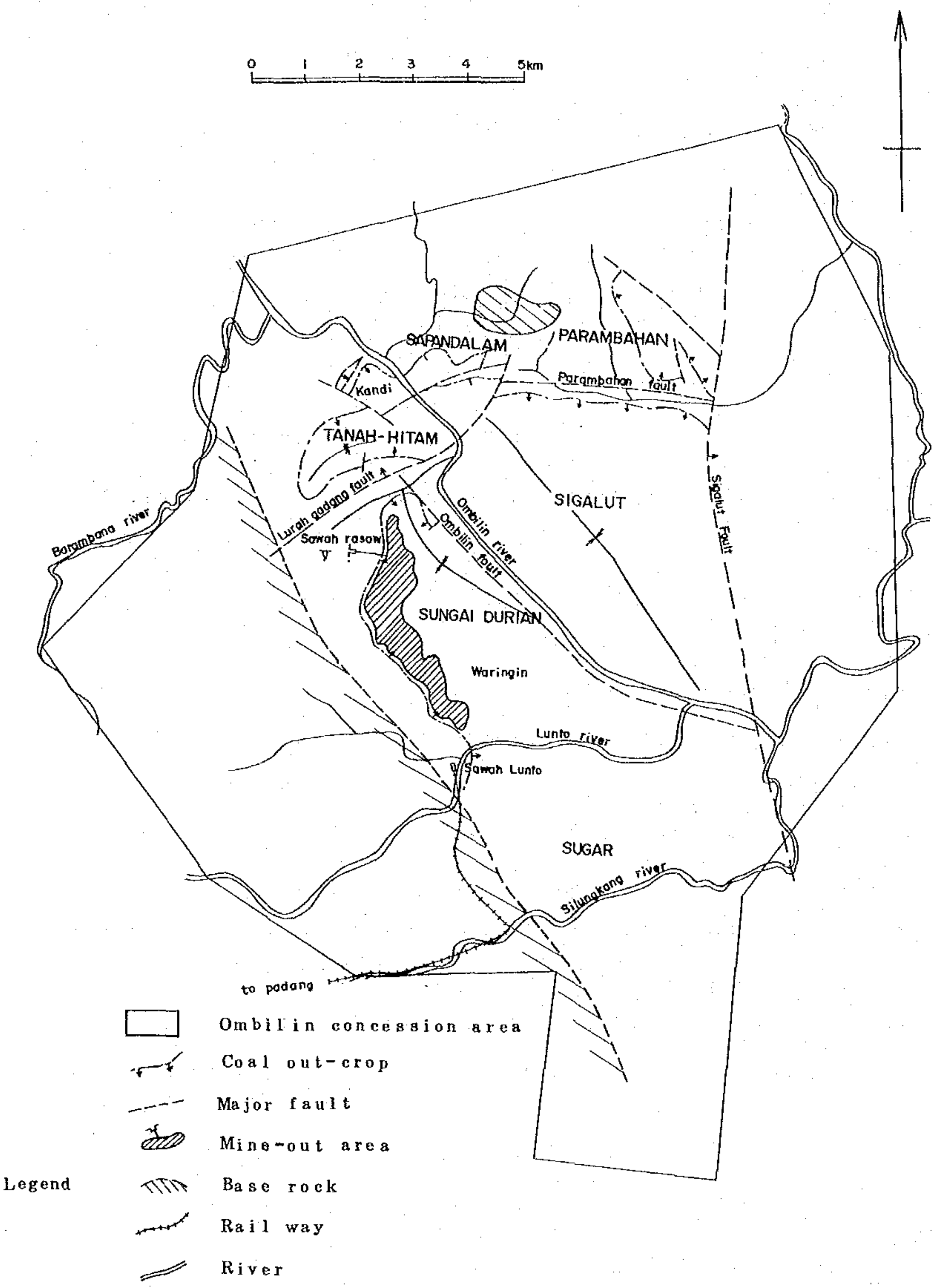
Coal distribution area of about 3.1 Km^2

Sapandalam : Eastward of Ombilin fault and west-northward of Lurah Gadang fault

Coal distribution area of 1.2 Km^2

Parambaham : Northward of Parambaham fault and westward of Sigalut fault

Fig. 6. Outline of geological structure around Ombilin area.



Coal distribution area of 2.7 Km^2

Sungai Durian : Southward of Lurah Gadang fault, westward of Ombilin fault and northward of Lunto River

Coal distribution area of 18.6 Km^2

Sigalut : Eastward of Ombilin fault, southward of Lurah-Parambaham fault and westward of Sigalut fault

Coal distribution area of 24.6 Km^2

Sugar : Southward of Lunto River

Coal distribution area of 31.3 Km^2

The center of Ombilin concession, which lies between the basement fault running in the west part of the area, in the direction of NNW-SSE, and Sigalut fault running in the east part of the area in the direction of about N-S, forms the synclinal structure with an axis of NE-SE, plunging towards the south. The eastward area of Sigalut fault (the thrown side is east) remains yet to be surveyed.

Outcrops of coal seams fairly reflect the synclinal structure. Around Sawahlunto the strike is in the NNW-SSE direction with dipping towards east. In Tanah-Hitam, it changes to the eastwest direction and south dip, ranging to Parambaham and the north part of Sigalut through Sapandalam.

In addition to the above two major faults, a good number of faults and partial small foldings can be observed, and that makes the geological structure of the area more complicated than those of other coal areas in Indonesia.

The geological structure of the object area of Sungai Durian and Sugar are as follows:

Sungai Durian

The area has generally a synclinal structure. In the range of about 5 Km from Lunto River to the neighborhood of the entrance of Sawah Rasau Pit-5, the strike shows NNW direction and dips towards eastwards, accompanied with some partial foldings. However, in the northern part of the area where under ground mining is currently in operation, the strike changes gradually to the direction over the east-west and northnorthwest and the dip towards south or west in the hooked shape. As the syncline is cut by Ombilin fault in east side (thrown 100 m towards east?), the distribution of the eastern flank is very limited. The formation assumes a gentler dip from the south towards north, that is, about 23° in the southern part, and 17° in the northern part. In the western part of the Sawah Rasau Pit-5 the dip is somewhat steep at 20 - 25°, but it becomes gentler towards downdip.

Five faults of the NE-SW direction (the maximum throw of about 100 m) crossing Ombilin fault at an angle of about 45° have been confirmed and they separate the area to some blocks.

Sugar

While the area has underogne so few surveys until now that the geological structure has not been made clear yet, it is considered to be a homocline having the strike of about the south-north direction and dipping towards east. The west side of this area abutted on a basement fault of the NW-SW direction, which is assumed to accompany 2 - 3 samll faults.

4.5 Coal Seam Developing Condition

4.5.1 General description

Sawahlunto formation in the object area has 3 workable coal seams, respectively called A, B and C seam from the upper horizon. (A and C seams are being mined at Sawah Rasau Pit-5) Although there are several thin coal seams interbedded, besides the above three, these are not workable. The lithofacies of the coal bearing formation generally presents a noticable change in the lateral direction, looking at the coal seams themselves, there is also seen a considerable change in thickness and feature. It, however, is not difficult to correlate coal seams all over the object area by understanding them as a coal zone. (Refer to Dwg. 6)

The strike of the coal seams is in the south-north direction and gently undulated. The dip is 10 - 15° towards east, with some, more than 20°. (In the currently mined area, that is to say, the northern part of the object area, the strike is gradually changed to the northeast-southwest direction and the dip towards southeast). Around the areas of SR-6, SR-5 and DH-7 is seen a synclinal structure having the axis of the northwest-southeast direction. In the north side of this axis the strike is changed to the westnorthwest-eastsoutheast direction and the dip towards south. The downdip of the goaf is considered to be dividable into several blocks by the extension of the fault confirmed at the goaf, but the structure there is not so complicated. (Refer to Dwg. 9).

Due to steep cliffs and successive cuesta, the depth from surface to coal seams is following a sharp increase except in areas along the velley. Taking C seam existing in the lower horizon, for instance, the relation between the elevation and the depth from surface is shown as follows:

Elevation of roof of C seam (m)	Depth from surface to C seam (m)
+ 150	200
+ 100	300
0	450 - 500
- 100	500 - 600
- 200	600 - 700

Note: Less than the above figures in the areas along the Lunto River.

Visual observation shows almost all coal parts are composed of bright coal except for those in the thick parts of C seam where the lower part has a shade of somewhat dull coal. Table 9, shows details on the conditions of minable parts of principal coal seams in each drilling. Additionally, details of coal columns are shown in Dwg. 7 and 8.

4.5.2 A seam

Existing almost all over the area, it covers a biggest minable area in 3 seams. The whole tickness of the seam is 1.48 (SR-7) - 5.49 m (W-2). The seam has no prting at SR-8, S-1 and S-2, but in the other drillings it was split into several layers by interbedding of coaly shale and sahle, with some cases in its upper or lower part the coal seam conditions being worsened.

The minable part of coal seam has the thickness of 1.41 m (SR-7) - 2.47 m (SR-2), and almost all over the area it is kept stable in the range of 2.0 m - 2.3 m. The prementioned part is often accompanied with a very thin parting of coaly shale.

At W-1, W-4 and W-8 the thickness of A seam is respectively 3.36 m, 2.31 m and 3.98 m, however, the seam has been strongly deteriorated there. Likely at DH-7 where sandstone is developed on the horizon of A seam, a badly deteriorated condition

Table 9. Condition of minable part of coal seams

(meter)

	Hole №	SR−2	SR−8	SR−7	DH−6	SR−4	DH−7′	W − 1	W − 2	DH−9	W − 7	W − 3	W − 4	W − 8	S − 1	S − 2	DH−8
	Height of collar	344.28	310.36	260.76	312.34	240.84	349.61	570.00	483.33	307.48	353.27	482.66	314.00	237.62	340.49	385.70	209.31
A Seam	Depth to seam	158.47	118.85	61.34	162.22	200.64	390.42	400.75	416.44	457.40	406.26	370.18	232.90	289.92	301.75	509.20	833.0
	Elevation (seam top)	185.81	191.51	199.42	150.12	40.20	− 40.81	169.25	66.89	−149.92	− 52.99	112.48	81.10	− 52.30	38.74	−123.50	−623.69
	Seam thickness	2.47	1.78	1.41	1.92	2.34	2.14	3.23	2.37	2.41	2.15	2.29	2.09	3.26	2.08	1.89	2.00
	Coal thickness	2.44	1.78	1.36	1.82	2.25	2.08	Ⓣ 1.04	2.26	1.76	2.05	2.27	Ⓣ 0.73	Ⓣ 0.74	2.05	1.83	2.00
	Number of parting	0	0	1	1	1	1	1	3	2	2	1	1		1	2	0
B Seam	Depth to seam	168.00	135.71	82.70	189.58	222.18	410.64	420.00	447.22	490.33	437.15	394.87	255.05	317.29	325.42	534.42	843.91
	Elevation (seam top)	176.28	174.65	178.06	122.76	18.66	− 61.03	150.00	36.11	−182.85	− 83.88	87.79	58.95	− 79.67	15.07	−148.72	−634.60
	Seam thickness	Ⓣ 0.60	Ⓣ 0.40	Ⓣ 0.68	Ⓣ 0.85	Ⓣ 0.69	Ⓣ 0.60	Ⓣ 0.59	1.02	Ⓣ 0.61	Ⓣ 0.67	1.11	1.35	1.66	Ⓣ 0.72	Ⓣ 0.97	Ⓣ 0.79
	Coal thickness	0.60	0.40	0.68	0.85	0.53	0.51	D	1.02	0.44	0.67	1.11	Ⓣ 0.96	1.66	0.57	0.78	0.62
	Number of parting	0	0	0	0	2	2		0	1	0	0	3	0	2	1	1
C Seam	Depth to seam	186.60	160.19	W.O.	W.O.	242.11	424.69	W.O.	462.88	498.14	449.05	425.70	275.55	327.89	352.86	557.12	852.90
	Elevation (seam top)	157.68	150.17			− 1.27	− 75.08		20.45	−190.66	− 95.78	56.96	38.45	− 90.27	− 12.37	−171.42	−643.59
	Seam thickness	12.15	2.53			9.84	4.24		1.72	2.65	3.21	1.37	11.16	10.03	19.37	1.40	3.83
	Coal thickness	D	D (1.64)			D	D		1.04	2.56	3.20	D	10.97	9.93	18.18	1.37	3.31
	Number of parting		7						4	1	1		1	1	4	1	2

Note: Thickness of coal seam in W & S series are revised with stratigraphycal inclination, but others are not revised.

Ⓣ : Not minable because of thin thickness

D : Not minabe because of deterioration

W.O : Wash − out (by contemporaneous erosion) is presented. (Refer to Dwg. 6)

Consequently A seam becomes poor in the zone which extends over more than 3.5 Km running in the NW-SE direction with the width of about 200 - 400 m along a line connecting these drillings, and that is not minable. (Refer to Dwg. 12 a)

The distance between A seam and the base of Lower Sawah Tambang formation remains almost constant in the range of 15 - 20 m and in the southern part several thin coal layers are interbedded between them. While S-2 and DH-8 present twice the distance, namely, 40 m or so, W-8 and S-1 have much less, and the uppermost part of the coal bearing formation looks that it was denudated.

4.5.3 B seam

B seam exists on the horizon 20 - 25 m below A seam covering most of the area except for W-1. The seam thickness varies within the range of 0.40 m (SR-8) - 3.58 m (S-2). B seam, in general, has undergone an intensitive change in its thickness and feature. Coaly shale and shale are interbedded and the coal part is thin.

The minable areas are only the narrow ones of W-2, W-3 and W-8 and the other areas can hardly be the object of operation, since the coal seam is thin or split there.

In the minable areas of W-2, W-3 and W-8, although the thickness of coal seam is relatively small, respectively 1.02 m, 1.11 m and 1.66 m, it is made of completely coal without any partings.

B seam has been mined in limited narrow area.

A thin coal seam (occasionally coaly shale) exists between the horizons of A and B seams and is relatively continuous.

4.5.4 C seam

C seam exists about 20 - 25 m below B seam and is 40 - 50 m apart A seam. The coal seam most develops at S-1 with the whole thickness of 23.23 m. It is split into two seams of upper and lower ones towards north and east and the lower seam tends to get rapidly deteriorated. Also in the upper seam the similar deterioration can be seen even though it is not so rapid as in the lower seam. Around the area of drilling holes W-8, W-4, W-7 and DH-9, the upper seam in minable, however, in the area north of them, drillings showed deteriorating coal seam.

Accroding to the drawings on the goaf, C seam was mined in the range of about 5 Km in the strike direction and about 300 - 700 m in the dipwise along the outcrop line and the seam thickness was said to be 5 - 6 m. (No detailed data for the seam thickness are available).

In the downdip adjacent to the goaf, there remain some areas not to be mined due to mining technology.

The area where C seam develops seems to extend along the outcrop line in the strike direction, however, around the horizontal rock galley of Sawahlunto pit the mined area is narrow. This can be attributed to gas emission or technological probelms of mining, but there also arises a possibility to think that some areas were abandoned due to coal seam deteriorarion.

At W-1, DH-7, DH-7', DH-6, SR-7, SR-8, SR-2 and DH-2 sandstone strata exist on the upper horizon of C seam. It was deposited in the relatively higher area that of basement upheaval or adjacent to it and was in marginal depositional environments. It shows that a part or whole of the upper part of C seam was not deposited and/or denudated during or just after depostiion (contemporaneous errosion). Taking into consideration the deteriorating tendency of the upper seam shown at DH-9, W-7 and W-2 and its deteriorated condition found in the above drillings, it may be fair to say that thick and good coal seam was not deposited over the wide area of the downdip of the goaf. Then the existence of thick and good coal seam in this area is hardly expected.

Judging from the above distribution of C seam, the minable area is limited only to the southern part convering S-1, S-2

8, W-4, W-7 and DH-9, wherein, the coal reserve density (reserves / unit area) is high because the coal seam is very thick. The change of the coal seam thickness is shown in Dwg. 12 c.

4.5.5 Coal seam conditions in the southern area of S-1 and S-2

Since the reference is made only to the drilling result of DH-8, about 3.4 Km apart S-2, as a relaiable data on coal seams in the southern area of S-1 and S-2, the coal seams condition can be thought as follows, whatever a matter of conjecture it may be.

Depthes of coal seams : Referring to geographical and geological maps and based on the data concerning S-1, S-2 and DH-8, Dwg. 9 a and 9 c show structure contour lines of coal seams.

A seam : The seam conditions at S-1, S-2 and DH-8 are as follows:

	S-1	S-2	DH-8
Seam thickness (m)	2.08	1.89	2.00
Coal thickness (m)	2.05	1.83	2.00

(Workable sections only)

At DH-8 coaly shale exists in the upper part of coal seam having the thickness of 1.10 m. The whole seam thickness is 3.10 m, in which cores were taken only in the range of 0.23 m and the other part was lost. Even though the accouracy is not so high, there is a good possibility that 1.6 - 1.8 m thick coal seam exists, when it comes to thick of the constant distribution of A seam in the northern areas.

B seam : The seam conditions at S-1, S-2 and DH-8 are as follows:

	S-1	S-2	DH-8
Seam thickness (m)	0.72	0.97	0.97
Coal thickness (m)	0.57	0.78	0.62

(Workable sections only)

At DH-8 only partings were cored and the others were lost, with low accuracy. All is said and done, more than 1 m thick coal seam is hardly expected to exist, leading to pessimistic view on B seam which may not be workable.

C seam : The seam conditions at S-1, S-2 and DH-8 are as follows:

	S-1	S-2	DH-8
Seam thickness (m)	19.37	1.40	3.83
Coal thickness (m)	18.18	1.37	3.31

(Workable sections only)

At S-2 good coal of 1.40 m thick with underlying coaly shale of 6.5 m thick seems to be corresponed to the upper C seam. At DH-8 the coal seam conditions are similar to those at S-2 and the total seam thickness including to coaly shale is 7.33m. In both cases the upper C seam presents a detriorated condition. (At DH-8 drilling did not reach the lower C seam). Futhermore, in the case of DH-8 ash content of coal is very high, namely 22.9 - 33.4 % in most coals, the exception of 8.6 % rated in some coal (Thickness is 0.32 m). It is rather akin to coaly shale and the coal seam deterioration at DH-8 seems to have progressed much remarkably than those at S-2 (For reference : 8 % ash and 9.8 % yield at SG 1.35).

Equally, on the end of heading in the southern Lunto pit that is located in the southwest of S-1, the coal seam condition of C seam is likely to get deteriotated according to the drawing of the goaf

(Heading along C seam is changed to rocky one, but its details are unknown without any record).

Considering the above-mentioned matters as a whole, there is a possibility that the upper C seam may exist continuously from S-1 and S-2 to DH-8. But whether C seam is in the minable condition or not should be answered pessimistically, considering a noticable change of C seam.

Sulfur content of coal seams : Both A and C seams show high sulfur content.

Sulfur contents of individual coal seams are as follows:

		W-4	W-8	S-1	S-2	DH-8
A seam		N.A	N.A	2.1	1.0	N.A
C seam	Upper part	1.0	1.2	1.7	1.4	2.27
	Middle part	-	0.5	-	-	
	Lower part	1.2	0.9	-	-	
	Mean	(1.1)	(0.9)			

(%)

Note : At S-1 only in the upper seam washed coal at S.G. 1.35

In comparison with coal in the northern areas, that in the southern areas has the higher sulfur content and is considered to account for 1 - 2 % of sulfur content ratio.

Summarizing the coal seam conditions in the southern area of S-1 and S-2, the following (1) - (5) assumptions can be considered, even though there remain many points uncleaned yet.

(1) In the area having the extension of about 3 Km and width of 700 - 800 m along the basement fault which runs at the west limit of this area, the coal seam is less deeper than the elevation of -200 m.

(2) A seam exists in the stable condition with the coal thickness of 1.6 - 1.8 m.

(3) B seam can not be expected for mining.

(4) The upper seam of C coal exists continuously, but too much expectation cannot be placed on it whether or not it is minable.

(5) In both A and C seams the sulfur content of coal is rather high, 1.0 % or more.

Since it became clear as a result of the current survey that coal seams are exclusively developed around W-8, S-1 and S-2, future exploitation will be centered in this area. If so, it is desirable to carry out further surveys in the area of S-1 and S-2 southward where the coal seam is assumed not so deep and then to proceed with a comprehensive exploitation plan upon understanding the coal seam conditions in the southern area to a certain degree.

4.6 Sedimentary Environments Analyzed by Mineral Assemblage

4.6.1 Clay mineral assemblage

(1) Method and identification

Mudstone samples are crushed throughly in an agate mortar, spreaded on slide glasses and analyzed by X-ray diffractmeter. The measuring conditions were as follows:

Voltage / Ampare	: 35 Kv, 20 mA
Full scale	: 1,000 cps
Slit system	: 1° - 1° - 0.4 mm
Goniometer speed	: 2° /1 min.
Chart speed	: 2 cm /1 min.
Target	: Cukα (Carbon monochrometer)

Good results were obtained and such minerals as kaolin, chlorite, illite, quartz, etc. were identified. Some samples were observed using scanning electron microscope. The following basis were applied for identifying clay minerals examined this time.

Chlorite : A mineral which has reflection at 15 Å and 7 Å and no shift of 15 Å reflection by the glycerol treatment is identified as chlorite.

Kaolin : A mineral which has sharp reflection at 7 Å and 3.5 Å is identified as kaolin.

Illite : All minerals which have reflection at 10 Å were identified as illite.

* As for samples in which kaolin and chlorite coexist, identification was no trouble because of the difference between their quantity in it. Other minerals (quartz, feldspar, calcite, etc.) were easily distinguishable from diffraction pattern.

(2) Analytical result

9 samples of W-2 and 8 of W-4 were analyzed. The obtained X-ray diffraction patterns are shown in Dwg. 14 and analytical result in Table 10. Chlorite was found in small quantity only in Upper Sawah Tambang formation of W-2 (95.90 and 105.80 m). Illite exists in common quantity all over the formations, but it seems to decrease from the lower part of Sawahlunto formation to Sangkarewang formation. Kaolin exists in large quantity all over the formation, especially abundant in the horizon from the lower part of Lower Sawah Tambang formation to Sangkarewang formation. As to other minerals, quartz is found in common quantity in all the formations, together with samll quantities of feldspar, calcite, etc. (Their quantities were too small, to make an accurate examination).

It is said that kaolinite is commonly formed in the terrestrial environment. And also it is well-khown as a general phenomenon that kaolin occurrs in the formation lying below coal seams. The occurrence of kaolin in this

Table 10. Claymineral assemblages in W–2 and W–4

W – 2

Formation	Sampling depth (m)	Lithology	Clayminerals			Other minerals	Remarks
			Chlorite	Illite	Kaolin		
upper Sawah Tambang	95.90	greenish gray mudstone, silty	△	○	○	Quartz, (Calcite)	
	105.80	dark greenish gray mudstone	△	△	○	Quartz, (Calcite)	
lower Sawah Tambang	199.90	pale gray siltstone, tuffaceous ?		○	○	Quartz, (Feldspar, Calcite)	
	279.50	gray & dark yellow mudstone.		○	○	Quartz, (Feldspar, Calcite)	
	340.50 a	reddish brown mudstone		○	◎	Quartz, (Calcite)	
	340.50 b	pale gray mudstone, silty	(△)	○	◎	Quartz, (Feldspar, Calcite)	
Sawah Lunto	417.40	gray black mudstone, with carbonaceous mat. (intercalation of A-seam)			◎	Quartz, (Feldspar)	Well crystarized kaolinite
	441.90	gray mudstone		◎	◎	Quartz, (Calcite)	
	515.00	gray black siltstone, sandy		△	◎	Quartz, (Feldspar, Calcite)	

W – 4

Formation	Sampling depth (m)	Lithology	Clayminerals			Other minerals	Remarks
			Chlorite	Illite	Kaolin		
lower Sawah Tambang	47.00	brownish gray mudstone		○	○	Quartz, (Feldspar, Calcite)	
	163.95	dark violet gray mudstone		○	◎	Quartz, (Feldspar, Calcite)	
Sawah Lunto	204.90	gray mudstone, with organic mat.		○	◎	Quartz, (Feldspar, Calcite)	
	263.70	gray black mudstone, with organic mat.		○	◎	Quartz, (Feldspar, Calcite)	
	300.70	pale brownish gray mudstone		△	◎	Quartz, (Feldspar, Calcite)	
	328.35	pale brownish gray mudstone		(△)	◎	Quartz,	Well crystarized kaolinite
Sangkarewang	334.80	gray mudstone, silty		(△)	◎	Quartz,	Well crystarized kaolinite
	342.45	gray mudstone		△	◎	Quartz, (Feldspar, Calcite)	

△ poor , ○ common , ◎ abundant

( ) doubtful determination for poor contents.

area well corresponds to this fact. It is especially interesting from the viewpoint of effects of coal seam on the formation of kaolin (probably effects of organic acids) that the thin parting in coal seam at 417.40 m of W-2 is well crystallized kaolinite. It is considered that very small quantity of feldspar all over the formation in comparison with the sedimentary rocks in other areas means the deterioration of almost all feldspar to kaolin by suffering kaolinization due to terrestrial environment. Therefore, a part of quartz may also be considered of the secondary origin.

Samples of W-4, 328.35 m and 334.80 m contain well crystallized kaolin. The horizon corresponds to the lower part of Sawahlunto formation and uppermost part of Sang-karewang formation. These formations are geologically in a conformable relation and considered to have been formed in a transitional environment from fluvial to lacustrine. The progress of kaolinization can be explained by weak up-lift around the boundary of these formations or water affection along the boundary after sedimentation.

A view generally shared is that illite and chlorite are easily formed in marine environment, but on some occasions they are known to be altered to kaolin by kaolinization in a terrestrial environment.

The analytical result of samples from this area shows an increase of illite towards upper formation, and an appearance of chlorite in Upper Sawah Tambang formation contrary to an increase of kaolin towards lower formations. From the viewpoint of sedimentary mineralogy there is no discrepancy in the paragenic relation of these minerals. Namely, it shows that the lower the horizon of formation is, the more terrestrial its formation environment was and that the effect of sea water becomes more vivid gradually towards upper formation. Especially existence of chlorite in Sawah Tambang formation means that the environment of its formation differs from the terrestrial environment of the lower formation. Also calcite existing in small quantity all over the formation supports the terrestrial environments. Concerning the depositional environments of the formation the analytical result somewhat differs from the geological analysis described in chapter 4.3. Namely, it is considered that the formation having completely suffered the effect of marine environment in this area is Ombilin formation from the viewpoint of fossils and Upper Sawah Tambang formation was formed just in continental environment. Therefore, considering both geological data and results of clay mineral assemblage, it seems to be said that at least a part of the area of Upper

Sawah Tambang formation began to suffer the effect of marine environment owing to the development of some tidal channels there.

4.6.2 Pyrite and other minerals

Pyrite is important in terms of sulfur content in coal and more detailed description on it will be made later in Chapter 5.2. Pyrite in coal seam in this area partially coexists with marcasite. Pyrite filling up cleets or in the authigenetic form of 5 mm ø was found by visual observation. And also it is considered that some pyrite is in the franboidal shape since pyrite was not completely removed by a floatation of S.G. 1.50. However, no inorganic sulfur was found in coal matrix by the observation with a scanning electron microscope.

The sulfur content of coal in the survey area, in general, is such low as about 1 %, although some 2 % or so was marked. It is generally said that high sulfur content coal exists mainly in formations with the effects of sea water or under deposits of marine sedimentation, but in this area there exists about 600 m thick continental Sawah Tambang formation between the coal seams and Ombilin formation, which is of marine, and that the formation of coal seams is considered to be of fresh water origin. The sulfur contents in the coal is, consequently, not so high. Giving an evidence for assuming that the large part of pyrite and marcasite filling up cleets or authigenetic forms were caused by organic materials in raw materials of coal. Besides pyrite and marcasite, such components as siderite, calcite, aragonite, dolomite, etc. are found each in small quantity in Sawahlunto formation, however, they are not inconsistent with those which are considered as terrestrial - fresh water deposits.

4.7 Palynological Analysis

The palynological analysis was made on mudstone, coaly shale and coal taken in drilling holes of W-4 and S-1 as the representative samples of the area with a commission given to the Palyno Survey Co., Ltd. Tokyo, Japan. The occurrence of pollens and spores was very poor in samples of W-4, shallower than 250.50 m, whereas in other samples, those were sufficiently recognized. The samples and their occurrence conditions are summarized in Table 11 and Fig. 7.

4.7.1 Results

The analytical results are shown by percentages of numbers of pollens and spores detected in individual smaple to their total number. The range chart of detected pollens and spores based on the above data is shown in Fig. 7. Their microscopic photographs are shown in Fig. 8.

Table 11. Age determination from palynological analysis

Formation	Sampling depth & lithology		Age determination by pollen and spore
	W−4	S − 1	
Lower Sawah Tambang	101.50 mudstone 219.20 mudstone		Determination is impossible by poor or non occurrence of pollens and spores. --- ? ---
Sawahlunto	250.50 coaly shale 255.05 coal (B-seam) 280.40 coal (C-seam) 325.70 mudstone	352.86 coal (upper C-seam) 368.00 coal (lower C-seam)	Eocene~pre-Eocene --- ? ---
Sangkarewang	344.10 mudstone		Pre-Eocene (Palaeocene)

Fig. 7 Range chart of pollen & spore occurrence

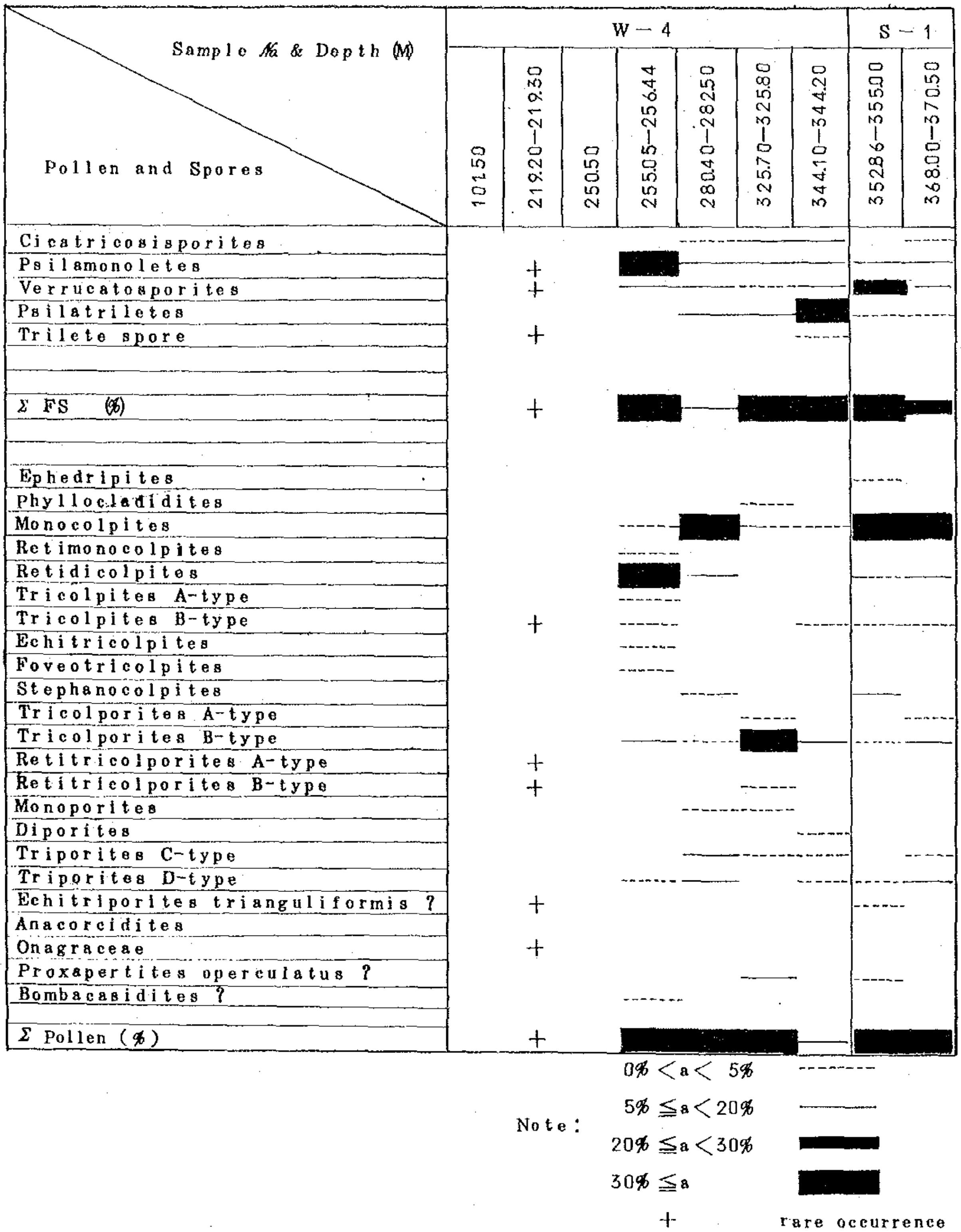
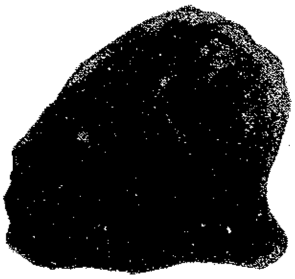
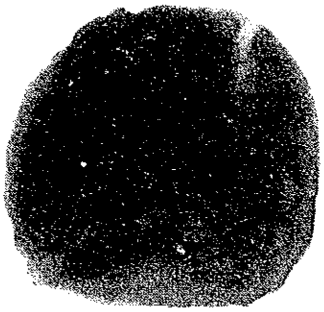


Fig. 8. Microscopic photograph of pollens occurred in Sawahlunto formation



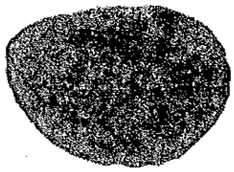
1

Cicatricosisporites
(W—4, 325.70m)



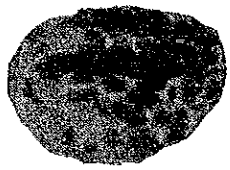
2

Cicatricosisporites
(W—4, 344.10m)



3

Verrcatosporites
(W—4, 344.10m)

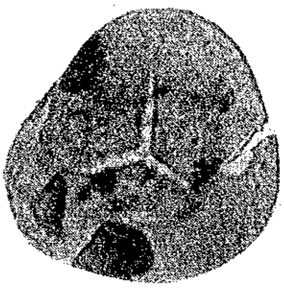


4

Verrcatosporites
(W—4, 255.05m)

5

Psilatriletes
(W—4, 344.10m)

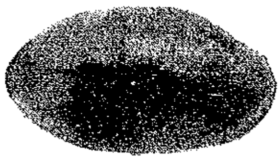


6

Psilatriletes
(W—4, 344.10m)

7

Monocolpites
(S—1, 351.86m)

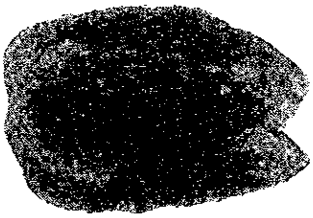


8

Monocolpites
(S—1, 351.86m)

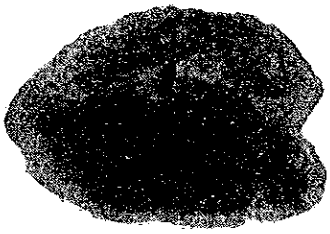
9

Monocolpites
(S—1, 351.86m)



10

Retidicolpites
(W—4, 255.05m)



11

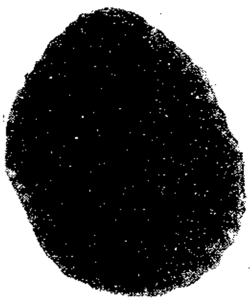
Retidicolpites
(W—4, 255.05m)

12

Tricolporites B—type
(W—4, 344.10m)

13

Foveotricolpites
(W—4, 255.05m)

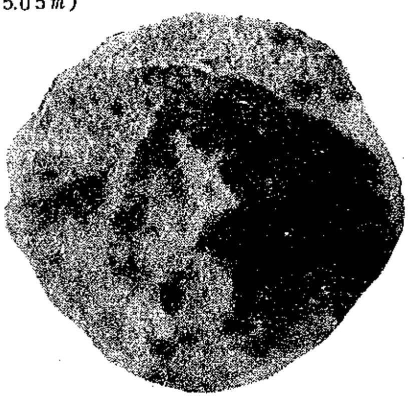


14

Foveotricolpites
(W—4, 255.05m)

15

Anacolosidites
(W—4, 219.20m)



16

Proxapertites operculatus ?
(S—1, 351.86m)

0 50μ

Below are the accounts of the palaeo-environment, age and so on, for each sample.

<u>W-4</u>

° 101.5 m

No pollen and spore were detected from the sample.

° 219.20 - 219.30 m

Pollens and spores detected were very few, numbered 27 in total. Those detected are mainly as follows: Psilamonoletes, Verrucatosporites, Retitricolporites B type, and R.A -type.

° 250.50 m

No pollen and spore were contained, the result of which made if difficult to make a full study on the palaeo-environment and others.

° 255.05 - 256.44 m

Total 127 microfossils were detected. Among them spores of Pteridophyta account for 43.3 % containing : Psilamonoletes 32.3 % and Verrucatoporites 11.0 %. Pollens account for 56.7 % containing : Retidicolpites 3.9 %, Tricolporites B-type 9.4 % and Retimonocolpites 3.9 %. Therefore, the floras composed of over 50 % of Angiospermae and remains of Pteridophyta can be considered for the palaeo-environment. The geological age of the sample is considered to fall on Eocene, since no Florschuetzia which is the index-fossil for the geological age of Post-Eocene in Southeast Asia was detected.

° 280.40 - 282.50 m

Total 101 microfossiles were detected. Most of them (83.24) were pollens originated from Angiospermae, with the main components: Monocolpites 34.6 %, Triporites D-type 14.9 %, T.C-type 11.9 %, Triporites B-type 11.9 % and Retidicolpites 7.9 %.

As spores of Pteridophyta, 7.9 % of Psilamonoletes, 6.9 % of Verrucatosporites and a small number of Cicatricosisporites were detected.

Therefore, it may be possible to consider in the palaeoenvironments Angiospermae were predominant. The geological age of the sample is considered to be older than those of the above-mentioned, probably Eocene or Pre-Eocene from the presence of Cicatricosisporties and the absence of Florschuethia.

° 325.70 - 325.80 m

Total 157 microfossils were detected, out of which 43.3 % were spores of Pteridophyta. Cicatricosisporites, Psilatriletes and Psilamonoletes were clearly detected respectively with the percentage of 19.7 %, 12.7 % and 9.6 %. It is the presence of abundant Cicatricosisporites features this sample.

As to pollen 37.6 % of Tricolporites B-type were detected followed by 10.2 % of Onagraceae, 3.2 % of Triporites C-type and 1.9 % of Tricalporites A type.

Therefore, it is possible to imagine such palaeo-environment were many plants of Pteridophyta were growing. Furthermore, it is considered that Angiospermae were more predominant than Pteridophyta.

The geological age of the sample seems to be Eocene or Pre-Eocene, since abundant Cicatricosisporites were detected.

° 344.10 - 344.20 m

Spores of Pteridophyta were detected in very large quantities, the percentage reaching 82 %. The component is 47.5 % of Psilatriletes, 17.2 % of Psilamonoletes, 9.0 % of Cicatricosisporites and 7.4 % of Verrucatosporites.

Speaking of pollen 12.3 % of or Tricolporites B-type was detected, as well as Tricolpites B-type, Triporites C-type, etc., each in small quantities.

Therefore, the palaeo-floras composed mainly of Pteridophyta is considered to have been the feature of the palaeo-environment, since many spores of Psilatriletes, Psilamonoletes, Cicatricosisporites and Verrucatosporites were detected.

The geological age of the sample may possibly be Eocene or before then.

S-1

° 352.86 - 355.00 m

39.1 % of Monocolpites was detected, followed by 10.0 % of Tricolporites B-type. Besides Ephedripites, Stephanocolpites, and Proxapertites operculatus were also detected, even though the number of them was very small.

As to spores of Pteridophyta, 27.3 % of Verrucatosporites and 6.4 % of Psilamonoletes were detected.

Therefore, it is considered that the plants of Pteridophyta-Angiospermae were thriven.

The geological age of the sample seems to be Palaeocene, since Proxapertites operculatus was detected. However, Eocene may also be a possibility, since the number of the above-mentioned microfossil was very small.

° 368.00 - 370.50 m

Abundant microfossils of Monocolpites, accounting for 41.4 %, were detected. Furthermore, 10.7 % of Tricolporites B-type was detected as well as Retidicolpites and Triporites D-type.

As to Pteridophyta, Psilamonoletes were predominant, accounting for 14.3 %, followed by 8.6 % of Verrucatosporites and 0.7 % of Cicatricosisporites.

Therefore, the palaeo-floras composed mainly of the above Angiospermae and Pteridophyta can be presumed.

The geological age of the sample is considered to fall on Eocene or before.

4.7.2 Considerations

The geological age of individual samples were described in the foregoing section and are summarized in Table 11.

As a result of the palynological analysis, the age of Sawahlunto formation (coal bearing formation) may be Eocene of or Pre-Eocene and there is a possibility that Sangkarewang formation at W-4 was found formed in Palaeocene.

Comparison of W-4 and S-1 samples shows that S-1 (C seam) has the most similar result to that of W-4, 280.40 m (C seam) and the stratigraphical correlation of individual coal seam coincides fairly with the results of the palynological analysis.

Since pollens in the form of Monocolpate which are considered as those of Palmae were well detected, it is presumed that the palaeoclimate was tropical.

Concerning the depositional environments, no proofs suggesting marine environments nor those for fresh water environment could not be found.

Many of detected pollens and spores suffered the deformation. This fact is considered to be due to the progress of carbonization or drift of materials (allochtonous coal).

CHAPTER 5

COAL QUALITY

CHAPTER 5. COAL QUALITY

5.1 General Description

All coal samples taken in the individual drillings were halved and they were analyzed and tested by both Indonesian and Japanese parties. The analysis and tests in Japanese side were conducted at Tokyo Coal and Mineral Research Institute on the basis of Japanese Industrial Standard (JIS).

The analysis and tests were executed only on samples taken from the workable sections of coal seams and these taken from thin coal seams, which has no possibility to be the object of mining, were omitted. At the time of sampling of coal samples such partings as coaly shale and sahle were previously removed and in the case of thick coal seam samples were taken separately from their upper and lower parts or upper, middle and lower parts. The sampling position of individual coal sample shall be referred to Dwg. 8.

Each sample was tested on the "raw coal" basis without gravity separation. The results (obtained by the Japanese party) are shown in Table 12 by drillings and coal seams.

The following description is mainly based on these results concerning the current survey area.

Table 12. Results of coal analysis and testing

	Hole №	W-2			W-3		W-4		W-7		W-8				S-1			S-2	
	Coal Seam	A	B	C	A	B	C-1	C-2	A	C	B	C-1	C-2	C-3	A	C-1	C-2	A	B
	Depth	416.44~419.10	446.86~448.34	462.83~463.60	370.18~372.56	394.87~396.22	275.55~280.40	280.40~287.16	406.26~408.50	449.05~452.40	317.29~319.00	327.89~331.00	331.00~334.00	334.00~338.56	301.75~304.00	352.86~364.50	364.50~372.50	509.20~511.67	557.12~558.72
Proximate Analyses (%)	Total Moisture	4.8	5.2	2.9	5.0	4.6													
	Inherent Moisture	4.7	4.7	2.9	3.4	3.5	3.5	3.6	3.8	3.1	4.1	3.2	3.1	3.0	3.4	3.1	3.4	3.3	2.4
	Ash	3.3	5.4	4.9	2.9	5.1	6.8	6.4	6.3	5.0	6.3	3.2	2.5	4.2	5.2	6.4	11.2	2.2	5.7
	Volatile Matter	39.4	36.8	41.4	40.2	37.9	39.1	38.0	38.8	40.2	36.1	39.7	41.1	39.5	37.3	37.6	34.6	40.9	41.9
	Fixed Carbone	52.6	53.1	50.8	53.5	53.5	50.6	52.0	51.1	51.7	53.5	53.9	53.3	53.3	54.1	52.9	50.8	53.6	50.0
	Total Sulfur	0.6	1.2	2.1	0.7	1.6	1.0	1.2	0.7	0.6	1.8	1.2	0.5	0.9	2.1	1.7	2.1	1.0	1.4
	Calorific Value (Kcal/kg)	7,440	7,310	7,530	7,610	7,410	7,280	7,370	7,360	7,620	7,370	7,780	7,740	7,680	7,490	7,440	6,910	7,770	7,610
	C.S.N	3 ½	3	4 ½	4	3 ½	4	3 ½	4 ½	4 ½	3 ½	4 ½	4 ½	4 ½	4	4	3 ½		
	Specific Gravity	1.33	1.34	1.31	1.29	1.32	1.33	1.33	1.33	1.30					1.33	1.34	1.38		
	Hardgrove Grindability Index	48	42	44	49	48	34	45	48	46	45	48	51	47	43	46	47	49	47
Ultimate Analyses (%)	C	78.1	76.3	76.3	78.3	76.5	75.8	76.5							77.5	76.4	71.5		
	H	5.5	5.5	5.8	5.5	5.3	5.8	6.0							5.2	5.1	4.9		
	N	2.1	1.9	1.8	2.2	2.0	1.7	1.8							1.9	1.8	1.6		
	O	10.2	9.5	9.0	10.4	9.4	8.8	7.9							8.0	8.5	8.3		
	Mineral Matter	3.5	5.7	5.1	3.0	5.3	7.1	6.7							5.3	6.6	11.6		
	Combustible Sulfur	0.6	1.1	2.0	0.6	1.5	0.8	1.1							2.1	1.6	2.1	1.0	1.4
Ash fusion point (℃)	Deformation	1,240	1,230	1,240	1,210	1,300	1,230	1,310	1,230	1,160	1,370	1,260	1,250	1,230	1,270	1,340	1,310	1,260	1,250
	Hemisphere	1,380	1,310	1,360	1,290	1,340	1,240	1,450+	1,330	1,200	1,450+	1,330	1,320	1,330	1,380	1,360	1,450	1,320	1,320
	Flow	1,390	1,350	1,390	1,330	1,370	1,250		1,380	1,230		1,380	1,340	1,350	1,400	1,370	1,470	1,370	1,340
Fluidity Test	Softning Temp. (℃)	413	407	407	409	411									410	404	407		
	Max. Fluidity (DDPM)	1.4	1.8	2.1	1.5	1.3									1.7	4.5	3.0		
	Max. Fluidity Temp. (℃)	426	420	432	423	423									428	430	432		
	Re-Solid (℃) Temp.	453	456	453	453	453									458	456	456		
	Range (℃)	40	49	46	44	42									43	52	49		
Ash Analyses (%)	SiO_2	48.66	38.78	25.94	34.54	35.54	39.48	41.83							40.93	29.14	41.62		
	TiO_2	0.63	0.99	0.65	0.49	0.97	0.33	0.81							0.57	0.58	0.68		
	Al_2O_3	27.27	26.21	18.80	16.96	26.41	8.68	32.27							19.49	23.80	30.45		
	Fe_2O_3	15.32	18.77	41.77	28.82	23.57	8.42	14.20							32.80	23.03	17.39		
	MgO	1.55	3.85	1.61	3.56	1.72	10.77	2.03							0.66	1.67	0.56		
	CaO	1.98	5.58	4.61	7.98	7.49	21.29	3.84							2.34	14.64	5.78		
	Na_2O	0.84	0.71	0.62	0.78	0.72	0.56	0.59							0.55	0.65	0.41		
	K_2O	1.58	0.88	1.27	0.54	1.09	0.20	1.25							0.51	0.67	0.77		
	P_2O_5	0.17	0.35	0.05	0.39	0.07	0.22	0.28							0.06	0.08	0.21		
	SO_3	1.82	3.77	3.93	5.83	2.25	9.69	2.58							1.37	5.15	1.85		

1) Analyses were prepared for the samples considered minable economically
2) Samples for w-1 were not analyzed because of poor thickness.
3) Analysed by Tokyo Coal and Mineral Research Institute.
4) Analysed on raw coal basis

5.2 Proximate Analysis, Total Sulfur, CSN and Calorfic Values

The average and range of qualities of raw coal from each coal seam is summarized as follows from Table 12.

(Raw coal base)

Items	A seam	B seam	C seam
I.M. (%)	3.7 (3.3-4.7)	4.1 (3.5-4.7)	3.0 (2.4-3.6)
Ash (%)	4.0 (2.2-6.3)	5.6 (5.1-6.3)	5.3 (3.4-6.6)
V.M. (%)	39.3 (37.3-40.9)	36.9 (36.1-37.9)	40.0 (37.6-41.9)
F.C. (%)	53.0 (51.1-54.1)	53.4 (53.1-53.5)	51.7 (50.0-53.5)
Fuel ratio	1.35 (1.31-1.45)	1.45 (1.41-1.48)	1.29 (1.19-1.41)
Total sulfur (%)	0.7 (Higher in southern area, 1.0-2.0)	1.5 (1.2-1.8)	1.3 (0.6-2.1)
C.S.N.	4 (3 $\frac{1}{2}$ - 4 $\frac{1}{2}$)	3 $\frac{1}{2}$ (3 - 3 $\frac{1}{2}$)	4 $\frac{1}{2}$ (3 $\frac{1}{2}$ - 4 $\frac{1}{2}$)
C.V. (Kcal/Kg)	7,530 (7,360-7,770)	7,360 (7,310-7,410)	7,540 7,330-7,730)

Note:

A seam : Arithmetical mean of W-2, W-3, W-7, S-1 and S-2.

B seam : Arithmetical mean of W-2 and W-8.

C seam : Arithmetical mean of W-2, W-4, W-7, W-8, S-1 and S-2.

C seam at S-1 : Only the results for sample taken at its upper part (C-1) were adopted here in order to unify the horizon.

C seam at W-4 and W-8 : The weighed average according to thcikness of individual sections were adopted here.

The value in ( ) shows the "range".

Furthermore, the coal qualities on the dry ash-free basis are calculated as follows:

Items	A seam	B seam	C seam
V.M. (%)	42.6	40.9	43.6
F.C. (%)	57.4	59.1	56.4
C.V. (Kcal/Kg)	8,160	8,150	8,220

Although it can be pointed out that among coals of the 3 seams coal of B seam has the somewhat lower volatile matter and coal of C seam has the slightly higher calorific value, these differences are very small, therefore, it is shown that coals of the 3 seams are of almost the same quality.

The coal qualities of these 3 seams can be classified as bituminous coal C_1 according to the classification of the Coal Field Exploration Council in Japan and correspond to class II, group 3, high volatile A bituminous coal according to ASTM.

The average sulfur contens in the Waringin area is considerably high (i.e. 0.7 % in A coal, 1.5 % is B coal 1.3 % in C coal) as compared to the same coal in Sawah Rasaw V (Table 13).

The properties of sulfur in the lower part (364.50 - 372.50 m) of C seam at S-1 were analyzed concerning kind of sulfur, sulfur contents by gravity separation and size (Table 14).

In spite of the fact that the same sample was used for the above-mentioned property examination of sulfur and float-and-

Table 13. Analysis of A and C coal in Sawah Rasau V

		A coal	C coal
Proximate analysis(%)	I. M.	5.1	4.8
	Ash	8.1	1.1
	V. M.	38.1	42.3
	F. C.	48.7	51.8
Total Sulfur(%)		0.50	0.22
C. V.(Kcal/kg)		7,050	7,710
C. S. N.		2½	3
Hardgrove Grindability Index		57.8	48.3
Ash fusion point (℃)		>1,450	1,380
Ultimate analysis (%)	C	82.1	80.2
	H	4.7	5.6
	O	10.8	12.7
	N	1.9	1.3
	S	0.5	0.2
	P	0.002	—

Analyzed by Akabira Colliery, Sumitomo Coal Mining Co.

Table 14. Properties of sulfur in the lower part of C seam at S-1 (364.50-372.50m)

Kind of sulfur

Property	Sulfur content (%)
Inorganic sulfur	
Pyritic sulfur	1.39
Sulfate sulfur	0.08
Organic sulfur	0.10
Total	1.57

Analyzed by Coal Mining Research Center, Japan.

Sulfur contents by gravity separation

Fraction	Individual			Cumulative		
	Weight (%)	Ash (%)	Sulfur (%)	Weight (%)	Ash (%)	Sulfur (%)
F1.25	44.8	1.9	0.54	44.8	1.9	0.54
S1.25-F1.30	19.4	5.2	1.33	64.2	2.9	0.78
S1.30-F1.40	11.7	13.3	2.51	75.9	4.5	1.05
S1.40-F1.50	8.9	21.0	3.41	84.8	6.2	1.29
S1.50-F1.60	6.0	30.3	4.20	90.8	7.8	1.49
S1.60-F1.70	4.9	37.9	5.29	95.7	9.4	1.68
S1.70-F1.80	1.0	43.8	5.31	96.7	9.7	1.72
S1.80	3.3	57.3	7.41	100.0	11.3	1.91
	100%	11.3%	1.91%			

Analyzed by Akabira Colliery, Sumitomo Coal Mining Co.

Sulfur contents by size

Size	Weight (%)	Sulfur (%)
-65mm +0.5mm	96.2	1.91
-0.5mm	3.8	1.74
	100.0	1.90

Analyzed by Akabira Colliery, Sumitomo Coal Mining Co.

sink test, sulfur contents differred. That is because of sampling bias.

From the results obtained by the above-mentioned tests it can be concluded as follows:

(1) Most of the sulfur of the Waringin coal are pyritic one.

(2) Since most of the pyrite particles are fine grained, dressing by specific gravity is not sufficient to reduce the sulfur content. (Reducing 1.9 % of sulfur content to less than 1 % accompanies about 70% of the recovery).

However, as these test resutls were obtained by revealed only from single sample, it is recommended to do more examinations.

the comparative study of the coal quality of A seam between the surveyed area and the northern area (holes: SR-2, SR-4, SR-7 and SR-8) is given below. As for as A seam is concerned carbonization is seen more progressed in the southern part than in the northern part.

Coal qualitities of A seam (Dry ash-free basis)

Item	Northern area (S.R.V. & its adjacent	Waringin area
V.M. (%)	43.6	42.6
F.C. (%)	56.4	57.4
C.V. (Kcal/Kg)	7,850	8,160

Note : The analytical values for coal in the northern area are the arithmetic means of those at SR-2, SR-4, SR-7 and SR-8.

The analytical values for coal in Waringin area are arithmetic means of those at W-2, W-3, W-7, S-1 and S-2. (above-mentioned)

5.3 Ultimate Analysis

The mean values of ultimate analysis of individual seam are summarized as follows:

Mean values of ultimate analysis

Item	A seam	B seam	C seam
	(%)	(%)	(%)
Carbon	78.0 (77.5-78.3)	76.4 (76.3-76.5)	76.3 (76.2-76.4)
Hydrogen	5.4 (5.2-5.5)	5.4 (5.3-5.5)	5.6 (5.1-5.9)
Nitrogen	2.1 (2.1-2.2)	1.9 (1.9-2.0)	1.8 (1.8-1.8)
Oxygen	9.5 (8.0-10.4)	9.5 (9.4-9.5)	8.6 (8.3-9.0)
Sulfur	1.1 (0.6-2.1)	1.3 (1.1-1.5)	6.2 (5.1-6.8)
Carbon (d.a.f.)	81.2 (80.7-81.8)	80.8 (80.8-80.9)	81.3 (80.4-81.8)
H / C (In number of atoms)	0.83 (0.81-0.85)	0.85 (0.83-0.87)	0.88 (0.80-0.93)
O / C (In number of atoms)	0.09 (0.08-0.10)	0.09 (0.09-0.09)	0.08 (0.08-0.09)

Note: A seam : Arithmetic mean of W-2, W-3 and S-1

B seam : Arithmetic mean of W-2 and W-3

C seam : Arithmetic mean of W-2, W-4 and the upper part of S-1.

Values in ( ) shows the range.

The assay results were plotted in relation to each carbonization degree, which is shown in Fig. 9, 10, 11 and 12. The difference between the assay results of each seam is very small and coals of this property belong to the medium bituminous rank.

From the above table the nitrogen and sulfur content are considerably high. In Japan, coal fired power stations prefer coal of less than 1.7 % nitrogen and if necessary less than 1.6 % of nitrogen.

5.4 Hardgrove Grindability, Ash Fusion Temperature and Analysis of Ash

5.4.1 Hardgrove grindability

The hardgrove grindability of coal in each seam is summarized as follows from Table 12.

Item	A seam	B seam	C seam
Hardgrove grindability index	47(43-49)	45(42-48)	47(44-51)

Note: These values were calculated from samples taken in 5 drillings for A seam, those in 3 drillings for B seam and those in 6 drillings for C seam.

Hardgrove grindability index over 45 is usually recommended for coal for power stations, there is then no problem here in 3 coal seams. Coal in the upper part of C seam at W-4 has very low hardgrove grindability (34) compared with others, but it is an exception.

Fig. 9 The relation between calorific values and carbon contents (d. a. F.)

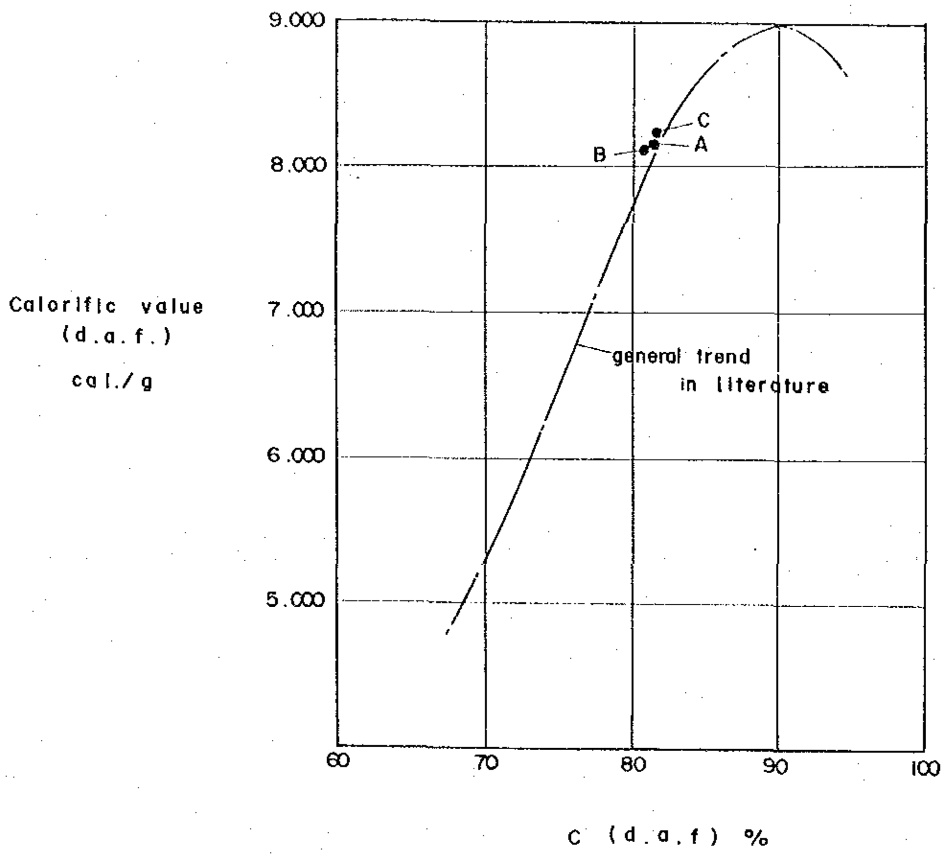


Fig. 10. The relation between O^*/C^* ratios (in number of atoms) and carbon contents (d. a. f.)

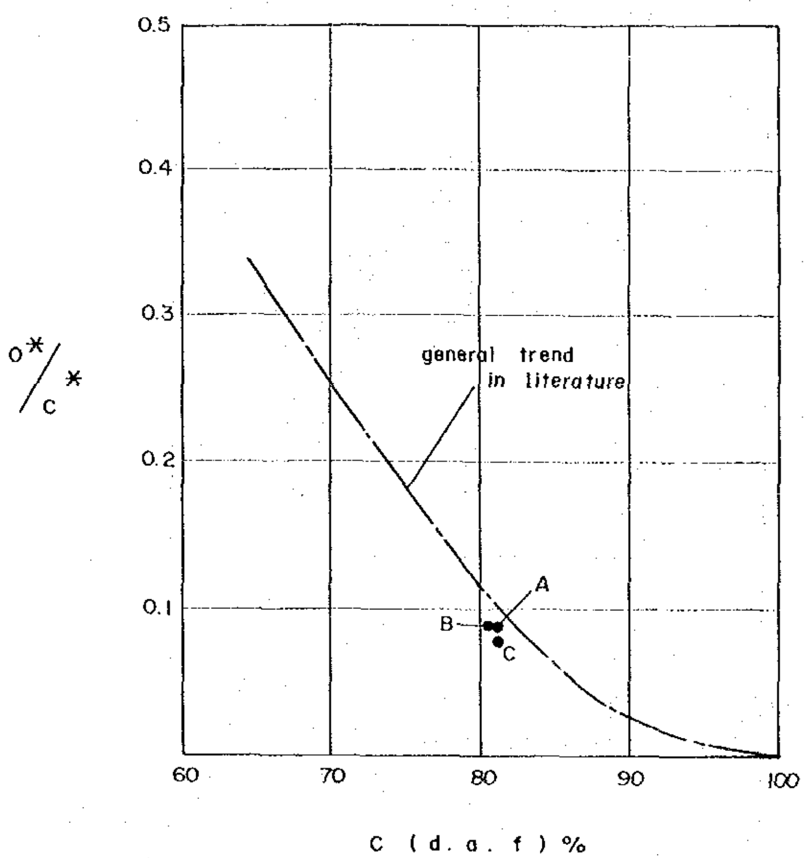


Fig. 11. The relation between H^*/C^* ratios (in number of atoms) and carbon contents (d. a. f.)

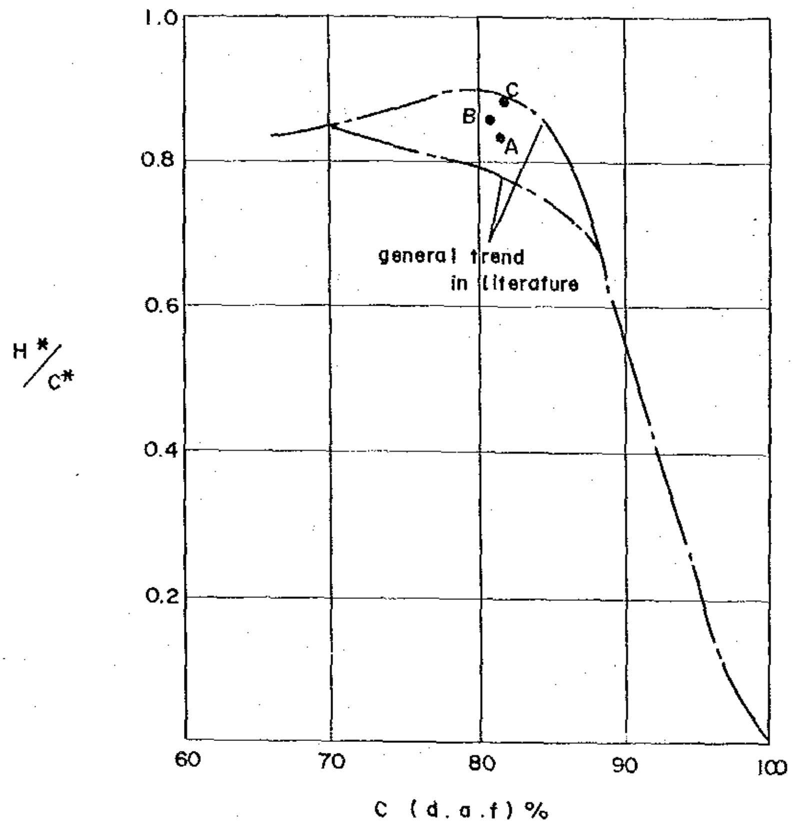
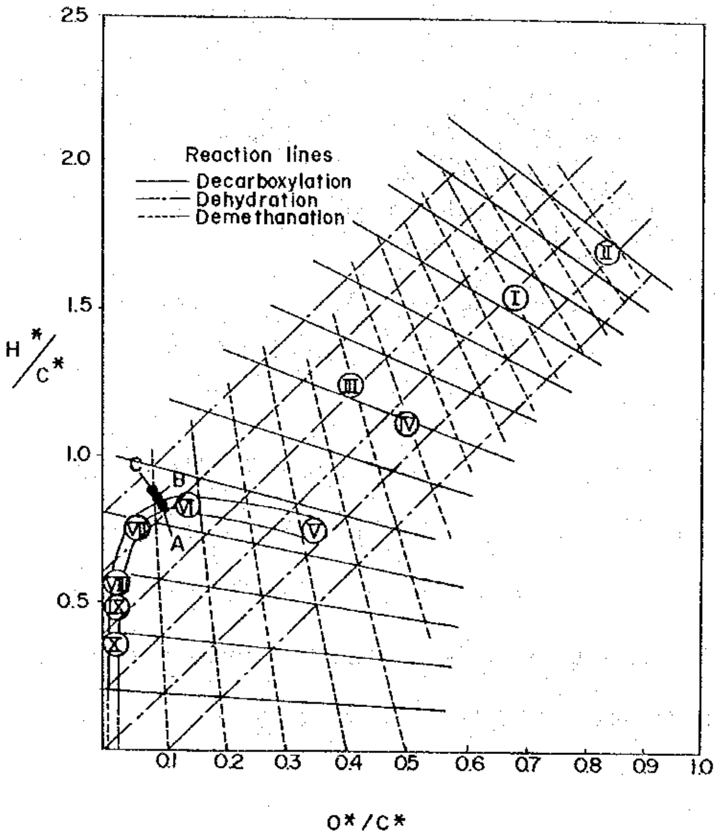


Fig. 12. The relation between H^*/C^* ratios and O^*/C^* ratios (in number of atoms) — Krevelen



Ⅰ: Wood
Ⅱ: Cellulose
Ⅲ: Lignin
Ⅳ: Peat
Ⅴ: Browncoal
Ⅵ: Low-rank bituminous coal
Ⅶ: Medium-rank 〃
Ⅷ: High-rank 〃
Ⅸ: Semi-anthracite
Ⅹ: Anthracite

5.4.2 Ash fusion temperature

The ash fusion temperature of coal in each seam is summarized as follows:

Item	A seam	B seam	C seam
Deformation (C°)	1,240 (1,210-1,270)	1,300 (1,230-1,370)	1,260 (1,160-1,340)
Hemisphere (C°)	1,340 (1,290-1,380)	1,370 (1,310-1,400+)	1,340 (1,200-1,450)
Flow (C°)	1,370 (1,330-1,400)	1,390 (1,350-1,400+)	1,360 (1,230-1,470)

Note: These values were calculated from samples taken in 5 drillings for A seam, those in 3 drillings for B seam and those 6 drillings for C seam.

The deformation point of over 1,150C° and hemisphere point of over 1,300 C° are desirable for coal for power stations. Therefore, it is considered that there is no probelm for coals in the 3 coal seams, but in the upper part of C seam at W-4 (275.55 - 280.40 m) and in C seam at W-7 show lower hemisphere points of 1,200 - 1,240 C°.

5.4.3 Analysis of ash

The ash analysis of coal in each seam is summarized as follows from Table 12.