JICA

PRE-FEASIBILITY STUDY REPORT
ON
THE LUBHUKU COALFIELD DEVELOPMENT PROJECT
IN
THE KINGDOM OF SWAZILAND

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JAPAN INTERNATIONAL
COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Kingdom of Swaziland, the Government of Japan decided to conduct a study on the Lubhuku Coalfield Development Project and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Swaziland a study team headed by Mr. Hajime Nozaki from 22 November, 1983 to 9 March, 1984 and from 5 June, 1984 to 1 March, 1985.

The team exchanged views on the Project with the officials concerned of the Government of Swaziland and conducted a field survey and collection of necessary data for coal mine development in the Lubhuku area. After the team returned to Japan, further geological and pre-feasibility studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Swaziland for their close cooperation extended to the team.

January, 1986

Keisuke Arita

Keisuke Arita

President
Japan International Cooperation Agency

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SUMMARY

SUMMARY

1. Background

The Kingdom of Swaziland has depended upon imported energy for about 40% of its demand. The Swaziland Government strongly intends to develop coal, which is the most important energy resource in the country, in order to achieve self-sufficiency of energy resources, to meet future increase of energy demand and to obtain foreign currency by export of coal. Thermal power plant project using domestic coal is now under studying.

2. Investigation

This study is to ascertain the modes of formation of coal seams in the Middle Ecca Formation occurring in the northern part of the Lubhuku area, and to prepare a draft of coal mine development plan for future planning of exploration and exploitation of the coal in the area.

A fieldwork was done in the fiscal years 1983 and 1984 and pre-feasibility study has been carried out in the fiscal year 1985. Total drilled length in this investigation sums up to 7,893.06 m in 20 boreholes.

3. Geology

More than 20 coal seams were found in the Lower Coal Zone of the Formation during the investigation. Three major coal seams, the Intermediate Marker, Main Seam and Footwall 3, are consistently distributed in the lower part of the Zone and the Main Seam is predominant among them. The Main Seam trends north-south, dips east around 5° and is gently folded. The seam thickness mostly exceeds 2.0 m throughout the area and attains 3.0 to 5.0 m in the northern part of the area.

Sills and dykes of the Karoo Dolerite extensively intruded in the area and have had thermal alteration on the surrounding coal seams. Intrusion frequency of the dolerite is low in the northern part of the area.

Most of the coals are classified into semi-anthracite and some of them are anthracite. The quality of the Main Seam compares favourably with that of the Mpaka mine and Natal anthracite. Therefore, the Lubhuku coal has the same marketability as these coals.

Total coal reserves of the three major coal seams in the area sum up to about 220 million tons and of these about 53% are in the Main Seam. Minable reserves of the Main Seam are calculated at about 69 million tons, 35 million tons of which are in the northern part.

On the basis of the study on seam thickness, depth of occurrence and minable reserves per unit area of the Main Seam and dolerite intrusions, the Main Seam in the northern part of the area is considered to be favourable. Consequently, the Main Seam in this northern part is selected for development.

4. Mine Development

A draft of coal mine development plan is prepared mainly from technical viewpoint and initial investment for the development and production cost at mine site are roughly estimated.

(1) Development Schedule

Detailed engineering	1st year
Procurement, construction and installation	2nd to 5th year
Full production	6th year and after

(2) Production Plan

4th year	100,000 tons (clean coal)
5th year	340,000 tons (clean coal)
6th year and after	510,000 tons (clean coal)

(3) Mining Plan

Development method: 2 inclined shafts (trackless and belt inclines), main entry (5 entries) and cross main entries (7 entries).

Mining method: Room and pillar mining method using continuous miner, shuttle car and roof bolter.

Raw coal production:

- Working days: 240 days/year
- Operating system: 4 shifts/day (1 shift for maintenance)
- Working face: 3 faces with 1 standby face
- Daily production: 2,670 tons (279 t/shift/face)
- Annual production: 640,000 tons

Transportation:

- Raw coal: Belt conveyor
- Workers and materials: Trackless carrier
- Ventilation: Central ventilation system
  - Air intake: Trackless incline
  - Air return: Belt incline

(4) Coal Preparation

Preparation process: Primary screening, hand picking, crushing, secondary screening, heavy medium separation, drain and rinsing screening and tertiary screening.

Clean coal production:

Feed (raw coal):	640,000 tons/year	
Clean coal:	510,000 tons/year (yield: 80%)	
Operating system:	2 shifts/day with 1 shift for standby and maintenance	
Capacity:	Primary crushing:	300 t/hr
	Preparation:	200 t/hr

Clean coal products:

Duff (0-22 mm), peas (10-22 mm), nuts (22-38 mm) and cobbles (38-75 mm)

(5) Personnel Plan

Total 298 persons (underground: 183, surface: 115)

(6) Initial Investment

US dollars 26.9 million

(7) Production Cost at Mine Site

around US$16.00/ton (clean coal)

5. Conclusion

It is concluded that development of new coal mine in the northern part of the Lubhuku area is a hopeful project to supply coal for both domestic and export markets.

PART I. GENERAL

CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 Energy Situation in Swaziland

The total quantity of energy supply in the Kingdom of Swaziland was approximately 20,000 $\times 10^9$ KJ (crude oil equivalent: 510,000 Kl) in the fiscal year 1980, 62.2% of which was domestically produced energy and 38.4% were imported (0.5%of transmission loss of electricity was included). Industrial waste by-products supplied 49.6% out of 62.2% of the domestic produced energy, 5.3% were supplied by coal (Mpaka mine),5.1% by firewood and 2.2% by hydroelectric generation. The imported energy was all from the Republic of South Africa and comprised 22.8% of oil, 11.9% of coal and 3.6% of electric power. On the other hand, 30.9% of the total energy was consumed by sugar industry, 25.5% by pulp industry, 16.5% by transportation industry, 9.7% by domestic sector, 5.2% by mining industry, 3.6% by agricultural sector and 3.1% by commercial sector.

5,340 $\times 10^9$ KJ of coal (equivalent to 176,000 tons) was produced by the Mpaka mine which is the only working colliery in Swaziland, and this amount was equivalent to 26.7% of the total energy supply. However, only 19.9% of the produced coal, which was equivalent to 5.3% of the domestic energy supply, was consumed in the country, and the remaining 80.1%were exported to foreign countries. This exported coal is an important source to acquire foreign currency for the country.

Primary energy and total electricity demands of Swaziland in the year 2000 are forecasted as follows (based on energy demand in the fiscal year 1980 = 100%);

Year 2000	Primary Energy	Total Electricity
Minimum Forecast	125%	160%
Maximum Forecast	150%	255%

As shown above, it is characteristic that the growth of the total electricity demand is remarkably large as compared with the increase in the primary energy demand.

Based on the investigation carried out to date, favourable resources of geothermal and nuclear fuel have not been found in the country. Consequently, coal, hydroelectric generation and industrial waste by-products are important domestic energy resources in Swaziland. However, there are only a few favourable locations for reservoirs and hydroelectric power stations in the country. Although supply of industrial waste by-products has remarkably increased in recent years, future growth of industry which will produce waste by-products is considered to be not so large. Such being the circumstances, these resources have their limits for future supply of energy.

Accordingly, coal, abundant reserves of which are expected in the country, is the most important domestic energy resource in Swaziland in future.

1.2 Circumstances of the Project

The Kingdom of Swaziland strongly intends to achieve self-sufficiency of energy resources as one of the major targets of the National Development Plan since fiscal year 1978, as the country has depended upon imported energy from the Republic of South Africa for about 40% of its demand. Especially, domestic coal is an important energy resource for Swaziland in future, and the Government greatly expects to solve the dependence on foreign countries for energy, to develop industrial activities and to increase employment opportunities by means of development of the coal resources.

Recently, the Government is studying a construction plan for a thermal power plant utilizing domestic coal resources in cooperation with the Government of the Republic of South Africa, and has taken a step forward to achieve the goal. Besides this, the Ngwenya iron mine, which had been developed to export iron ore to Japan and was one of the main foreign currency earners over the past fifteen years, was closed in 1978. Consequently, the Government intends to acquire foreign currency by the export of coal instead of that of iron ore in order to promote the economic development of Swaziland.

Exploration of coal in Swaziland has been performed discontinuously over the past century by the Government (Geological Survey and Mines Department) and private enterprises. However, most of the exploration was concentrated in a shallow part of the Swaziland coalfield. The Government paid attention to coal resources occurring in a deep part where few explorations have been performed. The Government prepared the Deep Coal Drilling Project to evaluate the potential of the deep coal resources and to study the development of a coal mine for the purpose of establishing a long-term energy policy for Swaziland.

Under the circumstances, the Swaziland Government requested technical cooperation from the Government of Japan for executing the Deep Coal Drilling Project in May, 1979. The Government of Japan complied with the request, and the "Scope of Work" stated the extent and contents of the exploration was concluded between the Japan International Cooperation Agency (JICA) and the Government of Swaziland on March 25, 1980 for the Lubhuku area which has top priority and is favourably located among five target areas proposed by the Swaziland Government.

The JICA team was organized to carry out the exploration. The exploration had been performed during fiscal years 1980 to 1982 including the drilling of 28 boreholes at 2 km intervals, and resulted in obtaining total coal reserves of 186 million tons in the investigated area. It has revealed that favourable coal seams occur in the northern part of the Lubhuku area.

Based on the results obtained, the Government of Swaziland decided to execute further drilling investigation in the northern part of the Lubhuku area which is considered to be promising. The Government had submitted a request to the Government of Japan for technical cooperation on the execution of this investigation. "Scope of Work" stated the extent and contents of the in-

vestigation including pre-feasibility study was signed between the Japan International Cooperation Agency and the Government of Swaziland on June 30, 1983. Technical cooperation on the Lubhuku coalfield development project was successively carried out. The JICA team was organized again to conduct the investigation, and the work was started in November, 1983.

1.3 Purpose of the Investigation

The object of investigation in this project is coal seams which occur in the Lower Coal Zone of the Middle Ecca Formation of the Karoo Supergroup in the northern part of the Lubhuku area in the Swaziland coalfield, especially those which exist in the deep part more than 200 m below the surface.

The investigation involved studying the modes of formation of the coal seams in preparation of basic data (depth and thickness of the coal seams, minable reserves, etc.), and to prepare a draft of a coal mine development plan as a model case by means of the pre-feasibility study mainly from a technical standpoint based on the results of the investigation. These studies will contribute to the making a plan of exploration and exploitation of these coal seams in future.

1.4 Method, Period and Organization of the Investigation

Drilling of 20 holes was the principal item of the investigation, and geophysical logging in the drilled holes, magnetometry survey around the planned drilling site and collection of data and information for the preparation of the draft of the coal mine development plan were also performed. The investigation for the fiscal year 1983 was started in November and completed in March, 1984 on schedule, although torrential rain accompanied by the greatest cyclone in the history of Swaziland fell in the area. The investigation in the fiscal year 1984 was started in June and completed in February, 1985 on schedule. Total drilled length exceeded the target through efforts devoted by all staff concerned in spite of interruption of the work caused by the torrential rain accompanied by a cyclone.

The drilling work in the fiscal year 1983 was subcontracted by Interdrills (Pty) Ltd. of the Republic of South Africa. However, the Government of Swaziland carried out the drilling work in the fiscal year 1984, employing the drilling machines provided by the Japan International Cooperation Agency. The drilling technique was transferred from the Agency to the Government of Swaziland during this drilling work. The geophysical logging (executed by BPB Instruments Ltd.) and magnetometry survey were carried out by the Government of Swaziland.

Main contents of the investigation are as follows:

Drilling Investigation:

Fiscal Year 1983: 4 holes, total length 1,500.06 m
Fiscal Year 1984: 16 holes, total length 6,393.00 m
Total: 20 holes, total length 7,893.06 m

Note: 28 boreholes were drilled with a total length of 10,660.84 m in the previous investigation. The grand total of drilling length sums up to 18,553.90 m in 48 boreholes since fiscal year 1980.

Magnetometry survey:

Fiscal Year 1983: 4 sites

Fiscal Year 1984: 16 sites

Geophysical logging:

Fiscal Year 1983: 3 holes

Fiscal Year 1984: 2 holes

Note: The logging was made only at 2 holes in the fiscal year 1984 because of circumstances in Swaziland.

In the fiscal year 1984, drilling engineers were dispatched to Swaziland for technical transfer of drilling to the Government of Swaziland, and also site investigation was conducted for the preparation of the draft for the coal mine development plan. In the fiscal year 1985, mechanical engineers were dispatched to the country for the maintenance of the drilling machines provided to the Swaziland Government. The Government of Swaziland extended conveniences such as transportation of equipment and staff, immigration services for the JICA team, office and office equipment for desk work, and tax exemption procedures for investigation instruments.

The summary of the investigation process and engineers engaged in the works are shown in Figure I-1. Table I-1 shows the members of the JICA team and counterparts of Swaziland.

The JICA team explained the draft report in detail to those concerned of the Government of Swaziland in November, 1985, and the report was accepted by the Government.

The authorities of the Swaziland Government in charge of the investigation are the Geological Survey and Mines Department of the Ministry of Natural Resources and Energy, and the Department of Economic Planning and Statistics is in charge of international cooperation.

Views of the investigated area and execution of the drilling works are shown in Plates 1 and 2.

Figure I-1 General Views of Works in Swaziland

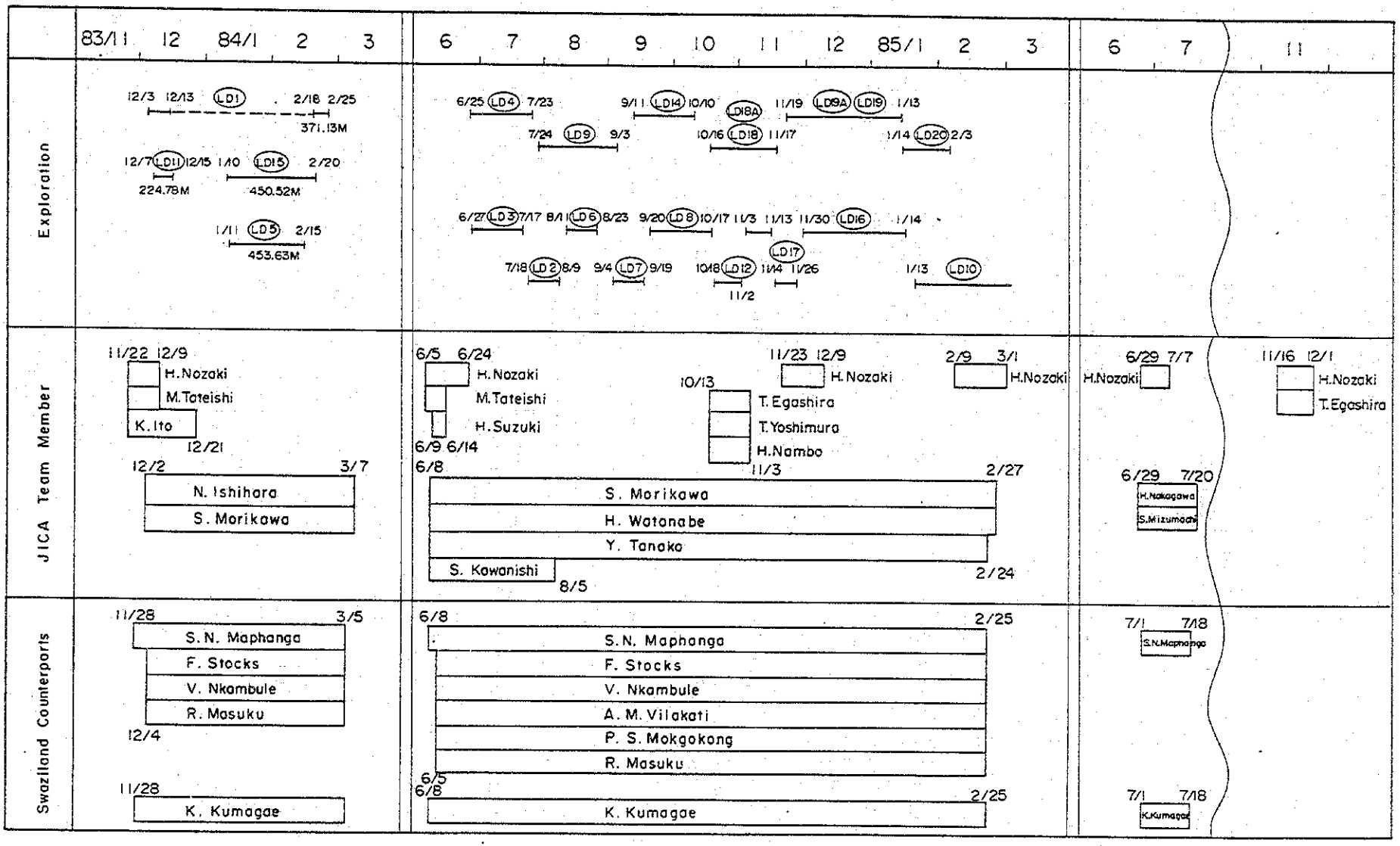


TABLE I-1. MEMBERS OF JICA TEAM AND SWAZILAND COUNTERPARTS

(A) JICA TEAM

Name	Charge	Position	Period
Haruo Suzuki	Representative	Head, Energy & Mineral Resources Survey Division, Mining & Industrial Planning and Survey Department, Japan International Cooperation Agency	F
Masaru Tateishi	Coordinator	Geologist, Energy & Mineral Resources Survey Division, Mining & industrial Planning and Survey Department, Japan International Cooperation Agency	A1, A2
Hajime Nozaki	Leader, Geology	Consulting Geologist, Registered, Engineering Department, Sumitomo Coal Mining Co., Ltd.	A1,A2,A3 B1,B2,C2 E3,H
Kimihiko Ito	Geology	Chief Geologist, Engineering Department, Sumitomo Coal Mining Co., Ltd.	A1,C1
Norio Ishihara	Geology, Drilling	Geologist, Engineering Department, Sumitomo Coal Mining Co., Ltd.	D1
Shin Morikawa	Geology, Drilling, Survey	Geologist, Engineering Department, Sumitomo Coal Mining Co., Ltd.	D1, D2
Hideaki Watanabe	Drilling, Survey	Geologist, Engineering Department, Sumitomo Coal Mining Co., Ltd.	D2
Shigeru Kawanishi	Drilling Expert	Drilling Supervisor, Engineering Depart-Ment, Sumitomo Coal Mining Co., Ltd.	E1
Yukio Tanaka	Drilling Expert	Assistant Drilling Supervisor, Engineering Department, Sumitomo Coal Mining Co., Ltd.	E2
Tadashi Egashira	Mine Develop-ment	General Manager, Engineering Department, Sumitomo Coal Mining Co., Ltd.	G, H
Toshihiko Yoshimura	Mine Develop-ment	Chief Mechanical Engineer, Combustion Equipment Department, Sumitomo Coal Mining Co., Ltd.	G
Hiroshi Nambo	Mine Develop-ment	Mining Engineer, Engineering Department, Sumitomo Coal Mining Co., Ltd.	G
Hiroshi Nakagawa	Machine Maintenance	Mechanician, Engineering Department, Sumitomo Coal Mining Co., Ltd.	I
Haruji Mizumachi	Machine Maintenance	Mechanician, Engineering Department, Sumitomo Coal Mining Co., Ltd.	I

Note:

A1: Preparation I November 22 to December 9, 1983

A2: Preparation II June 5 to June 14, 1984

A3: Preparation III June 29 to July 7, 1985

B1:	Final Management I	February 18 to March 9, 1984
B2:	Final Management II	February 9 to March 1, 1985
C1:	Fieldwork I	December 10 to December 21, 1983
C2:	Fieldwork II	June 15 to June 29, 1984
D1:	Main Fieldwork I	December 2, 1983 to March 7, 1984
D2:	Main Fieldwork II	June 8, 1984 to February 27, 1985
E1:	Drilling Instruction I	June 8 to August 5, 1984
E2:	Drilling Instruction II	June 8, 1984 to February 24, 1985
E3:	Drilling Countermeasure	November 23 to December 9, 1984
F;	Machine Providing Ceremony	June 9 to June 14, 1984
G:	Investigation of Mine Development	October 13 to November 3, 1984
H:	Draft Report Explanation	November 16 to December 1, 1985
I:	Machinery Maintenance	June 29 to July 20, 1985

(B) SWAZILAND COUNTERPARTS

Name	Charge	Position
S.N. Maphanga	Coordinator Geology	Head of Coal Unit, Geological Survey and Mines Department, Ministry of Natural Resources and Energy (MNRE)
F. Stocks	Drilling	Drilling Superintendent, Geological Survey and Mines Department, MNRE
A.M. Vilakati	Geology	Deputy Director, Geological Survey and Mines Department, MNRE
V. Nkambule	Geology	Geologist, Geological Survey and Mines Department, MNRE
P.S. Mokgokong	Geology	Geologist, Geological Survey and Mines Department, MNRE
R. Masuku	Drilling	Technical Assistant, Geological Survey and Mines Department, MNRE
K. Kumagae	Coordinator	JICA Expert, Geological Survey and Mines Department

Plate 1. Photographs of Investigated Area

Landscape of the Lubhuku area.
A distant view from the Lebombo Mountains.
The investigated area is located in the low land near the centre. Manzini-Siteki national road is running in the right.

Plate 2. Photographs of Drilling Work

1. Handing over ceremony of drilling machine at the Prince of Wales stadium in Mbabane held on 13th June, 1984.
2. Truck-mounted drilling machine (YBM 4) provided by JICA is removing to drilling site during rainy season.
3. Drilling work in the nighttime.

Plate 1

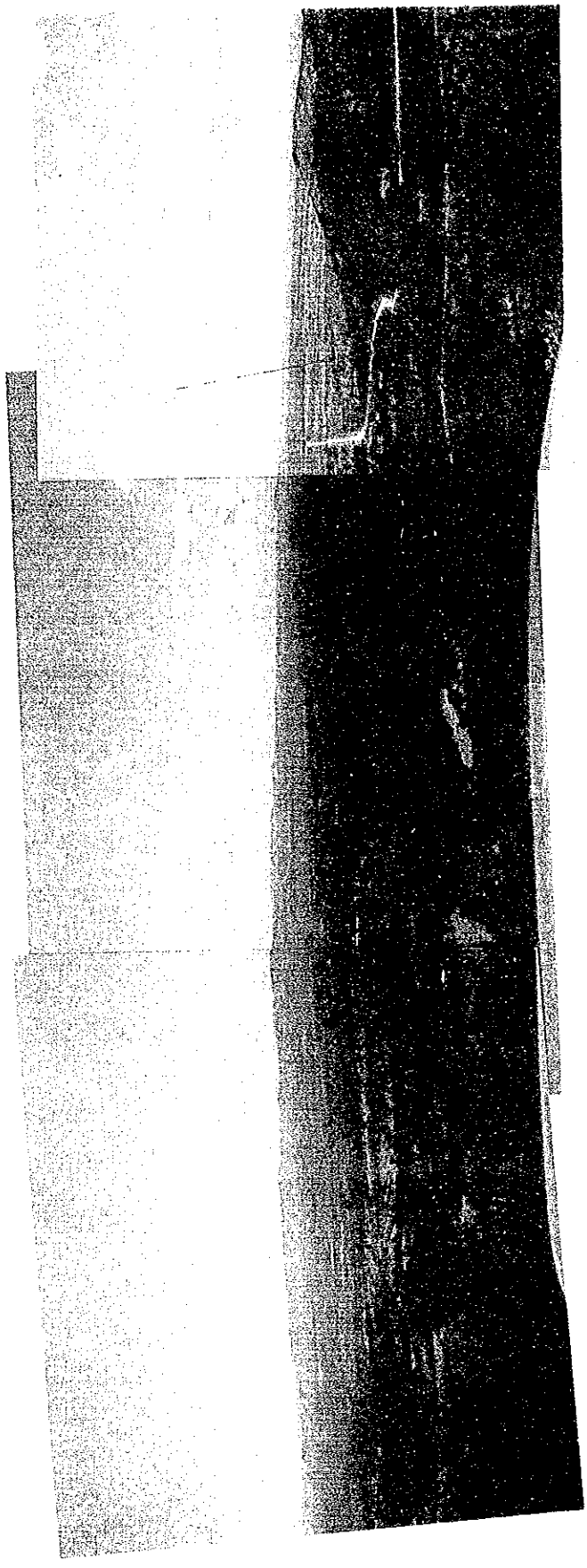
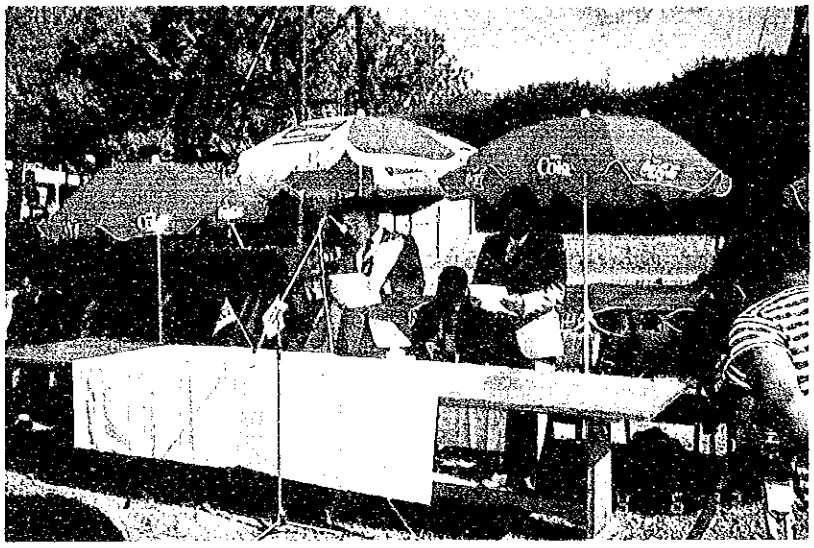


Plate 2



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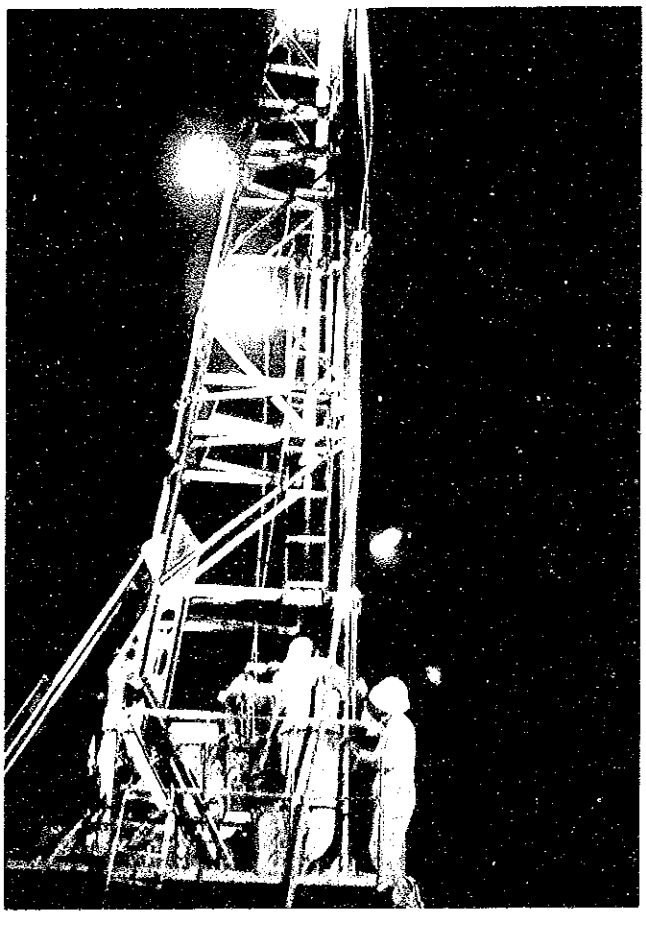


3

CHAPTER 2. GENERAL DESCRIPTION OF THE LUBHUKU AREA

CHAPTER 2. GENERAL DESCRIPTION OF THE LUBHUKU AREA

2.1 Location and Access

The Lubhuku area is located in the Lubombo District in the central eastern part of the Kingdom of Swaziland, and is about 70 km to the east-southeast of Mbabane, the capital city; about 40 km east of the commercial city Manzini; and about 20 km west-southwest of Siteki, the district headquarters. The area is located around longitude 31°50'E and latitude 26°30'S (Figure I-2).

A paved national road leading to Siteki from Mbabane through Matsapa where the international airport is located, and Manzini runs about 4 km north of the northern end of the investigated area. An unpaved road branches from the national road and runs to the south through the area, and another unpaved road to Siteki runs about 3 km to the southeast of the area. It takes about 90 minutes from the area to Mbabane and about 30 minutes to Siteki by car.

Besides, the Swaziland Railway (goods traffic only) leading to the ports of Maputo in Mozambique and Richards Bay in South Africa runs north and south along the western end of the area, so that access situation is very convenient.

2.2 Topography

The topography of Swaziland is divided into four zones elongating north and south based on altitude. From east to west they are called; the Lubombo (elevation: 370 to 780 m), Lowveld (elevation: 120 to 370 m), Middleveld (average elevation: 700 m) and Highveld (average elevation: 1,200 m) (Figure I-3).

The Lubhuku area is situated in the Lowveld and is a relatively flat lowland with gentle undulation ranging in elevation from 250 to 350 m. Streams running through the area empty into the Great Usutu River in the south, but most of them are wadis flowing only in the rainy season. The area is densely covered with shrubs and most of them are 2 to 4 m high.

The climate of the Lowveld is tropical and the annual rainfall ranges from 500 to 900 mm which is the lowest in Swaziland but its humidity is generally high. The rainy season is between October and February, and the rainfall is concentrated especially between December and February during which all roads in the area become muddy.

2.3 Investigated Area

The area to be investigated covers about 35 km^2, about 5 km in east-west direction and approximately 7 km in north-south. This area occupies the northern part of the Lubhuku area, which was investigated from the fiscal year 1980 to 1982, and its northern extension. An area investigated by the Geological Survey and Mines Department with many boreholes, and the mining licence area of SUMCOR Ltd. are located west of the investigated area. The Lower Coal Zone occurring in a shallow part was investigated in these areas. The Mpaka mine (Emaswati Colliery Pty. Ltd.), a sole working colliery in Swaziland, is situated northwest of the area. The mine produces coal at the rate of 100,000 to 150,000 tons a year. In addition, the Shell Coal Swaziland (Pty) Ltd. performed the drilling investigation for the Upper Coal Zone east of the area.

However, investigation for coal was not carried out in the Lubhuku area except a geologic mapping, 1:50,000 in scale, by the Geological Survey and Mines Department.

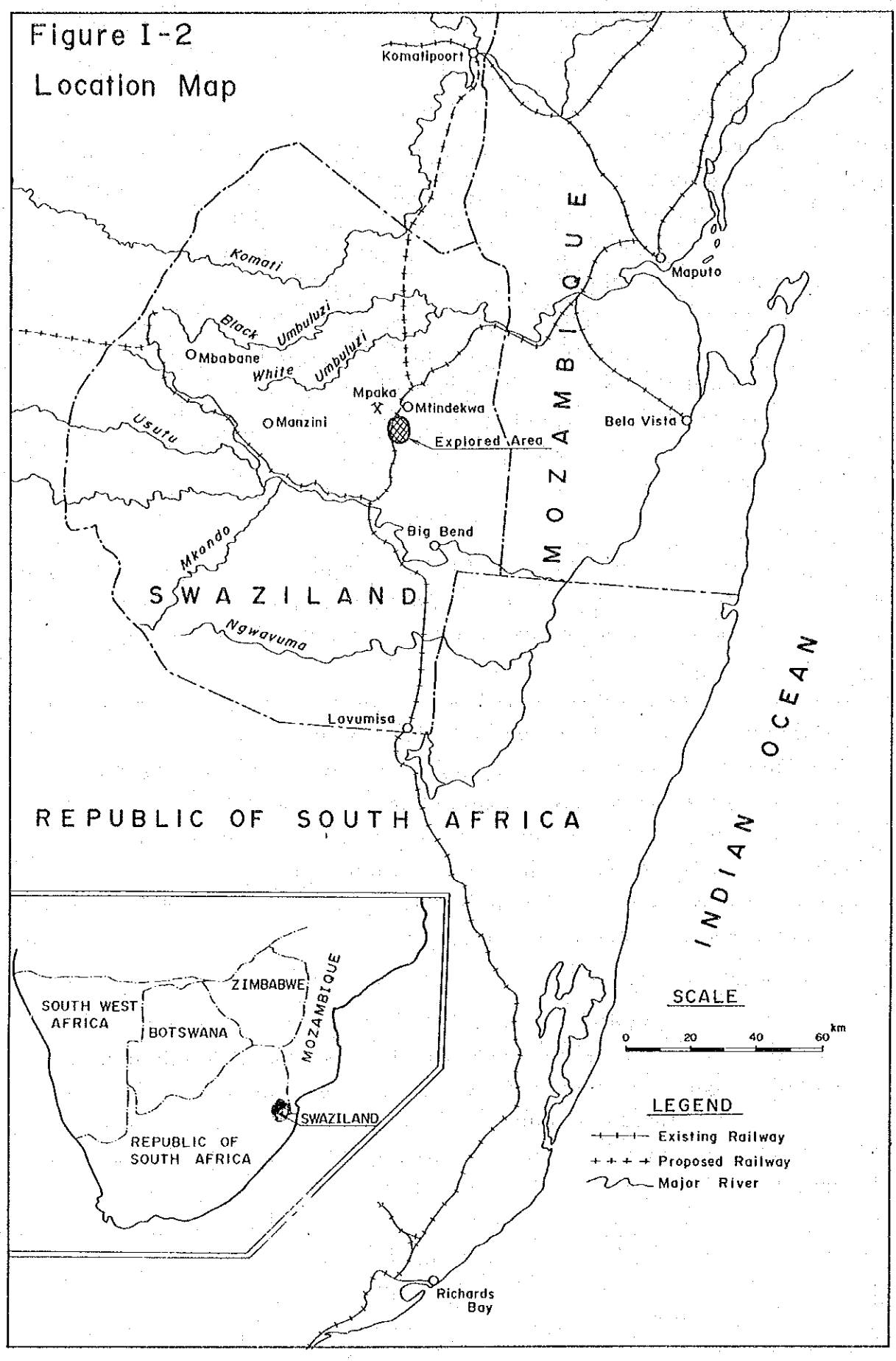


Figure I-2
Location Map
Komatipoort
Komati
Black Umbuluzi
White Umbuluzi
Mbabane
Mpaka
Mtindekwa
Manzini
Usutu
Explored Area
Bela Vista
Maputo
MOZAMBIQUE
Big Bend
Mkondo
SWAZILAND
Ngwavuma
Lovumisa
REPUBLIC OF SOUTH AFRICA
INDIAN OCEAN
ZIMBABWE
SOUTH WEST AFRICA
BOTSWANA
MOZAMBIQUE
SWAZILAND
REPUBLIC OF SOUTH AFRICA
Richards Bay
SCALE
0 20 40 60 km
LEGEND
Existing Railway
Proposed Railway
Major River

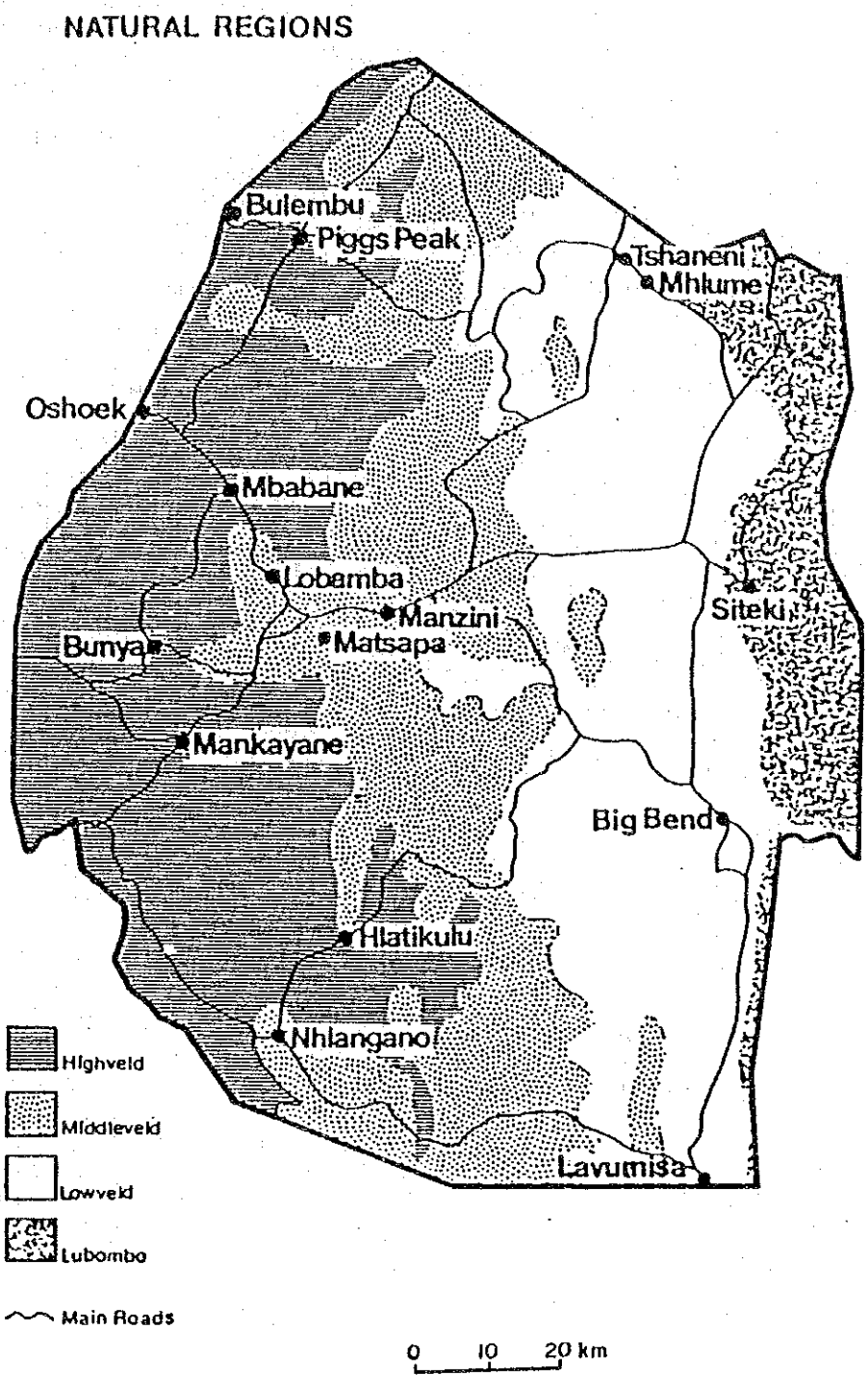


Figure I-3. Morphologic Region Map

PART II. GEOLOGY

CHAPTER 1. DRILLING WORK

PART II. GEOLOGY

CHAPTER 1. DRILLING WORK

1.1 Outline of the Drilling Work

Twenty boreholes in total were drilled on four lines in an east-west direction at 1 km intervals, to set drilling intervals at 1 km grid pattern, in principle, throughout the investigated area where the modes of formation of coal seams are considered to be promising. Location of the drilling performed in the area is shown in Figure II-1.

The drilling was all performed by the wire-line method and tractors were used to secure transportation of drilling water in the rainy season in order to avoid any delay of the work in consideration of experience obtained in the previous investigation. Interruptions of the work were minimized because sufficient countermeasures had been taken as stated above, although unexpectedly concentrated heavy rain fell during the work.

A weathered zone exists to a depth of 5 to 40 m below the surface in the area, and was drilled by the non-coring method. NXC casing pipes (diameter 88.9 mm) were set in order to avoid collapse in boreholes. For drilling below the setting depth of the casing, NQ diamond bits were used in all cases and cores were recovered. Core recovery was excellent, over 99% in both fiscal years.

One shift a day (occasionally 2 shifts/day) operation was employed in the fiscal year 1983, but 2 shifts/day was employed in the fiscal year 1984 in order to complete the scheduled work within the allotted period. Fresh water was used for drilling but drilling mud (CMC and bentonite) was used in case of the loss of circulating water. Cement grout was employed when circulating water was lost remarkably.

1.2 Transfer of Drilling Technique

In response to the strong request of the Government of Swaziland, the drilling work in the fiscal year 1984 was conducted by the drillers of the Geological Survey and Mines Department. Two truck-mounted drilling machines (300 m and 500 m classes) provided by the Japan International Cooperation Agency were used under the technical guidance of drilling engineers dispatched from Japan.

In transfer of drilling technique, the following matter was noted to prepare surrounding circumstances for transferring the drilling technique and to obtain fruitful results in consideration of present conditions in Swaziland:

1) Establishment of a management system for drilling work in the field, 2) Alteration of working system (from 1 shift/day to 2 shifts/day), 3) Construction of base camp for drillers, and 4) Technical guidance through on-the-job training.

Drilling length in an early stage of the work was far below the scheduled one, however, the transfer of drilling technique had gradually good results in the work and resulted in a remarkable increase in drilling rate. The drilling rate per shift per machine was 7.66 m/shift in the early stage, but it increased to 8.27 m/shift in the middle stage and 10.34 m/shift in the final stage. The total drilled length exceeded the scheduled 6,000 m by nearly 7% within the period of work. Thus the transfer of drilling technique led to obtaining fruitful results. Incidentally, the annual average total

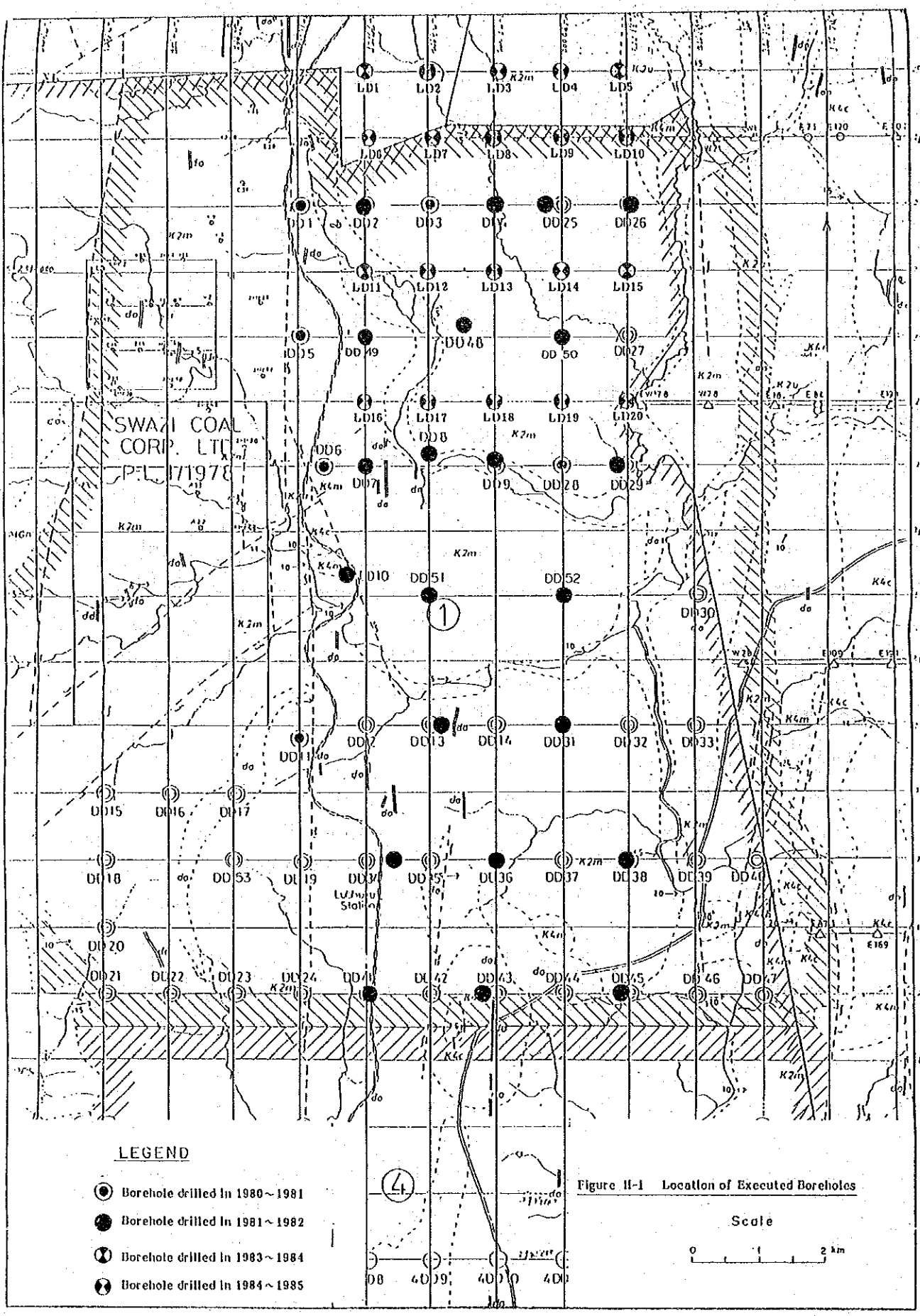


Figure II-1 Location of Executed Boreholes

drilled length was 1,340 m for coal investigation conducted by the Geological Survey and Mines Department in the past three years. However, the transfer of advanced drilling technique such as countermeasures against drilling accidents is considered to be still insufficient.

1.3 Performance of the Drilling Work

Period of drilling work in the fiscal year 1983 was from December 3, 1983 to February 25, 1984, and the total drilled length summed up to 1,500.06 m in 4 boreholes. The work in the fiscal year 1984 was started on June 25, 1984 and completed on February 19, 1985 after boring 16 holes with the total drilled length of 6,393.00 m. The grand total drilled length summed up to 7,893.06 m in a total of 20 boreholes. Figure II-2 shows the drilling process for each drilling machine employed, and Table II-1 indicates the outline of the performance of the work for each borehole. The drilling rate was 13.51 m/shift in the fiscal year 1983 and 9.17 m/shift in 1984.

The drilling work was smoothly completed without any serious drilling accident in the fiscal year 1983. In the fiscal year 1984, interruption of drilling caused by a jamming accident happened at one borehole (LD9). Drilling of two boreholes (LD18, LD19) was temporarily stopped due to breakage of rods. LD18 was redrilled at an adjacent location and LD19 was successfully redrilled using the wedge-off method.

Number of work shifts and the actual consumption of main items for drilling work carried out by the Geological Survey and Mines Department in the fiscal year 1984 are shown in Table II-2.

Figure II-2a EXECUTION PROCESS OF DRILLING OPERATION (RIG A ; JOYSULLIVAN D26)

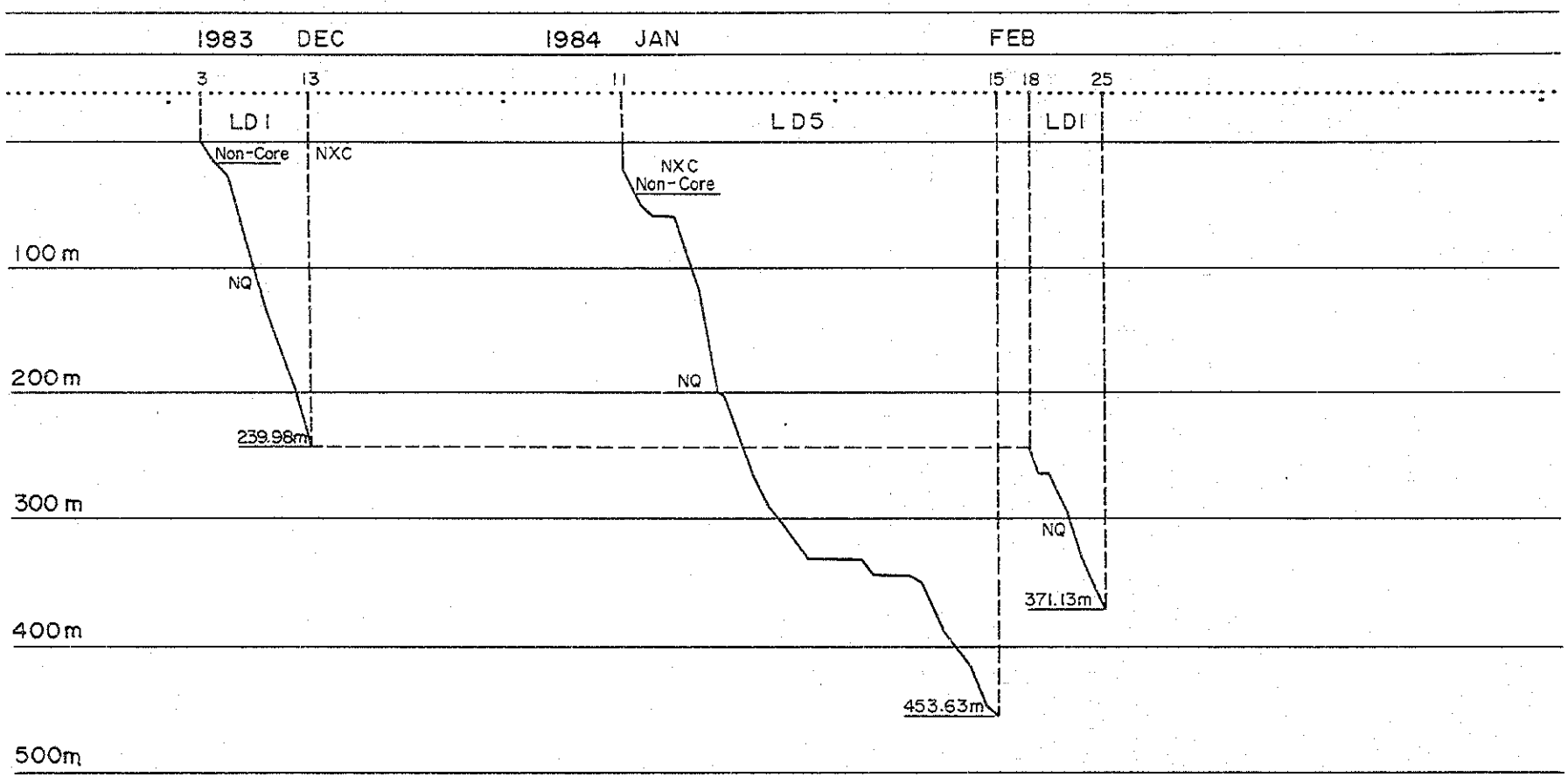


Figure II-2b EXECUTION PROCESS OF DRILLING OPERATION (RIG B ; JOYSULLIVAN D26)

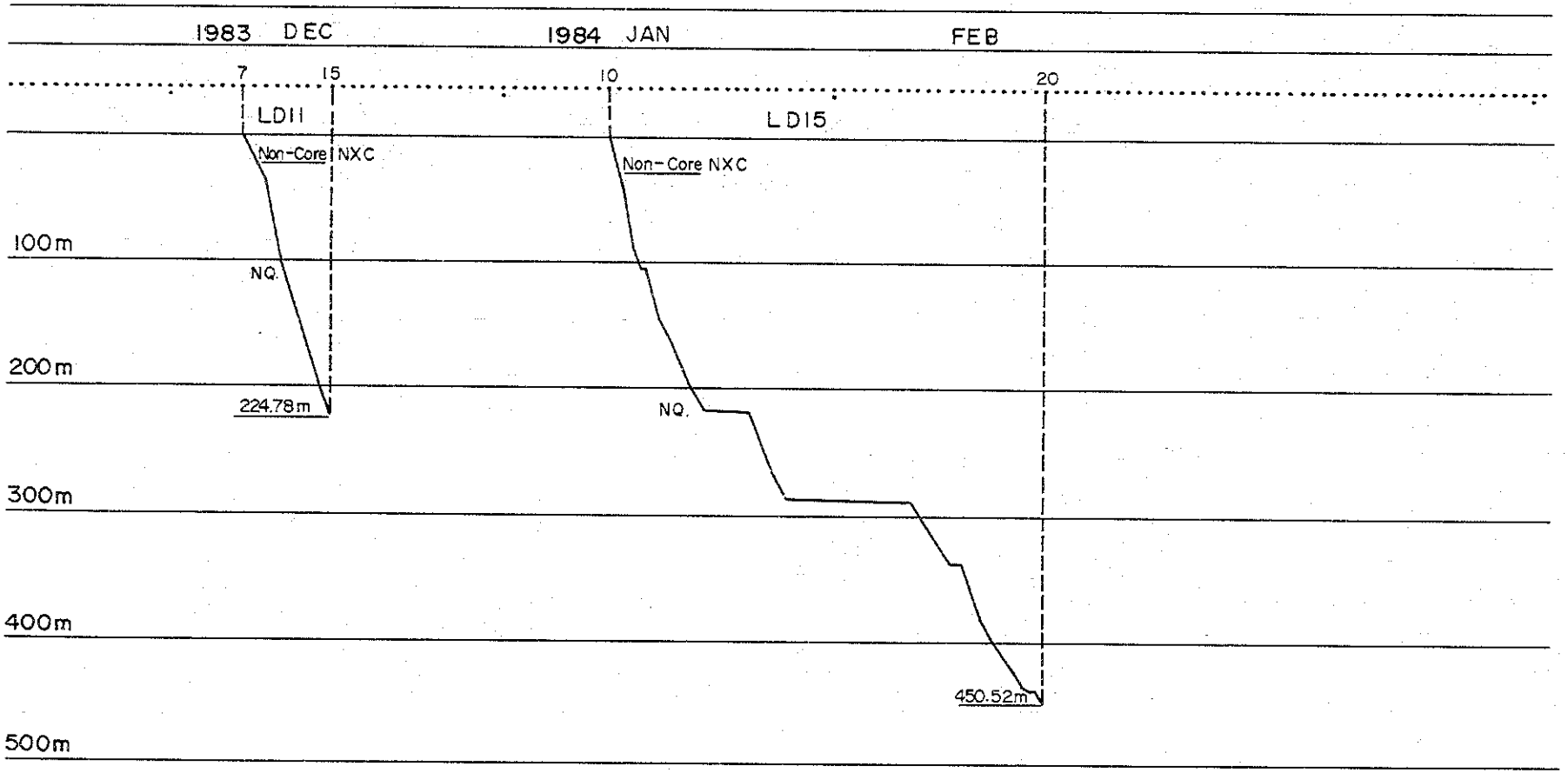


Figure II-2c EXECUTION PROCESS OF DRILLING OPERATION (RIG C ; YBM4)

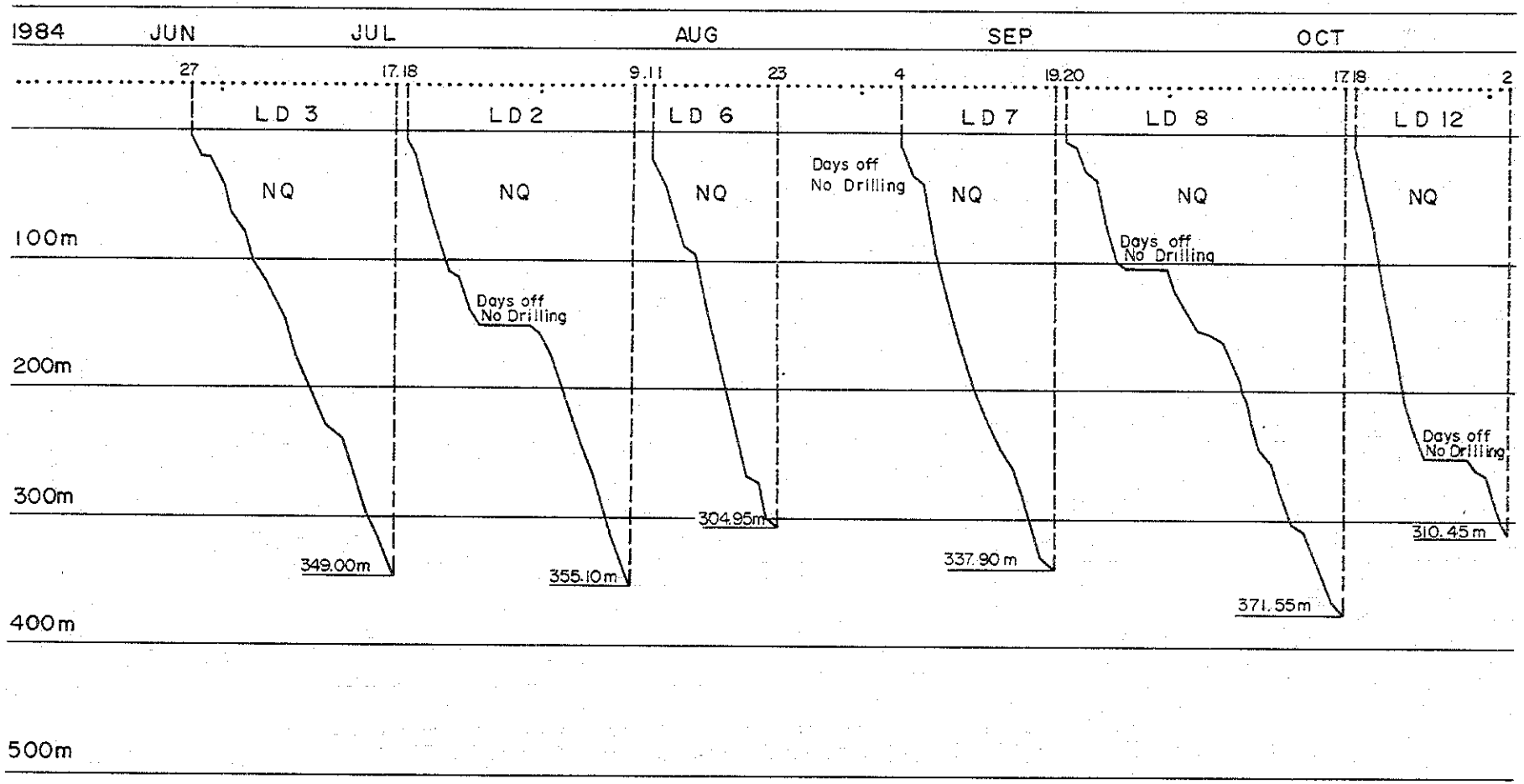


Figure II-2d EXECUTION PROCESS OF DRILLING OPERATION (RIG C ; YBM4)

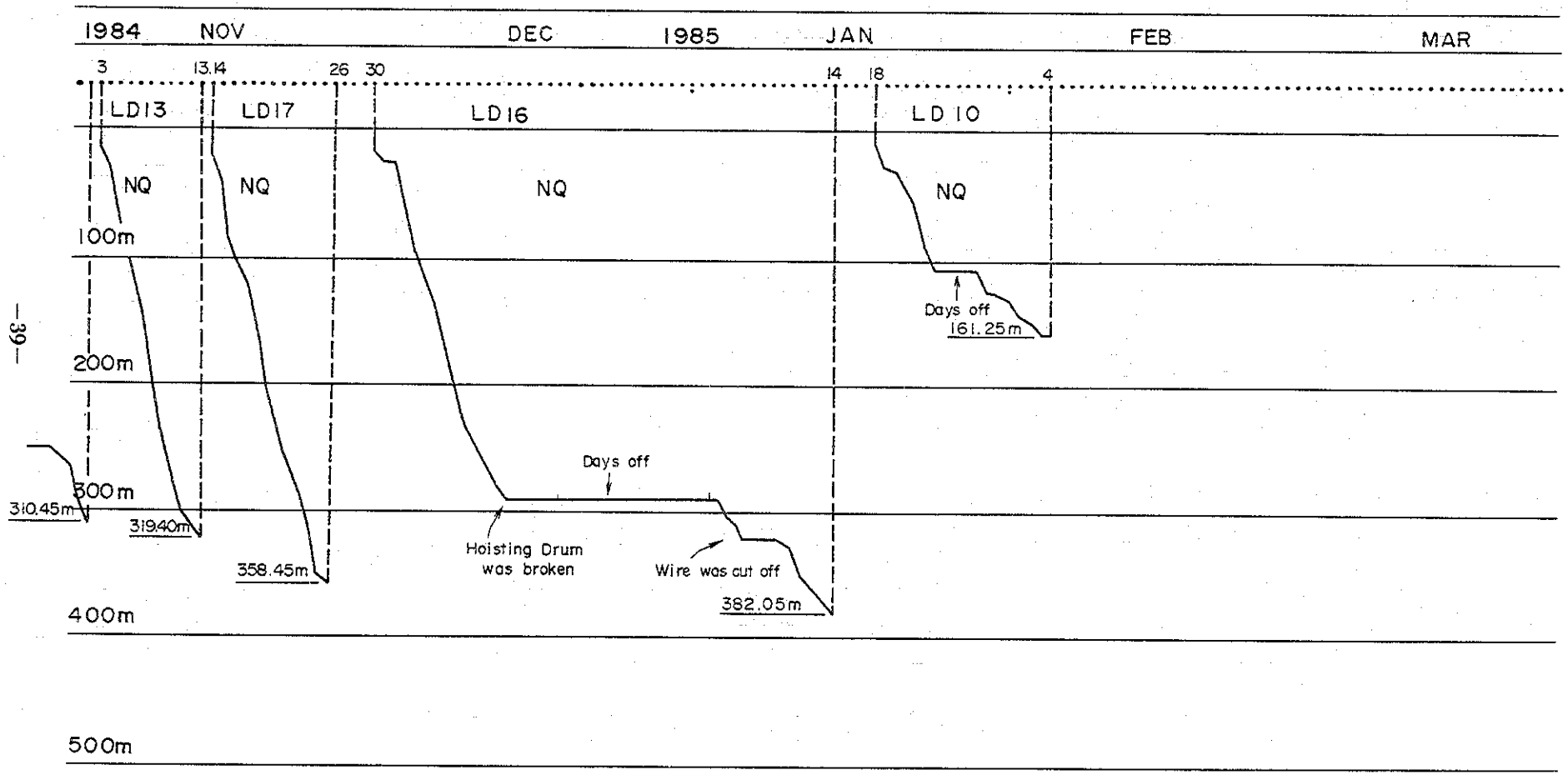


Figure II-2e EXECUTION PROCESS OF DRILLING OPERATION (RIG D ; YBM6)

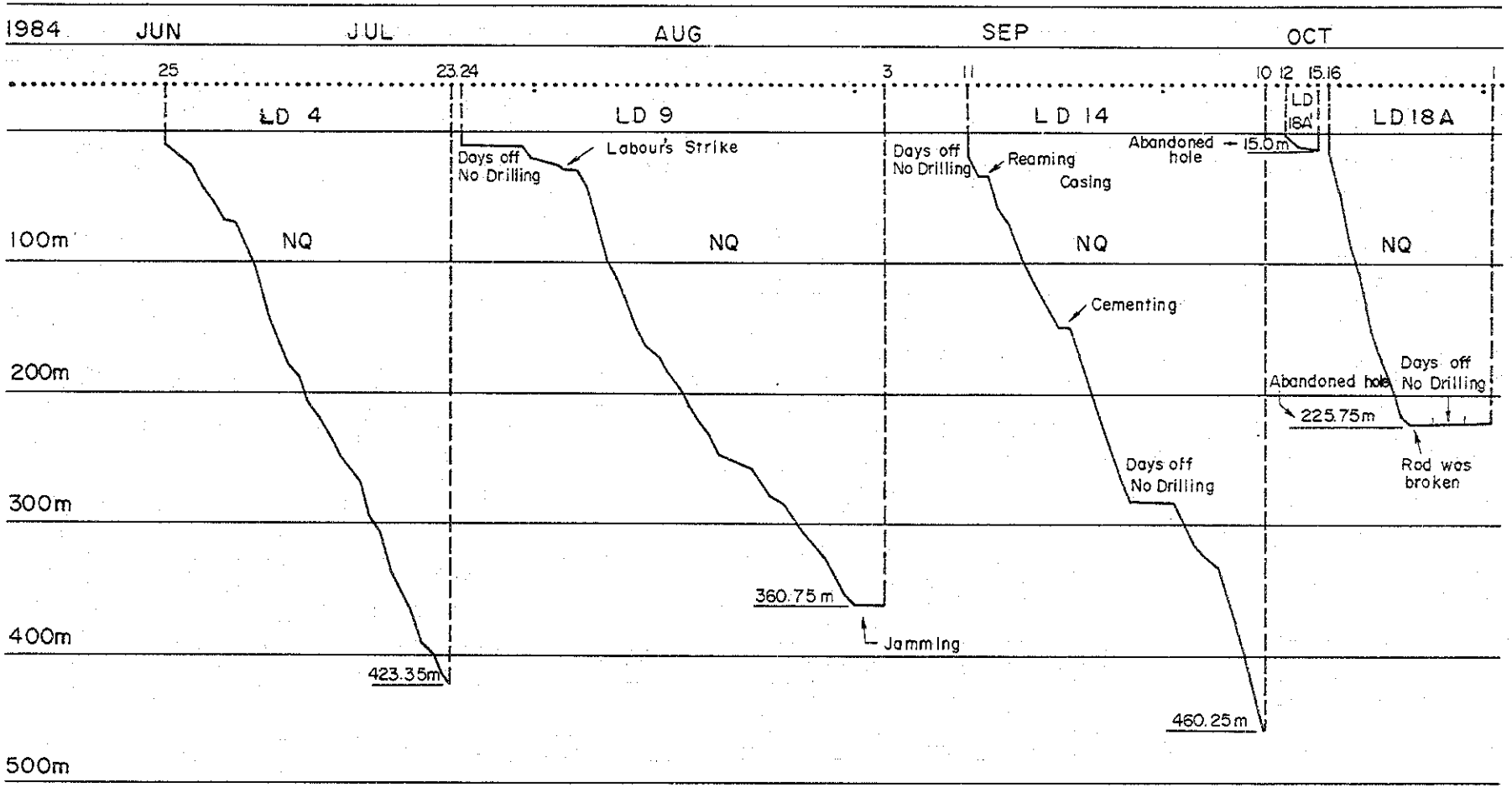


Figure II-2f EXECUTION PROCESS OF DRILLING OPERATION (RIG D; YBM6)

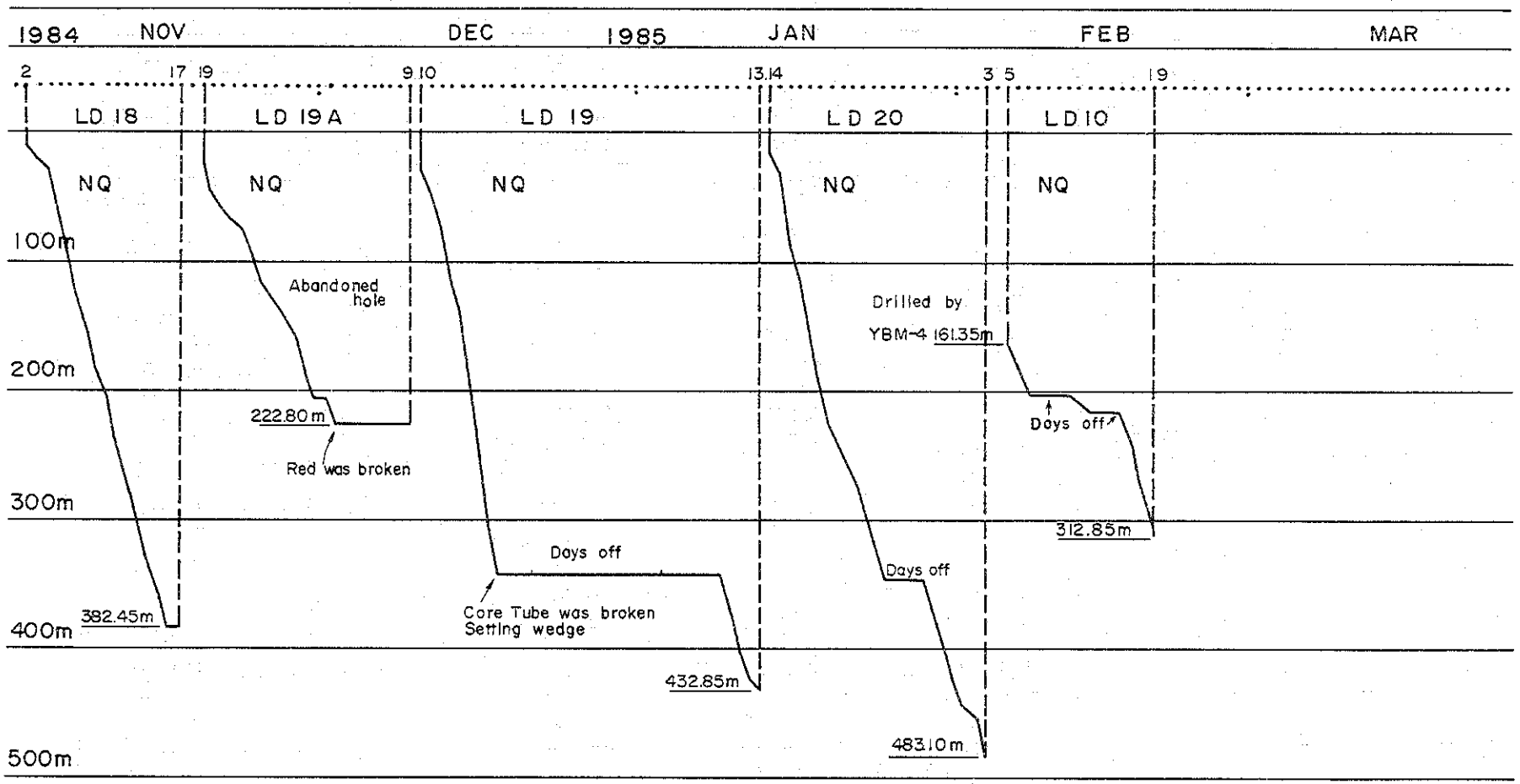


Table II-1a Drilling Record

	LD1	LD2	LD3	LD4	LD5
OPERATING PERIOD	3 DEC. 1983 – 13 DEC. 1983 18 FEB. 1984 – 25 FEB. 1984	18 JUL. 1984 – 9 AUG. 1984	27 JUN. 1984 – 17 JUL. 1984	25 JUN. 1984 – 23 JUL. 1984	10 JAN. 1984 – 15 FEB. 1984
ACTUAL OPERATING DAYS	17	18	21	29	23
COORDINATE X Y	+2,927,020 -77,000	+2,927,009 -78,000	+2,927,000 -79,079	+2,927,000 -80,002	+2,927,000 -80,871
ELEVATION OF COLLAR (M)	+298	+284	+280	+297	+273
PLANNED (M) DRILLING LENGTH	240	275	330	440	440
FINAL (M) DRILLING LENGTH	371.13	355.10	349.00	423.35	453.63
HOLE DEVIATION	-	N50°E 2°-30'	S35°W 2°-50'	S45°E 3°-00'	
CORING INTERVAL (M)	17.88-371.13	6.00-355.10	3.00-349.00	8.65-26.15 30.00-39.25 45.00-423.35	26.95-453.63
CORING RECOVERY (%)	99	99	100	100	99
REMARKS	*1				

*1. This hole had been stopped at the depth of 239.98 m and continued to be drilled up to the depth of 371.13 m in response to the request of Swaziland Government.

Table II-1b Drilling Record

	LD6	LD7	LD8	LD9	LD10
OPERATING PERIOD	11 AUG. 1984 - 23 AUG. 1984	4 SEP. 1984 - 19 SEP. 1984	20 SEP. 1984 - 17 OCT. 1984	25 JUL. 1984 - 3 SEP. 1984	18 JAN. 1985
ACTUAL OPERATING DAYS	13	16	24	35	
COORDINATE X Y	+2,928,000 -77,070	+2928,000 -78,050	+2,928,000 -79,000	+2,928,005 -80,010	+2,928,000 -81,000
ELEVATION OF COLLAR (M)	+300	+284	+267	+285	+282
PLANNED (M) DRILLING LENGTH	260	285	320	435	470
FINAL (M) DRILLING LENGTH	304.95	337.90	371.55	360.75	(439.85)
HOLE DEVIATION	N90°W 1°-45'	N40°W 2°-10'	N90°E 2°00'	-	
CORING INTERVAL (M) CORING RECOVERY (%)	2.40-304.95 100	6.00-337.90 99	6.00-371.55 100	11.0-360.75 100	
REMARKS				*1	

*1. This hole was abandoned because of jamming accident and will be redrilled by GSMD.

Table II-1c Drilling Record

	LD11	LD12	LD13	LD14	LD15
OPERATING PERIOD	7 DEC. 1983 – 15 DEC. 1983	18 OCT. 1984 – 2 NOV. 1984	3 NOV. 1984 – 13 NOV. 1984	11 SEP. 1984 – 10 OCT. 1984	10 JAN. 1984 – 20 FEB. 1984
ACTUAL OPERATING DAYS	9	12	11	26	25
COORDINATE X Y	+2,930,023 -76,885	+2,930,000 -78,000	+2,930,000 -79,000	+2,930,040 -79,910	+2,930,000 -81,000
ELEVATION OF COLLAR (M)	+271	+280	+264	+260	+255
PLANNED (M) DRILLING LENGTH	240	310	385	440	480
FINAL (M) DRILLING LENGTH	224.78	310.45	319.40	460.25	450.52
HOLE DEVIATION	-	N 0°-30'	S 1°-00'	S10°E 1°-40'	-
CORING INTERVAL (M) CORING RECOVERY (%)	15.88-224.78 99	3.40-310.45 100	7.25-319.40 100	21.35-460.25 100	25.74-450.52 99
REMARKS					

Table II-1d Drilling Record

	LD16	LD17	LD18A	LD18	LD19A	LD19	LD20
OPERATING PERIOD	28 NOV. 1984 - 14 JAN. 1985	14 NOV. 1984 - 26 NOV. 1984	12 OCT. 1984 - 1 NOV. 1984	2 NOV. 1984 - 17 NOV. 1984	19 NOV. 1984 - 9 DEC. 1984	10 DEC. 1984 - 12 JAN. 1985	13 JAN. 1985 - 3 FEB. 1985
ACTUAL OPERATING DAYS	33	13	17	16	21	21	18
COORDINATE X	+2,932,000	+2,932,000	+2,931,999	+2,931,999	+2,932,000	+2,932,000	+2,932,000
COORDINATE Y	-76,993	-78,000	-79,002	-79,000	-80,000	-79,998	-80,993
ELEVATION OF COLLAR (M)	+272	+277	+269	+269	+251	+251	+242
PLANNED (M) DRILLING LENGTH	295	370	415	415	450	450	500
FINAL (M) DRILLING LENGTH	382.05	358.45	225.75	382.45	222.80	432.85	483.10
HOLE DEVIATION	N85°E 1°-45'	N20°E 2°-00'	-	S80°W 2°-00'	-	N25°E 6°-50'	N35°E 2°-40'
CORING INTERVAL (M)	13.05-382.05	6.50-258.45	5.0-225.75	9.0-382.45	20.1-222.80	18.0-432.85	20.10-423.35
CORING RECOVERY (%)	99	100	100	100	100	100	100
REMARKS			*1		*2	*3	

*1,*2 These holes were abandoned because drill rod was broken.
*3 Drilling work was discontinued at the depth of 342.45 m because drill rod was broken. Then this hole was re-opened from the depth of 343 m using wedge.

Table II-2 WORKING SHIFT AND MATERIAL CONSUMPTION (1984)

Hole No.	Total Drilling Length	Working shift					Material Consumption		
		Preparing	Drilling	Repairing	Waiting	Total	Diamond Bit	Diesel Oil	Lubricating Oil
LD2	355.10 metre	1.0 shift	31.2 shift	0 shift	3.8 shift	36.0 shift	3.5 piece	2,430 litre	7.0 litre
LD3	349.00	2.0	40.0	0	0	42.0	5.0	2,340	11.5
LD4	423.35	1.0	51.2	3.8	0	56.0	9.5	2,610	18.0
LD6	304.95	2.5	24.5	1.0	0	28.0	4.5	1,940	6.5
LD7	337.90	2.5	29.5	0	0	32.0	4.7	2,310	8.0
LD8	371.55	2.0	39.0	0	9.0	50.0	6.5	2,510	12.0
LD9	360.75	2.0	48.3	9.3	7.4	67.0	5.5	2,730	13.5
LD10	312.85	5.0	20.6	3.0	6.4	35.0	2.0	1,400	3.5
LD12	310.45	1.0	18.1	1.5	0.5	21.1	2.1	1,180	5.5
LD13	319.40	1.0	19.5	0	0	20.5	3.0	1,370	5.5
LD14	460.25	1.5	41.3	3.0	6.2	52.0	1.8	2,100	11.0
LD16	382.05	2.5	29.0	0.4	1.6	33.5	1.8	1,810	9.5
LD17	358.45	1.0	23.8	0	1.5	26.3	2.9	1,610	6.5
LD18A	225.75	2.5	33.5	1.0	2.0	39.0	2.2	1,300	6.0
LD18	382.45	0	32.0	0	0	32.0	4.0	1,410	8.0
LD19A	222.80	2.3	24.9	0	10.0	37.2	3.0	1,060	6.5
LD19	432.85	0	39.0	0	1.0	40.0	4.0	1,890	8.5
LD20	483.10	2.0	46.8	0	0.6	49.4	4.0	2,110	8.5
Total	6,393.00	31.8	592.2	23.0	50.0	697.0	70.0	34,110	155.5
Rate or Percentage	9.17 m/shift	4.5%	85.0%	3.3%	7.2%	100.0%	87.9m/pce	5.34 l/m	0.02 l/m

Remarks: Total coring length computes 6,157.30 metres. LD18A and LD19A are abandoned original holes.

CHAPTER 2. GEOLOGY

CHAPTER 2. GEOLOGY

2.1 General Geology and Stratigraphy

The Kingdom of Swaziland is underlain by metamorphic, granitic, volcanic, ultrabasic and sedimentary rocks of the Precambrian age, sedimentary and volcanic rocks of the Palaeozoic and Mesozoic ages, and alluvium. The stratigraphy of these rocks is shown in Table II-3.

The basement rocks of the coalfields in Swaziland are composed of sedimentary and volcanic rocks of the Swaziland and Pongola Supergroups of the Archaean, gneisses derived from the Swaziland Supergroup through regional metamorphism, and granitic rocks. These basement rocks extensively outcrop mainly in the Highveld and Middleveld occupying about 70 percent of the country.

2.1.1 Karoo Supergroup in Swaziland

The Karoo Supergroup is extensively distributed in the inland area of the southern part of Africa and is the characteristic formation mainly of continental sediments. The supergroup is exposed in a north-south direction forming a narrow belt about 50 kilometres wide, through Swaziland along the Lebombo Graben from the eastern end of the Great Karoo basin in the Republic of South Africa, and extends further north of Swaziland.

The Karoo Supergroup is mainly exposed in the Lowveld and Lebombo in the eastern part of Swaziland and occupies about 30 percent of the country. The supergroup unconformably overlies the Precambrian basement but is also partially in fault contact with the basement. The strata are characterized by their lithofacies which begin with a glacial stage, follow with a sedimentary stage and end in a volcanic stage. The strata trend north-south and dip very gently 5 to 10°E, but dips increase in the eastern part from 10 to 20°E. Table II-4 and Figure II-3 show the general stratigraphy of the Karoo Supergroup in Swaziland.

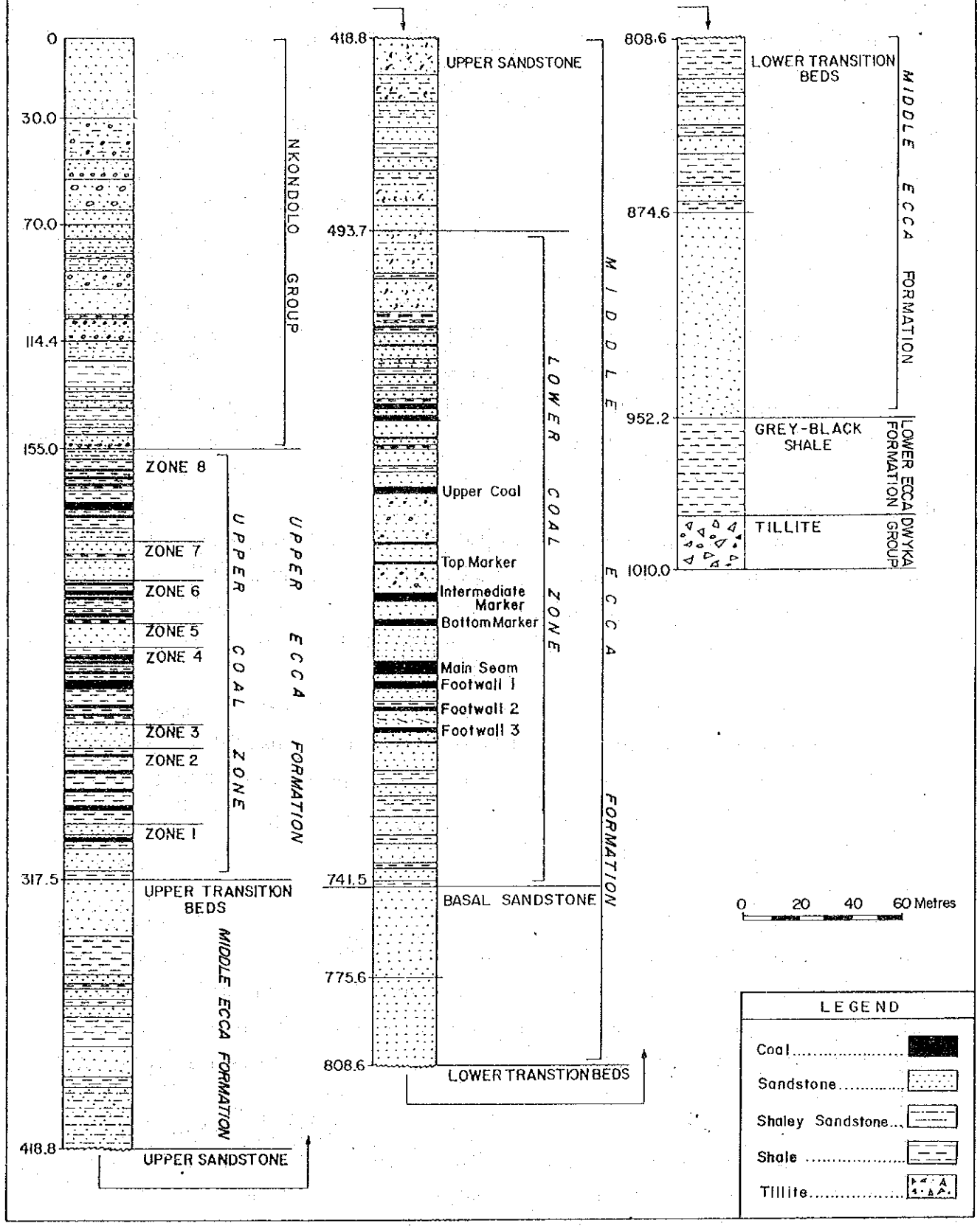
Table II-4 Karoo Supergroup Stratigraphy in Swaziland

Group	Formation	Lithology	Thickness in metres
Lebombo	Lebombo Rhyolites	Rhyolite, dacite, ignimbrite, tuff, tuffaceous sandstone	±5,000
	Sabie River Basalts	Basalt, tuff, tuffaceous sandstone	±5,000
Nkondolo		Sandstone, shale, conglomerate, tuff	± 150
Ecca	Upper Ecca	Carbonaceous shale, sandstone, coal	± 160
	Middle Ecca	Sandstone, coal, carbonaceous shale	± 550
	Lower Ecca	Shale, mudstone	± 40
Dwyka		Tillite, sandstone, shale	0 - 300

Table II-3 Geological Formations of Swaziland

Geological Age	Sedimentary Rocks		Igneous and Metamorphic Rocks
Quarternary	Alluvium		
Jurassic-Cretaceous			Karoo Dolerite
Jurassic Triassic Permian Carboniferous	Lebombo Group Nkondolo Group Ecca Group Dwyka Group	Karoo Supergroup	
Archaean			Granites
			Usushwana Complex
			Granites
	Mozaan Group Insuzi Group	Pongola Supergroup	
			Granites and Gneisses
	Moodies Group Fig Tree Group Onverwacht Group	Swaziland Supergroup	

Figure II-3 SWAZILAND COALFIELD TYPE SECTION OF THE KAROO SUPERGROUP IN CENTRAL SWAZILAND



The Dwyka Group, the lowest bed of the Karoo Supergroup, is considered to be of Late Carboniferous in age and is exposed in restricted areas of the country. The group is composed of hard tillite containing glacially derived rubble of granite, pegmatite, gneiss, quartzite, etc. with intercalated thin beds of sandstone, siltstone and shale. The thickness of the strata attains a maximum of 300 m.

The Ecca Group, a coal-bearing formation, conformably overlies the Dwyka Group and is considered to be of the Permian age. The group is divided into three formations, the Upper, Middle and Lower Ecca Formations, and the total thickness exceeds 800 m. The coal-bearing formation occurs in the Upper (Upper Coal Zone) and Middle Ecca (Lower Coal Zone) Formations.

The Lower Ecca Formation is composed of nonfossiliferous greyish black shale and is about 40 m in thickness. The Middle Ecca Formation is subdivided into five beds, namely, Lower Transition Beds, Basal Sandstone, Lower Coal Zone, Upper Sandstone and Upper Transition Beds in ascending order. The total thickness is about 550 m and the formation is composed mainly of sandstone containing muscovite and shale with intercalated carbonaceous shale and coal. The thick arenaceous beds generally exhibit cross-bedding and small fragments and flakes of carbonaceous matter are often found in the sandstone above the upper part of the Basal Sandstone. *Glossopteris browniana, G. indica* have been occasionally reported from the formation in the southern part of Swaziland. The Upper Ecca Formation is composed of alternating cycles of carbonaceous shale-coal zone and sandstone zone, and the sandstone generally contains small carbonaceous fragments. The thickness is about 160 m.

The Nkondolo Group conformably overlies the Ecca Group and is mainly composed of fluviatile and aeolian feldspathic or quartzose sandstone with shale, mudstone, conglomerate, etc. The group is considered to be deposits of the Triassic age and the thickness is about 150 m. The uppermost part of the group contains a few intercalated tuff beds and intense volcanic activity began in the following period.

The Lebombo Group is divided into a lower part, the Sabie Riber Basalts (basalt, basaltic tuff, etc.) and an upper part, the Lebombo Rhyolites (rhyolite, rhyolitic ignimbrite, tuff, sandstone, etc.). The total thickness of these volcanic rocks ranges up to 10,000 m although the uppermost part of the group is not found in Swaziland. The volcanic rocks are considered to be the result of eruption through fissures during the Jurassic time.

2.1.2 Karoo Dolerite

Dark greenish-grey basic igneous rocks extensively intruded into Precambrian rocks and the Karoo Supergroup in Swaziland are called the "Karoo Dolerite". The dolerite intrudes into almost all parts of the Karoo Supergroup, however, only local intrusions of the dolerite are found in the Precambrian rocks except for that in the southern part of the country. Dolerite dykes are predominant in the Sabie River Basalts in the eastern part of the country but sills predominate in other rocks.

The composition of the Karoo Dolerite is extremely similar to that of the basalt of the Sabie River Basalts. The rock types are ranging from fine-textured basalt to coarse-textured dolerite, gabbro-like rock is also found locally. The intrusion of the dolerite is considered to have started during Jurassic time and continued on into early Cretaceous time.

2.2 Geology of the Ecca Group

The Ecca Group, the coal-bearing formation in Swaziland, is distributed in a north-south trending narrow belt about 150 km long, 6 to 22 km wide in the Lowveld. The group extends northward to Transvaal and southward to Natal, the Republic of South Africa. Small outcrops of the group are also found along the southwestern border of Swaziland.

Stratigraphy of the Ecca Group is shown in Table II-5, and both the Upper and Middle Ecca Formations are exposed in the Lubhuku area. Drilling was started at a horizon between the lower part of the Upper Ecca Formation and the upper part of the Lower Coal Zone of the Middle Ecca Formation, to reach the lowest part of the Lower Coal Zone (refer to Drawings 1 to 5).

2.2.1 Basal Sandstone

These strata are divided into upper and lower parts; the lower part consists of fine- to medium-grained white homogeneous sandstone, and the upper part consists of medium- to coarse-grained sandstone or grit containing scattered carbonaceous fragments and intercalates with micaceous mudstone or shale at the uppermost part. The lower part is about 32 m in thickness and the upper part is about 34 m. No cross-bedding and fragments of carbonaceous and micaceous matters are found in sandstone in the lower part. On the contrary, sandstone in the upper part is characterized by its remarkable cross-bedding, the first appearance of scattered carbonaceous fragments and no intercalation of coal seams. The boundary between the strata and the overlying Lower Coal Zone is the base of a thin stratum of mudstone or medium- to fine-grained sandstone existing about 65 m below the Footwall 3 Seam, or 12 to 13 m below the thin coal seam occurring at the lowest horizon.

No drilling was performed through the strata during this investigation, but the uppermost part of the strata had been drilled in 4 boreholes in the previous investigation.

Table II-5 Ecca Group Stratigraphy in Central Swaziland

Formation	Member	Lithology	Average thickness in metres
Upper Ecca	Zone 8	Carbonaceous shales and coals	34
	Zone 7	Sandstone with shale parting	15
	Zone 6	Carbonaceous shales and coals	17
	Zone 5	Sandstone	9
	Zone 4	Carbonaceous shales and coal seams up to 6 metres thick	29
	Zone 3	Sandstone	8
	Zone 2	Carbonaceous shales and coals Dolomitic inclusions	29
	Zone 1	Sandstones with carbonaceous shale and coal	21
Middle Ecca	Upper Transition Beds	Alternation of gray shales and sandstones with intercalations of narrow limestone bands	101
	Upper Sandstone	Gray sandstones, sandstones with carbonaceous shale partings. Characterized with irregular carbonaceous wisps	75
	Lower Coal Zone	Sandstones, grits, gritty sandstones with mudstones, carbonaceous shales and coal seams	249
	Basal Sandstone	Upper: Sandstones and grits with mudstone Lower: White homegeneous sandstone	66
	Lower Transition Beds	Upper: Alternation of shale and sandstone Lower: Sandstones but no carbonaceous matter	143
Lower Ecca		Gray - black shales	36

2.2.2 Lower Coal Zone

The strata are mainly composed of medium- to coarse-grained arkose to subarkosic sandstone, and contain intercalated gritty sandstone, fine-grained micaceous sandstone, coaly shale, sandy shale and coal seams, and also include occasional bands of granule and pebble. The strata are characterized by their remarkable cross-bedding and commonly accompanied by muscovite. The main constituent of sandstone is quartz, with subordinate amounts of orthoclase, plagioclase and microcline, and a small amount of muscovite and biotite occupy interspaces of these minerals. Grain size of these particles is generally 0.3 to 1.0 mm in diameter and most of them are of subangular to sub-rounded grains (roundness: 0.15 to 0.40) whilst rounded grains are occasionally found. The sandstone is generally somewhat ill-sorted but occasionally somewhat well-sorted. Constituent minerals, roundness and sorting of the sandstone are quite similar throughout the whole horizon, and heavy minerals are present but in very minor amounts.

The thickness of the strata is about 250 m. The strata intercalate with more than 20 coal seams, some of which are expected to be developed as they have sufficient thickness. The strata are divided into the upper and lower parts at the top of the Top Marker, based on the occurrence of coal and lithofacies. The coal seams in the upper part are generally thin and are restricted in a small areal extent. Only two or three coal seams including the Upper Coal in this part exceed 1 m in thickness but varies markedly. Sandstone is predominant in the upper half, the lower half consists of sandstone and shale.

Thick coal seams predominate in the lower part and are widely traceable. Major coal seams are the Top Marker, Intermediate Marker, Bottom Marker, Main Seam, Footwall 1, Footwall 2 and Footwall 3 in descending order. Sandstone is predominant in the upper half and the lower half is made up of sandstone and shale in contrast to the lithofacies of the upper part. Sandstones existing in a horizon from Top Marker to Main Seam are generally white to light yellowish grey, coarse- to very coarse-grained, feldspathic and frequently contain granules and pebbles. The strata are relatively thin in the western part of the area and tend to thicken to the east.

2.2.3 Upper Sandstone

The strata are about 70 m thick and are composed generally of greyish white, fine- to medium-grained sandstone with occasional beds of coarse-grained sandstone and grit. Fragments of carbonaceous matters are predominant in the strata, and grey shale is rarely intercalated in the strata. The strata tend to thicken to the east similar to that of the Lower Coal Zone.

The lower boundary of the strata is at the top of a thin coal seam which exists at the uppermost horizon among thin coal seams being found below the Upper Transition Beds. In case this thin coal seam thins out, the base of the strata is assigned to the equivalent horizon.