INVESTIGATION REPORT ON DEVELOPMENT PROJECT OF NGANA COAL FIELD IN THE REPUBLIC OF MALAWI

FEB 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

TOKYO JAPAN

INVESTIGATION REPORT ON DEVELOPMENT PROJECT OF NGANA COAL FIELD IN THE REPUBLIC OF MALAWI
FEB 1978
JAPAN INTERNATIONAL COOPERATION AGENCY TOKYO

INVESTIGATION REPORT ON DEVELOPMENT PROJECT OF NGANA COAL FIELD IN THE REPUBLIC OF MALAWI

FEB. 1978

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO , JAPAN

PREFACE

The Japanese Government contemplated the investigation for the coal mining development plan in the Ngana coal field of the Republic of Malawi at the request of its government and entrusted Japan International Cooperation Agency with carrying out of it.

As a considerable part of natural resources in Malawi has been left undeveloped and it is important for this country to secure the energy resources upon its going ahead with the industrialization policy, the development of the domestic coal is extremely worthy for Malawi from an economic and social view point. In consideration of the above, Japan International Cooperation Agency has performed the on-the-spot investigation by dispatching the mission which is consisted of six members, heading by Mr. Masayuki Aoki of Japan Overseas Coal Development Co., Ltd., for a period of 56 days between July 23 and September 16, 1977.

This Report is the results of comprehensive study based on the investigation and analysis of the informations as well as materials collected there.

It will our great pleasure that this report would contribute to the coal development of the Republic of Malawi and also to increasing further economic exchange as well as friendly relations between the country and Japan.

We tender many thanks to the officials concerned of the government of Malawi for all of the cooperation they have given us in the investigation and also to the officials of the Ministry of Foreign Affairs as well as the Ministry of International Trade and Industry of Japan for their support on dispatch of the investigation mission.

February, 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

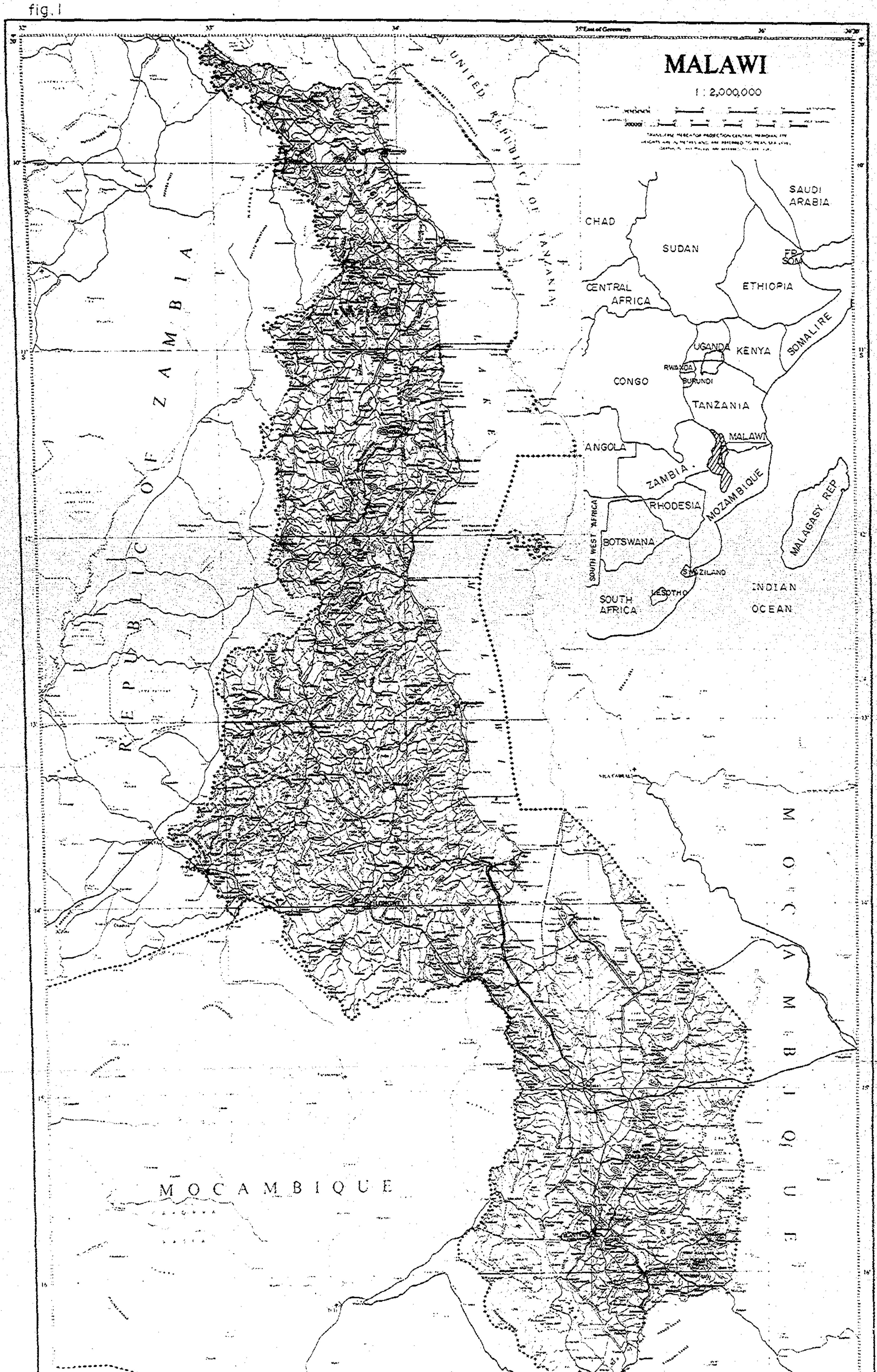
Shinsaku Hogen
President

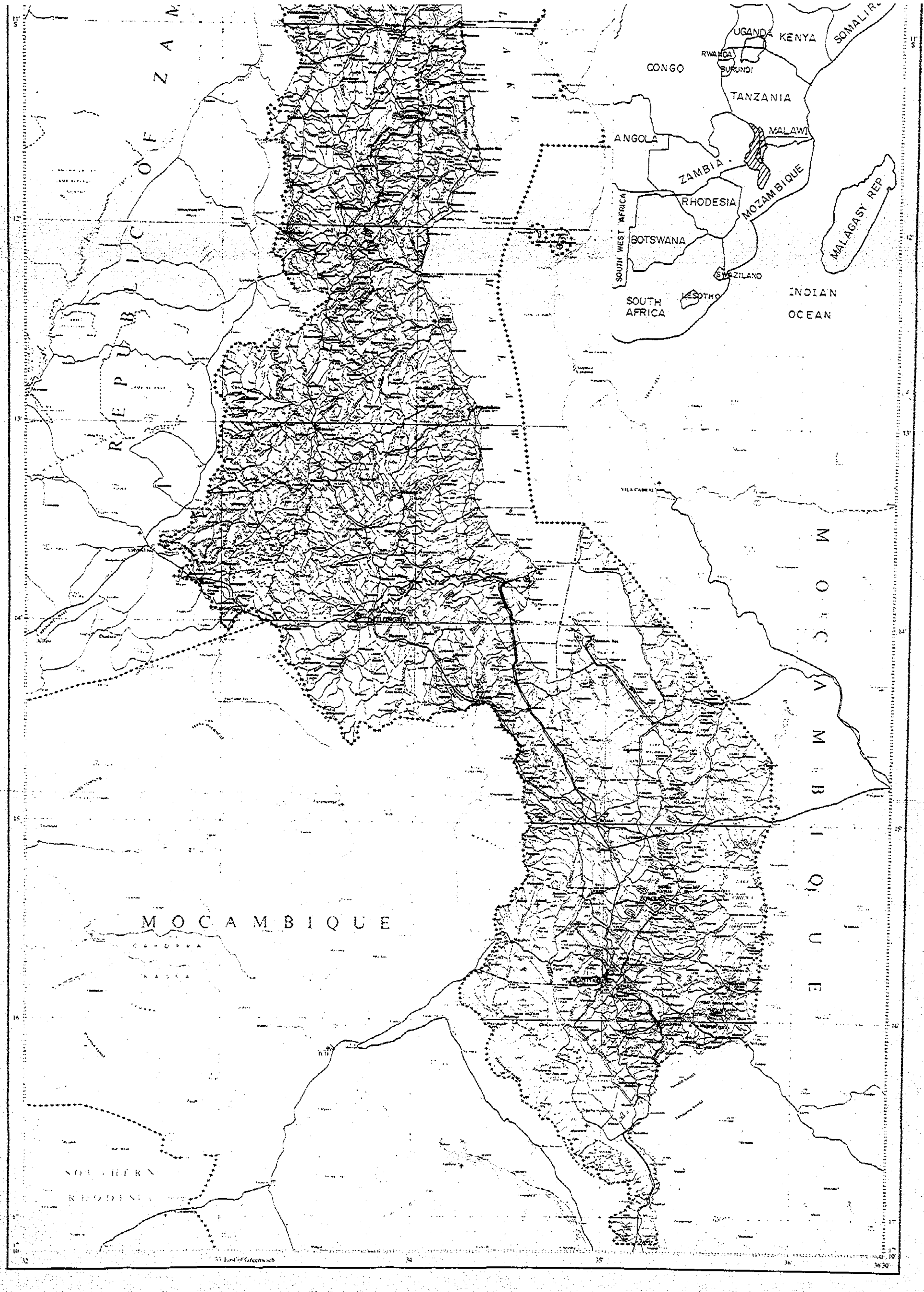
Investigation Report on Development Project

of Ngana Coal Field in the Republic of Malawi

Table of Contents

fig. 1


MALAWI
1 : 2,000,000
REPUBLIC OF ZAMBIA
UNITED REPUBLIC OF TANZANIA
LAKE MALAWI
MOCAMBIQUE
MOCAMBIQUE
CHAD
SUDAN
SAUDI ARABIA
FR. SOM.
ETHIOPIA
CENTRAL AFRICA
SOMALIRE
UGANDA
KENYA
RWANDA
BURUNDI
CONGO
TANZANIA
ANGOLA
MALAWI
ZAMBIA
MOZAMBIQUE
RHODESIA
SOUTH WEST AFRICA
BOTSWANA
MALAGASY REP
SWAZILAND
LESOTHO
SOUTH AFRICA
INDIAN OCEAN


REPUBLIC OF ZAM
LAKE MALAWI
MOCAMBIQUE
MOCAMBIQUE
SOUTHERN RHODESIA
33 East of Greenwich
UGANDA
KENYA
SOMALI R.
CONGO
RWANDA
BURUNDI
TANZANIA
ANGOLA
MALAWI
ZAMBIA
MOZAMBIQUE
RHODESIA
SOUTH WEST AFRICA
BOTSWANA
MALAGASY REP
SWAZILAND
LESOTHO
SOUTH AFRICA
INDIAN OCEAN

Investigation Report on Development Project of Ngana Coal Field in the Republic of Malawi

Chapter 1. Introduction

1.1. Procession up to This Investigation

The Republic of Malawi essentially is an agricultural country; it has been producing tea, tobacco, rice and other farm products. But since its independence in 1964, the nation, eager to establish self-sustaining economy, has been directing considerable efforts to the development of relatively rich forestry resources, cultivation of limnetic fish in Lake Malawi that occupies approximately 1/4 of the nation's entire area, silkworm culture and some other industries. Not a few Japanese specialists in these fields have been invited to offer technical cooperation.

In 1971 the Government of Malawi formulated the Statement of Development Policies, 1971-1980. This 10-year economic plan lays emphasis on the development of agriculture and aims at the improvement of agricultural and industrial productivities. It projects to make the nation's real gross domestic product (GDP) approximately double that of 1970 and achieve a GDP per capital of about 95 kwacha per year (1970 = K57 per year). To attain these ends, the GDP is expected to grow at a rate of 7.2 per cent per year between 1970 and 1975, and 7.9 per cent between 1976 and 1980.

As a part of its development policies, the Government contemplates developing the mining industry, though the nation has no experience in it.

As regards coal for energy-source use, several investigations were made on coal fields throughout the country until about 1960. With subsequent social and economic changes, however, the nation's interest in coal diminished, and not only development but also investigation was suspended. But the interest in coal has recently deepened again, and the Government has come to engisage the development of domestic coal fields. In October 1973, the secretary to the Treasury L.P. Anthony requested the Japanese ambassador to Kenya to dispatch a mission to investigate and plan the development of two relatively promising coal fields in Livingstonia and Ngana. In answer to this request, Japan dispatched its investigation mission to the Republic of Malawi in September 1974, which also visited the Kingdom of Swaziland and the United Republic of Tanzania, as an undertaking organized by the Overseas Investment Investigation Subsidies.

Of the aforesaid two coal fields, the mission discovered that the western district of the Ngana coal field would be easier to investigate, require less initial investment, and involve relatively simpler mining techniques. Therefore the mission recommended the development of this district as most favorable.

After studying the mission's report, the Government of Malawi requested Japan again to make a more detailed development investigation on the western district of the Ngana coal field.

Complying with this request, the Japanese Government first dispatched a four-man mission for preliminary talks with interested parties, for a period of 14 days from April 26 to May 9, 1977. Based on the agreement reached by this preliminary mission, a Ngana coal field development project investigation mission, comprising six specialists, was dispatched to perform field investigations, for a period of 56 days between July 23 and September 16, 1977.

1.2. Object of the Investigation

The object of this investigation was to perform field investigations, at the request of the Government of Malawi, as to the development feasibility of the western district of the Ngana coal field, which had been selected as promising by the investigation of 1974.

Basically, the Government of Malawi desires to attain the following three objects by developing domestic collieries:

(1) To as quickly as possible substitute domestic

coal for imported one.

(2) To engage the nation's colliery workers, now working in neighboring countries, in the domestic coal mining industry.

(3) To minimize the colliery development cost (which usually tends to become enormous) as well as the production cost, and start coal production in the shortest possible period.

The mission's investigation was carried out in compliance with these basic requirements set forth by the Malawi Government. The investigation comprised confirmation of the coal seam conditions, coal quality and reserves, and mining conditions in the object district, general investigation of road conditions and proposed jetty sites on Lake Malawi, and examination of the development feasibility.

1.3. Contents of the Investigation

The following are the major contents of the investigation conducted by the mission:

1.3.1. Preparation in Japan (Topographic Map Drawing)

The Malawi Government requested to prepare a 1/5000-scale topographic map of the object district, which was indispensable to this investigation, by using aerial photographs possessed by the nation's Department of Survey. Therefore, the 1/5000 topographic map was prepared in Japan, using six 1/25000-scale photographs (Nos. 184 to 189;

photographed in October 1972, at a focal distance of 152.5 mm) obtained from the Department of Survey. But these photographs did not cover the area near the Tanzania border. So a 1/40000-scale color aerial photograph of that area, taken in August 1967, was obtained from the Directorate of Overseas Surveys in London, England. From this photograph, a 1/5000-scale topographic map was prepared for the missed portion near the coal field, and a 1/10000 one for the area necessary for the road investigation between the project site and Iponga. Further, general geological conditions of the object district were read from these aerial photographs before proceeding to the field investigation.

1.3.2. Field Investigation

(1) Discussion with Related Parties and Collection of Necessary Data

Three advance members of the mission visited the Ministry of Agriculture and Natural Resources in Lilongwe and discussed details of field investigation with the secretary to the ministry and other related persons. Then they inspected the project site, with a Malawi co-worker, to decide the camp site to be used during the investigation. On returning to Blantyre, they prepared necessities of camping and discussed details of the field investigation with the people of the Department of Geological

Survey. They also obtained necessary data from the Department of Survey and the National Statistical Office.

On completion of the field investigation, the mission briefly reported the investigation results and discussed problems involved in the development of the Ngana coal field at the Ministry of Agriculture and Natural Resources in Lilongwe. The mission also requested the ministry to answer its questionnaire and collected additional data.

(2) Field Investigation

The field investigation was given to a range of approximately 5 km between the rivers Songwe and Labasha in the western district of the Ngana coal field. This district was divided into the north, central and south areas, as separated by faults, and the following investigations were made:

a) Prospecting

To determine the coal seam condition, trenches were dug in 26 places in the north area, 37 places in the central area, and 2 places in the south area.

b) Sampling

A total of 71 coal samples were taken from those of the trenches which were weathered to a minor extent.

c) Survey

To confirm the location of the trenches and the boreholes drilled by the South African Chamber of Mines, traversing was effected by using a handy transit, and they were plotted on the 1/5000-scale topographic map.

d) Brief Investigation of Road and Jetty

A brief investigation was made on the road condition between the colliery site and Iponga and some proposed jetty sites on Lake Malawi.

1.3.3. Analytical Work in Japan

(1) Analysis of Coal Samples

The 71 coal samples collected from the trenches were subjected to the following analytical tests for the determination of coal quality:

a) Coal grade test (proximate analysis, sulfur content and calorific value)

b) Coal properties test (ultimate analysis and Hardgrove test)

c) Coal ash properties test (chemical analysis and fusibility)

d) Coal characteristic test (petrographic analysis)

e) Coal washability test (sink-float test)

(2) Examination of Development Concept and Future Problems

From the coal seam condition and coal quality revealed by the investigation, it seemed most appropriate to mine the Nos. 2 and 3 coal seams together by the underground method. Accordingly, application of the retreating longwall mining to the Nos. 2 and 3 coal seams was studied, which comprises driving drifts from mine mouths to the coal seams and providing hydraulic props and kappes above the mine mouth level.

This investigation, laying emphasis on confirmation of the coal seam condition, was preliminary to a feasibility study on the development of the colliery. So the development feasibility and other problems expected to arise in future were also examined.

1.4. Make-up of Investigation Mission

The investigation mission was made up of the following six members:

	Name	Occupation	Assignment
Chief	Masayuki Aoki	Investigation Dept., Japan Overseas Coal Development Co., Ltd.	General administration and geology
Member	Seiji Shimizu	Ditto	Mining, transportation, etc.
Member	Masaharu Shibata	Ditto	Mining and transportation
Member	Minoru Matsumura	Ditto	Geology
Member	Hirobumi Yamazaki	Ditto	Survey
Member	Sadayuki Nagahata	Mining & Manufacturing Industries Planning & Investigation Dept., Japan International Cooperation Agency	Coordination

During the field investigation, Messrs. Frank W. Chapusa (geology) and Joseph R Gwaza (liaison) of the Department of Geological Survey, Messrs. McPherson Kambeta (geology) and Benitla J. Jowampingo (general) who served as assistants, and four other persons skilled in investigation work offered their willing and valuable cooperation.

1.5. Investigation Period and Itinerary

The field investigation was carried out for a period of 56 days from July 23rd to September 16th, 1977. The itinerary and details of the investigation work are as given in Table 1.

Table 1. Investigation Itinerary

No.	Day	Itinerary & Work	Lodging	Transportation Means	Remarks
1	Jul. 23, Sat.	Tokyo - Hongkong - Colombo - Seychelles	In airplane	Airplane	(Tour) Advance party: Aoki, Shimizu and Nagahata
2	24, Sun.	Seychelles - Nairobi	Nairobi	Airplane	(Tour)
3	25, Mon.	Visiting related parties Nairobi - Blantyre	Blantyre	Airplane	Explaining investigation plan to Japanese Embassy in Kenya
4	26, Tues.	Discussion with related parties, Blantyre - Lilongwe	Lilongwe	Airplane	Discussion of investigation plan with JOCV
5	27, Wed.	Visiting related parties	Lilongwe	Automobile	Explaining investigation plan to Ministry of Agriculture and Natural Resources
6	28, Thur.	Visiting related parties Lilongwe - Karonga	Karonga	Airplane	Explaining investigation plan to Karonga district commissioner
7	29, Fri.	Preliminary investigation on Ngana camp	Karonga	Landrover	

8	30, Sat.	(Advance) Karonga - Blantyre, Preparation for investigation	Blantyre	Airplane	(Tour)
		(Rear) Tokyo - Hongkong - Colombo	In airplane	Airplane	Rear party: Shibata, Matsumura and Yamazaki
9	31, Sun.	(Ad.) Preparation	Blantyre		
		(Rear) Waiting	Colombo		Airplane trouble
10	Aug. 1, Mon.	(Ad.) Discussion with related parties	Blantyre	Automobile	Discussion of investigation plan with Dept. Geological Survey
		(Rear) Colombo - Seychelles - Johannesburg	Johannesburg	Airplane	(Tour)
11	2, Tues.	(Ad.) Preparation	Blantyre		
		(Rear) Johannesburg - Blantyre	"	Airplane	(Tour)
12	3, Wed.	Preparation	"		Merging of ad. and rear parties
13	4, Thur.	Blantyre - Karonga	Karonga	Airplane	(Tour)
14	5, Fri.	Karonga - Ngana camp	Ngana camp	Landrover	(Tour)

15	6, Sat.	Preparation	Ngana camp		
16	7, Sun.	Topographic survey	"		
17	8, Mon.	Field investigation (locating outcrops and drilled boreholes)	"	Landrover	J-1 to 3 Nos. 1, 2, 5 and 6
18	9, Tues.	Trenching Survey	"	"	J-2 and 3 Line A
19	10, Wed.	"	"	"	J-4 to 7 Lines A and B
20	11, Thur.	"	"	"	J-8 and 9 Line B
21	12, Fri.	"	"	"	J-10 to 12 Line C
22	13, Sat.	"	"	"	J-12 and 12' Line D
23	14, Sun.	"	"	"	J-13 to 15 Lines D and E
24	15, Mon.	"	"	"	J-16 and 17 Line E

25	16, Tues.	Trenching	Ngana camp	Landrover	J-18 to 23
26	17, Wed.	Trenching	"	"	J-24 to 26
	-	Survey	"	"	Between lines B and C
27	18, Thur.	"	"	"	J-27 to 30
					Between lines B and C, and D and E
28	19, Fri.	Trenching	"	"	J-31 and 2
29	20, Sat.	Trenching	"	"	J-32 and 33
		Survey			Between lines A and B, and north of line A
30	21, Sun.	Investigation of jetty sites	"	"	Kambwe Port Chilumba
31	22, Mon.	Trenching	"	"	J-34 to 37
		Survey			North of line A
32	23, Tues.	"	"	"	J-38 to 40
					North of line A
33	24, Wed.	Trenching	"	"	J-41 to 43
		Road investigation	"		Karonga - Iponga
34	25, Thur.	Trenching	"	"	J-42 to 44
		Road investigation			Iponga - camp site
		Survey			Between lines C and D

35	26, Fri.	Trenching	Ngana camp	Landrover	J-45 and 47
		Road investigation			Camp site - mine site
		Survey			Between lines C and D
36	27, Sat.	Trenching	"	"	J-46, 48 and 49
		Mine site investigation			
37	28, Sun.	Data arrangement	"		
38	29, Mon.	Trenching	"	Landrover	J-48 to 53
		Sampling			
		Topography check			
39	30, Tues.	Trenching	"	"	J-54 to 57
		Topography check			
40	31, Wed.	"	"	"	J-58 to 61
41	Sep. 1, Thur.	Trenching	"	"	J-60, 62 to 65
		Survey	"	"	Between lines D and E, and south of line E
42	2, Fri.	Outcrop investigation in the eastern district	"	"	
43	3, Sat.	"	"	"	
44	4, Sun.	Limestone investigation	"	"	

45	Sep. 5, Mon.	Preparation for leaving camp Sending coal samples	Ngana camp	Landrover	
46	6, Tues.	Ngana camp - Karonga	Karonga	"	Leaving camp site
47	7, Wed.	Karonga - Lilongwe	Lilongwe	Airplane	(Tour)
48	8, Thur.	Data arrangement	"		
49	9, Fri.	Visiting related parties Lilongwe - Blantyre	Blantyre	Automobile Airplane	Explaining investigation outline to Ministry of Agriculture and Natural Resources (Tour)
50	10, Sat.	Visiting related parties Packaging	"	Automobile	Discussing investigation results with Dept. of Geological Survey
51	11, Sun.	Packages and data arrangement	"	"	
52	12, Mon.	Sending packages Blantyre - Nairobi	Nairobi	Airplane	(Tour)
53	13, Tues.	Visiting related parties	"		Explaining investigation outline to Japanese Embassy in Kenya and JICA Nairobi office

54	14, Wed.	Nairobi - Cairo -	In airplane	Airplane	(Tour)
55	15, Thur.	London - Anchorage -	"	"	"
56	16, Fri:	Tokyo	Tokyo	"	"

Chapter 2. Conclusion

This chapter summarizes the results of the field investigation, the development concepts and plan based on the findings and data obtained during the investigation, and the problems to be solved hereafter.

2.1. Investigation Results

(1) Investigated Area

The field investigation was conducted on the Ngana coal field near the Tanzania border in the northern part of the Republic of Malawi. At the request of Malawi, the 1/5000- and 1/10000-scale topographic maps necessary for the field investigation were made from aerial photographs in Japan.

The Ngana coal field is a sedimentary basin of the Karroo system, surrounded by highlands of basement rocks. The area is approximately 500 m above sea level and exhibits minor ups and downs. In the northernmost part flows the river Songwe, which constitutes the border of Tanzania, from west to east.

Considering the siting and mining conditions, the investigation was mostly confined to the north and central areas of the western district of the Ngana coal field.

(2) Results of Field Investigation

Major coal seams in the western district were trenched from the north. The coal-bearing K-2 beds comprises the upper shale member, the middle sandstone member and the lower shale member. The upper shale member contains seven coal seams and the lower member contains one. Of these, five coal seams, Nos. 2 to 6, in the upper shale member appear workable.

Geologically, the district exhibits a monoclinal structure striking substantially in the south-north direction and dipping between 25 and 29 degrees to the east, free of large faults except those running along the rivers Ndamtakwa and Labasha. The aforesaid two faults divide the district into the north, central and south areas. The north, central and south areas were trenched in 26, 37 and 2 places, respectively, to confirm the coal seam conditions. Also coal samples were taken from less-weathered places.

According to an analysis of the coal samples done in Japan, the coal is low-volatile, high-ash, low-bituminous coal. Although it belongs to the Karroo system of the Palaeozoic era, the coal is not highly coalified.

From the analytical results, the minable coal seems to have a moisture content of 7 per cent or less, an ash content of 25 per cent or thereabout, and a calorific value of approximately 5300 kcal/kg. The north and central areas contemplated to be developed have theoretical reserves of 1,909,000 tons and minable reserves, calculated from the mining plan, of 1,249,000 tons, with a recovery rate of

65 per cent.

2.2. Development Concepts

(1) Examination of Development Plan

To compare underground and open-cut mining, applicability of the latter method in the object areas was studied. Open-cut mining will permit coal extraction from almost all coal seams occurring in the areas. Accordingly, despite a decrease in the workable area, minable reserves will increase to 2,708,000 tons. Further, this method, practiced on the surface, will offer an advantage of higher safety, as compared with underground mining.

But considerable mining difficulties are expected to be encountered in the object areas, because the overburden is hard and solid, the stripping ratio is as high as 10:1, and there are many thin coal seams. The need for preparing many bulldozers, shovels, crawler drills, trucks and other heavy machinery entails heavy capital investment in open-cut mining. The resulting depreciation and interest account for high percentages of production cost, too. Besides, localized heavy rain, occurring frequently during the rainy season, will impede the operation. Though not fully investigated yet, open-cut mining proved to have the above disadvantages. Consequently, the development plan was based on the simplest possible underground mining method.

(2) Development Plan Based on Underground Mining

For lack of electricity, usually required by underground mining, in the object district, it is planned to apply the retreating long-wall mining method, employing hydraulic props and kappes, to Nos. 2 and 3 coal seams, in combination, above the mine mouth, which is simple, uses little timber, and insures high recovery and safety. Tubs are to be used for roadway transportation, with their maximum running distance, in principle, established as 300 m. In a mining pit, a rising slope will be provided at the center, striking 600 m long. The north and central areas each will have three pits. In each pit, a mouth will be provided in a suitable place near the flat ground, with a drift driven through rocks and a material passage as well as a coal and a refuse pocket provided near the coal seam. The slope is to be driven through to the surface. All this forms a skeleton-like coal mining system with diagonal ventilation. The drift mouth serves as an intake port and the slope mouth as a return port. Several roadways are to be driven on both sides of the slope, and the upper and lower roadways connected and mining faces secured at their ends

Safety pillars will be left between the individual pits, excepting that they are to be connected in the lowermost roadways. Mined roadways will be closed. These measures for preventing spontaneous fires, air leakage and other accidents.

(3) Production Scale

By considering the coal seam thickness, inclined roof and floor conditions, coal quality and minable reserves disclosed by the investigation as well as the mine life and mining plan, it is contemplated to extract coal from 60 m long mining faces by the retreating longwall mining method. Allowing for the local technical level, a daily coal production of 210 tons on three shifts plus 23 tons resulting from driving, making a total of 233 tons, or an annual production of 70,000 tons is envisaged.

(4) Assumptions for Development Plan

During the field investigation, only outcropped coal seams were confirmed by trenching. Therefore, the development plan is based on an assumption that similar coal seam occurrence continue to the lower mine mouth level.

The strata pressure and the quantities of underground water and gas necessary for the contriving of an underground mining plan are unknown. Besides, electricity is unavailable. So the mining area is confined to above the mine mouth level. The roof rock and coal quality manifest that their influence is not great.

The colliery is to be operated on 300 days in the year, with underground and other directly related work on three shifts, coal preparation on two shifts and office work on one shift. Each shift comprises eight hours.

All engineers are to receive proper education and training and at least one-third of laborers must have experience in mining.

2.3. Development Plan

The following plan covers the development of a colliery producing 70,000 tons of coal annually.

2.3.1. Driving Plan

Driving comprises initial and operative driving. Initial driving consists of driving up to the mining face in the first pit and subsequent provision of the drift, materials passage and pockets, and operative driving consists of other driving.

The initial driving covers a total length of 3238 m, which consists of 2268 m long through rock and 970 m long along coal seam.

To maintain normal production and keep up with the progress of the working face operation, 991 m per year of operative driving will suffice. But, allowing for unexpected fluctuations, 130 per cent of that or 1288 m of annual operative driving is planned. To drive 60 m per month, always in two places, on three shifts by employing 10 men per shift per place, 60 men will be necessary.

6.4 tons of coal will be obtained from each meter of driving. This amounts to 7000 tons per year, allowing for a safety factor of 85 per cent.

2.3.2. Mining Plan

Retreating longwall mining employing hydraulic steel props and kappes will be applied. Coal blast-extracted from the 60 m long mining face runs by gravity through a trough to a lower roadway, where it is loaded directly into tubs. If advanced 1.4 m per shift over a distance of 30 m, or a half of the mining face length, daily production will be 217 tons. Annual production will be 65,000 tons, and 72,000 tons when 7,000 tons of coal from driving is added. But the plan is conservatively finalized at 70,000 tons.

As each shift requires 22 miners, the daily requirement on three shifts will be 66 miners. The mining productivity will be 3.3 tons per man per shift.

2.3.3. Transportation Plan

(1) Transportation of Coal and Refuse

Coal and refuse from roadway driving and mining face will be transported to the slope in 50 tubs running on double-track rails laid on the roadway. A separate coal and a refuse trough will be provided on both sides of the slope, through which the coal and refuse will drop by gravity to pockets at the bottom. The drift will have a large cross section so that a 4.5-ton dump truck can enter.

The coal and refuse in the pockets will be loaded directly onto the dump truck and hauled to a preparation plant and a refuse disposal yard. Three dump trucks will be used.

(2) Transportation of Materials

Materials and supplies will be transported by a dump truck to the materials passage. They will be loaded onto two slope cars which are lifted to the desired roadway by a 15 horsepower air hoist, and then transloaded on a roadway push car for transportation to the correct mining face. Ten roadway materials cars will be prepared.

There will be 22 transport men per shift, or 66 men per day.

2.3.4. Ventilation, Drainage and Safety Plans

A diagonal ventilation system, with the drift mouth serving as an intake port and the slope mouth as a return (exhaust) port, will be provided to each pit. Because of a level difference of over 100 m between the two ports, there will be a natural ventilation. To insure a minimum ventilation of 500 m^3 per minute for one mining face and two driving faces, a fan of about 4.5 horsepower (plus one spare) will be installed at the return port. Also, there will be two air fans for localized ventilation.

To eliminate underground water, the drift and roadway will have drain ditches and the slope 4-inch drain pipe.

Mining safety is as important as production.

Because mining is confined to above the mine mouth level, strata pressure, underground water and gas will be limited, But all underground engineers and miners will carry cap lamps, CO-gas masks and other safety equipment. Also, safety pillars will be left on both sides of the slope and between individual pits, and mined pits will be closed.

2.3.5. Surface Facilities Plan

There will be provided an office building, workshop, coal preparation plant, supplies and oil warehouse, generator room, explosive warehouse and shop, and refuse disposal yard. To supply the minimum electricity required, two 75 KVA generators must always be in operation. Therefore, three 75 KVA generators will be provided, one of which is to be maintained as a spare.

As a total of 17.6 m^3/min. of air will be consumed underground, two diesel compressors (each discharging 25.5 m^3/cm^2 of air at a pressure of 7 kg/cm^2) will be provided at the mine mouths.

Two wheel loaders (1.2 m^3) and one bulldozer (D4) will be used for coal handling and dump and road maintenance.

In addition, houses for 51 staffs, road and water supply facilities will be provided.

2.3.6. Manpower Plan

The manpower plan for normal colliery operation with 70,000-ton annual production is based on an assumption that

Table 2 . Manpower Plan and Productivity

Type of Work	Actually Working	Employed	Remarks
Underground Laborers			
Mining	66		22 x 3 shifts x 1 face
Driving	60		10 x 3 shifts x 2 places
Others	123		Repair = 36 Transportation = 66 Others = 21
Sub-total	249	311	Workability = 80 %
Surface Laborers			
Coal Preparation	30		15 x 2 shifts
Mechanical & Electrical	28		Machinery repair = 18 Electrician = 10
Others	35		Office, safety lamp, materials and supplies, transportation, dump, etc.
Sub-total	93	103	Workability = 90 %
Total Laborers	342	414	
Staffs and Officers	51	51	General manager = 1 Underground manager = 27 Surface technical engineer = 11 Surface office worker = 12
Total	393	465	
Productivity (Ton per Man-Month)	14.8	12.5	70,000 ton/yr ÷ 12 ÷ (393 or 465 men)

Table 3. Summarized Capital Investment on Colliery Equipment

Description	Investment ¥1,000	Investment K1,000	Remarks
Initial Driving	224,582	749	Rock 2268 m + coal 970 m = 3238 m
Mining Equipment	64,162	214	Hydraulic steel props, kappes, augers, picks, etc.
Driving Equipment	3,785	13	Hammers, augers, etc.
Transportation Equipment	8,144	27	Air hoists 15 hp x 3, troughs, etc.
Other Underground Equipment	7,069	23	Ventilation 1,619, drainage 540, and safety 4,910 (¥1,000)
Preparation Equipment	16,400	55	Building, pockets, screens, etc.
Electric Equipment	56,427	188	Generators 75 KVA/60 kw x 3, telephones, safety lamps, ilumination system, and distribution lines
Air Compressor	23,528	78	Air compressors 25.5 m^3/min x 2 and piping
Other Surface Equipment	15,027	50	Water supply and spray systems and work shop
Transportation Vehicles	40,160	134	Tubs 50, materials cars 12, trucks 3, wheel loaders 2, and bulldozer 1
Ground construction and Building	133,170	444	Road 2400 m, operation site 25,100 m^2, office and plant buildings, and 51 houses
Miscellaneous	59,246	197	592,454 x 10 %
Total	651,700	2,172	

Table 4 Schedule of Colliery Development & Coal Production

		The 1st Year	The 2nd Year	The 3rd Year	The 4th Year
Underground	N 1 Drift	435m			
	N 1 Material passage	25m			
	N 1 Pockets		23m		
	N 1 Slope		310m		
	N 1 Left No.1		300m		
	N 1 Left No.2		300m		
	N 1 Left No.2 face			60m	
	N 1 Road ways			480m	550m
	N 1 Road ways			400m	550m
	N 1 Mining face			Test mining	
Surface	Compressor Eq.				
	Ventilation Eq.				
	Coal preparation Eq.				
	Electricity Eq.				
	Ground construction				
	Building				
Coal Production	Driving	—	4,800	7,000	7,000
	Mining	—	—	35,400	63,000
	Total (Tons/Year)	—	4,800	42,400	70,000

suitably educated and trained technical engineers and laborers experienced in mining work, at least one-third of the total, will be obtained. (see Table 2.)

2.3.7. Capital Investment Plan and Development Schedule

The colliery capital investment, including investment in initial driving, will amount to 651,700,000 yen (2,172,000 kwacha), as shown in Table 3 . This becomes 9309 yen (31 kwacha) per ton of coal produced in a year, considerably lower than 20,000 to 30,000 yen for ordinary cases.

For lack of actual price data in Malawi, Japan's current prices are used for the estimation of indefinite and unknown items.

The development schedule is planned as shown in Table 4 . Especially, the mining face laborers will take five months to become skilled in the work. Normal coal production will start in three years and eight months after the start of development.

2.3.8. Production Cost

Production cost with normal coal production of 70,000 annual tons is presented in Table 5 . This calculation is as much as possible based on the data furnished by Malawi, but where definite data are unavailable Japan's current prices are used.

1976's imported coal prices in Blantyre were 33.18

Table 5 . Production Cost

Description	Per Ton Yen	Per Ton Kwacha	Remarks
Materials and Supplies	1,346	4.48	Timber, explosives, steels, etc.
Labor	957	3.19	Underground laborers 249, surface laborers 93, and non-labor staffs 51
Expenses	1,001	3.34	Repairs, fuel oil, taxes and public imposts, etc.
Sub-total	3,304	11.01	
Depreciation	743	2.48	Initial driving - proportioned to production, machinery and transportation equipment - fixed instalments over 5 to 10 years, and others by mine life
Interest	502	1.67	10 % per annum
Sub-total	1,245	4.15	
Total	4,549	15.16	

kwacha for Rhodesian coal and 13.46 to 28.16 kwacha for Mozambique coal. The price of this colliery's coal in Blantyre will be 36 kwancha (15.16 kwacha of production cost plus 20.84 kwacha of transportation cost to Blantyre) and higher than the imported coals. Yet the development of this colliery has a merit that substitution of domestic coal for imported ones saves foreign currency and affords employment to the nation. Development of coal-consuming industries in the northern region will reduce the transportation cost and entail a greater merit.

2.3.9. Road and Jetty

In developing a colliery, a transportation route should be secured for the shipment of coal produced and the intake of machinery and supplies. The Ngana coal field will be most advantageously connected to the industrial centers in the central and southern regions by the combination of barge transport over Lake Malawi and trucking between colliery site and Kambwe, which necessitates the repairing of an old jetty (now unusable) at Kambwe north of Karonga.

Fixing of the road between the colliery site and Iponga as well as repairing of the old jetty at Kambwe is indispensable.

2.4. Problems to Be Solved before Colliery Development

In the formulation of this 70,000 ton-per-year colliery development plan, the following problems are left unsolved:

(1) When demand increases, production can be increased by operating two mining faces in each pit. Because of the limited minable reserves, however, this unavoidably shortens the mine life. To obtain greater minable reserves, investigation should be extended to the south area lying next to the central area.

(2) Deep exploration holes should be drilled to determine changes in the coal seam condition, dip and coal quality in depth. The drilling plan should be based on the results of an investigation made by the Republic of South Africa.

(3) Additional investigation should be made as to the place where the drift contacts the coal seam and the detailed mining conditions so as to prevent the miscarriage of the mining plan.

(4) The strata pressure, underground water and gas should be carefully checked to permit provision of adequate safety measures.

(5) Unlike surface mining, underground mining involves various hazards. Therefore, safety in mine operations is as important as production itself.

Technical engineers and laborers skilled in underground mining are not easy to secure. Present technical levels in Malawi and effects of education and training should be examined. Probabilities must be studied as to the education and training of the technical engineers in foreign collieries and the invitation of experienced foreign instructors. The laborers may be employed from among the local inhabitants and others, but at least one-third of them should have experience in underground mining. The availability of such experienced laborers should be studied, too.

(6) Because no coal-mining industry exists in Malawi, most of materials, machinery and equipment necessary for development and mining operations should be imported. The procurability, prices and transportation involved in their import should be investigated. Also, prices and transportation of domestically obtainable items should be carefully investigated.

In addition to the above problems, it is also desired that extensive investigations be made as to the infrastructure and environmental assessment related to this colliery development. This investigation has revealed a probability that a colliery be developed in the western district of the Ngana coal field. It should therefore be followed by a feasibility study that is indispensable to colliery development.

Chapter 3. Ngana Coal Field

3.1. General Conditions

3.1.1. Outline of North Region

The outline of the north region including the Ngana coal field is as follows:

In Malawi, the north region represents 28.6 per cent of the land area, and about 12 per cent of the population, which results in the lowest population density in the country. There is no noteworthy industry. The greater part of the people is engaged in self-supporting agriculture, but the region's farmland is only 12.3 per cent of the nation's total. Principal products are corn, beans, cassavas, peanut, millet and rice.

Among main roads are one that runs up north from the central region to Zambia via Mzuzu, the region's administration center, and Karonga, and one leading from Nkata Bay on Lake Malawi through Mzuzu to Katumbi. As of 1975, the region had a total of 2740 km long road; 5.3 per cent of which was asphalted, 3.6 per cent graveled and the remainder unpaved.

In addition to overland transportation, there are ship transportation routes over Lake Malawi, using jetties at Chilumba and Nkata Bay.

This region largely comprises highlands and the climate is mild. But high temperature and humidity characterize the flats on Lake Malawi and along main rivers.

3.1.2. Location and Traffic

The Ngana coal field lies to the south of the river Songwe, which constitutes the Malawi-Tanzania border, in the northernmost end of Malawi, or 30 km west of the north end of Lake Malawi. This coal field is covered by a 1/50000-scale topographic map of Misuka (Sheet No. 093301) issued by the Department of Survey.

Access to the coal field can be attained by following a road that runs north from the nearby town of Karonga, along the shore of Lake Malawi, via Kaporo to Ngoto. From Ngoto, there is a road that extends northwest through Iponga to the village of Mwanjawala, along the river Songwe, which lies at the approximate center of the northern part of the coal field.

A bus service is available along an approximately 40 km long section with good road condition between Karonga and Iponga. But the 23 km long road between Iponga and the coal field is very bumpy and completely bridgeless. So the vehicles traffic in this section will be impeded for a fairly long period during the rainy season. There is a road that runs into the coal field, approximately to Mwansalano in the center. With some repairs, this road will permit the use of a land rover during the dry season.

3.1.3. Topography

This coal field extends approximately 8 km in both east-west and north-south directions and its topography faithfully reflects the geological structure of the locality. The river Makeye and the river Mugwisi, a major tributary of the former, erode rocks of the Karro system and gently flow down, substantially along the strike of the strata. The sedimentary basin of the Karroo system constituting this coal field approximately corresponds to the drainage basins of the river Makeye and its tributaries. Nampatata ridge and Kapembe hills extend in the direction of the stratum strike, whereas Lupumba hills manifests itself as a cuesta.

The east and south ends of the coal field present 150 to 300 m high fault scarps that contact basement complexes. The basement complexes lying on the east, west and south of the coal field form hills and mountains, generally between 800 and 1000 m in height, that surround the coal field. The coal field exhibits a basin-like topography, approximately 500 m above sea level or 300 m lower than the surrounding mountains and hills, and gently undulates except in its eastern part.

3.1.4. Climate

The climate of this area is shown in Table 6 . Measurement of the rainfall in the area was started in the recent past. The measurement record obtained indicates very useful, but its details are unknown at present.

Table 6. Climate Conditions (Rainfall in mm; Temperature in °C)

Place	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total & Mean
Rainfall	(mm)													
Ngana	1976	-	-	-	-	138	48	37	32	0	4	0	239	1,656
	1977	298	133	323	441	164	4	6	6					
Iponga	1975	94	148	503	1,174	310	279	54	6	4	1	48	212	2,833
	1976	140	275	489	464	352	117	21	0	0	5	8	282	2,153
	1977	307	55	555	675		37							
Reference	1941 -70	Tokyo 1500 mm, Oshima 3000 mm, and Owashi 4200 mm												
Rainy Days														
Ngana	1976					23	20	7	4	0	4	0	14	138
	1977	23	11	21	28	13	3	2	2					
Monthly Averaged Temperature (°C)														
Karonga	Airport													
High	1975 -77	29.1	29.5	28.6	28.2	28.0	27.1	26.5	27.4	30.2	31.2	33.3	30.9	29.2
Low	1975 -77	21.5	21.8	21.2	21.2	19.9	18.1	16.9	17.2	19.4	21.3	23.2	22.8	20.4
Reference		High: Sapporo 26.5, Tokyo 31.0, Kyoto 33.2; Low: Sapporo 17.8, Tokyo 23.5, Kyoto 23.0												

that approximately 1700 mm of rain falls in the year, with the greater part of it being concentrated in the rainy season between December and May. During the rainy season, rainy days account for a little under 60 per cent of calendar days. The annual rainfall in Iponga, a town by the river-side of Songwe 20 km downstream of Ngana, is as much as 2000 to 3000 mm.

A temperature data at nearby Karonga airport was obtained, which averages the highest and lowest temperatures of everyday over the month. The highest and lowest temperatures in the coldest July are 26.5°C and 16.9°C, and those in the hottest November are 33.3°C and 23.2°C, respectively. Situated at the inland mountain base, Ngana seems to present a greater temperature difference than in Karonga.

3.1.5. Investigations in the Past

In 1896, a German named W. Bornhardt made the first simple investigation on this coal field, which was followed by several other investigations. In 1955 K. Bloomfield, a geological surveyor, reviewed all investigation results obtained previously, trenched the coal seams, and proposed the necessity of drilling exploration boreholes. An investigatbion party of the South African Chamber of Mines drilled 11 boreholes (approximately 100 m deep) and dug some trenches in the coal field. This borehole data is considered to be

3.2. Drawing of Topographic Maps and Field Survey

3.2.1. Drawing of Topographic Maps

This investigation covers the western district of the Ngana coal filed and the road leading to Iponga. Topographic maps covering them are available at the Department of Survey. They are Sheet No. 0933D2 (Tanzania 272/2) Edition 4 D.O.S. 1971, Series Z 742 (DOS 425) and Sheet No. 0933D1, both drawn on the scale of 1:50,000. To prepare 1/5000-scale topographic maps required for the field investigation, 1/25000-scale aerial photographs were obtained from the Department of Survey for the Ngana coal field, and a 1/40000-scale aerial photograph (in color) from the Directorate of Overseas Surveys, England for the Tanzania border area.

By using these aerial photographs and the 1/50000-scale topographic maps, the topographic maps of the coal field and the road route were prepared in Japan, on the scales of 1:5000 and 1:10000, respectively.

They were prepared as follows:

(1) As regards the four sheets covering the coal field, Nos. 2, 3, 4 and 5, six plane control points (1601, 1602, 1603, 1604, 1605 and 1606) and two elevation control points (2601 and 2602) were read from the 1/25000-scale aerial photograph and the 1/50000-scale topographic map, and their coordinates and elevations were read on the latter

Table 7 Airphoto (1/25,000) measured values

Points №	Coordinates X	Coordinates Y	Elevations H	
0841	8936451.11	570612.99	790.64	Pass point
0842	8933755.63	570388.16	764.90	
0843	8931223.08	570299.57	802.66	
0844	8933908.03	570695.03	771.94	
0851	8936113.98	573055.28	747.48	
0852	8933620.31	572804.76	757.72	
0853	8930995.71	572894.20	604.26	
0854	8933643.96	573117.59	736.40	
0861	8936298.81	575735.79	502.28	
0862	8933646.27	575385.63	585.94	
0863	8931001.08	575307.78	662.76	
0864	8933628.22	575775.82	536.91	
0871	8936097.24	578280.71	539.53	
0872	8933387.23	577338.21	734.77	
0873	8931312.08	577828.19	625.86	
0874	8933245.20	578333.77	712.59	
1601	8930774.90	570130.43	644.23	
1602	8934686.38	571259.88	717.19	
1603	8930606.73	572592.64	598.58	Horizontal control point
1604	8936369.67	573330.50	798.38	
1605	8934978.40	578083.99	764.86	
1606	8932123.93	577562.57	586.98	
2601	8934658.43	572680.48	691.56	Elevation point
2602	8932680.20	575367.78	545.96	

map (see Attached Fig. No. 1 and Table 7).

By employing these control points, analytical aerial triangulation was done on a computer. Also, a total of 16 pass points (0841-0844, 0851-0854, 0861-0864 and 0871-0874) were read from the four stereo-models, four each individually, to accomplish their tying. Then a 1/5000-scale topographic map was made on the Wild Stereo Plotter A-8 by use of all these data.

(2) For Sheet No. 1 covering the coal field, three plane control points (1801, 1802 and 1803) were established at the same positions as the three pass points (0851, 0861 and 0871) on the 1/25000-scale aerial photograph, as the tie points for tying together the 1/40000 and 1/25000 aerial photographs.

By this means, a 1/5000 topographic map showing the distribution of coal-bearing formations was completed.

(3) As to the access road to Iponga, two plane control points (3601 and 3602) as well as three each plane and elevation control points, (1801, 1802 and 1803) and (4601, 4602 and 4603) respectively, serving as tie points for the tying with the 1/25000 aerial photograph, were selected on the 1/40000 aerial photograph and 1/50000 topographic map. Analytical aerial triangulation was effected based on their coordinates and elevations. By reading 24 pass points (0031-0034, 0041-0044, 0051-0054, 0061-0064, 0071-0074 and

Table 8 Airphoto (1/40,000) measured values

Points №	Coordinates X	Coordinates Y	Elevations H	
0031	894243223	588004.16	479.50	Pass point
0032	893807679	587803.77	488.43	〃
0033	893416528	588425.87	502.82	〃
0034	893852390	588382.06	494.87	〃
0041	894240543	584473.57	489.86	
0042	893809088	584591.39	822.56	
0043	893387439	585151.24	569.77	
0044	893836771	584942.91	803.77	
0051	894180114	581554.15	523.87	
0052	893749988	581700.54	648.96	
0053	893422801	582310.87	767.76	
0054	893799249	582547.14	854.00	
0061	894144451	579152.94	516.07	
0062	893788253	579047.23	602.53	
0063	893391452	579227.60	741.18	
0064	893765984	579896.89	662.24	
0071	894187440	576765.16	518.93	
0072	893769716	575927.84	514.93	
0073	893341766	575834.60	521.50	
0074	893764090	576830.11	501.06	
0081	894144866	573320.31	803.61	
0082	893737217	572443.81	715.62	
0083	893366669	573210.08	686.41	
0084	893746169	573248.05	766.46	
3601	894152287	587511.09	505.16	Horizontal contral point (1/25,000)
3602	893747632	589246.71	488.77	
1801	893611428	573054.81	744.57	0851 Tie point
1802	893628536	575718.93	510.64	0861
1803	893611120	578310.23	543.79	0871
4601	893945707	574981.17	576.63	Elevation point
4602	894090842	582745.80	602.45	
4603	893736163	584623.85	888.13	

0081-0084), stereo-models were tied together. A 1/10000-scale topographic map was plotted on the plotter, by the use of all these data (see Attached Fig. No. 1 and Table 8). Then the topographic map was made from the plastic base prepared on the plotter.

Owing to inadequate basic data and working procedure, the topographic maps thus prepared may involve some errors as described hereunder. But in the plotting from aerial photographs, errors equivalent to about 75 per cent of the contour interval are tolerable. Since the contour interval of 10 m is employed now, deviations up to 7.5 m are tolerable.

(1) When high accuracy is required, it is essential to establish definite control points by providing air-photo signals and performing a control point survey before taking photographs. This time the control points were read from the existing aerial photographs and topographic maps prepared without such steps. The control points read from the 1/50000 topographic map devoid of triangulation points and bench marks will produce some errors.

(2) The 1/25000 aerial photographs obtained from the Department of Survey are contact prints, from which positive films were prepared for the plotting work in Japan. Accordingly, errors due to the expansion and contraction of the contact prints and the reversing to the positive films will be inevitable.

(3) The 1/40000 color aerial photograph was a positive film directly made from a negative film. As the negative film is poorly developed and blurred, some errors are likely to arise from this cause, too.

3.2.2. Field Survey

(1) Summary

The investigated part of the western district of the Ngana coal field was surveyed simultaneously with trenching in order to accurately plot the positions of the trenches and the boreholes drilled by the South Afraican Chamber of Mines on the 1/5000 topographic map. The survey period was between August 9 and September 1, 1977, during which actual field work was done on 14 days. Traverse survey was made, using a Ushikata S-25 handy transit (which permits reading by 5' horizontal and 1° vertical increments) and 50 m steel tape.

(2) Survey Work

In the traverse survey, the 1/5000 topographic map plotted from the aerial photographs obtained from the Department of Survey etc., as described in 3.2.1, was used. For lack of air photo signals, however, there were no definite control points on the aerial photographs. Therefore, two clearly visible houses were selected on the 1/5000 topographic map, and one corner of the individual houses was made the control point of the north and central areas.

These points were designated as Points A and C and used as control points, reading their coordinates and elevations from the 1/5000 topographic map as follows:

	Coordinates		Elevation
	Latitude	Departure	
Point A	8,937,090 m	574,766 m	512.5 m
Point C	8,935,190 m	574,457 m	562.0 m

By traverse survey starting from the control point, angles of intersection between individual traverse courses and vertical angles (angles of depression and elevation) and oblique distances between individual stations were measured. Their azimuthal angles and horizontal distances were calculated from the measured values. Finally, the latitudes and departures of the trenches and drill holes were determined from them, and they were plotted on the 1/5000 topographic map.

(3) Survey Details

The routes surveyed are shown in Attached Fig. 2, with major stations. The number of stations and the total length of traverse courses (in horizontal distance equivalent) were 168 and 6185 m in the north area, 196 and 7345 m in the central area, and 364 and 13,530 m in total (see Table 9. List of Traverse Courses). In the north area, survey was started from the control point A1, turning counterclockwise from A21 through A25 to A42 and clockwise from

Table 9. List of Traverse Courses

Area	Traverse Course	No. of Station	Total Length (m)
North	Line A		
	A1 - A21 - A42, A43	43	1579
	A42, A42-1 - A42-8 - A42-14	14	675
	A42-1 - A42-6'	5	163
	A42-8 - A42-8-20	20	748
	Line B		
	A21 - B15 - B28 - B30	30	1150
	B30 - B30-21 - B30-32	32	1006
	B28 - A42	24	864
		(168)	(6185)
Central	Line C		
	C1 - C9 - C29	29	1006
	C29 - C29-8 - C29-24 - D37	31	988
	C29-8 - C29-8-10	10	357
	C29-24 - C29-24-1	1	41
	C29 - C29-13	13	341
	Line D		
	C9 - D21 - D34 - D37	37	1775
	D34 - D34-24 - E36	25	883
	D34-24 - D34-24-11	11	325
	Line E		
	D21 - E20 - E35, E36	36	1520
	E35 - E35-3	3	109
		(196)	(7345)
	Total	364	13530

B15 through B28 to A42, the counterclockwise and clockwise courses closing at A42. Between A25 and A42, and B15 and B28, drill holes Nos. 1, 2, 5 and 6 were measured. Trenches were measured between A42-1 and A42-14, A42-1 and A42-6', A42-8 and A42-8-20, A42 and B28, and B30 and B30-21.

In the central area, survey was started from the control point C1, turning counterclockwise from C9 through C29 to D37 and clockwise from D21 through D34 to D37, the counterclockwise and clockwise courses closing at D37. Additional survey turned counterclockwise from D21 through D34 to E36 and clockwise from E20 through E35 to E36, the two courses closing at E36. Drill holes Nos. 3 and 4 were measured between C9 and C29, Nos. 7 and 8 between D21 and D34, and Nos. 9 and 10 between E20 and E35. Trenches were measured between C29 and D34 and D34 and E35. Trenches were also measured between C29 and C29-13, C29-8 and C29-8-10, D34-24 and D34-24-11, and E35 and E35-3.

(4) Survey Results

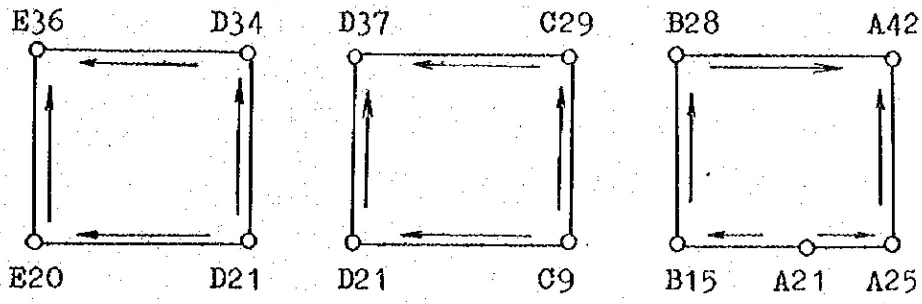
The object of the survey was to achieve accurate plotting of the positions of the drill holes and trenches on the 1/5000-scale topographic map. Because of the limitation on survey apparatus transport and the need for expediting, traverse survey using a handy transit and a steel tape was done.

In addition to this traverse survey, one and two closed surveys were carried out in the north and central areas, respectively, as given in Table 10.

Table 10. Closed Surveys

Start Point	Close Point	Distance (m)	Coordinates Latitude (m)	Coordinates Departure (m)	Closing Error (m)	Closing Error Ratio	Relative Height Dif-ference (m)
A21	A42	2725	6.7	5.2	8.5	1/320	1.0
C9	D37	3485	0.5	8.0	8.0	1/440	1.1
D21	E36	3078	4.8	5.7	7.5	1/410	0.5

fig. 2 . Closed Survey Diagrams

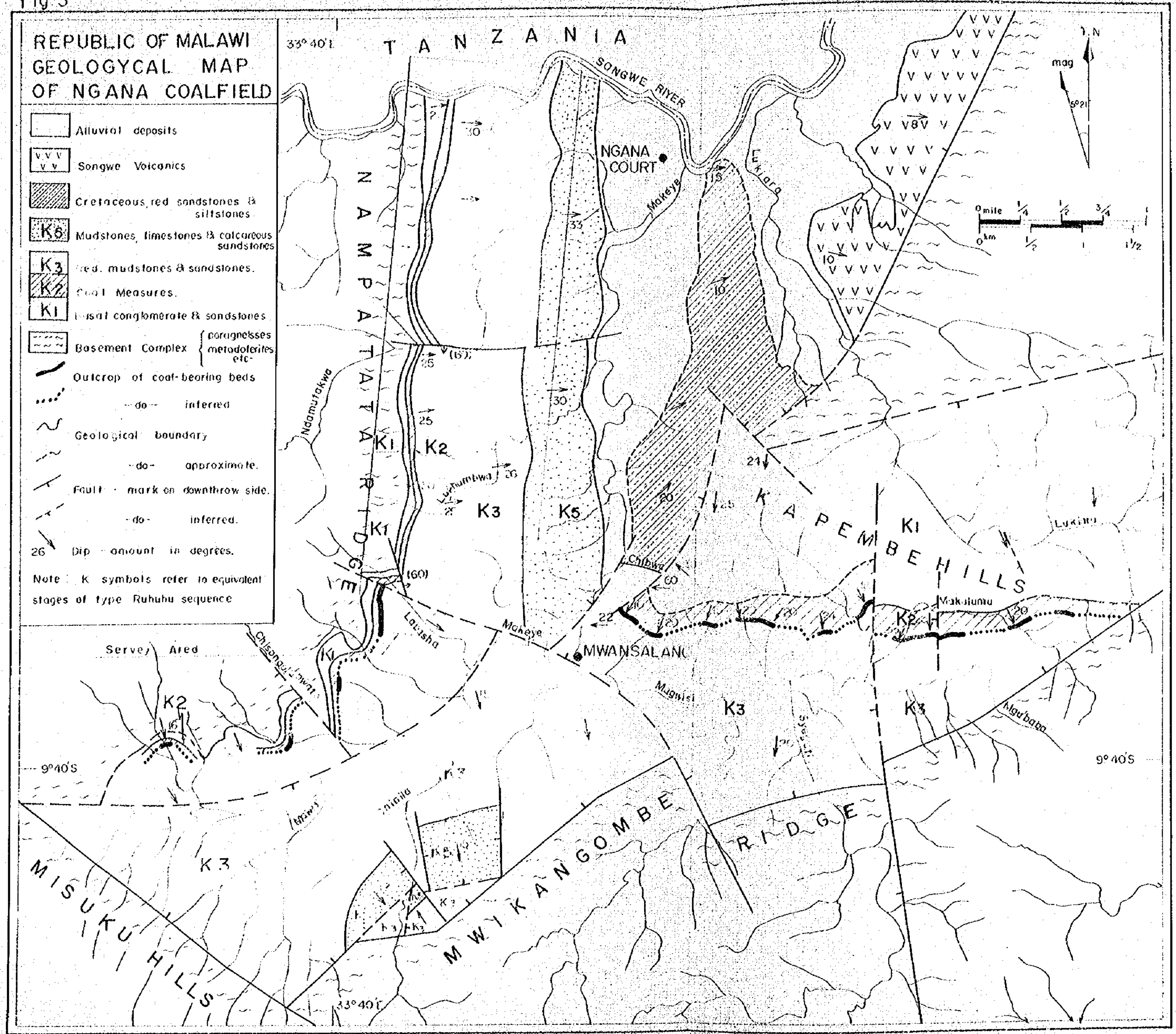


Start at D21
Close at E36

Start at C9
Close at D37

Start at A21
Close at A42

The closing error, its ratio and relative height difference averaged approximately 8 m, 1/400 and 1 m, respectively. For the traverse survey by a handy transit, the errors are relatively small and offer no accuracy problem. But these errors are tolerable only in the plotting of the positions of trenches and drill holes on the 1/5000 topographical map. For the study of actual development fig.3


REPUBLIC OF MALAWI
GEOLOGYCAL MAP
OF NGANA COALFIELD
Alluvial deposits
Songwe Volcanics
Cretaceous red sandstones & siltstones
K5 Mudstones, limestones & calcareous sandstones
K3 ed. mudstones & sandstones.
K2 oal Measures.
K1 asal conglomerate & sandstones
Basement Complex { paragneisses metadolerites etc.
Outcrop of coal-bearing beds
-do- inferred
Geological boundary
-do- approximate.
Fault - mark on downthrow side.
-do- inferred.
26 Dip amount in degrees.
Note : K symbols refer to equivalent stages of type Ruhuhu sequence
33°40'E
TANZANIA
SONGWE RIVER
NGANA COURT
NAMPATA RIDGE
KAPEMBE HILLS
MWANSALANG
MWIKANGOMBE RIDGE
MISUKU HILLS
9°40'S
mag
N
0 mile 1/4 1/2 3/4 1
0 km 1/2 1 1/2
Servey Area
Makeye
Ndamutakwa
Chibwa
Mugnisi
Makulumu
Lukina
Ngu'baba

plans and other purposes, maps of greater accuracy should be prepared by use of suitable survey apparatus.

4.3. Stratigraphy

General stratigraphy of this coal field is given below. Subdivision of the Karroo system follows the one made by Storkley (1931) who investigated the Ruhuhu coal field in Tanzania, which is deemed as the type locality for Tanzania and Malawi. (See fig. 3.)

Recent		Pebble Beds
Late Pliocene Pleistocene		Songwe Volcanics
	------ Unconformity ------	
Cretaceous		Redgrits, sandstones and silt-stones with concretionary limestones
	------ Unconformity ------	
Karroo	K5 Beds	Greenmudstones, orgillaceous limestones and calcareous sandstones
	K3 Beds	Red and purple mudstones with bands of red grit and arkose
		Calcareous concretions
	K2 Beds	Coal measures
	K1 Beds	Basal conglomerate, arkose and flaggy sandstones
	------ Great Unconformity ------	
Basement Complex		Paragneisses, metadolerites, etc.

3.3.1. Basement Complex

The basement complex in the coal field vicinities comprises amphibolitic paragneis associated with metadolerite. Schist and phyllite also occur in some places.

3.3.2. Karroo System

The K1 through K5 beds of the Karroo system, occurring in the coal field, belong to the Ecca series. The K6 and K7 belong to the Beaufort series and the K8 to the Stormberg series, but these beds do not occur in the coal field.

The fault at the center divides the coal field into the eastern district (Kapenbe hill) and the western district (Nampatata or Nabatata ridge), where rock facies and bed thicknesses are more or less different from each other. The difference is most conspicuous in the lowermost stratum. In the western district, the Karroo system and the basement complex are unconformable, with rocks exhibiting typical marginal characteristics. Rocks in the eastern district are finer-grained and thicker-bedded, which suggests that this district is closer to the center of the Karroo sedimentary basin.

(1) K1 Beds

In the western district, the K1 beds unconformably lie on metamorphic rocks that make up the basement complex. Above approximately 4 m high basal conglomerates lie rough-grained sandstones, and then fine-grained sandstones that contain carbides and define the upper limit of the K1 beds. The beds thickness is approximately 110 m, with localized variations dependent on the basement complex configurations.

In the eastern district, the beds thickness is thought to be approximately 450 m. The lowermost is a thick bed of fine-grained, white sandstones, on which silt-stone and mudstone lie alternately. They are overlain by gray mudstone and topped by a mudstone-carbonaceous bed.

(2) K2 Beds

The K2 beds are broadly grouped into the lower shale member, middle sandstone member and upper shale member. Principal coal seams occur in the upper shale member.

In the western district, the lower shale member is approximately 5 m thick. The middle sandstone member is confirmed as 28 m thick between J-2 and J-32 in the north area (defined later) and 18 m thick between J-4 and J-42 in the central area (defined later). The upper shale member thickness is confirmed to be 18 at the No. 1 drill hole in the north area and 13 m between J-13 and J-62 in the south end of the central area. The K2 beds that are over 50 m thick in the north area become increasingly thinner prog-ressing southward; they are 36 m thick near the south end of the central area. In the eastern district, they are as thick as 90 m. Fossils of Glossopteris indica and Vertebraria SP representing the Ecca era were found in the K2 beds.

(3) K3 Beds

The lower portion, approximately 50 m thick, of the K3 beds consists mainly of white to light-brown, arkosic, medium-to rough-grained sandstones, while the 150 m thick upper portion of red to pruplish red mudstones. Calcareous nodules, having a maximum thickness of approximately 1 m, have a very common occurrence in the upper red mudstones.

The K4 beds (upper coal-bearing formation) usually occurring above the K3 beds are not found in this coal field. Various studies have disclosed that this coal field has no space to permit the sedimentation of the K4 beds between the K3 and K5 beds.

(4) K5 Beds

The K5 beds comprise green to grayish green sandy mudstones and mudstones, containing partings, with a maximum thickness of approximately 1 m, of siliceous and lutaceous limestones.

The limestone partings occurrence increases progressing upward. In the upper half of the K5 beds, the ratio of limestone to mudstone becomes approximately 1 : 2.

The following table lists the results of chemical analyses made on three typical samples of these limestone partings taken for the purpose of reference:

	CaO	MgO	SiO_2	R_2O_3	Ig loss	Total	Appearance
L-1	24.59	14.86	20.18	2.72	37.74	100.09	Soft marl-like
L-2	45.38	1.00	13.99	1.48	37.80	99.65	Siliceous
L-3	47.92	0.23	12.20	1.10	38.27	99.72	Siliceous

Note. $R_2O_3 = Al_2O_3 + Fe_2O_3$

Because of their probable usability as cement or fertilizer, these partings were investigated several times. The South African investigation group made an especially detailed investigation in 1975 and 1976. The K5 beds are approximately 75 m thick in total.

3.3.3. Cretaceous System

The Cretaceous system is a thick system of strata unconformably lie above the Karroo system, with the greater part of which being covered with alluviums and degraded soil. This system may be underlain by the upper beds (K6) of the Karroo system, but they do not outcrop in this coal field.

The strata comprise red grits, sandstones, silt-stones containing limestone nodules, etc. and the thickness is estimated to be approximately 650 m.

This system is considered comparable to the Dinosaur bed of the late Jurassic or the early Cretaceous that unconformably covers the Karroo system in the vicinities of Mt. Wallar and Mpata.

3.3.4. Songwe Volcanic Rocks

Songwe volcanic rocks directly cover the sediment of the Cretaceous period. They consist primarily of well-stratified tuffs deposited in the lacustrine circumstances. The thickness is approximately 75 m.

3.4. Geological Structure

This coal field is defined by faults on the south and east, and by unconformity on the west. A center fault running in a NE-SW direction divides the coal field into the eastern and western districts, in which strata strike and dip considerably differently. The sediment in the coal field generally thickens toward the east.

3.4.1. Western District of Ngana Coal Field

Though slid by faults in some places, the unconformity on the west of this district can be traced for approximately 8 km southward from the river Songwe. The unconformity itself is thought to dip substantially like the upper Karroo system. The Karroo system in this district is a monocline that generally strikes in a north-south direction and dips to the east, at angles of 20 to 30 degrees. The dip becomes slightly gentler proceeding to the south. According to South Africa's explorative drilling, (details unknown), the dip flattens to between 5 and 10 degrees in depth.

This district is subdivided into the north, central and south areas by the Ndamutakwa fault (normal fault of H ≑ 90 m, N52W60S) and the Labasha fault (probable fault). The investigation was made chiefly on the north and central areas.

3.4.2. Eastern District of Ngana Coal Field

Two trenches were dug in this district. The district is defined by faults on the south, but its eastern limit has not been confirmed. The strata are monoclinic, striking substantially in an east-west direction and dipping to the south at angles of 12 to 30 degrees. The dip steepens toward the east.

According to the conventional geological maps, the entirety of the southern slope of Kapembe hill is classed as the K3 beds. But there is a probability that the K1 beds outcrop locally.

3.5. Faults

The faults in this coal field show two marked tendencies. The older faults generally run from northeast to southwest. The newer faults run from NNW to SSE or from northwest to southeast, and intersect the former. The aforesaid center fault, striking from northeast to southwest, mostly dips to the west. But there is a probability that it dips to the south at the southwestern end. The depth of this fault is unknown, but is supposed to be approximately 300 m in the vicinity of Kapembe hill. Another major fault is one that defines the south end of the coal field, striking from northeast to southwest. Partings of coarse-grained conglomerate were found in grits, containing fine-grained conglomerate, of the K3 beds outcropping in the bed of the river Syegati approximately 15 m north of the fault. The conglomerate consists of gneiss that is thought to have been supplied from the nearby fault scarp. All this seems to indicate that the fault had already started its activity when the K3 beds deposited.

The following is a detailed description of the faults in the western district.

3.5.1. Faults in North Area of Western District

In plotting, J-1 and J-40 were not put together smoothly, which seems to suggest the presence of an approximately 30 m high fault. In addition, the presence of such minor faults as J-38 (2 m throw normal fault, N56W65^{o}E), J-21 (4 m throw normal fault, N72E80^{o}S) and J-16 (2 m throw) was confirmed.

In the vicinity of J-16, the Ndmutakwa fault (N52-W60S), which runs along the south end of this area and has an approximately 2 m of fracture zone, was confirmed. According to topographical reading from aerial photographs, this fault is supposed to generally strike in an east-west direction, as shown in fig. 3.

3.5.2. Faults in Central Area of Western District

Between the Ndamtakwa and J-63 (5 m throw normal fault, N6W60E) faults, general strike is in a south-north direction. On the south, the strike suddenly changes to an east-west direction, with suddenly steepening dips. For example, an outcrop was found that dipped to the south at such a steep slope as 45 degrees.

But both strike and dip return to normal on the south of the river Labasha, which seems to suggest the presence of a fault running substantially along that river. From the aerial photographs, this probable fault is considered to be a westward extension of a fault that runs near Mwansalano from northwest to southeast.

3.6. Coal Seams

During this investigation, 26, 37 and 2 trenches, totaling 65, were dug in the north, central and south areas of the western district, respectively, in order to confirm the conditions of coal seams. The results are shown in Table 11 , Coal Seam Condition, and Attached Fig. 6, Correlation of Coal Seams. Standard geologic and coal seam columnar sections shown in Attached Fig. 3 were drawn based on the trenching results. In the eastern district, two trenched spots were reinvestigated. It was then found that principal coal seams in the upper shale members do not differ much from those in the western district, in respect

Table 11　　Coal Seam Condition　(1)

North Area

unit : cm

Trench №	Dip of Coal Seam	№ 1	№ 1 ~ № 2	№ 2 (a)	№ 2 ~ (b) № 3	№ 3 (c)	№ 3 ~ № 4	№ 4	№ 4 ~ № 5	№ 5	№ 5 ~ № 6	№ 6
1	31°			78	28	38	58	40	43	(60^{+}/63^{+})		
40	25°			77	33	43	65	40	45	52/67		
39	23°	10	75	62	33	35	54	30	52			
38	32°	8	58	53	25	35	60	35				
37	22°	8	61	75	32	38	68	43				
36	25°			81	29	50	61					
35	23°	7	76	83	34	46	67	44	46	83		
34	23°	8	77	65	35	47	55	45				
2	24°				39	48	77	46	48	42	260	(33^{+})
31	25°	7	77	76	37	38	73	45	75	(56^{+}/73^{+})		
30	28°	11	64	74	41	40	64	42				
29	30°			80	42	50	59	43	62	74/91		
26	24°	13	73	70	35	40	63	37				
27												56/63
28	24°			91	42							
3	30°			69	39	36	60	33/40	74	30/33	269	(48^{+}/58^{+})
25	26°			72	33	44	60	43				
24		11	64	62	25							
21	31°	8	76	74	40	42	67	37	58	(38^{+})		
22	30°	12	67	84	34	47	70	45				
23	25°									(0/6)	250	(39/60)
20	27°					37	83	40	61	(50^{+})		
19	26°	11	79	69								
18	30°	10	71	79	35							
16	23°	12	81	(57^{+})					(57^{+})	70/87 1)※	(220^{+})	64/72
Sample	23°	14	14	20	20	18	18	17	10	6	3	2
Total	607°	136	999	1,474	691	754	1,164	688	564	351/403	779	120/135
Mean	26°	10	71	74	35	42	65	40	56	59/67	260	66/68

Table 11 Coal Seam Condition (2)

Central Area

unit : cm

Trench No.	Dip of Coal Seam	No. 1	No. 1 ~ No. 2	No. 2 (a)	No. 2 ~ (b) No. 3	No. 3 (c)	No. 3 ~ No. 4	No. 4	No. 4 ~ No. 5	No. 5	No. 5 ~ No. 6	No. 6
17	25°	6	63	76	37	41	62	33	66	71		
41	26°	16	46	90	35	50	68	50				
4	(19°)	13	87	76/84								
43	26°				33	50	60	45	53	75*1)		
5	25°			92	42	47	92	35/44	50	11		
44	24°			74	20	37	61	40	47	32		
45	30°			82	31	37	35					
46	27°	9	78									
47	27°			79	35	40	65	40	58			
48	25°							48	62	(30^{+})		
49	26°							58	56	90/117		
50	25°							70				
51	26°			92	38	50	73	54	64	$59^{+}/72$		
52	23°			82	38	51	73	44	70	66/78		
53	21°			78								
6	23°			65								
7	30°	16	70	81	35	48	62	56	47	$(50^{+}/65^{+})$		
54	20°	13	65	65	30	30	(30)	(28)	(34)			
55	28°							47	50	41/53		
56	24°	20	89	8,0	35	(45^{+})						
57	24°	11	83	77	34	40	49					
10	25°			105	35	48	88	59	66	70/100*1)		
9	25°			95	27	37	46	42	44	27		
11	26°			86	37	49	65	50	45	50/57	250	49/74
12,12'	27°							50	72	52/85	258	43/85
60	27°			80	38	42	61	(46^{+})				
58												64/72
59	26°											
61	22°	17	80									
8	21°	11	80	82	25	54	65	55	45	75	255	62/69
63	20°											(29^{+})
64	23°	(20)	(63)	(52)		(45)	(63)	(51)	(80)	$(24^{+}/44^{+})$		
65	27°	(10^{+})	(63)	(60)								
13	31°				$(51^{+}?)$	(47/54)	(71)	(25/50)	(62)	(68)		
Sample	32°	10	10	20	18	17	16	18	16	14	3	5
Total	805°	132	741	1,637	605	751	1,025	876	895	744/878	763	275/357
Mean	25°	13	74	82	34	44	64	49	56	57/63	254	55/71
Auerage	26°	12	73	78	35	43	66	45	56	58/65	257	58/70

of coal seam thickness and inter-seam distance.

The following description is confined to the western district.

One and seven coal seams occur in the lower and upper shale members, respectively. Of these, the Nos. 2, 3 and 4 coal seams are particularly stable in seam thickness and inter-seam distance. The coal seams have a general tendency to thicken from north to south and are well stratified. All of them comprise thin alternate layers of dull and bright coal, except the lower one-third of the No. 2 coal seam that consists mostly of bright coal. The coal seams strike, substantially in parallel, in a south-north direction on the east slope of Nabatata hill and dip to the east at angles of 20 to 30 degrees. In the north area, the dip of the coal seams scheduled to be mined averages 29 degrees, but flattens to 20 degrees or thereabout in depth. In the central area, the respective dips are 25 and 10-odd degrees. Outcrops are 650 to 700 m above sea level, and 100 to 200 m above surface level.

3.6.1. Lower No. 1 Coal Seam

This coal seam is as thin as between 20 and 40 cm. In some places, there occur two or three thin coal seams (10 to 20 cm thick) in this horizon. This coal seam is unworthy of mining.

3.6.2. No. 1 Coal Seam

This coal seam is only 10 to 20 cm in thickness. It proceeds to the middle sandstone member, usually underlain by 10 to 20 cm thick silt, and is separated from the No. 2 coal seam by about 60 to 80 cm. This coal seam mainly comprises dark-gray shale and contains several characteristic partings of black and coaly shale. This coal seam also is not worth mining.

3.6.3. No. 2 Coal Seam

This is the most important coal seam, generally ranging between 70 and 90 cm in thickness and exhibiting a marked tendency to thicken from north to south. It is 30 to 40 cm apart from the No. 3 coal seam, and overlain by coaly or black shale and dark-gray shale totaling a little less than 10 cm in thickness. Since it is narrowly separated from the No. 3 coal seam, the two coal seams can be mined by the underground method.

3.6.4. No. 3 Coal Seam

This is a stable, 35 to 50 cm thick coal seam, separated from the No. 4 coal seam by 55 to 75 cm. It is overlain by coaly or black shale and dark-gray shale totaling a little less than 10 cm in thickness. As mentioned above, this coal seam can be underground-mined, together with the No. 2 coal seam.

3.6.5. No. 4 Coal Seam

This coal seam is 40 to 50 cm thick, and shows a marked tendency to thicken from north to south. It is 45 to 70 cm apart from the No. 5 coal seam, and overlain by coaly or black shale and dark-gray shale totaling 10 cm in thickness. This coal seam generally is unsuited for underground mining.

3.6.6. No. 5 Coal Seam

The thickness and condition of this coal seam exhibit irregular and extensive horizontal changes. It becomes as thin as between 20 and 30 cm (J-5 and -47), and further reduces to coaly shale of only a few centimeters (J-23). Conversely, it becomes as thick as about 1 m in such places as J-35, -49 and so on. Generally, it ranges between 50 and 70 cm in thickness, and carries a little less than 10 cm thick coaly shale parting in the vicinity of its middle portion. It is approximately 2.5 m apart from the No. 6 coal seam, and overlain by coaly or black shale and dark-gray or gray shale, totaling a little under 20 cm in thickness. This coal seam generally is unsuited for underground mining.

3.6.7. No. 6 Coal Seam

This coal seam is approximately 60 cm thick, and carries an approximately 10 cm thick coaly shale parting slightly above the middle portion.

It is separated from the No. 7 coal seam by approximately 5 m, and overlain by about 10 cm thick black shale and dark-gray or gray shale containing a few partings of black shale. This coal seam generally is unsuited for underground mining.

3.6.8. No. 7 Coal Seam

This coal seam was confirmed only in one place (J-62). Washed out atop by the upper coarse-grained sandstone, the coal seam and coal thicknesses in that place are 56 and 15 cm, respectively. But the No. 1 borehole disclosed the presence of approximately 4 m high shale on top of this coal seam. This coal seam also is unminable.

3.7. Coal Quality

During the field investigation, coal samples were collected from the trenches dug in the outcropped coal seams. The samples taken totaled 73; 32 from the north area, 39 from the central area, and 2 from the south area. The samples were tested in Japan as follows, and basic data for determining the quality of coal in the western district of the Ngana coal field was obtained.

The analytical tests were conducted at the Kasukabe Laboratory of the Japan Coal Mining Research Center. The obtained analytical results are shown in Tables 12 to 14, and the estimated coal quality is described hereunder.

Table 12 Coal Analytical Results

No. 1

No.	Sample Name	Proximate Analysis I.M.	Ash	V.M.	F.C.	Fuel Ratio	Calorific Value Hq	d.m.f	Ultimate Analysis C	H	N	O	S	Total Sulfer	Hardgrove Index	Ash Fusibility(℃) I.S.P.	M.P.	F.P.	Chemical Analysis of Ash SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	P_2O_5
1	J-1-2	8.4	23.2	28.7	39.7	1.38	5160	7750	76.86	5.07	1.45	12.02	4.60		52	1250	1370	1390							
2	J-1-3	14.6	25.1	26.6	33.7	1.27	3750	6430	70.81	4.07	1.37	23.17	0.58		91	1240	1320	1370							
3	J-1-4	12.0	20.5	28.2	39.3	1.39	4480	6800	73.42	4.50	1.43	20.11	0.54		62	1260	+1450	+1450							
4	J-1-5	11.0	21.5	27.7	39.8	1.44	4560	6930	73.99	4.42	1.42	19.64	0.53		55	1250	+1450	+1450							
5	J-2-3	11.9	28.8	26.4	32.9	1.25	3520	6180																	
6	J-2-4	13.3	23.3	27.6	35.8	1.30	3940	6400																	
7	J-2-5	17.7	26.1	25.8	30.4	1.18	2980	5510																	
8	J-3-2	8.1	21.7	29.7	40.5	1.36	5400	7890	77.47	5.38	1.39	12.16	3.60			1280	1440	+1450							
9	J-3-3	8.4	26.3	27.0	38.3	1.42	4880	7720	77.06	5.22	1.36	14.05	2.31			1280	+1450	+1450							
10	J-3-4	11.0	20.9	29.1	39.0	1.34	4590	6910						0.53											
11	J-3-5	12.4	32.5	24.9	30.2	1.21	3210	6110						0.27											
12	J-4-2	11.0	18.3	28.8	41.9	1.45	4840	6990						1.17											
13	J-5-2下	16.6	16.0	28.7	38.7	1.35	3900	5900																	
14	J-5-2上	16.2	25.6	26.9	31.3	1.16	3080	5490																	
15	J-5-3	14.1	30.3	25.0	30.6	1.22	3120	5870																	
16	J-7-2	10.0	18.4	29.2	42.4	1.45	4960	7070						2.12		1280	1430	1450	65.84	15.74	9.49	0.69	0.51	0.35	0.02
17	J-7-3	9.7	23.1	26.4	40.8	1.55	4810	7360						1.59		1320	+1450	+1450	66.65	20.38	7.31	0.60	0.48	0.05	0.03
18	J-7-4	10.2	22.9	28.9	38.0	1.31	4790	7360						0.94											
19	J-8-2	12.3	14.7	29.7	43.3	1.46	4790	6670	72.40	4.22	1.28	20.51	1.59		110	1300	+1450	+1450							
20	J-8-3	14.0	26.9	26.4	32.7	1.24	3480	6110	68.20	3.74	1.28	25.75	1.03		135	1320	+1450	+1450							
21	J-8-4	18.6	28.6	25.1	27.7	1.10	2880	5700							179										
22	J-8-5	15.1	25.7	27.2	32.0	1.18	3500	6120						0.37	135										
23	J-9-2	13.9	21.8	26.7	37.6	1.41	4030	6440																	
24	J-10-2	16.1	25.6	27.3	31.0	1.14	3730	6630						1.06											
25	J-10-3	15.0	27.5	25.6	32.1	1.25	3730	6720						0.73											
26	J-10-4	16.1	21.5	28.0	34.4	1.23	3920	6460																	
27	J-11-2	15.5	17.3	29.9	37.3	1.25	3850	5850						1.03											
28	J-11-3	14.1	26.7	26.5	32.7	1.23	3340	5850						0.63											
29	J-12-5	14.0	29.5	26.1	30.4	1.16	3340	6170																	
30	J-14-2	12.8	22.9	27.5	36.8	1.34	3960	6340						0.25		1320	+1450	+1450	62.41	22.43	7.75	0.83	0.50	0.05	0.16
31	J-14-3	10.5	40.4	21.8	27.3	1.25	3040	6630						0.20		1320	+1450	+1450	60.70	24.50	4.05	0.91	0.42	0.13	0.09

№	Sample Name	Proximate Analysis I.M.	Ash	V.M.	F.C.	Fuel Ratio	Calorific Value HG	d.m.f	Ultimate Analysis C	H	N	O	S	Total Sulfer	Hardgrove Index	Ash Fusibility (C) I.S.P.	M.P.	F.P.	Chemical Analysis of Ash SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	P_2O_5
32	J-16-2	10.3	17.5	31.4	40.8	1.30	5620	7940						1.23											
33	J-17-2	8.9	21.3	27.5	42.3	1.54	5160	7580	75.50	4.73	1.31	13.37	5.09		53	1270	1380	1390							
34	J-17-3	9.9	19.9	27.0	43.2	1.60	5180	7550	77.86	4.76	1.31	14.24	1.83		66	1270	+1450	+1450							
35	J-17-4	12.4	17.3	29.5	40.8	1.38	4660	6760	72.58	4.17	1.48	21.01	0.76		65	1270	+1450	+1450							
36	J-17-5	12.8	24.6	26.7	35.9	1.34	4000	6600	71.76	4.08	1.48	21.99	0.69		89	1310	+1450	+1450							
37	J-18-2	13.7	21.2	28.1	37.0	1.32	3970	6260																	
38	J-20-3	10.4	15.8	29.0	44.8	1.54	5280	7280						0.92											
39	J-20-4	8.2	17.3	32.9	41.6	1.26	5700	7800						1.06											
40	J-22-2	11.7	21.2	27.7	39.4	1.42	4250	6500						0.74											
41	J-22-3	11.5	21.4	27.7	39.4	1.42	4270	6530						0.58											
42	J-28-2	10.0	17.0	29.9	43.1	1.44	5350	7470						1.89											
43	J-29-2	10.5	18.0	30.6	40.9	1.34	5140	7340						0.96		1290	+1450	+1450	67.11	20.30	4.44	0.69	0.59	0.11	0.04
44	J-29-3	11.6	26.1	26.6	35.7	1.34	4090	6790						0.53		1300	+1450	+1450	65.94	22.07	4.93	0.60	0.44	0.00	0.02
45	J-35-2	12.6	22.9	27.9	36.6	1.31	3890	6210						0.59											
46	J-35-3	13.9	26.3	27.6	32.2	1.17	3520	6100						0.45											
47	J-35-4	18.1	31.4	24.5	26.0	1.06	2670	5560																	
48	J-35-5	16.4	34.6	23.0	26.0	1.13	2650	5730																	
49	J-38-2	14.5	31.3	24.9	29.3	1.18	3040	5880																	
50	J-38-3	15.5	38.3	22.4	23.8	1.06	2370	5490																	
51	J-41-2	14.2	16.0	27.9	41.9	1.50	4560	6650																	
52	J-41-3	16.4	29.8	24.9	28.9	1.16	2960	5760																	
53	J-45-2	14.5	15.0	28.1	42.4	1.51	4650	6710						1.21											
54	J-45-3	18.2	29.5	25.3	27.0	1.07	2720	5450						0.61											
55	J-47-2	16.4	24.0	26.0	33.6	1.29	3430	5950																	
56	J-47-3	17.9	30.9	23.9	27.3	1.14	2650	5440																	
57	J-48-4	8.2	17.0	32.4	42.4	1.31	5710	7780																	
58	J-57-2	15.2	17.5	28.4	38.9	1.37	4170	6330																	
59	J-57-3	16.6	38.8	23.2	21.4	0.92	2250	5420																	
62	J-60-2	11.7	22.2	27.0	39.1	1.45	4440	6900																	
63	J-60-3	17.3	30.5	24.4	27.8	1.14	2770	5570																	

	North Area	Central Area	South Area	Total
Proximate Analysis	26	33	2	61
Calorific Value	26	35	2	63
Total Sulfur Content	12	12	2	26
Ash Fusibility	8	8	2	18
Hardgrove Index	4	8	-	12
Ultimate Analysis	6	6	-	12
Petrographic Analysis	3	3	-	6
Ash Chemical Analysis	2	2	2	6
Sink-Float Test	6	2	-	8

3.7.1. Proximate Analysis Etc. (See Table 12.)

The coal seam in the western district of the Ngana coal field investigated deposited in old times, belonging to the k2 beds, Ecca series, Karroo system of the Palaeozoic era. Collected from the outcropped parts, however, the samples show considerable influences of weathering.

The inherent moisture ranges between 8 and 18 per cent, affected by weathering. One taken from the trenched depth indicated 8 per cent.

The ash content is as high as 20 to 30-odd per cent. This high ash content seems to be due to the admixture of foreign matters resulting from the permeation of soil at or near the surface. The samples generally are of high-ash, banded shaly coal. The upper coal seam tends to contain more coaly shale and indicate higher ash content.

The fuel ratio (the ratio of fixed carbon to volatile matter) is 1.0 to 1.6, rather lower for Palaeozoic coal. This is because of the aforesaid fact that the coal is high-ash one consisting primarily of shaly coal.

The total calorific value falls within the range of 2200 to 5700 kcal/kg. This indicates the very great influence of the high ash content as well as the increased inherent moisture under the effect of weathering in the outcropped coal seams. The net calorific value is as low as 5500 to 7800 kcal/kg, which indicates that the coal itself is of low-calorie grade.

Sulfur content in general is 1 per cent or under, though it becomes as high as 2 to 3 per cent locally. The general tendency is: the higher the coal seam, the lower the sulfur content. This is considered to stem from the fact that the lower coal seams deposited not in a perfectly fresh water environment but in a brackish water environment.

The melting point of ash mostly exceeded 1450°C The wide temperature difference between the softening and melting points seems to be ascribable to the nature of the aforesaid foreign matters mixed in the coal.

The Hardgrove index exceeds 50. Unlike its appearance, the coal seems to be considerably grindable.

According to the result of the ultimate analysis,

Table 13 Petrographic Analysis

No.	Sample Name	Reactive Entities						Inert Entities				Mean Reflectance	Composition Balance Index	Strength Index	Calculated Coke Strength
		Vitrinite Type				Exinite	Totals	Micrinite	Fusinite	Mineral Matter	Totals				
		V_4	V_5	V_6	Total										
8	J- 3-2	5.3	56.6	3.9	65.8	4.9	70.7	17.7	0.8	10.8	29.3	0.54	1.58	2.17	0
9	J- 3-3		53.9	10.3	64.2	2.9	67.1	15.4	4.3	13.2	32.9	0.56	1.84	2.01	0
10	J- 3-4	1.4	36.5	8.9	46.8	8.8	55.6	32.2	1.8	10.4	44.4	0.57	3.00	1.20	0
33	J-17-2		37.6	23.1	60.7	8.7	69.4	18.6	1.4	10.6	30.6	0.58	1.62	2.19	0
34	J-17-3		24.2	39.4	63.6	3.3	66.9	20.8	2.3	10.0	33.1	0.59	1.79	2.10	0
35	J-17-4		14.2	42.6	56.8	10.9	67.7	22.2	1.5	8.6	32.3	0.62	1.70	2.15	0

carbon content is as low as about 75 per cent. This coal is of Palaeozoic origin, but its carbon content is close to that of sub-bituminous coal with low coalification. This seems to suggest that the coal is shaly, as mentioned previously. Hydrogen and nitrogen contents are 4 to 5 per cent and approximately 1.4 per cent, respectively. Oxygen content is as high as between 12 and 25 per cent, which is another indication of low coalification and a cause for the low calorific value. As mentioned before, sulfur content increases with increasing coal seam depth.

The chemical analysis of ash revealed as high SiO_2 content as about 65 per cent, indicating its resemblance to peat ash that contains 50 to 70 per cent SiO_2. Al_2O_3 and Fe_2O_3 contents are approximately 22 per cent and between 4 and 9 per cent, while CaO content is as low as 0.6 to 0.9 pre cent. Falling within the range of 86 to 92, the silica ratio ($\frac{SiO_2}{SiO_2+CaO+Fe_2O_3+MgO}$ x 100) determined from these analytical values exceeds 75. Accordingly, the coal's slag viscosity will pose a problem to the slag-tap boilers. Considering the aforesaid melting point of 1350°C and above, however, no problem will arise with ordinary boilers. The fouling index ($\frac{CaO - MgO}{Fe_2O_3}$), between 0.1 and 0.02, also falls below the maximum limit of 1.0 and offers no problem.

3.7.2. Petrographic Analysis

As shown in Table 13, six samples were petrographically analyzed to investigate coalification and other properties of the coal. The content of reactive vitrinite is as low as approximately 60 per cent, with the vitrinite type falling between V4 and V5 and the mean reflectance being as low as 0.55 to 0.60. All this indicates that the coal is not extensively coalified. The coal contains as much as 30 to 40 per cent inert entities; among which the content of mineral matters, approximately 10 per cent, is highest. As explained before, this seems to be ascribable to the fact that the coal is high-ash shaly coal, and that the samples taken from the outcropped coal seams contain much foreign matters permeated through surface soil.

From the result of the petrographic analysis, the coal is established as low-coalified non-coking coal.

3.7.3. Sink-Float Test

The coal occurring in the areas investigated contains a high percentage of ash. The sink-float test was made on eight samples to determine how much ash can be decreased by washing and to study washability.

The samples were screened on a 0.5 mm sieve, and those over 0.5 mm were divided into eight groups of 1.3, 1.4, 1.5, 1.6, 1.7, 1.8 and 2.0 by specific gravity. The results of the sink-float test are shown in Table 14, and the washability curves derived therefrom in fig. 4.

According to the test results, 70 to 80 per cent of

Table 14. Float and Sink Test

Sample No. 64 (J-3-2)

S.G	a Weight g	a Weight W%	b Ash A%	c $\Sigma W_{n-1}+\frac{W_n}{2}$	d WA	e ΣWA	f ΣW	g $\frac{\Sigma WA}{\Sigma W}$	h Total Ash $-\Sigma WA$	i $100-\Sigma W$	j $\frac{h}{i}$
-1.3	72	3.5	1.7	1.75	5.95	5.95	3.5	1.7	2,214.20	90.6	24.4
1.3~1.4	720	35.0	12.1	21.00	423.50	429.45	38.5	11.2	1,790.70	55.6	32.2
1.4~1.5	670	32.6	21.6	54.80	704.16	1,133.61	71.1	15.9	1,086.54	23.0	47.2
1.5~1.6	139	6.8	29.6	74.50	201.28	1,334.89	77.9	17.1	885.26	16.2	54.6
1.6~1.7	57	2.8	33.9	79.30	94.92	1,429.81	80.7	17.7	790.34	13.4	59.0
1.7~1.8	32	1.5	38.3	81.45	57.45	1,487.26	82.2	18.1	732.88	11.9	61.6
1.8~2.0	16	0.8	40.6	82.60	32.48	1,519.74	83.0	18.3	700.41	11.1	63.1
+2.0	229	11.1	63.1	88.55	700.41	2,220.15	94.1	23.6			
-0.5%	121	5.9	29.0		171.10	2,391.25	100.0	23.9			
Total	2,056	100.0									

Sample No. 65 (J-3-3)

S.G	a Weight g	a Weight W%	b Ash A%	c $\Sigma W_{n-1}+\frac{W_n}{2}$	d WA	e ΣWA	f ΣW	g $\frac{\Sigma WA}{\Sigma W}$	h Total Ash $-\Sigma WA$	i $100-\Sigma W$	j $\frac{h}{i}$
-1.3	16	0.9	3.6	0.45	3.24	3.24	0.9	3.6	2,467.27	95.3	25.9
1.3~1.4	395	21.2	9.6	11.50	203.52	206.76	22.1	9.4	2,263.75	74.1	30.5
1.4~1.5	690	37.1	21.8	40.65	808.78	1,015.54	59.2	17.2	1,454.97	37.0	39.3
1.5~1.6	267	14.4	27.6	66.40	455.04	1,470.58	73.6	20.0	999.93	22.6	44.2
1.6~1.7	153	8.2	34.6	77.70	283.72	1,754.30	81.8	21.4	716.21	14.4	49.7
1.7~1.8	33	1.8	38.7	82.70	69.66	1,823.96	83.6	21.8	646.55	12.6	51.3
1.8~2.0	20	1.1	41.0	84.15	45.10	1,869.06	84.7	22.1	601.45	11.5	52.3
+2.0	213	11.5	52.3	90.45	601.45	2,470.51	96.2	25.7			
-0.5%	71	3.8	27.0		102.60	2,573.11	100.0	25.7			
Total	1,858	100.0									

Sample №66 (J−3−4)

S.G	a Weight g	W%	b Ash A%	c $\Sigma W_{n-1} + \frac{W_n}{2}$	d WA	e ΣWA	f ΣW	g $\frac{\Sigma WA}{\Sigma W}$	h Total Ash − ΣWA	i 100 − ΣW	j $\frac{h}{i}$
−1.3	1	0.1	3.8	0.05	0.38	0.38	0.1	3.8	1,767.85	92.1	19.2
1.3〜1.4	590	33.1	8.8	16.65	291.28	291.66	33.2	8.8	1,476.57	59.0	25.0
1.4〜1.5	634	35.6	16.0	51.00	569.60	861.26	68.8	12.5	906.97	23.4	38.8
1.5〜1.6	234	13.1	25.5	75.35	334.05	1,195.31	81.9	14.6	572.92	10.3	55.6
1.6〜1.7	50	2.8	30.7	83.30	85.96	1,281.27	84.7	15.1	486.96	7.5	64.9
1.7〜1.8	11	0.6	38.1	85.00	22.86	1,304.13	85.3	15.3	464.10	6.9	67.3
1.8〜2.0	21	1.2	45.7	85.90	54.84	1,358.97	86.5	15.7	409.26	5.7	71.8
+2.0	101	5.7	71.8	89.35	409.26	1,768.23	92.2	19.2			
−0.5mm	138	7.8	26.9		209.82	1,978.05	100.0	19.8			
Total	1,780	100.0									

Sample №67 (J−7−2)

S.G	a Weight g	W%	b Ash A%	c $\Sigma W_{n-1} + \frac{W_n}{2}$	d WA	e ΣWA	f ΣW	g $\frac{\Sigma WA}{\Sigma W}$	h Total Ash − ΣWA	i 100 − ΣW	j $\frac{h}{i}$
−1.3	6	0.4	3.3	0.20	1.32	1.32	0.4	3.3	1,466.98	89.6	16.4
1.3〜1.4	407	27.1	7.1	13.95	192.41	193.73	27.5	7.0	1,274.57	62.5	20.4
1.4〜1.5	670	44.6	15.8	49.80	704.68	898.41	72.1	12.5	569.89	17.9	31.8
1.5〜1.6	150	10.0	23.1	77.10	231.00	1,129.41	82.1	13.8	338.89	7.9	42.9
1.6〜1.7	52	3.4	26.9	83.80	91.46	1,220.87	85.5	14.3	247.43	4.5	55.0
1.7〜1.8	10	0.7	32.6	85.85	22.82	1,243.69	86.2	14.4	224.61	3.8	59.1
1.8〜2.0	14	0.9	39.8	86.65	35.82	1,279.51	87.1	14.7	188.79	2.9	65.1
+2.0	44	2.9	65.1	88.55	188.79	1,468.30	90.0	16.3			
−0.5mm	150	10.0	23.7		237.00	1,705.30	100.0	17.1			
Total	1,503	100.0									

Sample №68 (J－7－3)

	a		b	c	d	e	f	g	h	i	j
	Weight		Ash	ΣWn-1 + Wn/2				ΣWA/ΣW	Total Ash −ΣWA	100 −ΣW	h/i
S.G	g	W%	A%		WA	ΣWA	ΣW				
−1.3	16	08	1.9	0.40	152	152	0.8	1.9	2,55270	91.1	280
1.3～1.4	449	228	8.0	1220	18240	18392	23.6	7.8	2,37030	68.3	34.7
1.4～1.5	395	20.1	192	33.65	38592	56984	43.7	13.0	1,98438	482	412
1.5～1.6	275	14.0	292	50.70	40880	97864	57.7	17.0	1,57558	342	46.1
1.6～1.7	326	16.6	37.1	66.00	61586	1,59450	74.3	21.5	959.72	17.6	545
1 7～1.8	78	4.0	438	76.30	17520	1,769.70	78.3	22.6	78452	13.6	57.7
1.8～2.0	131	6.6	47.7	81.60	31482	2,08452	84.9	24.6	469.70	7.0	67.1
+2.0	138	7.0	67.1	88.40	469.70	2,55422	91.9	27.8			
−0.5㎜	160	8.1	31.0		251.10	2,80532	100.0	28.1			
Total	1,968	100.0									

Sample №69 (J－7－4)

	a		b	c	d	e	f	g	h	i	j
	Weight		Ash	ΣWn-1 + Wn/2				ΣWA/ΣW	Total Ash −ΣWA	100 −ΣW	h/i
S.G	g	W%	A%		WA	ΣWA	ΣW				
−1.3	2	0.1	52	0.05	052	0.52	0.1	52	1,83349	96.7	19.0
1.3～1.4	839	448	10.9	22.50	48832	48884	44.9	10.9	1,34517	51.9	25.9
1.4～1.5	716	382	203	64.00	77546	1,26430	83.1	152	569.71	13.7	41.6
1.5～1.6	132	7.1	27.5	86.65	19525	1,459.55	902	162	37446	6.6	56.7
1.6～1.7	41	22	33.9	91.30	7458	1,53413	924	16.6	299.88	4.4	682
1.7～1.8	6	0.3	404	92.55	1212	1,54625	92.7	16.7	287.76	4.1	702
1.8～2.0	15	0.8	46.2	93.10	3696	1,58321	93.5	16.9	250.80	3.3	76.0
+2.0	61	3.3	76.0	95.15	250.80	1,834.01	96.8	18.9			
−0.5㎜	60	3.2	32.2		10304	1,937.05	100.0	19.4			
Total	1,872	100.0									

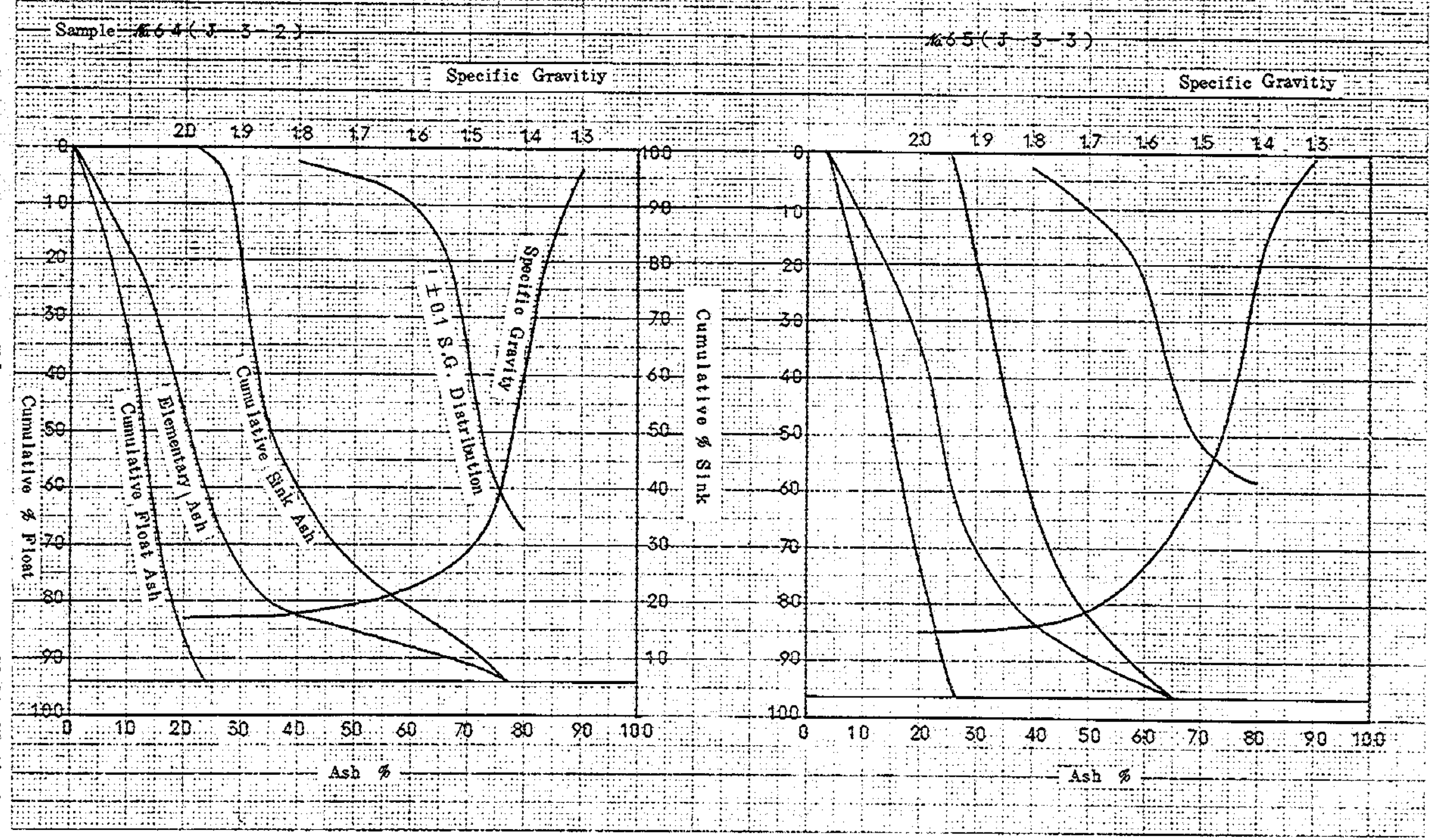
Sample №72 (J－35－2)

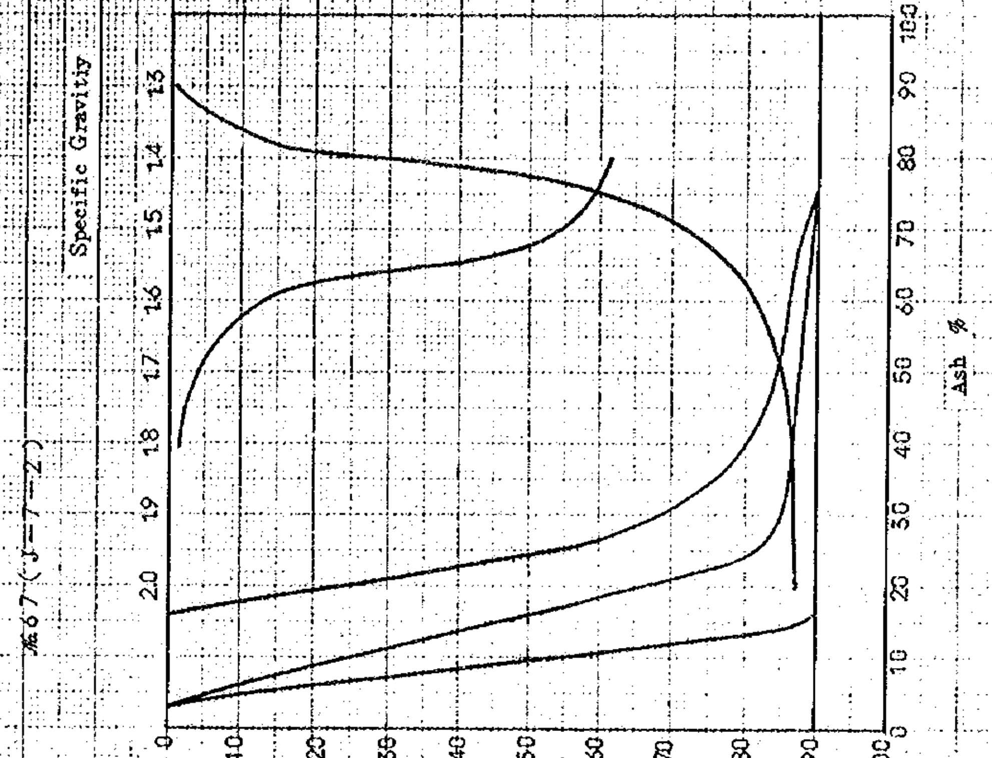
S.G	a Weight g	a Weight W%	b Ash A%	c $\Sigma W_{n-1} + \frac{W_n}{2}$	d WA	e ΣWA	f ΣW	g $\frac{\Sigma WA}{\Sigma W}$	h Total Ash $-\Sigma$WA	i $-\Sigma$W	j $\frac{h}{i}$
－1.3	0	0									
1.3～1.4	73	3.8	6.9	1.90	26.22	26.22	3.8	6.9	2,736.50	90.2	30.3
1.4～1.5	851	44.1	14.1	25.85	621.81	648.03	47.9	13.5	2,114.69	46.1	45.9
1.5～1.6	409	21.2	25.3	58.50	536.36	1,184.39	69.1	17.1	1,578.33	24.9	63.4
1.6～1.7	94	4.9	33.2	71.55	162.68	1,347.07	74.0	18.2	1,415.65	20.0	70.8
1.7～1.8	13	0.7	37.2	74.35	26.04	1,373.11	74.7	18.4	1,389.61	19.3	72.0
1.8～2.0	55	2.8	50.2	76.10	140.56	1,513.67	77.5	19.5	1,249.05	16.5	75.7
＋2.0	319	16.5	75.7	85.75	1,249.05	2,762.72	94.0	29.4			
－0.5㎜	115	6.0	32.1		192.60	2,955.32	100.0				
Total	1,929	100.0									

Sample №73 (J－35－3)

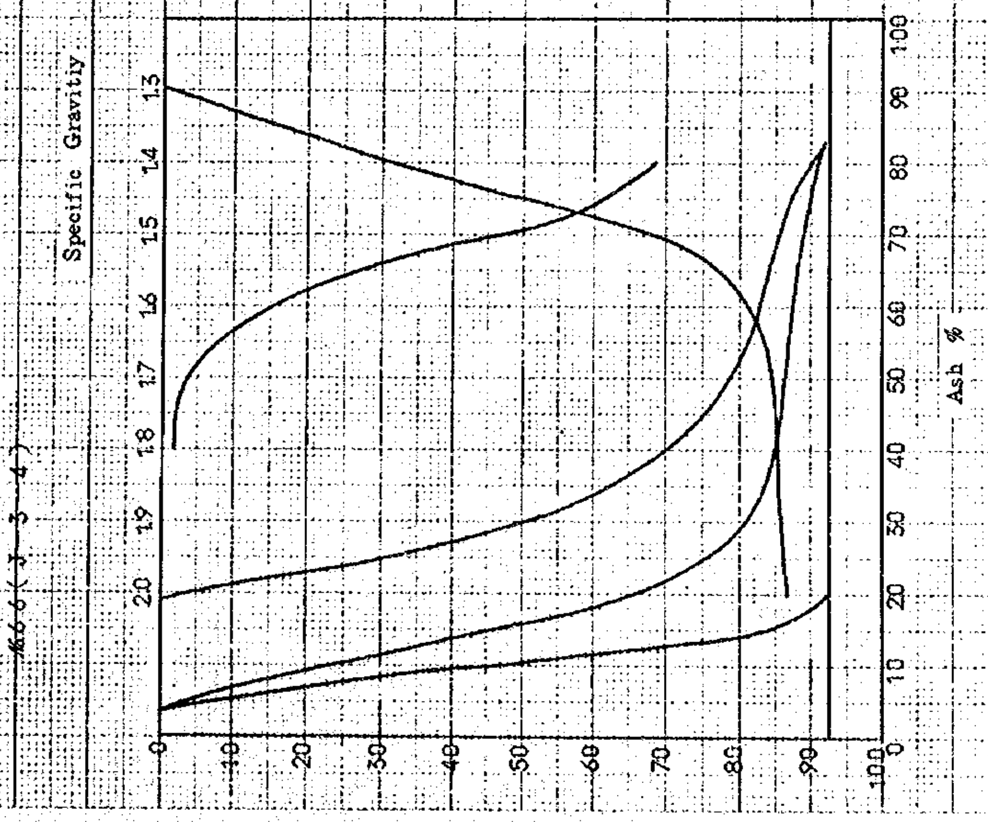
S.G	a Weight g	a Weight W%	b Ash A%	c $\Sigma W_{n-1} + \frac{W_n}{2}$	d WA	e ΣWA	f ΣW	g $\frac{\Sigma WA}{\Sigma W}$	h Total Ash $-\Sigma$WA	i $-\Sigma$W	j $\frac{h}{i}$
－1.3	0	0									
1.3～1.4	165	8.3	8.6	4.15	71.38	71.38	8.3	8.6	2,397.93	79.7	30.1
1.4～1.5	599	30.1	17.0	23.35	511.70	583.08	38.4	15.2	1,886.23	49.6	38.0
1.5～1.6	296	14.9	26.6	45.85	396.34	979.42	53.3	18.4	1,489.89	34.7	42.9
1.6～1.7	361	18.1	37.3	62.35	675.13	1,654.55	71.4	23.2	814.76	16.6	49.1
1.7～1.8	89	4.5	42.2	73.65	189.90	1,844.45	75.9	24.3	624.86	12.1	51.6
1.8～2.0	156	7.8	45.6	79.80	355.68	2,200.13	83.7	26.3	269.18	4.3	62.6
＋2.0	86	4.3	62.6	85.85	269.18	2,469.31	88.0	28.1			
－0.5㎜	240	12.0	32.4		388.80	2,858.11	100.0	28.6			
Total	1,992	100.0									

Fig. 4. Washability Curves



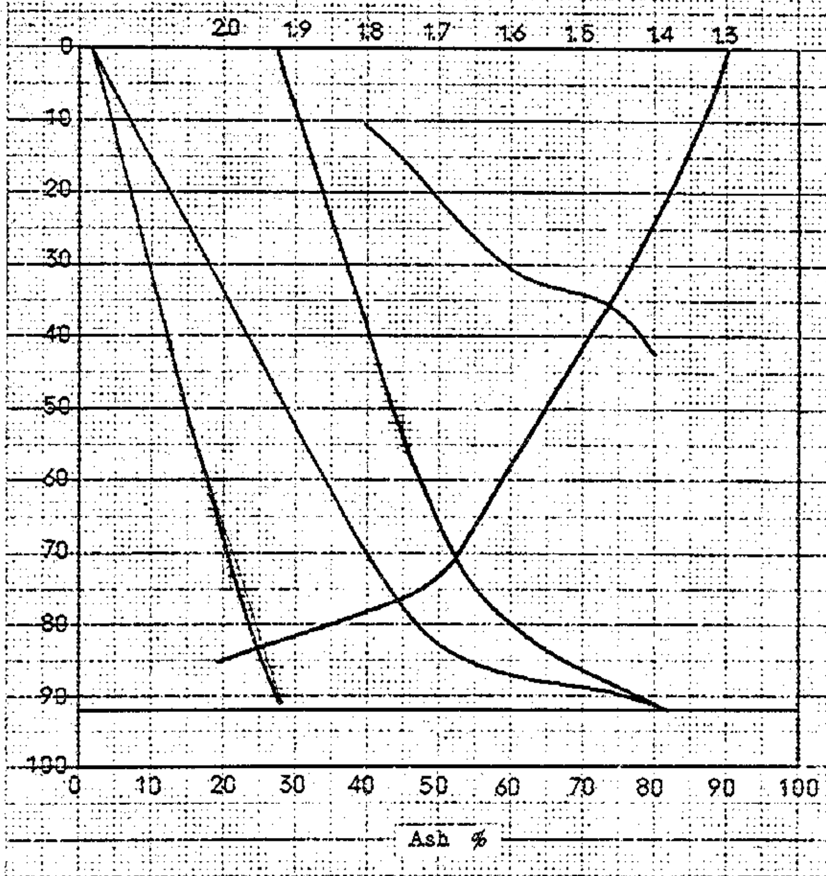


No.67 (J-7-2)
Specific Gravitiy
1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Ash %
0 10 20 30 40 50 60 70 80 90 100



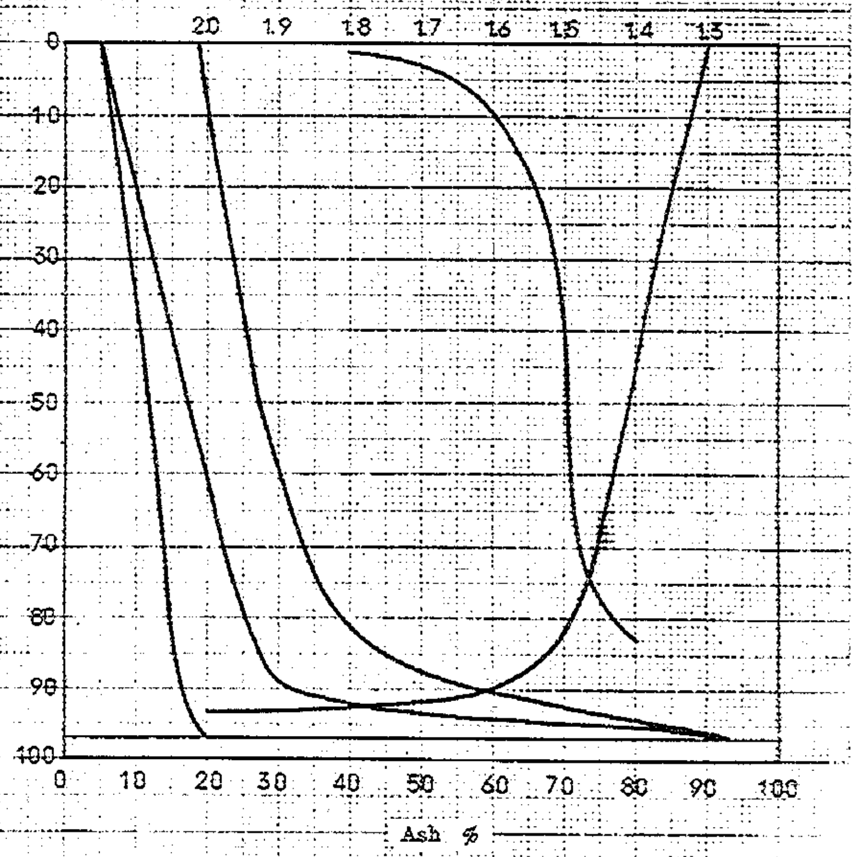
No.66 (J-3-4)
Specific Gravitiy
1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Ash %
0 10 20 30 40 50 60 70 80 90 100

№68 (J—7—3)



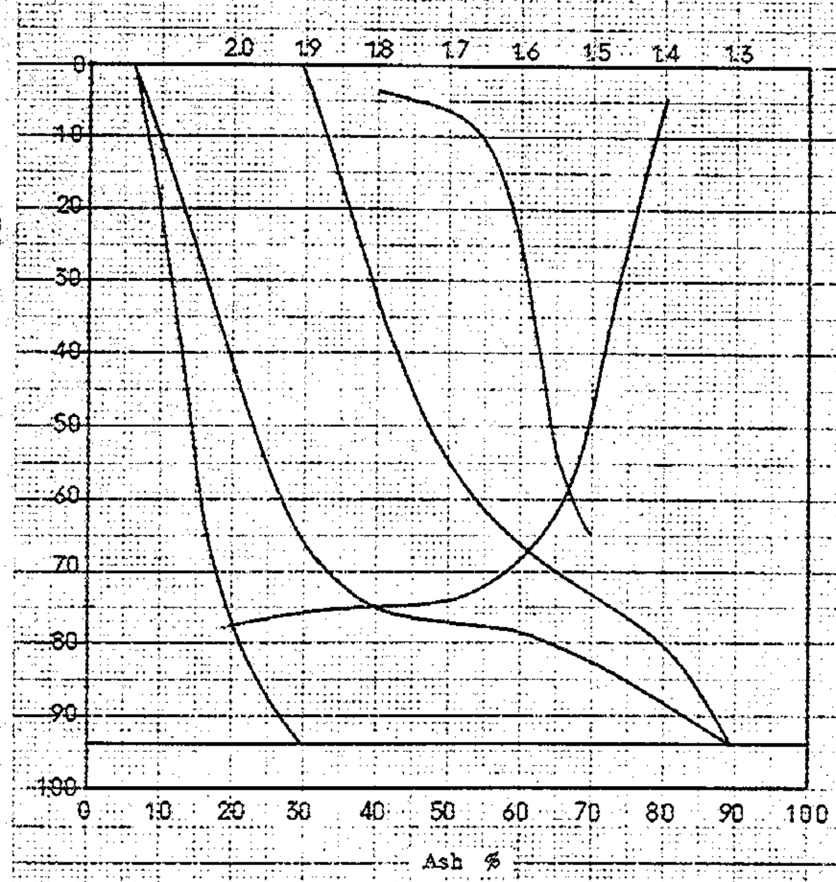
Specific Gravitiy
2.0 1.9 1.8 1.7 1.6 1.5 1.4 1.3
0 10 20 30 40 50 60 70 80 90 100
Ash %

№69 (J—7—4)

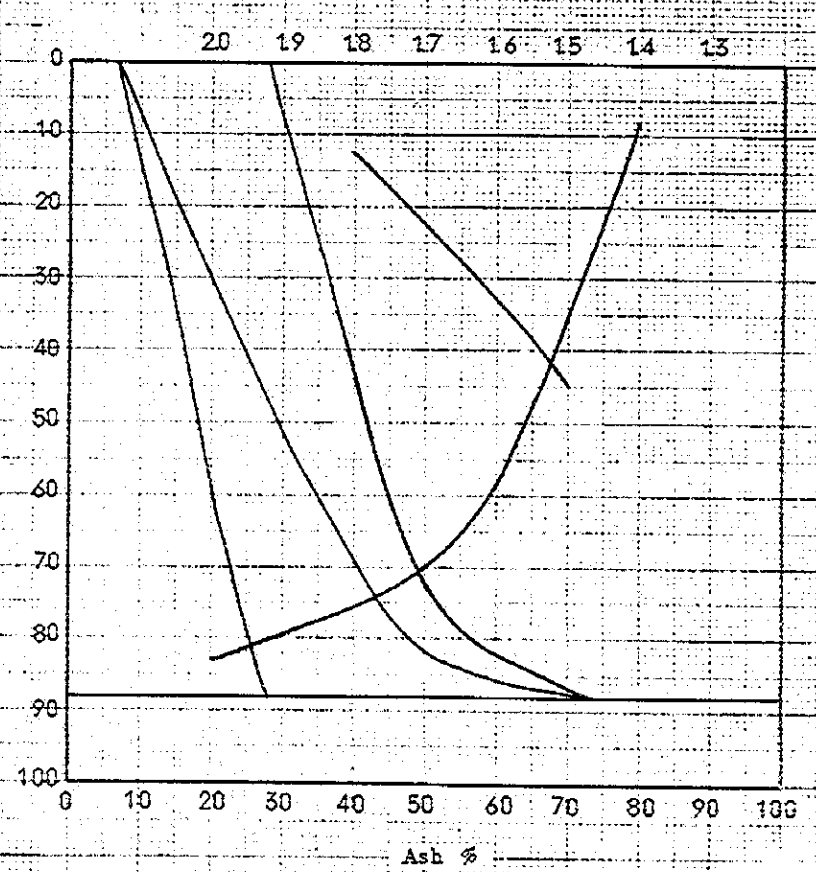


Specific Gravitiy
2.0 1.9 1.8 1.7 1.6 1.5 1.4 1.3
0 10 20 30 40 50 60 70 80 90 100
Ash %

№72 (J−35−2)



№73 (J−35−3)



the coal concentrates around the specific gravity of 1.5, with ash content in that vicinity averaging as high as 15 to 20 per cent. So it seems difficult to lower the ash content below 20 per cent. Since 1.5 seemed to represent the mean specific gravity of the coal, it was used in the calculation of coal reserves.

The following is an estimation of the coal quality based on the analytical and test results described above.

(1) Despite its Palaeozoic origin, the coal contains a high percentage of ash, because it is banded shaly coal and contains much foreign matters permeated through surface soil in the outcropped portion. The coal itself is supposed to be shaly coal or banded coaly shale that deposited with considerable admixture of clay and similar materials.

(2) Generally, the upper coal seams tend to deteriorate in coal quality, but improve in respect of sulfur content.

(3) Because of high ash content, the coal has a low calorific value. The high inherent moisture content caused by weathering is largely responsible for the low calorific value of the samples taken from the outcropped coal seams.

(4) Judging from its ash properties, the coal is usable as steaming coal for boilers. Also, it seems to be suited for the thermal power plant use, since the Hardgrove

index indicates higher grindability than the appearance of the coal does.

Accordingly, the coal is defined as steaming coal for the boiler use. The high ash content and low calorific value are its defects. The sink-float test revealed the difficulty in decreasing ash content to below 20 per cent. Because of their occurring conditions and coal quality, the Nos. 2 and 3 coal seams will be mined together. But there lies an approximately 35 cm high parting between these two coal seams. Therefore every possible care should be taken to prevent the mixing of the parting in the mined coal which will lead to calorie lowering in the clean coal.

The grade of the coal is estimated as follows:

(1) The samples taken from the outcropped portion indicated a high inherent moisture content. But it is thought to become 7 per cent or under in the underground portion to be mined.

(2) Ash content will be 25 per cent or thereabout, since some mixing of the parting, roof and floor will be inevitable.

Based on the analytical and test results described before, the clean coal will have a calorific value of 5500 to 5000 kcal/kg, though it cannot be finalized until we learn the analytical results on the drill cores made by the South African Chamber of Mines.

Taking into account the high ash content and low calorific value of the coal and the transportation cost from the coal field to the consuming area, it is desirable that a thermal power plant be built near the colliery to permit its future use as power generating fuel.

3.8. Coal Reserves

The following is an estimation of theoretical coal reserves for above the mine mouth of the Nos. 2 and 3 coal seams that are contemplated to be mined. In this calculation, safety pillars within a 30 m range from the outcrop line and protective pillars within a fracture angle of 60 degrees under main rivers are excluded.

Table 15. Theoretical Coal Reserves

Area	Mine Mouth Level (m)	Plane Area (m^2)	Mean Inclination (sec θ)	Mean Coal Thickness (m)	Specific Gravity (t/m^3)	Theoretical Coal Reserves (1000 t)
North, A	S.L. 525	481,250	29° (1.1433)	1.16	1.5	956
Central, B	S.L. {555, 570}	333,250				
C	S.L. 575	142,500				
Total		475,750	25° (1.1038)	1.21	1.5	953
Total		957,000				1909

Bibriography:

The Geology of the Nkana Coalfield, Karonga District, Geological Survey Bulletin No. 8 by K. Bloomfield, 1957

The Geology and Mineral Resources of Malawi,
Geological Survey Department Bulletin No. 6
by G.S. Carter and J.D. Bernett

Chapter 4. Development of the Western District of the Ngana Coal Field

On the basis of the coal seam conditions, coal quality and researves revealed by the investigation, a study was made as to the development of the north and central areas of the western district of the Ngana coal field as follows:

4.1. Examination of Development Plan

To select a suitable development method for the projected areas, the applicability of both open-cut and underground mining methods were studied.

The following are the results of the study on the open-cut mining method.

(1) Minable Areas

To facilitate draining in the mining areas, assumption was made to provide drain ditches, with an incline of 2/100, at their utmost depth, leading to the nearby large river. Based on this assumption, the maximum mining depths of the individual areas were determined as follows: 550 m for the north area, 585 m for the northern part of the central area and 600 m for the southern part thereof. Therefore, mining was assumed to be effected between these deepest lines and the outcrops.

(2) Amount of Stripping and Minable Reserves

Nine cross-section lines were taken in the north

Table 16 Calculation of Coalreserve & Stripped Volume

Area·name	Plane area (000m²)	ave·dip (secθ)	Slope area (000m²)	total coal thickness №2～№6 (m)	Specific gravity	Theoretical coal reserve (000t)
A	353	29° (1.1433)	404	2.75	1.5	1,667
B	274	25° (1.1038)	302	2.87	〃	1,300
C	88	〃	97	2.87	〃	418
						3,385
	〃	〃	〃	№2～№5の total band coal thickness —№6 coal thickness	Stripped Volume (000m³)	
A	353	29° (1.1433)	404	0.96	389	
B	274	25° (1.1038)	302	0.99	299	
C	88	〃	97	0.99	96	
Total					784	

Minable coalreserve	A	1,667×0.80(0.95×0.85)=1,334 (000t)
	B	1,300× 〃 =1,040
	C	418× 〃 = 334
Stripped Volume	A	16,849+389=17,238 (000m³)
	B	10,733+299=11,031
	C	2,861+ 96= 2,957
Stripping ratio	A	17,238/1,344=12.8
	B	11,031/1,040=10.6
	C	2,957/ 344= 8.9
	average	31,226/2,718=11.5

Table 16-1 Calculation of Stripped volume

Profile №	Sectional area (m^2)	average (m^2)	Interval (m)	Stripped Volume (m^3)
	0			
1 ~ 1′	9,200	4,600	365	1,679,000
2 ~ 2′	11,600	10,400	250	2,600,000
3 ~ 3′	11,600	11,600	200	2,320,000
4 ~ 4′	8,400	10,000	200	2,000,000
5 ~ 5′	7,700	8,050	200	1,610,000
6 ~ 6′	5,600	6,650	200	1,330,000
7 ~ 7′	8,100	6,850	200	1,370,000
8 ~ 8′	6,900	7,500	214	1,605,000
9 ~ 9′	7,000	6,950	200	1,390,000
	0	3,500	270	945,000
				16,849,000
	0			
10 ~ 10′	6,300	3,150	216	680,000
11 ~ 11′	8,300	7,300	200	1,460,000
12 ~ 12′	6,700	7,500	200	1,500,000
13 ~ 13′	7,600	7,150	200	1,430,000
14 ~ 14′	7,000	7,300	200	1,460,000
15 ~ 15′	8,200	7,600	200	1,520,000
16 ~ 16′	8,700	8,450	176	1,487,000
17 ~ 17′	1,700	5,200	230	1,196,000
				10,733,000

Profile №	Sectional area (m^2)	average (m^2)	Interval (m)	Stripped Volume (m^3)
	0			
18 ~ 18′	3,900	1,950	200	390,000
19 ~ 19′	3,800	3,850	200	770,000
20 ~ 20′	2,900	3,350	200	670,000
21 ~ 21′	4,000	3,450	100	345,000
22 ~ 22′	2,100	3,050	100	305,000
	0	1,050	134	141,000
				2,621,000

area, eight and five in the northern and southern parts of the central area, respectively, to draw cross-sectional drawings. Based on the drawings thus prepared, the amount of stripping and minable coal reserves associated with the open-cut mining of the Nos. 2, 3, 4, 5 and 6 coal seams are determined as shown in Table 16. Because all coal seams can be mined, the minable coal reserves are large for the limited mining area. But the stripping ratio is considerably high; 12.8 : 1 in the north area, 10.6 : 1 in the northern part of the central area, and 8.9 : 1 in the southern part of the central area, averaging 11.5 : 1 in the entire district. Besides, accumulation of the thin coal seams will make the open-cut mining rather difficult.

(3) Quality of Stripped Rocks

White or light brown, arkosic, medium- to coarse-grained, solid massive sandstones represent the major portion of the stripping. Their bedding is relatively indefinite and contains large grains of quartz and feldspar. Accordingly, the stripping operation will be very difficult and costly.

When measured in Japan for reference, a South African drill core indicated an unexpectedly low compressive strength of 584 kg/cm^2. Since the drill core had been left outdoors for over one year, that low value must have been due to the influence of weathering. Naturally, the compressive strength must be as high as 1000 to 1500 kg/cm^2.

(4) Mining Equipment

The bench-cut method is deemed applicable to this district. This method requires considerable numbers of bulldozers, crawler drills, power shovels, trucks and other equipment, though their quantities depend on the mining scale. Consequently, not only the initial investment and their maintenance cost but also the mining cost will become considerably high.

(5) Climate Conditions

The climate of this district is clearly divided into the dry and rainy seasons. Little rain falls during the dry season, whereas localized heavy rain, associated with thunders, falls during the rainy season extending from November to April. The heavy rainfall during the rainy season will adversely affect the open-cut mining.

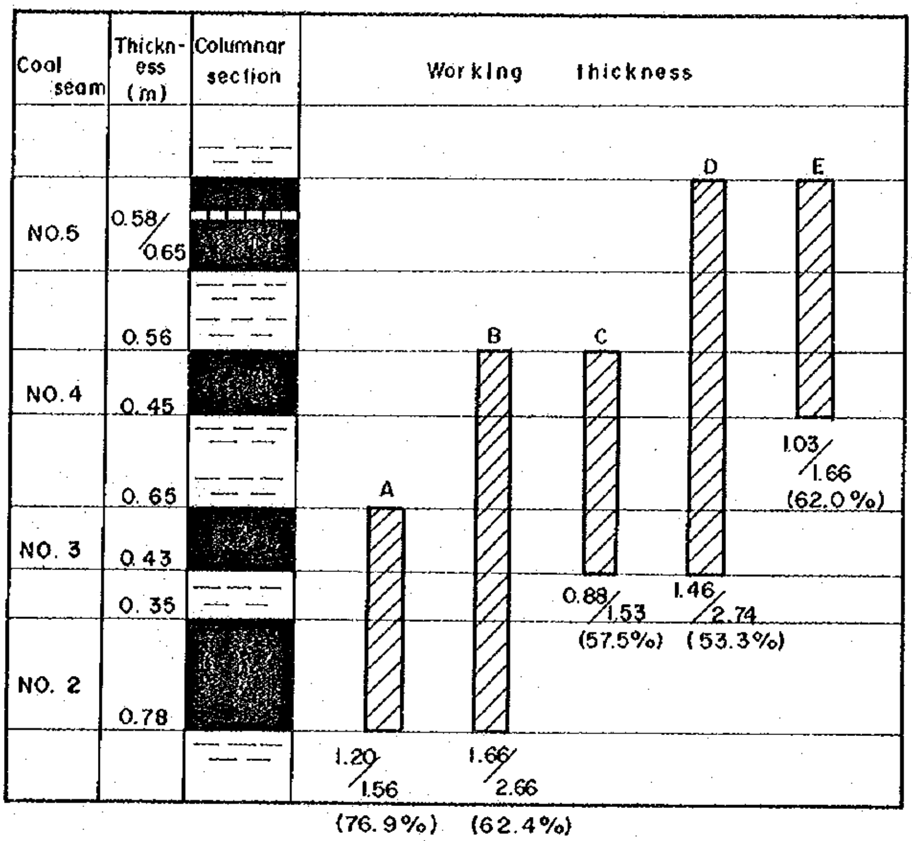
All in all, open-cut mining in this district is more detrimental than advantageous.

4.2. Development by Underground Mining

As described above, open-cut mining is disadvantageous to this district. Therefore, the following plan is made based on the application of the underground mining method to above the mine mouths.

4.2.1. Selection of Minable Coal Seams

This district contains five coal seams, Nos. 2 to fig. 5 Working Thickness Compared Map



6, in the upper shale member of the K2 beds in the Karroo system. The conditions of these coal seams are shown in Attached Fig. 6.

To select minable coal seams, the five coal seams were variously combined, and their mining coal seam and coal thicknesses and their ratios were studied, as shown in fig. 5.

Each coal seam is too thin to permit independent mining, but when any three of them are combined, the total thickness becomes too great for simultaneous mining. Both of the single- and triple-seam mining are technically difficult. Therefore, the double-seam mining becomes practicable. Judging from the coal thickness, the coal seam to coal thickness ratio and coal quality, combination of the Nos. 2 and 3 coal seams proves most advantageous.

4.2.2. Mining Method

Underground mining of this district is planned as follows:

(1) Division into Pits

Mine mouths will be provided at the base of the eastern slope. From each mouth, a drift will be driven to the object coal seam. Then, a rising slope with a true dip will be driven to the outcrop. Roadways will be driven both sides from the rising slope, and mining faces for coal extraction will be provided where they reach the object coal seam.

Trnasportation in the roadway will be done by use of tubs. So the roadway distance is limited at 300 m (though some exceed 300 m). Therefore, the mining range in each pit is planned to extend 600 m along the strike. Accordingly, the north and central areas each are divided into three independent pits.

(2) Position of Mine Mouth

First, the position of the rising slope, which becomes the center of each pit, was decided. Then, the mine mouth was located at the lowest possible position on the plane at the mountain base where the drift distance could be minimized. As shown in Attached Fig. 10, the mine mouths are NI, NII and NIII in the north area, and CI, CII and CIII in the central area.

The mine mouths were planned to be provided on the extension of the rising slopes. The mouth NI, however, was planned to be provided on the extension of the southeastwardly turning drift, because of the need to provide it at the lowest possible level and build the office center to the northeast of NII.

To prevent the inflow of surface water during the rainy season, the mine mouths will be opened 3 to 5 m above the surface level. Also, a space to place compressor and emergency supplies must be secured in its vicinity.

(3) Underground Structure

In each independent pit, a drift will be driven through rock from the mouth, and a material passage will be provided near where it reaches the coal seam. A rising slope will be driven along the coal seam from the material passage to the surface, so as to constitute a ventilation system. After reaching the coal seam, the drift will be turned and extended to below the rising slope, and a coal and a refuse pocket will be provided therebetween (see fig. 7 , Pockets Plan).

At 60 m intervals, roadways will be driven both sides for 300 m from the rising slope. A passage to connect the upper and lower roadways will be driven and a mining face formed at the end of each roadway.

(4) Mining in Pit

In each area, 30 m from the outcrop will be left as safety pillars to prevent the inflow of surface water and insure ventilation. Also, 20 m each safety pillars will be left on both sides of the rising slope for the purpose of its maintenance.

On completion of the mining face, the upper roadway will be closed, while the lower roadway will be reinforced with auxiliary braces and prop posts so that it can serve as a passage for materials transportation and air return to and from the next mining face.

The lowermost roadways of the individual pits will be connected each other to pass the ventilation, drainage, compressed air and other piping systems therethrough.

On completion of mining in each pit, 20 m wide safety pillars will be left and all roadways, except the aforesaid lowermost one, closed to prevent spontaneous fires and insure ventilation.

4.2.3. Minable Coal Reserves

When the previously described 30 m safety pillars from the outcrop line and protective pillars within the 60-degree fracture angle under main rivers are excluded, theoretical coal reserves in the north and central areas will be 956,000 and 953,000 tons, respectively, making a total of 1,909,000 tons.

Based on the above-described mining plan, minable coal reserves, defined as the total of coal extracted from the mining face operation and the roadway driving will be 610,000 and 639,000 tons in the north and central areas, and a total of 1,249,000 tons, as shown in Table 17.

Consequently, recovery ratios for the north and central areas and the entire district will be 64, 67 and 65 per cent, respectively.

4.2.4. Production Scale

The production scale of a newly developed colliery depends on the following conditions:

Table 17. Minable Coal Reserves

Area	Mine Mouth	Mining		Driving		Total
		Advanced Length of Face (m)	Coal Production (1000t)	Roadway & Slope Length (m)	Coal Production (1000t)	(1000t)
North	N-I	2035	195	3575	22	217
	N-II	1945	187	3375	21	208
	N-III	1720	165	3280	20	185
	Total	5700	547	10230	63	610
Central	C-I	2110	220	3800	24	244
	C-II	1765	184	3345	21	205
	C-III	1640	171	3130	19	190
	Total	5515	575	10275	64	639
Total		11215	1122	20505	127	1249

Bases for Minable Coal Reserves Calculation

Coal from Mining Face

	A	B	C	D	E	
North:	1.16m	x 60m	x 1.0m	x 1.5t/m^3	x 0.95	= 96t per advance of 1.0m
Central:	1.26	x 60	x 1.0	x 1.5	x 0.95	= 104t

Coal from Driving

	F	G	H	
Roadway:	4.1m^2	x 1.0m	x 1.5t/m^3	= 6.15t per advance of 1.0m
Slope:	4.4	x 1.0	x 1.5	= 6.6t

A = coal thickness; B = face length; C = advance; D = specific gravity; E = safety factor; F = coal area; G = advance; and H = specific gravity

(1) Natural and Mining Conditions

(2) Social Conditions

These conditions will be considered hereunder.

(1) Natural and Mining Conditions

(i) Coal Seams Occurrence

Based on the investigation results, the Nos. 2 and 3 coal seams are planned to be mined simultaneously. They have sound roofs and floors and medium dips ranging between 25 and 27 degrees. The coal seam tracing and the surface investigation revealed that they occur in relatively stable conditions.

(ii) Minable Coal Reserves

As mentioned before, the coal seams to be mined will have minable coal reserves of 1,249,000 tons above their mine mouth level. Addition of some pumps, winding machine (37.5 kw) and other equipment will add 697,000 tons of reserves, which are minable from the two roadways below the mouth level, making a total of 1,928,000 tons.

In planning development of a new colliery, it is generally desirable to secure such minable coal reserves that permits the operation to last at least for 20 years.

(iii) Mining Method and Coal Production Capacity

Considering the medium-dipped, stable coal seams and the limited minable reserves above the mine mouth level, simple, easy and highly productive longwall mining is envisaged. By giving consideration to various conditions, the mining face length is established as 60 m. Daily coal production will be 210 tons if coal-cutting advances 30 m over the 60 m long face during each of three shifts of the day. Addition of 23 tons of coal from roadway driving makes total daily production of 233 tons. With this daily production, annual coal production will be 70,000 tons. When mined at this rate, the mine life will be 17.8 years for above the mouth level, and 27.5 years if the two roadways under the mouth level are included.

(2) Social Conditions

(i) Demand

The coal of this coal field should be consumed domestically, as its export seems impossible because of its grade and transportation difficulties. At present, Malawi is totally depending on imports from Rhodesia, Mozambique and other countries for the supply to its home coal demand. Approximately 80,000 tons of coal, with over 6000 kcal/kg of calorific value, is imported. The Ngana coal field will produce 70,000 tons per year of coal, ranging between 5000 and 5500 kcal/kg in grade. Therefore, even if shipped exclusively for domestic use, the coal will be somewhat insufficient to fill the overall home demand.

(ii) Labor and Technical Level

In Malawi, other industries than agriculature are not much developed yet. Accordingly, employed laborers in 1975 were approximately 245,000, accounting for only about 5 per cent of the total population. So the nation is expected to have adequate latent labor force. In addition, a considerable number of people are working in the coal and other mining industries in South Africa, Rhodesia, Zambia and other nearby countries. But the internal latent laborers cannot be expected to have high technical levels required for this colliery development. It is therefore desirable to employ, as much as possible, those who have experience in working underground in foreign collieries.

(iii) Transportation of Coal and Mining Equipment

In Malawi, railway service is available only in its south region. But a considerably good road runs from south to north. Lake Malawi, extending north and south in the east of the country, permits water transportation. Therefore, if a 23 km long road between the colliery site and Iponga is repaired, there will be no transportation problem up to the shore of Lake Malawi.

(iv) Relation with Local Community

There exists no townsite or the like, except some sporadic farmhouses, in the projected colliery site. Accordingly, bank, post office, hospital, police station and other facilities, depending on the scale of development, should be provided simultaneously with the development of the colliery.

Satisfaction of the aforesaid conditions is indispensable to the development of the colliery. These interrelated requirements should also be carefully studied when deciding the production scale.

During this investigation, however, little study was made about the social conditions. So many factors remain to be determined in this respect. The annual production scale of 70,000 tons has been established mostly on the basis of the natural and mining conditions studied.

4.3. Preconditions for Development Plan

This investigation was confined to the probability of colliery development in the western district of the Ngana coal field, and more particularly to the coal seams in the north and central areas of the district. At the same time, the proposed sites for the mine mouths and surface facilities and the access road between the colliery site and Iponga were investigated as much as practicable. By submitting a questionnaire, other necessary information was obtained from the responsible party of Malawi. But, for lack of experience in the coal mining industry, Malawi's answers were inadequate. Since this investigation was not a feasibility study, more extensive, detailed data were not collected. Therefore, Japan's actual performance data were substituted where our investigation failed to clarify. The development plan formulated is based on the following preconditions:

4.3.1. Geological Conditions

Trench exploration was given to the coal seams in the upper shale member of the K2 beds in the north and central areas of the western district. Consequently, the Nos. 2 and 3 coal seams are planned to be underground-mined together. Here an assumption is made that the same coal occurrence as is seen in the outcrop continue to the depth (down to the mine mouth level). The coal seam dips also are estimated from those confirmed at the surface and a cross-sectional drawing based on the boreholes drilled by the South African Chamber of Mines.

Taken from the outcrop trenches affected by weathering, the coal samples represented different qualities from those to be extracted from underground. Therefore, the real coal quality will be better than the best one determined by the analytical results. This leads to an assumption that the coal to be produced will have an inherent moisture content of under 7 per cent, ash content of about 25 per cent, and calorific value of approximately 5300 kcal/kg, and that all coal produced is supplied to domestic consumers.

Theoretical coal reserves are calculated by assuming that the coal seam occurrence outcropped continues to the depth and excluding 30 m safety pillars from the outcrop line and protective pillars within the 60-degree fracture angle under main rivers. Minable coal reserves are determined by adding coal from the mining faces and the roadways, in accordance with the mining plan. The recovery rate of the coal from the mining faces is estimated as 95 per cent, and its specific gravity as 1.5 from the specific gravity distribution resulted from the washability test (see Table 14 and fig. 4).

4.3.2. Mining Conditions

The mining and surface rights are assumed to be used freely. Underground mining without washing will not cause environment pollution.

Mining is confined to above the mine mouth level, because the strata pressure, amounts of underground water and gas are unknown, and for unavailability of electricity.

4.3.3. Labor Conditions

The colliery is planned to be operated on 300 days a year, based on the following working days list for 1977 in Malawi.

The number of shifts per day will be three for underground and other directly related work, two for preparation work, and one for office work. Each shift will comprise eight hours.

Month	Calendar Days	Sundays	Public Holidays	Working Days
Jan.	31	5	1	25
Feb.	28	4	-	24
Mar.	31	4	1	26
Apr.	30	4	3	23
May	31	5	1	25
Jun.	30	4	-	26
Jul.	31	5	1	25
Aug.	31	4	1	26
Sep.	30	4	-	26
Oct.	31	5	1	25
Nov.	30	4	-	26
Dec.	31	4	2	25
Total	365	52	11	302

Another assumption is that suitably educated and trained technical engineers necessary for colliery development will be secured. Also, at least one-third of laboerers will have experience in underground mining. Without them, even if other requirements are satisfied, the development period will become longer by the duration needed for education and training.

Chapter 5. Colliery Development Plan

Based on the development concepts described in the preceding chapter, development of a colliery with an annual production of 70,000 tons is planned hereunder.

5.1. Driving Plan

Depending on their character and driving time, the in-pit roadways, slopes, etc. making up the underground structure described in the preceding chapter are divided into the initial driving and the operative driving.

5.1.1. Initial Driving

The initial driving comprises a horizontal drift duck through rocks from the mouth of each pit to the object coal seam, pockets near where the drift reaches the coal seam, and a materials passage. For the N-I pit where coal extraction starts, North No. 1 slope leading from the materials passage to the outcrop, Left Nos. 1 and 2 roadways and Left No. 2 face slope used for the arrangements of the mining face are included in the initial driving.

As shown in Table 18, the initial driving totals 3,238 m in length, comprising 2,268 m long passages through rocks and 970 m long passages along the coal seams. The design and specification of each of them are as follows:

The horizontal drift passed through rocks will be a semicircular, open passage, 5.3 m wide, 3.7 m high with a cross-sectional area of 16.3 m^2. But supports will be

Table 18. Initial Driving

No.	Description	Use	Length (m)	Dip (Deg.)	Support Type	Effective Cross-Sectional Area (m^2)	Level (SL, m)	Remarks
1	N-I, horizontal drift	Coal/equipm't transport & intake	435	+1/200	A 5.3	16.3	+525	Thru rocks
2	N-I, materials passage	Equipm't transport & intake	25	+1/200	A 5.3	16.3	"	"
3	N-I, pockets	Coal & refuse	23	90°	Open	5.0		"
4	N-I, rising slope	Coal/equipm't transport	310	29	10' x 8'			Along coal seam
5	N-I, left No. 1 roadway	Equipm't transport & return	300	1/100	9' x 8'			"
6	N-I, left No. 2 roadway	Coal transport & intake	300	1/100	9' x 8'			"
7	N-I, left No. 2 face slope	Coal cutting	60	29	Hydraulic prop & kappe	3.9		"
8	N-II, horizontal drift	Coal/equipm't transport & intake	270	+1/200	A 5.3	16.3	+525	Thru rocks
9	N-II, materials passage	Equipm't transport & input	30	+1/200	A 5.3	16.3	+525	"

10	N-II, pockets	Coal & refuse	23	90°	Open	5.0		Thru rocks
11	N-III, horizontal drift	Coal/equipm't transport & intake	270	+1/200	A 5.3	16.3	+525	"
12	N-III, materials passage	Equipm't transport & intake	30	+1/200	A 5.3	16.3	"	"
13	N-III, pockets	Coal & refuse	23	90°	Open	5.0		"
14	C-I, horizontal drift	Coal/equipm't transport & intake	310	+1/200	A 5.3	16.3	+555	"
15	C-I, materials passage	Equipm't transport & intake	30	+1/200	A 5.3	16.3	"	"
16	C-I, pockets	Coal & refuse	23	90°	Open	5.0		"
17	C-II, horizontal drift	Coal/equipm't transport & intake	300	+1/200	A 5.3	16.3	+570	"
18	C-II, materials passage	Equipm't transport & intake	30	+1/200	A 5.3	16.3	"	"
19	C-II, pockets	Coal & refuse	23	90°	Open	5.0		"

provided in the vicinity of the coal seam and other places where the roof is weak. The drift will have a drainage ditch. (See fig. 6.)

The pockets and materials passage will be designed as shown in fig. 7 . The pockets for coal and refuse will be provided separately, and have facilities for direct loading onto trucks.

As shown in fig. 8 , the rising slope will have troughs for coal and refuse on both sides, and equipment and materials hauling rails at the center.

The roadways are shown in fig. 9 . They are driven from the rising slope, in the direction of the coal seam strike. The lower one is for taking out coal from the mining face to the surface, while the upper one is used for transporting mining materials and returning air. In their design, consideration was given to their maintenance that is important for the effective acheivement of their individual functions.

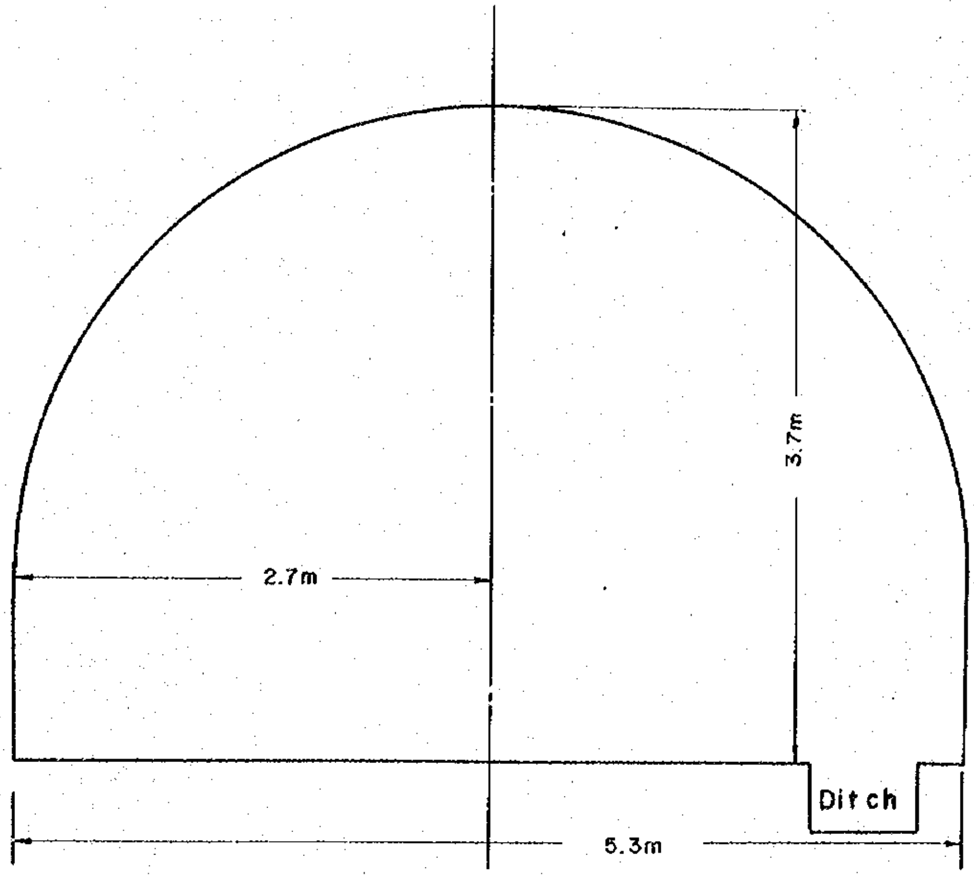
5.1.2. Operative Driving

The operative driving comprises digging other passages than the above-described initial ones that are necessary for the assurance of normal, stable coal production.

(1) Driving Length (along Coal Seams)

For securing normal stable coal production, it is essential to drive roadways in accordance with the advance fig.6 Drift Section

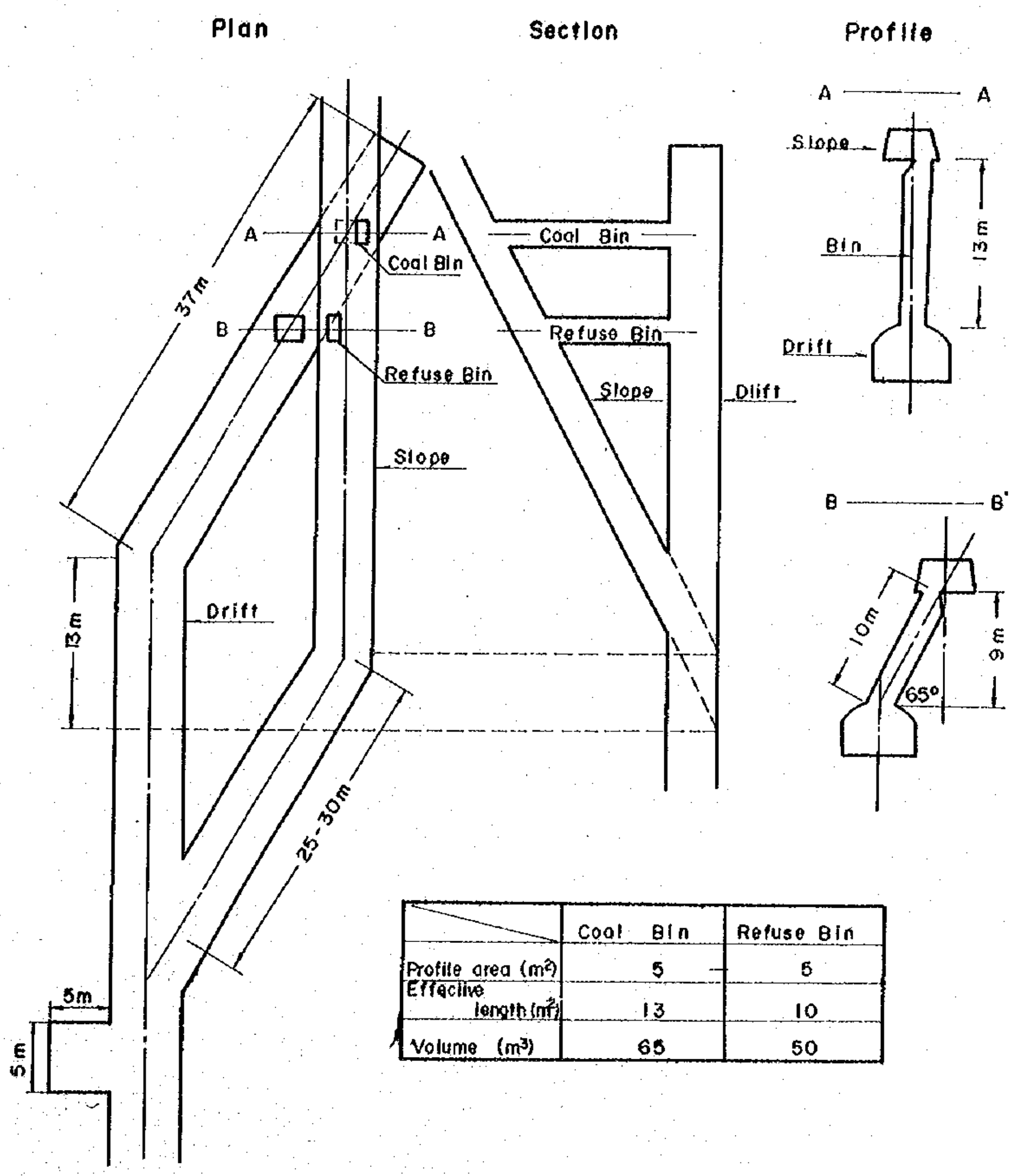
Scale 1 : 40



Sectional area 16.4 m^2

fig. 7 Plan of Bins

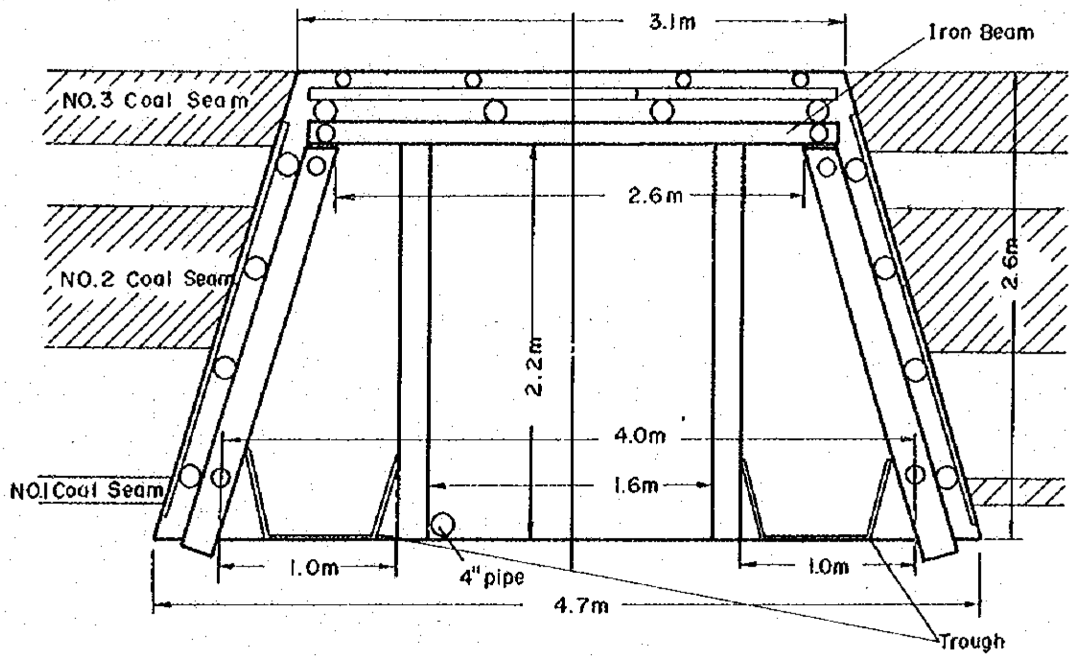
Scale 1 : 500



	Coal Bin	Refuse Bin
Profile area (m^2)	5	5
Effective length (m^2)	13	10
Volume (m^3)	65	50

fig.8 Slope Section

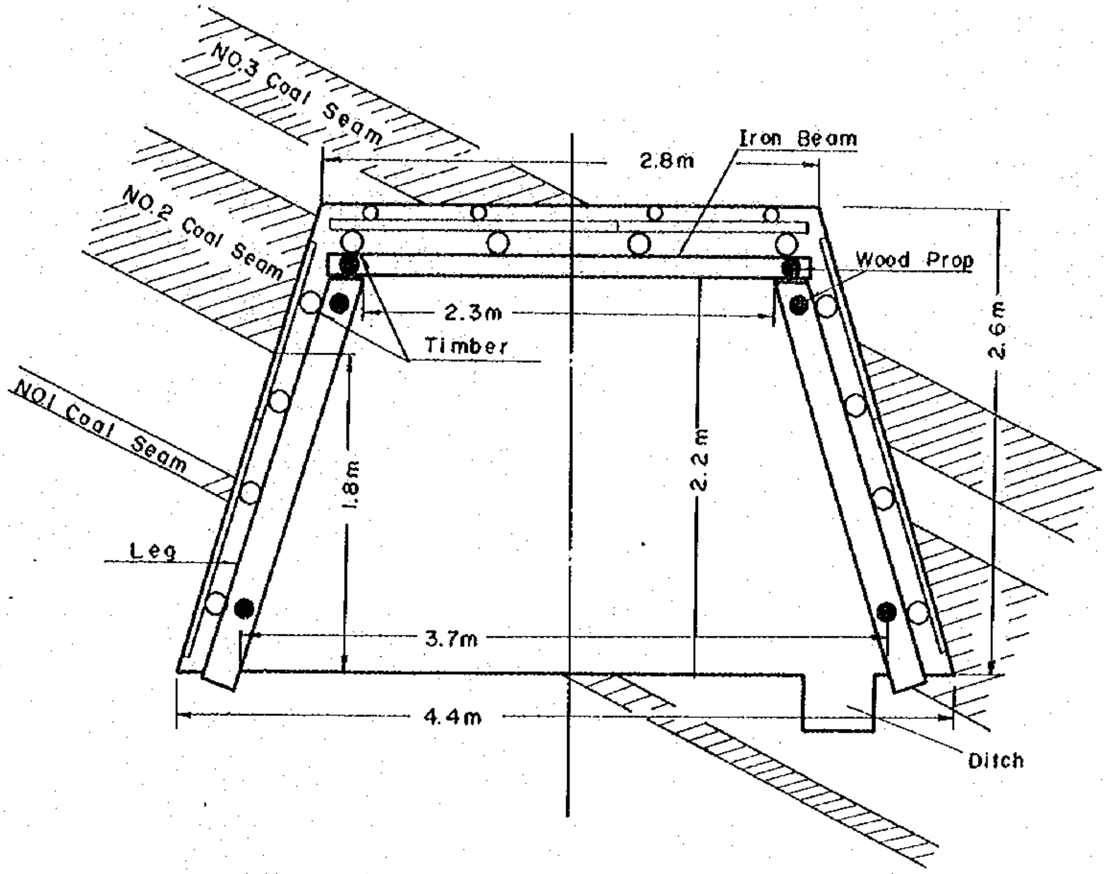
Scale 1:40



Iron Beam	3.0 m	Sectional area	10.1 m^2
Wood Leg	2.4 m	Effective area	7.3 m^2

fig. 9 Road Way Section

Scale 1 : 40



Iron Beam	2.7 m	Sectional area	9.4 m^2
Wood Leg	2.4m	Effective area	6.6 m^2

of the mining face and the operation schedule of each pit and secure the spread of the pit.

The development plan contemplates producing 70,000 tons per year of coal by cutting one mining face. The corresponding annual driving will be as follows:

(A) Roadways and Face slopes

The following calculations are based on the yearly advance of the mining faces:

Roadway = 52.5 m/month (a) x 12 x 1 (b) x 1.2 (c)

= 756 m/year

where (a) = advance of mining face

(b) = roadway

(c) = miscellaneous driving

$$\text{Face slope} \fallingdotseq \frac{52.5 \text{ m/month} \times 12}{300 \text{ m} - 20 \text{ m}} \times 60 \text{ m (d)}$$

= 135 m/year

where (d) = mining face length

(Note. The safety pillar of 20 m is subtracted from the roadway length of 300 m in the denominator.)

Consequently, the total driving length related to the mining face becomes 891 m per year (74 m per month).

(B) Rising Slopes

Judging from the minable coal reserves, a new 300 m long slope becomes necessary every three years. So the yearly driving length will be 300 m ÷ 3 = 100 m.

Therefore, the total driving amount is (A) + (B) = 991 m per year. Allowing for a safety factor of 130 per cent, by way of precaution against the occurrence of unexpected fault and the like, the total driving amount is established as 991 m per year x 1.30 = 1,288 m per year.

(2) Driving Manpower Requirement

On a three-shift basis, monthly driving ability will be 60 m. It will amount to 720 m per year for one driving place. To insure the driving length of 1,288 m, driving should be carried out always in two places, as 1,288 m ÷ 720 m ≑ 1.8.

To achieve the monthly driving of 60 m (2.4 m per day), the following manpower will be required:

Face cutting (explosion, loading supporting, etc.)	6 men
Others (transportation, rail maintenance, air tube extension, etc.)	4 men
Total	10 men

So the three-shift operation requires 30 men per day, and driving two places necessitates 60 men.

(3) As established above, 1,288 m long roadways will be driven every year. But in calculating coal production, a safety factor of 85 per cent should be allowed for. Therefore, 1,288 m x 0.85 ≑ 1,100 m per year.

With the specified cross-section of the roadway, coal production from each meter of driving will be as follows:

Raw coal = 16.4 tons per meter

Clean coal = 6.4 tons per meter

Annual production will therefore be established as follows:

Raw coal = 16.4 t/m x 1,100 m ≑ 18,000 tons per year

Clean coal = 6.4 t/m x 1,100 m ≑ 7,000 tons per year

5.2. Mining Plan

5.2.1. Selection of Mining Method

The following mining methods are technically simple and easy, and require relatively low capital investment.

(1) Blasting Mining with Steel Props and Gravity Flow through Troughs

This method is popularly used as longwall mining. Steel props and kappes support the mining face, and coal seams are broken by means of explosives set in shot holes drilled in the face. Raw coal cut from the face is transferred through the in-face troughs down to the lower roadway. The steel props, kappes and troughs are moved ahead with the advance of the face. The use of the steel props and kappes requires relatively higher initial investment, but they are more advantageous than timbers in respect of operating cost. They are also preferable from the standpoint of safety, as roof control can be attained easily with their strong supporting force.

(2) Blasting Mining with Timbers, Lengthy Rock Packing and Gravity Flow through Troughs

This is a kind of longwall mining that was extensively used before the spread of steel props and kappes The face is supported by many timbers and wood props and the roof is controlled by some lengthy rock packing. Coal cutting and trough transportation are the same as with the preceding method. A large number of timbers require troublesome transportation. Compared with steel props, their roof control ability is lower and, therefore, can afford less face safety. Rock packing requires additional manpower, too.

(3) Room-and-Pillar Mining

Tunnels are carved into the seam between the upperlying and lower roadways, excavating rooms and leaving pillars of coal for support. This method, comprising high percentages of tunnel driving, involves low recovery ratio or coal productivity, and increased use of timbers and explosives. To increase production, more tunnels must be driven, which naturally increases consumption of timbers and explosives. Transportation in the roadway will be congested, too.

(4) Sub-Rise Stoping

Paired parallel rising slopes are driven between the lower and upper roadways, connecting the two slopes at intermediate points. Coal is mined by blasting explosives set in shot holes drilled on both sides of the rising slopes. Like the preceding method, this one also centers on tunnel driving, characterized by low productivity and excessive use of timbers. To maintain a reasonable production level, many faces should be worked. The overmuch transportation will occur in the lower roadway. No supports are used when cutting coal from both sides of the rising slopes, and coal pillars are blasted from both sides. All this will involve considerable hazards and technical difficulties.

As a result of comparative studies, the first mentioned method has been selected as most desirable, both technically and from the standpoint of safety, though it requires somewhat higher initial investment. The reasons for the selection are as follows:

(1) High mining yield increases coal recovery and prolongs mine life.

(2) Simple underground structure requires less tunnel driving.

(3) Limited use of timbers saves cumbersome under-

ground transportation.

(4) Intensive mining faces permit high-efficiency mining.

(5) Steel props and kappes with strong supporting forces insure easy roof control and high face-safety.

5.2.2. Mining Face Standards

The Nos. 2 and 3 coal seams will be mined simultaneously by the retreating, caving longwall method, always mining one face.

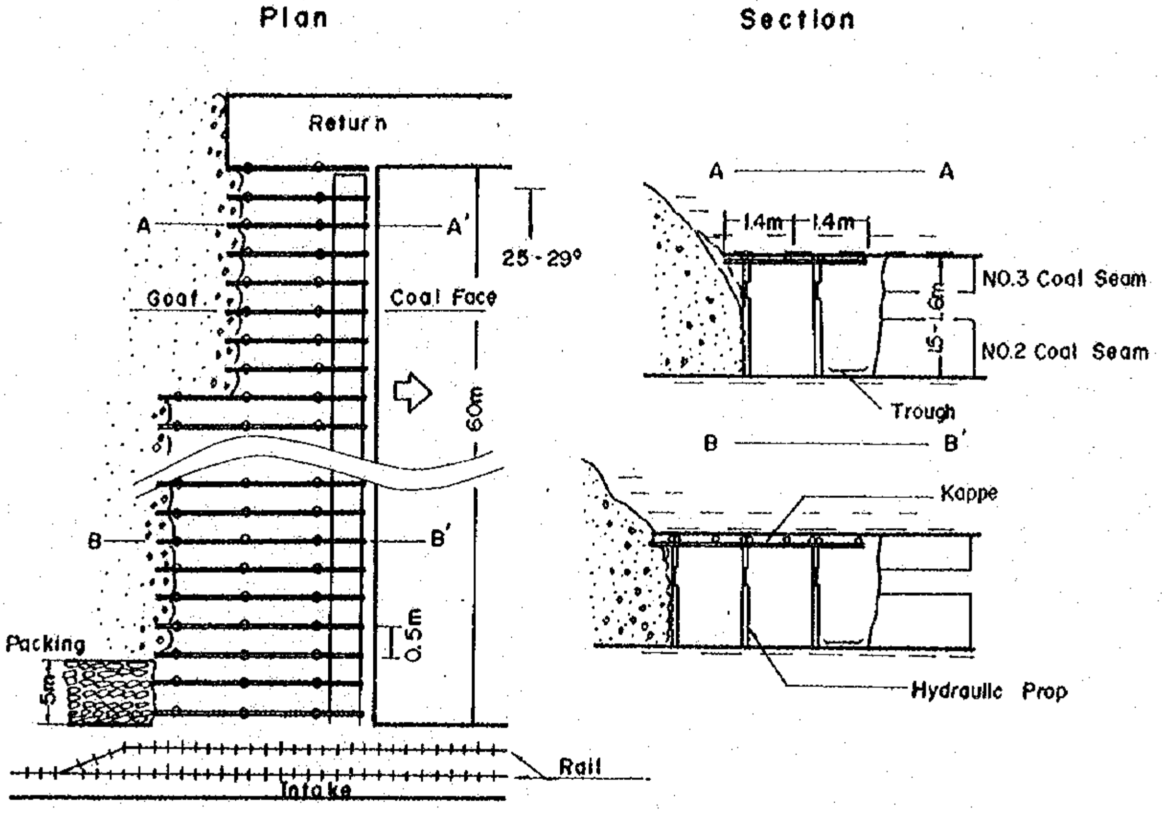
Considering the unavailability of electricity and the assurance of good face control, the face length is established as 60 m.

The mining face standards are shown in fig. 10, and details of the mining faces in the individual areas are described below.

	North Area	Central Area	Mean
Face Length	60 m	60 m	60 m
Dip	29^{o}	25^{o}	27^{o}
Coal Seam Thickness	1.51 m	1.60 m	1.56 m
Coal Thickness	1.16 m	1.26 m	1.21 m

To maintain the lower roadway, 5 m wide length packing will be provided in the lower part of the face. In working the next face, this lower roadway is used as the upper roadway for materials transportation and air return.

As the face advances, rails, iron beams and the fig.10 Longwall Face



Face length	60m
Seam thickness	1.5 – 1.6m
Coal thickness	1.2 – 1.3m
Dip	25 – 29°
Support interval	0.5m
Support	Hydraulic Prop 4 Kappe
Goaf	Total Caving
Filling	Narrow packing

Hydraulic Prop

Type		Duty 2P-60
Height	max	1.8m
	min	1.2m
Weight		56.2kg

Kappe

Type	Pin type
Length	1.4m

like are removed from the upper roadway, which will eventually be completely closed for prevention of air leakage. Working of each face will be completed by leaving the safety pillar of 20 m from the rising slope.

5.2.3. Coal Production from Mining Face

Under the aforesaid face conditions, the face will be cut at an average rate of approximately 40 m per shift, including explosion, gravity flow and provision of supports. But, allowing for the lack of underground mining experience in Malawi, the mean working rate per shift is established as 30 m.

At this rate, coal production averaged over the north and central areas will be as follows:

Working rate per shift	30 m
Working rate per day	90 m,(on 3 shifts)
Face advance per day	2.1 m,(1.4 m x 90/60)
Coal production per day	217 tons, (1.21 x 60 x 2.1 x 1.5 x 0.95)
Raw coal production per day	300 tons,(217 ÷ 0.72)
Coal production per month	5,425 tons,(25 days/month)
Raw coal production per month	7,500 tons,(25 days/month)
Annual coal production	65,000 tons,(300 days/year)

Each face will therefore produce 65,000 tons of coal per year. Allowing for unskilled miners and unexpected fluctuations, however, the annual production is established as 63,000 tons.

If 40 m per shift of face cutting is possible, the mining face will produce 87,000 tons of coal annually.

5.2.4. Mining Personnel Allocation Plan

To perform the aforesaid face operation, each shift will require the following manpower.

Coal mining (explosion, loading and supporting)	10 men
Clearance (prop removal and refuse disposal)	4
Thru-trough coal flow	2
Roadway tub loading	2
Lower packing	2
Materials transportation	2
Total	22 men/shift

Therefore, the daily manpower requirement per face is 22 men x 3 shifts = 66 men. So actual productivity becomes

Clean coal	217 tons/day ÷ 66 = 3.3 tons/day
Raw coal	300 tons/day ÷ 66 = 4.5 tons/day

5.2.5. Summary of Coal Production

7,000 tons of coal from roadway driving plus 63,000 tons of coal from mining face makes a total annual coal production of 70,000 tons. Coal production is summarized in Table 19.

In this plan, capital investment, construction work and production cost are determined based on the annual production of 70,000 tons.

Table 19. Summary of Coal Production (M/T)

Description	Clean Coal	Raw Coal	Remarks
Per Shift			
Coal from roadway driving	8	20	
Coal from mining face	70	97	
Total	78	117	
Per Day			
Coal from roadway driving	23	60	
Coal from mining face	210	290	
Total	233	350	
Per Month			
Coal from roadway driving	583	1,500	
Coal from mining face	5,250	7,250	
Total	5,833	8,750	
Per Year			
Coal from roadway driving	7,000	18,000	Yield 38.9 %
Coal from mining face	63,000	87,000	72.4
Total	70,000	105,000	66.7

5.3. Transportation Plan

5.3.1. Transportation of Raw Coal

In the rising slope and mining face, raw coal will be transported by gravity flow through troughs, utilizing the dip of the coal seam, and by manpower.

Transportation in the roadway will be effected by hand-pushed wooden tubs. Since hand-push transportation is thought to be limited to about 300 m, the roadway also is designed with a length of 300 m.

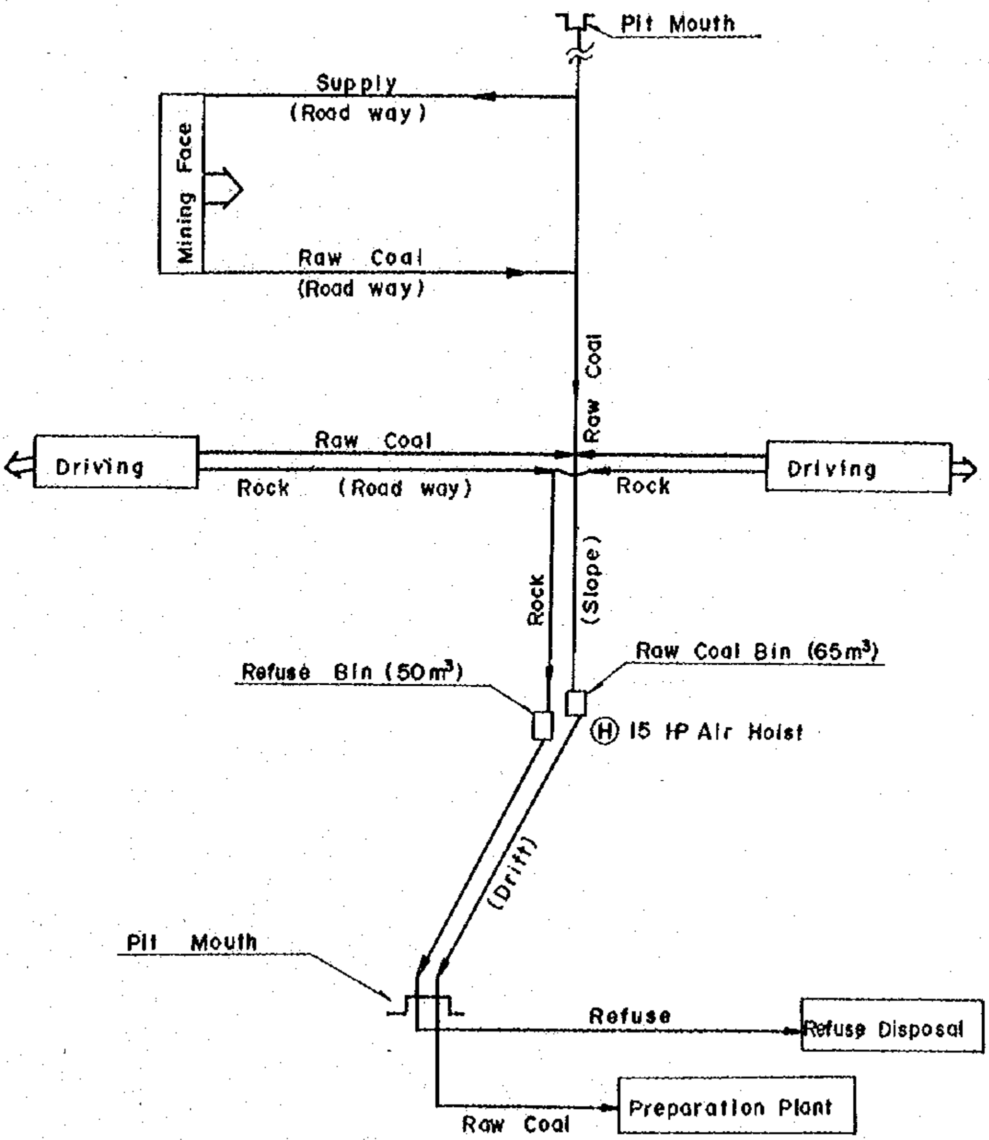
Transfer between the coal pocket to the preparation plant, and the refuse pocket to the refuse disposal yard will be done by use of trucks.

The troughs will be made of reinforced vinyl or steel plate. The side-dump tubs, made of wood, will have a loading capacity of 1 m^3. The trucks will be 4.5-ton dump trucks. The transportation system is shown in fig. 11.

5.3.2. Transportation of Materials

Timbers, iron beams and other mining materials will be transported by the aforesaid trucks from the surface storage yard to the underground materials passage. The necessary quantity of such materials will always be stored in the materials passage. For further transportation, they will be loaded onto material cars, which are air-hoisted to the rising slope and hand-pushed to the upper and driving roadways.

fig.11 Transportation System



5.3.3. Transportation Personnel

To perform the above-described transportation, the following personnel will be required.

Roadway transportation	8 men
Roadway tub operation	1
Gravity coal flow	4
Pocket loading	1
In-pit materials transportation	3
Trucking	5
Total	22 men per shift

Accordingly, the daily transportation manpower requirement will be 66 men, on 3 shifts.

5.4. Drainage Plan

Because this mining plan is limited to above the mine mouth level, little underground water is expected to spring out during the dry season. During the rainy season, most of the rain water will fall over the slope of mountains. Therefore, a gravity flow underground drainage system is contemplated.

A draining ditch will be provided in the roadways and drifts. The rising slopes will be provided with pipe through which water from the roadways is to be drained into the ditch of the drifts.

It is difficult to estimate the inflow of rain water through various fissures including those due to ground subsidence in the mined out areas. The quality of overlying rocks and the underground water veins should be investigated by future drilling and other methods.

5.5. Ventilation Plan

Formulation of a ventilation plan usually requires an investigation on the liberation of methane and other gases in the coal seam. But, as mentioned previously, this mining plan is limited to the area above the mine mouth level, and, therefore, the overlying rock will be as thin as 120 m or under. Besides, the coal to be mined is of high-ash, low-volatile grade. These facts lead to an assumption that no significant gas liberation will be encountered. It is therefore planned to provide such a ventilation system as is adequate for the maintenance of good underground working environment.

5.5.1. Amount of Ventilation Required

The following ventilation requirements are based on the above assumption that methane gas liberation be limited.

Mining face	350 m^3/min. x 1 face	= 350 m^3/min.
Driving	70 m^3/min. x 2 faces	= 140 m^3/min.
Total		490 m^3/min.

Considering the simple underground structure, a diagonal ventilation system with a capacity of 500 m^3 per minute is planned to be provided.

5.5.2. Ventilation System

In this diagonal ventilation system, intake air is taken in through the mouth of the drift, and return air is discharged by a fan through the mouth of the rising slope provided in the outcrop, as shown in fig. 12.

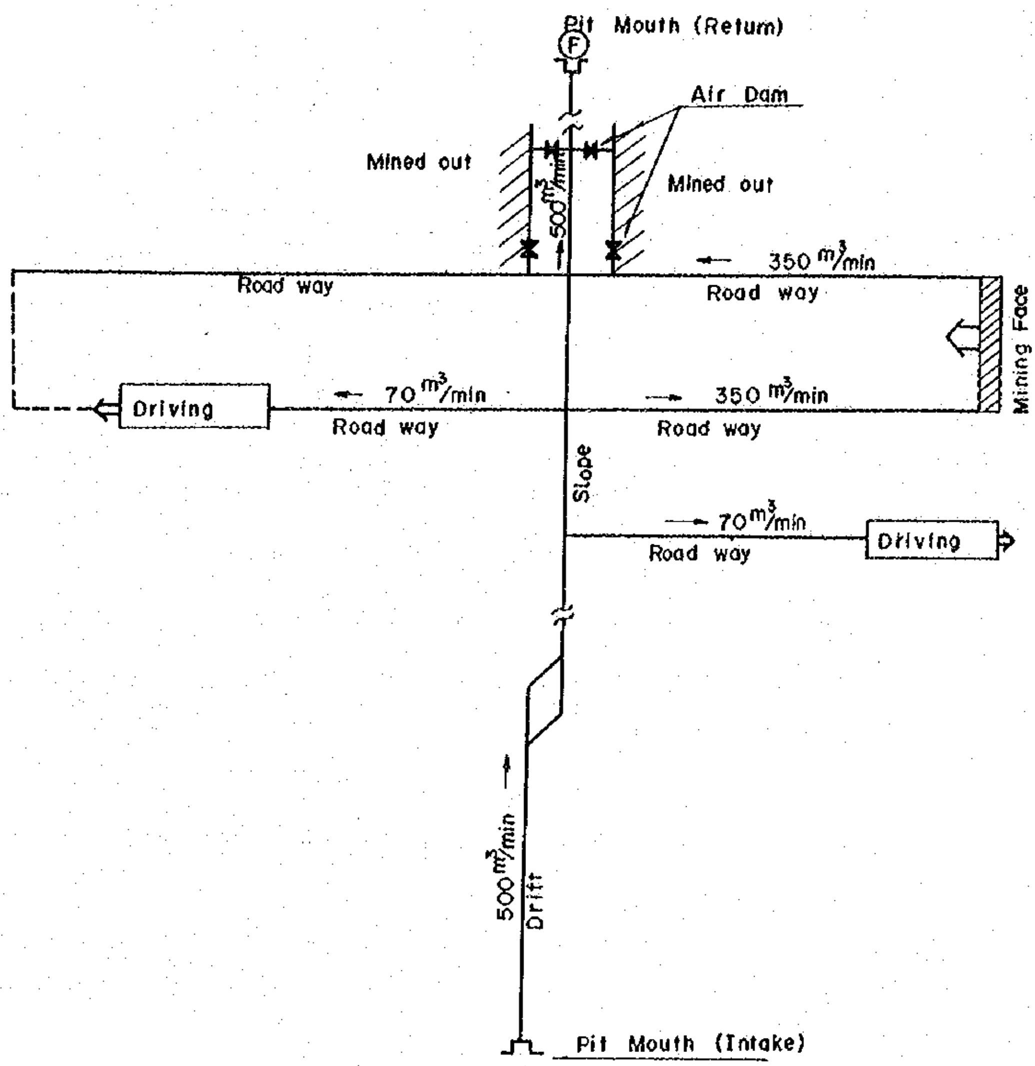
Combined with the simple underground mining structure having a few mining faces and roadways, this diagonal ventilation system, employing the drift mouth as the intake port and the slope mouth as the return port, affords effective, leakless ventilation. Further, owing to the level difference between the intake and return ports, it can utilize advantageous natural ventilation force.

Table 20. By-Tunnel Vaccum Calculation

Description	Tunnel Length (m)	Circum ferential Length (m)	Coefficient of Friction	Cross Section (m^2)	Air Flow (m^3/sec)	Vacuum (mm)
Drift	300	15.8	0.0010	16.3	8.33	0.08
Rising Slope	380	11.2	0.0025	7.3	8.33	1.90
Lower Roadway	300	10.6	0.0030	6.6	5.83	1.13
Mining face	60	8	0.0035	3.6	5.83	1.22
Upper Roadway	300	8.5	0.0030	5.3	5.83	1.75
Total						6.08

From the above table, the total vacuum is established as 10 mm.

fig. 12 Ventilation System



5.5.3. Fans

Each pit will have approximately the same ventilation system as described above. By assuming a typical ventilation condition, capacity requirements of the fan to be provided at the return port were calculated.

To insure the aforesaid ventilation of 500 m^3/min, a vacuum of as low as 10 mm of water column will be needed. Therefore, a small fan rated at 4.5 hp or thereabout will suffice at the return port. Because no electricity is supplied, the return port fans will be diesel-operated. At every return port, two fans will be provided, one of which is to be maintained as a spare.

Air-fans will be provided for assuring localized ventilation in the roadways being driven.

5.6. Safety Plan

In the underground mining, assurance of safety is as important as production. This mining plan includes the following safety considerations:

(1) Three each mine mouths, individually leading to independent pits, are to be provided in the north and central areas. But the lowermost roadways in these pits will be connected each other so that the ventilation, drainage and compressed air piping be passed therethrough.

(2) The simplest possible underground structure will be combined with a diagonal ventilation system.

(3) Longwall mining with hydraulic props and kappes will be employed.

(4) The mining face will be of retreat-type, and, on completion of extraction, it will be closed for preventing air leaks and spontaneous fires.

(5) The roadways will be supported by iron beams and timbers, which are to be maintained by 36 repair men per day.

(6) Cap lamps will be used for underground lighting. For surface-underground communication, explosion-proof telephones will be installed. Water supply and spray facilities and other safety equipment will be provided to prevent coal dust scattering and fires.

To insure underground safety, the following general precautions should be exercised:

(1) To secure adequate ventilation to eliminate stagnant gas, though gas liberation is expected to be limited because of the shallow mining and the specific quality of the coal.

(2) To spray fine-grained rock and water to control coal dust scattered.

(3) To close the mined out areas to prevent occurrence of spontaneous fires.

(4) To provide adequate draining pipe and troughs to permit smooth drainage, though liberation of underground

water is expected to be limited.

(5) To use "permissible" explosives underground, establishing suitable standards for their handling and blasting operation.

(6) To provide appropriate safety devices to underground transportation facilities, and establish their operating standards.

(7) To train underground laborers to work safely in accordance with the specified working standards.

(8) To establish measures and procedures to cope with such accidents as underground fire, explosion and roof falling.

(9) To give safety education and training to colliery workers at the time of employment and at suitable intervals.

(10) To elevate the safety-mindedness of all workers through the management's safety inspection and the workmen's self check.

It is also indispensable to formulate the safety rules, and all workers should work in conformity therewith.

5.7. Surface Facilities Plan

Surface facilities are planned to correspond to the annual production scale of 70,000 tons.

The office building, coal preparation plant, work shop, warehouses and other surface facilities will be confined to a site secured in the east of the north area.

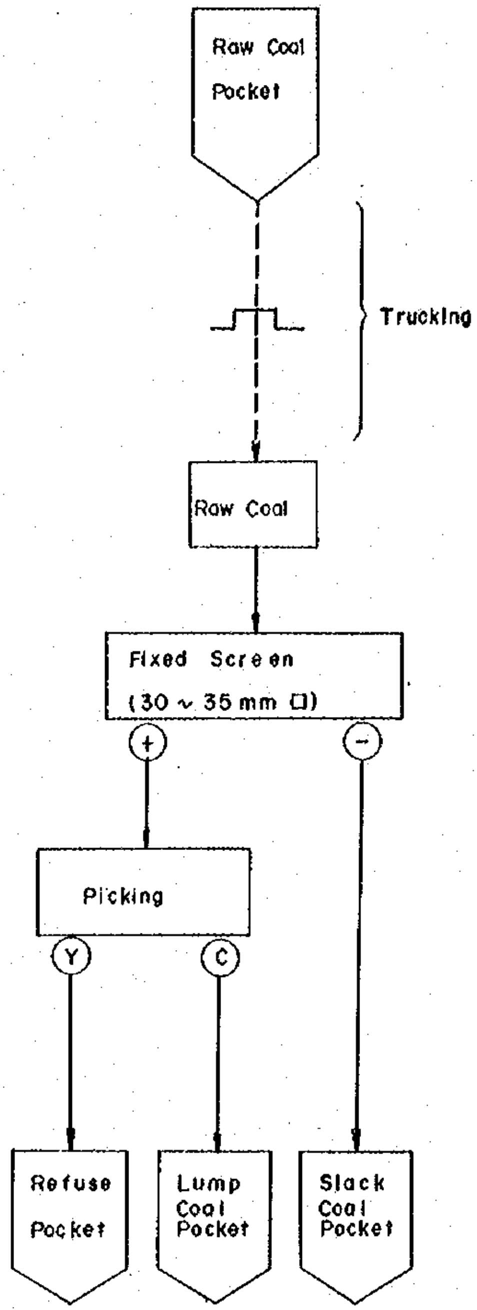
New roads for raw coal and materials transportation will be constructed between the office building and the individual mine mouths.

Their layout is shown in Attached fig. No. 11.

5.7.1. Coal Preparation

In view of the minable coal reserves and limited capital investment, this development envisages hand picking, the simplest of all coal preparation methods. But this method is not altogether free of uncertainty, from the viewpoint of coal grade assurance. It is therefore desirable to replace it with a washing device when additional production from below the mine mouth level comes to be practiced in the future.

Raw coal will be transported by dump trucks from the underground pocket to the preparation plant. This plant is designed to utilize the topographic level difference in place of artificially generated power. The coal is to be placed on a screen fixed on the slope. The mesh size of the screen depends on the properties (especially grade) of the coal. At present, 30 to 35 mm is deemed appropriate. The coal passed through the screen will be shipped as clean coal, while the portion remaining on the screen manually separated into coal and refuse. Depending on the demand situation, manually selected coal lumps may be ground to fig. 13 Preparation Flow sheet



finer sizes, and mixed with the screened slack coal to improve the latter's quality, if required.

The coal pocket will have a capacity to store 150 tons of slack coal and 50 tons of lump coal, a total of 200 tons. The refuse pocket's capacity will be 70 tons. It is also necessary to secure a coal storage yard to prepare for the traffic stumbling due to heavy rainfall or other reasons.

The manually selected refuse and underground refuse will be deposited by dump trucks into the refuse disposal yard.

The coal preparation flow sheet is as shown in fig. 13.

5.7.2. Electrical Equipment

Electricity supply will be unavailable in Ngana, at least for some time to come. Therefore, minimum electricity requirements, for underground safety (cap lamps) and surface facilities, are envisaged to be obtained by means of home generation.

(1) Required Electricity

The electricity requirements are as listed below.

Description	Motive Power	Illumination	Remarks
1. Work shop 48 m^2	30 kw	1.5 kw	Welder, 19 KVA x 2 Milling machine, grinder & drill, each 1kw F.L. 40 w x 2 x 5, etc.
2. DG & compressor room, 180 m^2		2.6	F.L. 40 w x 2 x 20, etc.

3. Materials warehouse, 50 m^2		0.5	F.L. 40 w x 2 x 5, etc.
4. Oil warehouse, 15 m^2		0.12	F.L. 40 w x 1 x 3
5. Pump rooms, 20 m^2, one each for potable and spray water	10	0.16	F.L. 40 w x 2 x 2 2.2 kW x 1, 7.5 kw x 1
6. Water purification plant	1		Sterilizing pump etc.
7. Office & safety lamp room, 435 m^2	10	7	Charging stands, 2 kw x 4 F.L. 40 w x 2 x 44, etc.
8. Staff's house, 51 houses		10	F.L. 40 w x 1 x 4 per house x 51, etc.
9. Coal preparation plant, 200 m^2		2	F.L. 40 w x 2 x 20, etc.
Total	51 + 24 = 75 kw		

Note 1. The explosive warehouse and handling yard are not to be illuminated.

2. The average luminous intensity is 300 lx.

3. F.L. is fluorescent light.

(2) Determination of Generator Capacity

In relation to the above power requirement, the following three items (a), (b) and (c) were studied on the basis of equipment capacity = 75 kw, load factor = 0.8, load efficiency = 0.95, load power factor (in operation) = 0.85 and load power factor (in start-up) = 0.4:

(a) Capacity required for normal operation

(b) Capacity required when the highest-load item starts during partial normal operation

(c) Capacity required to hold the momentary voltage drop of the generator at 15 per cent when the highest-load item starts

The capacities determined were 75 KVA for (a), 104 KVA for (b), and 127 KVA for (c).

The highest of these is the required power generating capacity. Allowing for additional power consumption and overload operation, two generators plus one spare, each having a capacity of 75 KVA, are planned to be provided.

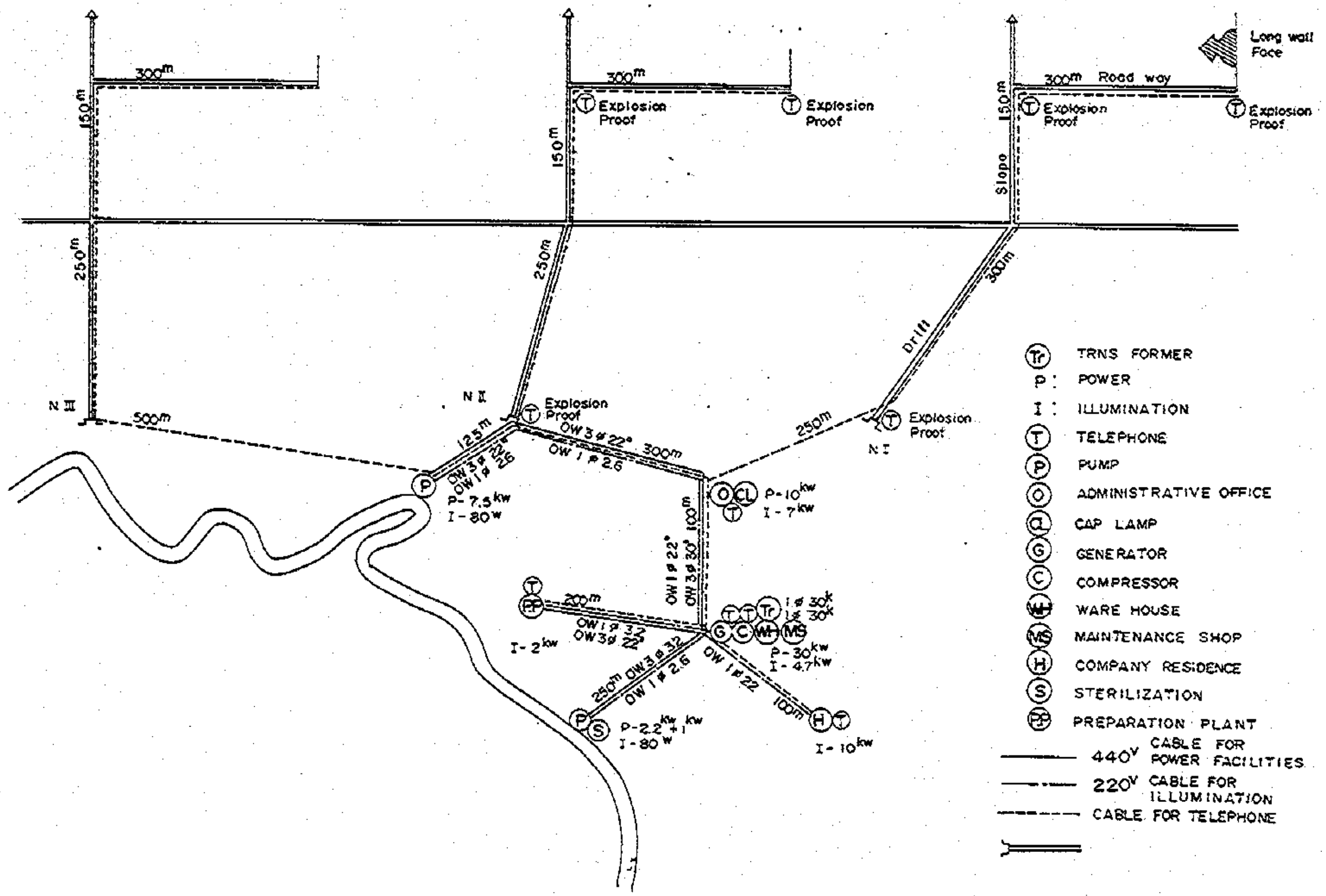
This home-generated electricity will be consumed at a rate of approximately 342,000 kwh (5 kwh per ton of coal produced) per year.

(3) Layout of Electrical Equipment

Electrical equipment under this development plan will be installed as shown in fig. 14.

5.7.3. Air Compressors

Compressed air will be used for the operation of underground mining machines, local fans and materials transporting hoists. More particularly, they include air drills, air augers, coal picks and other mining machines used for tunnel driving and face working, local fans for securing localized ventilation in working areas, and air fig.14 LAYOUT PLAN OF ELECTRICAL EQUIPMENT



hoists (15 hp each) for materials transportation through the rising slopes. Their total air consumption will be 17.6 m^3 per minute. Allowing for a safety factor of 25 per cent, with consideration for piping loss etc., the air requirement is established as approximately 22 m^3 per minute.

Two diesel-operated air compressors (each discharging 25.5 m^3 per minute of air at a pressure of 7 kg/cm^2) are to be provided, with one as a spare.

They will be installed near the mine mouth, and connected to the underground piping with 4-inch dia. pipe. When opening the next mine mouth, the spare unit will be employed. The adjacent pits are to be connected through the piping on the surface or in the lowermost underground roadway.

5.7.4. Other Facilities

(1) Ventilation Equipment

According to the aforesaid ventilation plan, two main fans (diesel-operated, 500 m^3/min.) are to be provided at the mine mouth of the rising slope in the outcrop, and one of them will be maintained as a spare. Further, air fans will be provided for localized ventilation in the underground driving faces.

(2) Water Supply Equipment

Equipment to supply potable water to the office building, houses and so on will be provided. The well, distribution piping, service reservoir and other equipment will be positioned as shown in Attached fig. No. 11.

Water requirement will be as follows:

Office 100 l/man x 500 men = 50 m^3/day

Houses 200 l/man x 58 houses x 8 men/house

= 92.8 m^3/day

Total 142.8 m^3/day

Water supply per hour 142.8 m^3 ÷ 24 ≑ 6 m^3/hr

Max. water supply per hour 6 m^3 x 1.5 = 9 m^3/hr

= 0.15 m^3/min.

A well will be drilled by the river near the office building, and the subsoil water will be sent through 2-inch pipe (510 m long) to a service reservoir (capacity: 10 m^3) by use of an underwater pump (capacity: 3.7 kw, 40 mh and 0.16 m^3/min.).

The water sterilized at the exit of the reservoir is to be supplied to the office building and houses through 2-inch pipe (100 m long) and 40 mm pipe (800 m long).

(3) Water Sprinkling Equipment

For sprinkling to prevent scattering of coal dusts, water taken from the river near the mine mouth will be supplied underground through pipe. The equipment comprises two electrically operated turbine pumps (capacity: 7.5 kw, 250 mh, 0.1 m^3/min.) and 2,400 m of 2-inch piping.

(4) Work Shop

Machines and tools necessary for repairing steel props, kappes, tubs, troughs, etc. will be provided. They include electric welders, milling machines and other repairing tools.

5.7.5. Vehicles

Three dump trucks (4.5 tons each) will be provided to transfer raw coal and refuse from their individual underground pockets to the coal preparation plant and the refuse disposal yard, respectively.

Two wheel loaders (1.2 m^3) for shipping stocked coal, loading refuse and other purposes and one multi-purpose bulldozer (D-4) for road repairing, refuse disposal yard leveling, etc. will be provided, too.

5.7.6. Office Building

In a site in the east of the north area, there will be built a office building, materials warehouse, work shop, oil warehouse and the like. An explosive warehouse and an explosive handling house also will be provided in a suitable nearby site. All buildings will be one-storied and made of wood, excepting that the generator and air compressor rooms will be steel-framed to make them fire-proof.

5.7.7. Housing

Because of the colliery location, houses or dormitories should be provided to those who can not come to work from the nearby areas. This plan envisages building houses only for engineers and staffs (51 men).

5.7.8. Land Construction Plan

Road and building construction at the surface are planned as follows:

(1) Road Construction

The roads that connect the individual mine mouths in the north and central areas to the office building are important for the transportation of raw coal and mining materials. Because these areas narrowly extend south and north, the transportation roads will be constructed on the flat land at the mountain base. Also, a road in the building site and one leading to the refuse disposal yard will be constructed.

(A) Transportation Roads

The transportation roads are designed based on an assumption that 4.5-ton dump trucks run at a speed of 25 km per hour, carrying approximately 100,000 tons of raw coal and various mining materials.

Road specifications are as follows:

Road width:	6.0 m
Radius of curvature:	50 m or above
Pavement:	Gravel-compacted, with 20 cm banking and 15 cm excavation

Drainage: This district has an annual rainfall of 2,800 mm, the major portion of which concentrates in the rainy season (November to April). Therefore, as-dug ditches will be provided on both sides of the road, one on the mountain side being 400 mm x 400 mm, and one on the opposite side 300 mm x 300 mm in cross-section. Further, crosscut drainage culvert will be provided at about 300 m intervals.

Road grade: The central area with much undulation will have a 200 m long section with a 4 per cent upgrade (empty car). The remainder is designed with downgrade (max. 7 per cent), with a minimum of ground excavation.

Others: In the central area, a bridge (4 m wide and 28 m long) will be built, and the river course (28 m wide and 200 m long) will be changed in one place.

The transportation roads will extend 1,500 m in the north area, and 3,300 m in the central area (between N-I in the north area and the central area).

Because mining in the central area will take place several years behind one in the north area, its road construction is not included in the present capital investment plan.

Concerning road construction, only rough field investigation has been made. It is therefore necessary to perform detailed investigations on topography, surface rocks, rainfall (especially in the rainy season) and equipment and materials for road construction.

(B) Building-Site Road

This road will be 4 m wide and 500 m long, and the above specifications for the transportation roads will be applicable in other respects.

(C) Refuse Disposal Road

This road, 5 m wide and 400 m long, leads from the office building to the refuse disposal yard. The above transportation road specifications are applicable, too.

(2) Building Site Construction

(A) Building Site

The projected location of the building site is shown in Attached Fig. No. 11. A total of 12,000 m^2 of area will be needed, which comprises 6,000 m^2 of flat land and 6,000 m^2 of hill area. Timber-felling and hill-leveling of 6,000 m^2, earth-filling and compacting of 20,000 m^3, turfing, draining and other land construction work will be done.

The office building, work shop, materials and oil warehouses, and some other buildings will be built in this site.

(B) Coal Preparation Plant Site

The coal preparation plant site will be located in the border area between the flat and hilly lands in the building site, to utilize their level difference. Earth removing and filling (1,000 m^3), provision of retaining wall (30 m), and draining ditches, and other construction work will be done.

(C) Housing Site

The housing site will be located as shown in Attached Fig.No. 11. Earth removing (4,000 m^3), road construction (4 m wide and 500 m long), and provision of draining pipe (700 m long) are the major construction work. This housing site will have an area of 10,600 m^2, and about 60 houses will be built in it.

5.8. Manpower Plan

Based on a work-by-work study of manpower requirement for the 70,000-ton-per-year production, personnel allocation is planned as shown in Table 21. This manpower plan is for the normal operation periond (during the north area mining). As no colliery exists in Malawi at present, it seems difficult to fill the manpower requirement with experienced workers in a short time. But the plan is based on an assumption that approximately one-third of laborers have experience in working in foreign collieries and engineers and superintendents are all suitably educated and trained. Considering the laborers' skillfulness and attending rate in today's Malawi, the planned personnel allocation seems to be a minimum necessary one.

Table 21. Manpower Plan

Job	Actually Working	Employed	Remarks
Underground			
Coal cutting	66 men	83 men	22 men x 3 shifts x 1 face
Driving	60	75	30 men x 2 faces
Repair	36	45	4 men x 9 places
Transport	66	82	22 men x 3 shifts
Others	21	26	Machine operator, ventilation, carpenter, etc.
Total	249	311	(Workability = 80 %)
Surface			
Coal preparation	30	33	15 men x 2 shifts
Maintenance	18	20	Equipment repair & compressor operation
Electrical	10	11	Electrical operation, maintenance & control
Materials	10	11	Receipt & disbursement of materials & coal
Office etc.	25	28	Workers for office, safety lamp & explosive warehouse control, refuse disposal, road maintenance, etc.
Total	93	103	(Workability = 90 %)
Total	342	414	(Workability = 83 %)
Engineers & Staffs	51	51	
Mining Productivity (ton/man/month)	14.8	12.5	70,000 t/yr ÷ 12 ÷ (393 or 465)

Note. Engineers and staffs comprise:

General manager 1

Underground 27

Three-shift mining engineers and superintendents

Surface 23

Mechanical, electrical, coal preparation, planning, survey and other technical engineers (11)

General affairs, accounting, materials control and other office managers (12)

5.9. Capital Investment Plan

As shown in Table 22, the initial tunnel driving and colliery construction will require an investment of 651,700,000 yen (2,172,000 kwacha). This becomes approximately 9,309 yen (31 kwacha) per ton of coal produced per year. Compared with the current Japanese investment of 20,000 to 30,000 yen, this figure is very small. This is mainly due to the confinement of mining to above the mine mouth level, because of minable coal reserves, that necessitates only simple equipment of relatively small size.

The prices and transportation costs of domestically procurable equipment and materials for colliery development are unknown. Likewise, the items, supplying countries, prices and transportation costs of those which are to be imported are unknown, as well. Therefore, this plan is based on the current prices and costs of equivalent equipment and materials in Japan.

This is a rough estimation of the expected capital investment that is necessary for the determination of the probability of colliery development. In making a feasibility study, therefore, more detailed studies must be made on such unknown price and cost factors.

5.9.1. Capital Investment on Colliery Equipment

The expected capital investment is summarized in Table 22, and detailed in Table 22-1.

This estimate does not include the costs of transportation road construction in the central area (3,300 m long, at 102,362,000 yen or 341,000 kwacha) and an additional truck (one, at 2,610,000 yen or 8,700 kwacha), because they are to be invested later.

Table 22. Summarized Capital Investment

Description	Investment ¥1,000	Investment K1,000	Remarks
1. Mining equipment	64,162	214	Steel props, kappes, augers, picks & troughs
2. Driving equipment	3,785	13	Hammers & picks
3. Transport equipment	8,144	27	Air-hoists & troughs
4. Ventilation equipment	1,619	5	Main fans, air fans, & air tubes
5. Draining equipment	540	2	4-in pipe
6. Air-compressing equipment	23,528	78	Air compressors (2) & piping
7. Safety equipment	4,910	10	Gas detectors & CO masks
8. Vehicles	40,160	134	Tubs (50), materials cars (12), trucks (3), wheel loaders (2) & bulldozer (1)
9. Coal preparation equipment	16,400	55	Building, pocket & screen
10. Electrical equipment	56,427	188	75 KVA generators (3), safety lamps, telephones & distributing equipment
11. Other equipment	15,027	50	Water supply & sprinkling equipment, & work shop
12. Land construction	66,200	221	Road construction (2400 m), & building & housing sites (25,100 m^2)
13. Buildings	21,100	70	Office, work shop, materials & explosive warehouses

14. Houses	45,870	153	51 houses
Sub-total	367,872	1,226	
15. Tunnels	224,582	749	3,238 m
Total	592,454	1,975	
Miscellaneous (10 %)	59,246	197	
Total	651,700	2,172	

Table 22-1. Detailed Capital Investment

1. Tunnels

Item	Description	Investment (¥1,000)	Remarks
1. N-I, horizontal drift	435 m	32,789	Through rocks
2-3. N-I, materials passage & pockets	25, 23 m	4,323	"
4. N-I, rising slope	310 m	17,118	Along coal seams
5-6. N-I, left Nos. 1 & 2 roadways	600 m	27,786	"
7. N-I, left No. 2 face slope	60 m	868	"
8. N-II, horizontal drift	270 m	20,862	Through rocks
9-10. N-II, materials passage & pockets	30, 23 m	5,020	"
11. N-III, horizontal drift	270 m	20,862	"
12-13. N-III, materials passage & pockets	30, 23 m	5,020	"
14. C-I, horizontal drift	310 m	23,753	"
15-16. C-I, materials passage & pockets	30, 23 m	5,020	"
17. C-II, horizontal drift	300 m	23,030	"
18-19. C-II, materials passage & pockets	30, 23 m	5,020	"
20. C-III, horizontal drift	370 m	28,091	"
21-22. C-III, materials passage & pockets	30, 23 m	5,020	"
Total	3,238 m	224,582	(K749,000)

2. Equipment

Item	Description	Investment (¥1,000)	Remarks
Mining equipment			
Drilling & blasting equipment	Augers, picks, etc.	1,162	
Steel props & kappes	600 pcs. each	63,000	
Total		64,162	(K214,000)
Driving equipment			
Drilling & blasting equipment	Hammers, picks, etc.	3,785	(K13,000)
Transportation equipment			
N-I, slope - air hoist	Air hoist 15 hp x 2	3,946	
N-I, slope - coal & refuse troughs	Steel plate made	1,497	
N-I, face- coal trough	Steel plate made, for 2 faces	472	
N-II, slope - air hoist	Air hoist 15 hp	2,229	
Total		8,144	(K27,000)
Ventilation equipment			
Main fans	4.5 hp x 2	885	
Local fans	Air fan x 3	734	
Total		1,619	(K5,000)
Draining equipment			
Draining pipe	4B	540	(K2,000)

Air compressing equipment			
Air compressor	25.5 m^3 x 2	23,400	
Piping		128	
Total		23,528	(K78,000)
Safety equipment			
Gas detectors	30 pcs.	2,250	
CO masks	380 pcs.	2,660	
Total		4,910	(K10,000)
Vehicles			
Slope materials cars	2 cars, steel made	480	
Roadway materials cars	10 cars, steel made	2,400	
Roadway tubs	1 m^3 x 50 cars, wood made	9,000	
Dump trucks	4.5 t x 3	7,830	
Wheel loaders	1.2 m^3 x 2	12,800	
Bulldozer	D-4 x 1	7,650	
Total		40,160	(K134,000)
Coal preparation equipment			
Building & pocket	Building 200 m^2 Pocket 270 tons	11,800	
Screen etc.	Screen 140 m^2, chute, etc.	2,300	
Civil engineering	Foundation etc.	2,300	
Total		16,400	(K55,000)

Electrical equipment			
Power generating equipment	75 KVA/60 kw x 3	13,250	
Communication equipment	Telephones 19	3,485	
Surface distribution line	2 km	7,892	
Illumination equipment		6,900	
Power line		7,140	
Safety lamps	Safety lamps 400, & stands	17,760	
Total		56,427	(K188,000)
Other equipment			
Water supply equipment	Pump & piping reservoir	5,800	
Water sprinkling equipment	Pump & piping	3,632	
Work shop machinery	Welding machines etc.	1,535	
Office appliances		4,060	
Total		15,027	(K50,000)
Land construction			
Road construction	2,400 m	38,300	
Building site	12,000 m^2	4,700	
Coal preparation plant site	2,500 m^2	7,200	

Housing site	10,600 m^2	16,000	
Total		66,200	(K221,000)
Buildings			
Office building	One-storied, wood made, 435 m^2	7,100	
Work shop	One-storied, wood made, 90 m^2	1,040	
Air compressor room	Steel-framed, 64 m^2	5,820	
Generator room	Steel-framed, 64 m^2	5,820	
Materials & oil warehouses	One-storied, wood made, 50 & 15 m^2	740	
Pump and main fan rooms	One-storied, wood made, 10 & 24 m^2	395	
Explosive warehouse & handling house	One-storied, wood made, 7 & 5 m^2	185	
Total		21,100	(K70,000)
Housing			
Houses	One-storied, wood made - 51 houses	45,870	(K153,000)
Total		367,872	(K1,226,000)

5.9.2. Development Schedule

The development schedule based on the colliery development plan described before is shown in Table 4 .

This development schedule has been made only for the sake of reference, assuming that an adequate number of skilled laborers and all necessary equipment and materials can be obtained. Also, the progress of surface facilities construction, for instance, depends largely on the rainfall in the rainy season. Accordingly, all these conditions should be carefully investigated beforehand.

It is scheduled that the initial underground driving be completed by the end of the first quarter of the third year and the surface facilities by the end of the second year.

The mining face operation is planned to be started in the second quarter of the third year, allowing for a 6-month test mining period for the workmen to master the mining technique. Coal production during the test mining period is estimated to start with 20 per cent and reach the planned normal monthly output in the fifth month, increasing by 20 per cent increments every month, as shown in the aforesaid table. Namely, normal coal production starts in the third quarter of the third year.

Table 4 Schedule of Colliery Development & Coal Production

		The 1st Year	The 2nd Year	The 3rd Year	The 4th Year
Underground	N 1 Drift	435m			
	N 1 Material passage	25m			
	N 1 Pockets		23m		
	N 1 Slope		310m		
	N 1 Left No.1		300m		
	N 1 Left No.2		300m		
	N 1 Left No.2 face			60m	
	N 1 Road ways			480m	550m
	N 1 Road ways			400m	550m
	N 1 Mining face			Test mining	
Surface	Compressor Eq.				
	Ventilation Eq.				
	Coal preparation Eq.				
	Electricity Eq.				
	Ground construction				
	Building				
Coal Production	Driving	—	4,800	7,000	7,000
	Mining	—	—	35,400	63,000
	Total(Tons/Year)	—	4,800	42,400	70,000

5.10. Production Cost (As-Mined)

To determine the probability of colliery development, the production cost at the annual coal production of 70,000 tons is estimated on the basis of the aforesaid mining, manpower and equipment plans.

Because no colliery exists in Malawi, no actual operation data useful for the production cost estimation are available. Although some investigation data have been obtained, many factors still remain indefinite. So this production cost estimation is based on the following assumptions:

5.10.1. Assumptions for Production Cost Estimation

(1) Equipment and Materials Prices and Transportation Costs

The prices and transportation costs of equipment and materials needed for the development and operation of the colliery are unknown. Also, which of such equipment and materials should be imported, at what prices and from what countries are unknown. So their current prices in Japan (excluding transportation costs) are used, except for timbers, explosives, iron beams and rails whose prices were obtained in Malawi.

(2) Labor Cost

Based on the current standard wages in Malawi and allowing for overtime and miscellaneous allowances, welfare expenses, bonus and the like that are not included therein, the colliery's wages are established as double the standard wages. The consequent mean daily wages are as follows:

Engineer and Staffs	K5.12 (¥1,536)
Laborers (Underground)	K1.52 (¥456)
Laborers (Surface)	K1.12 (¥336)

(3) Expenses

(a) Repairing Expenses and Fuel Cost

Because all machinery and equipment are planned to be procured in Japan, their repairing expenses and cost of their fuel are based on their actual figures in Japan.

(b) Taxes and Public Imposts

The mine product tax, fixed property tax and other public imposts depend on the scale and type of colliery development. With the planned annual production of 70,000 tons, the total amount of such expenses is provisionally established as K28,000 per year (or ¥120 per ton).

(c) Depreciation Expenses

The aforesaid colliery equipment is planned to be depreciated as follows:

Initially driven tunnel	Proportional to production
Machinery Transportation equipment	Fixed instalments in 5 or 10 years

Air compressors Electrical equipment Buildings and houses Civil engineering items	Mine-life-wise depreciation

(d) Capital Fund and Interest

All development fund required is planned to be borrowed at an interest of 10 per cent per annum.

5.10.2. Production Cost

The production cost based on the above assumptions is shown in Table 23, and the basic data used in the estination are given in Table 23-1.

The production cost is estimated as 4,549 yen (15.16 kwacha) per ton of coal. This production cost plus the transportation cost to the consuming district will be compared with the prices of coals being imported from nearby countries. At present, the imported coals (C&F Blantyre) are priced as follows:

	Rhodesian Coal	Mozambique Coal
Coal grade	7,390 kcal/kg	5,280 kcal/kg (estimated)
FOR Mine Site	11.92 K/M.T.	24.30-9.60 K/M.T.
Freight etc.	21.26 "	3.86 "
C&F Blantyre	33.18 "	28.16-13.46 "

The C&F Blantyre price of the Ngana coal is estimated to be as follows:

Production cost at Ngana 15.16 K/M.T.

Freight

(1) Trucking (5-ton) from the mine site to Kambwe Jetty (on Lake Malawi): 0.48 K/mile

0.48 K ÷ 5 tons x 40 miles = 3.84 K/M.T.

(2) Barging 300 miles over Lake Malawi between Kambwe and Chipoka and railway hauling 100 miles between Chipoka and Blantyre:

0.037 K/M.T./mile

0.037 K x 400 miles ≒ 15 K/M.T.

Other charges

Loading, unloading and other charges at the mine site, Kambwe, Chipoka and Blantyre: 2.0 K/M.T.

Accordingly, the coal price, C&F Blantyre, is estimated as 36.0 K/M.T.

This suggests that the domestic Ngana coal will be more costly than the coals imported from Rhodèsia and Mozambique. Of course, this comparison is based on a very rough estimation and, therefore, demands more detailed investigation and calculation.

Even if somewhat costly, domestic use of Ngana coal will have the merits of saving valuable foreign currency and affording employment to the nation's people.

It will be noted that the freight constitutes a large percentage of the coal price. It is therefore desirable that some industries or thermal power plant, operating on the high-ash coal from the Ngana coal field, be established in or north of the central region, preferably in some near district in the northern region of the country.

Table 23. Production Cost

Item	Description	Production Cost ¥/Ton	Production Cost K/Ton	Per Cent
Equipment & Materials				
Timbers	0.0214 m^3/t	215	0.71	
Explosives	Explosives 0.387 kg/t	392	1.31	
	Detonators 1.79 pcs./t			
Structural steels	0.94 kg/t	160	0.53	
Others	Steel props, kappes, etc.	579	1.93	
Total		1,346	4.48	30 %
Labor Cost				
Laborers	Underground 249 men	621	2.07	
	Surface 93 men			
Engineers & Staffs	51 men	336	1.12	
Total		957	3.19	21 %
Expenses				
Repairing	Mechanical, electrical, trucks, etc.	157	0.52	
Fuel	Fuel 520 kl/year	524	1.75	
	Lubricant 32 kl/year			
Taxes & Public Imposts	Real estate tax, public imposts, etc.	120	0.40	
Others	Office expenses etc.	200	0.67	
Total		1,001	3.34	22 %
Depreciation		743	2.48	16 %
Interest	10 % per annum	502	1.67	11 %
Production Cost		4,549	15.16	100 %

Table 23-1. Basic Data for Production Cost Estimation

(1) Equipment & Materials

Item & Place	Calculation Basis	Unit Price (¥)	Amount (¥)
Timbers			
Face	$10m^3/1000t$ x 63,000t = $630m^3$		
Tunnel	$0.5m^3$ x 1,100m/year = $550m^3$		
Repair	$0.2m^3$ x 4 x 300days = $240m^3$		
Others	5 % of the above $71\ m^3$		
Total	$1,491m^3$ ($0,9213m^3/t$)	¥10,080 per m^3	¥15,029,000 (¥215 per t)
Explosives			
Face	0.3kg/t x 63,000t = 18,900kg		
Tunnel	$0.8kg/m^3$x$9.3m^3$/mx1,100m/year = 8,184kg		
Total	27,084kg (0.39kg/t)	¥620 per kg	¥10,641,000 (¥240 per t)
Detonators			
Face	1.5pc/t x 63,000t = 94,500 pcs.		
Tunnel	$3pc/m^3$x$9.3m^3$/mx1,100m/year = 30,690 pcs.		
Total	125,190 pcs. (1.79pc/t)	¥85 per pc.	¥10,641,000 (¥150 per t)
Iron Beams			
Tunnel	72kg x 1,100m/1.2m=66,000 kg (0.94kg/t)	¥170 per kg	11,220kg (¥160 per t)
Others			
Steel props & kappes	600pcs x 3%/month x 12 months	¥105,000	¥22,680,000
Face & tunnel making equipment	(1,162,000 + 3,785,000) x 20%/month x 12 months		¥11,873,000
Air tube etc.	500,000/month x 12 months		¥6,000,000
Total			¥40,553,000 (¥579 per t)

(2) Labor Cost

Job Classification	Number	Daily Wage (¥)	Annual Working Days	Amount (¥1,000)
Laborers	Underground 249 men	456	300	34,063
	Surface 93 men	336	300	9,374
	Total			43,437 (¥621 per ton)
Engineers & Staffs	51 men	1,536	300	23,501 (¥336 per ton)
Total				66,938 (¥957 per ton)

(3) Expenses

Description	Calculation Basis	Amount (¥1,000)
Repairing Expenses	Mechanical equipment Repairing & maintenance	8,578
	Electrical equipment DG maintenance, illumination, safety lamps, etc.	2,400
	Total	10,978 (¥157 per ton)
Fuel & Lubricant	Mechanical equipment Fuel 386.8 kl/year @58 ¥22,434,000 Lubricant 31.8 kl/year @200 ¥6,266,000	28,700
	Electrical equipment Fuel 133.3 kg/year @58 ¥7,731,000 Lubricant 1.28 kg/year @200 ¥256,000	7,987
	Total	36,687 (¥524 per ton)

5.11. Road and Jetty

When developing a colliery, a transportation route should be secured to ship produced coal and take in equipment and materials necessary for mining operation. From the topography of the Ngana coal field, transport by truck seems to be achieved at low cost and with considerable ease. In conjunction with the surface geological investigation, general road conditions of the district were investigated, too.

The investigation was made on an approximately 63 km section between Karonga and the Nagana coal field, which can be subdivided as follows:

A good, wide road extends 40 km from Karonga via Kaporo, Ngoto and Mwangulukuku to Iponga. The bus service is maintained here. But wood bridges on the road requires considerable reinforcements to withstand frequent transportation of heavy mining equipment and materials during the developing period and shipment of produced coal in the subsequent operating period. As the investigation was made in the dry season, the road condition during the rainy season is unknown, but provision of additional graveling and draining ditches will be necessary.

An approximately 23 km road, running along the river Songwe from Iponga to the Ngana coal field, is as bumpy as to permit passage of only land rovers. It necessitates construction of new bridges and culverts crossing rivers and dales, expansion, grade and curve modification and graveling.

The road investigation was largely made on the latter section between Iponga and the Ngana coal field. The locations requiring bridges, culverts and various repairs were plotted on the 1/10000 topographic map, which had been prepared in Japan based on the aerial photographs.

The investigation results are summarized hereunder. Being perfectly bridgeless now, this section will require 16 new bridges, extending approximately 190 m in total. Also 15 culverts should be provided across rivers and dales, and where water gathers on slopes. The portions requiring course changing, grade and curve modifications amount to approximately 23 km. To facilitate draining during the rainy season, ditches should be provided throughout the entire length between the coal field and Iponga.

To supply the coal to the southern or central region where coal-consuming industries exist, barge transportation over Lake Malawi will follow the overland transportation through the aforesaid road. Therefore, the following coal shipment jetty sites on Lake Malawi were investigated.

(a) Kasyata

This lakeshore is nearest to the Ngana coal field, approximately 1.6 km from the main road between Ngoto and Kaporo. This site is most favorable for reducing the overland freight that tends to become relatively higher than the barge freight. Being marshy, however, piling and other reinforcement will be indispensable in constructing a new truck road in the 1.6 km section to the lake. Because of the difficulty in access, the marshy lakeshore was not investigated.

(b) Chakwera

This is the second nearest site from the Ngana coal field. From a point approximately 1.7 km south of Kaporo, there extends an approximately 2 km long road to the lakeshore. This road is suited for truck transportation up to approximately 300 m apart from the lake. Like Kasyata, this lakeshore is marshy and requires the same reinforcement. The sand from the river Kibwe depositing here necessitates dredging, as well.

(c) Kambwe

As this site was used for rice shipment until several years ago, a perfect road, approximately 500 m long, leads from the main road to the lakeshore. The rice warehouses are being used, but the jetty is broken and not used. Likewise, some barges are left abandoned. Compared with the aforesaid two locations, this site is disadvantageous because it requires longer overland transportation. But it advantageously has a perfect road leading to the lake and a jetty that can be reused after some repairs. From the viewpoint of capital investment, this site seems most promising.

For the sake of reference, the jetty facilities at Chilumba were investigated. Serving as the lake transport base for the northern region, this jetty is used for loading and unloading various commodities and human transportation. Approximately 77 km apart from Karonga, however, the use of this jetty for the coal shipment will make the overland freight prohibitive.

Rendering any of the roads and jetty sites investigated usable for the coal transportation will require a huge amount of construction cost. But their construction should not be done only for the purpose of the colliery development. Consideration must be given to the local community development. Coal mining is a labor-intensive industry. So the development of the colliery will entail a sharp increase in population. It will also attract many related industries. The imperfect transportation system seems to have impeded the industrial development of this district. Improvement of such infrastructure, therefore, will contribute not only to the development of the colliery under consideration, but also to the entire local community.

Chapter 6. Problems to Be Solved before Colliery Development

This investigation has revealed the possibility of mining the Nos. 2 and 3 coal seams in the upper shale member of the K2 beds by the underground longwall mining method. So the development concepts, capital investment, production cost and other details have been studied. But the following problems remain to be solved hereafter.

6.1. Geological Problems

At present, underground mining is planned to be confined to above the mine mouth level, considering the minable coal reserves, coal seam conditions, and workmen's mining technique. The colliery projected will produce 70,000 tons of coal annually from the north and central areas of the western district of the Ngana coal field.

6.1.1. Expansion of Mining Area

During the investigation, two each trenches were dug in the south area, lying on the south of the central area, and in the eastern district. Coal seams in the trenched areas were not much different from those in the north and central areas. As mentioned above, this investigation was confined to the north and central areas of the western district that are readily accessible from the main road. If Malawi's demand requires greater production, however, two pits may be mined simultaneously. But it cannot be accomplished without securing greater minable coal reserves. For this purpose, investigation should be extended to the south area.

6.1.2. Coal Seams in Depth

The coal seams in the investigated areas reach the alluvium of the main rivers in depth. The monocline coal seams are thought to dip to the east, but, due to insufficient outcrop, their conditions in depth are not definite. In this connection, the data of the borehole drilling performed by the South African Chamber of Mines will be helpful. The trenching disclosed that the coal seams exhibit relatively minor thickness changes in the direction of their strike, except some thickening in the south. But their dip changes and other characteristics in depth are unknown.

6.1.3. Coal Quality

During the field investigation, coal samples were collected from some deeper trenches, and they were subjected to various analyses and tests in Japan. But, as the samples represent the outcropped coal considerably affected by weathering, it is difficult to estimate the grade of coal to be mined from underground on the basis of their analytical results.

As mentioned before, production expansion requires an additional investigation in a more extensive area. At the same time, borehole drilling should be done to confirm the coal seam occurrence and coal grade in depth. If the data obtained by the South Africa's drill-hole exploration are available and useful, the number of boreholes may be decreased.

6.2. Mining Problems

The north and central areas are planned to be divided into three each pits, and a mine mouth will be provided in a suitable place of each pit. A drift leads from the mouth to the coal seam at the center of the pit. Thence, a rising slope having a true dip extends to the surface. There will be driven roadways, at 60 m intervals, on both sides of the rising slope. Retreating longwall mining is to be effected at a mining face established at the remotest end of each roadway.

6.2.1. Confirmation of Drift-Coal Seam Contact Point

Not only the drift, but also the materials passage, rising slope and roadways will be driven in the vicinity of the point where the drift contacts the coal seam. It is therefore desirable to prevent the miscarriage of the driving plan by previously ascertaining the contact point by drilling.

6.2.2. Coal Seam Dips

The Nos. 2 and 3 coal seams will be mined jointly by longwall mining at 60 m long mining face above the mine mouth level. For unavailability of electricity, coal and refuse in the mining face and roadway will be transferred by gravity through troughs. The coal seams dip at angles of 25 to 27 degrees; very close to the minimum inclination that permits gravity flow. The coal seam dips in greater depth should be confirmed by drilling.

6.2.3. Use of Hydraulic Props and Kappes

With consideration for the difficulty of obtaining timbers and the ease of natural collapse after mining and of roof control, the mining faces are planned to be supported by hydraulic steel props and kappes. It is therefore desirable to establish the specifications and designs of the hydraulic props and kappes by grasping the accurate coal seam thickness in the dip direction (combining the Nos. 2 and 3 coal seams) and collecting data for estimating the stratum pressure.

6.2.4. Maintenance of Tunnels

As shown in figs. 8 and 9, the rising slope and roadways will be cut to the floor rock of the No. 2 coal seam to facilitate underground transportation. To insure their maintenance, the influence of underground water liberation on the swelling of partings and floor rocks and other problems should be carefully investigated.

6.2.5. Safety

Liberation of underground water and gases and spontaneous fire hazards are important safety problems. Owing to the absence of comparable colliery in the neiborhood, however, collection of useful reference data will be difficult. This specific colliery is expected to be comparatively free of gas liberation and, therefore, spontaneous fire hazards, because the mining area is limited to above the mine mouth level and the coal is of high-ash, low-volatile grade. At any rate, as much efforts as possible should be made for the collection of useful reference data.

6.3. Securing and Training of Engineers and Laborers

Employment of the necessary colliery laborers, engineers and superintendents depends on the labor situation in Malawi. Some Malawi laborers have experience in working in collieries in the Republic of South Africa and other nearby countries.

As envisaged by the Government of Malawi, one of the objects of this colliery development is to afford stable employment to the nation's people. Accordingly, it is desirable to employ such experienced laborers.

To maintain the desired production and prevent as much accident as possible, approximately one-third of the planned laborers should have experience in underground mining. They will produce favorable results in respect of both mining operation and safety. Mining engineers, controlling these laborers, should have high enough technical ability and safety knowledge.

But such mining engineers seem to be unavailable, because Malawi has no underground colliery or mine. Therefore, it becomes necessary to give suitable technical and safety education and training to the engineers and laborers, both experienced and inexperienced. Especially, higher education and training should be given to the technical engineers, including practical training in foreign collieries. During the initial stage of development, some foreign technical instructors should be invited. Not only mining engineers, but also mechanical and electrical engineers must be trained. The laborers, both experienced and inexperienced, must be made acquainted with the geology and coal seam conditions in the development district. Also, they should be trained to work in compliance with the driving, mining, transportation, supporting and other operating standards. No less important is the training to assure compliance with the safety rules.

6.4. Procurement of Supplies, Machines and Equipment

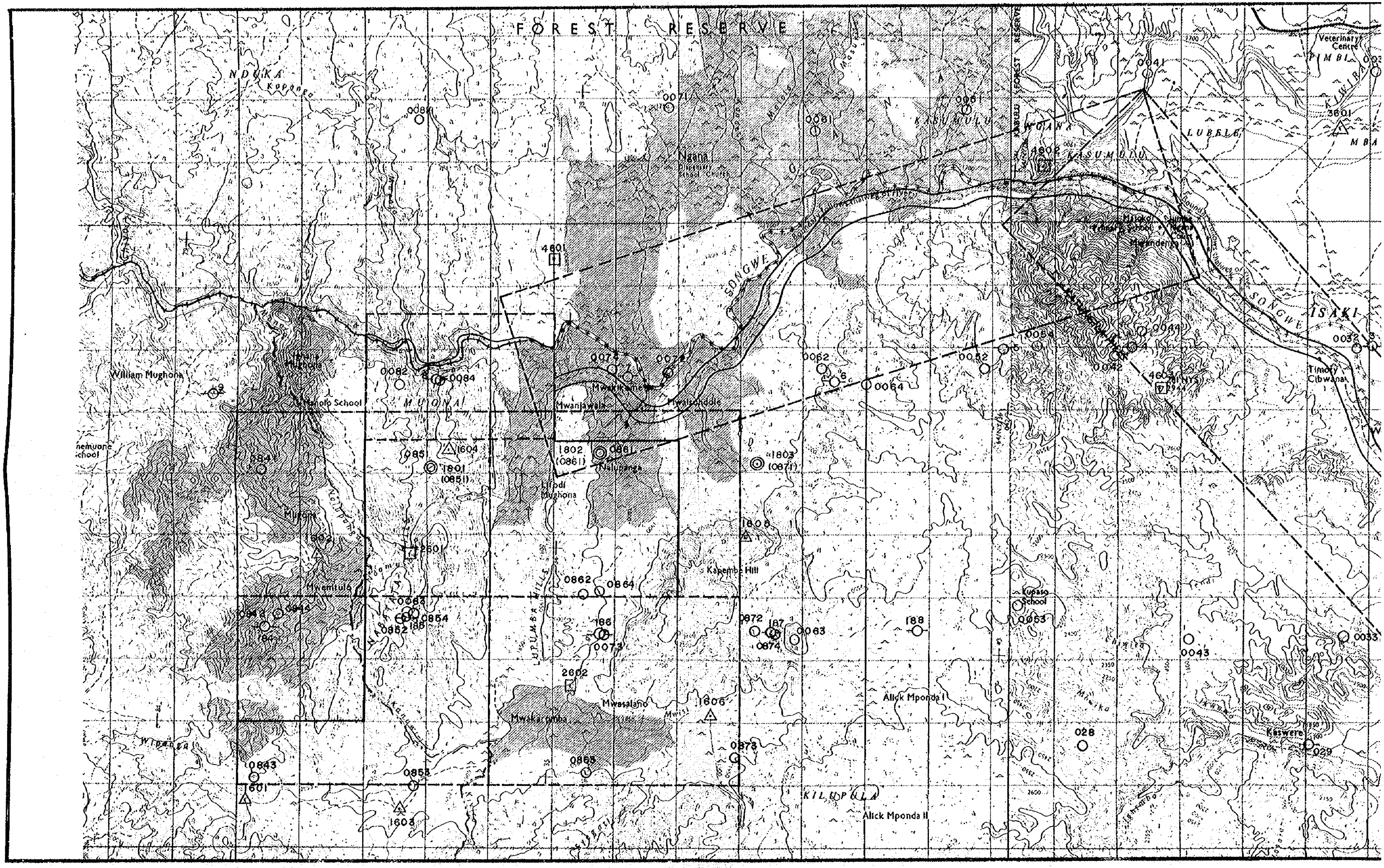
This colliery development plan for the western district of the Ngana coal field has been formulated with the greatest possible effort to minimize the capital investment. Because Malawi has no colliery industry, however, considerable quantities of equipment and materials must be imported.

In making a feasibility study, the prices and transportation costs of both domestic and foreign products, as well as their suppliers and procurability, should be investigated.

The afore-mentioned problems should be solved before proceeding to the development of the colliery in this district. Additional investigations should be made on such infrastructures as roads, houses and townsites that are indispensable to the development. As many people are expected to come to live in the currently sparsely-populated locality, close investigation must be made as to environmental assessment, too.

As this investigation laid emphasis on the study of the mere probability of colliery development, a more detailed feasibility study should follow.

LIST OF APPENDIX


FOREST RESERVE
NDUKA
Ngana
KASUMULU
SONGWE
4601
4608
3601
Veterinary Centre
PIMBI
LUBELE
ISAKI
William Mughona
Manolo School
MUYONAI
Mwanjawala
Nalupanga
1601
1602
1603
1604
1606
1801
1802
1803
2601
2602
Kapembe Hill
LUPUMBA HILLS
Mwemitula
Mwakaromba
Mwasalano
Alick Mponda I
Alick Mponda II
KILUPULA
Kupaso School
Kaswere
Timoty Cibwana
0041
0042
0043
0044
0062
0064
0071
0073
0081
0084
0862
0864
0863
0873
0874
0853
0843
0033
029
028
188

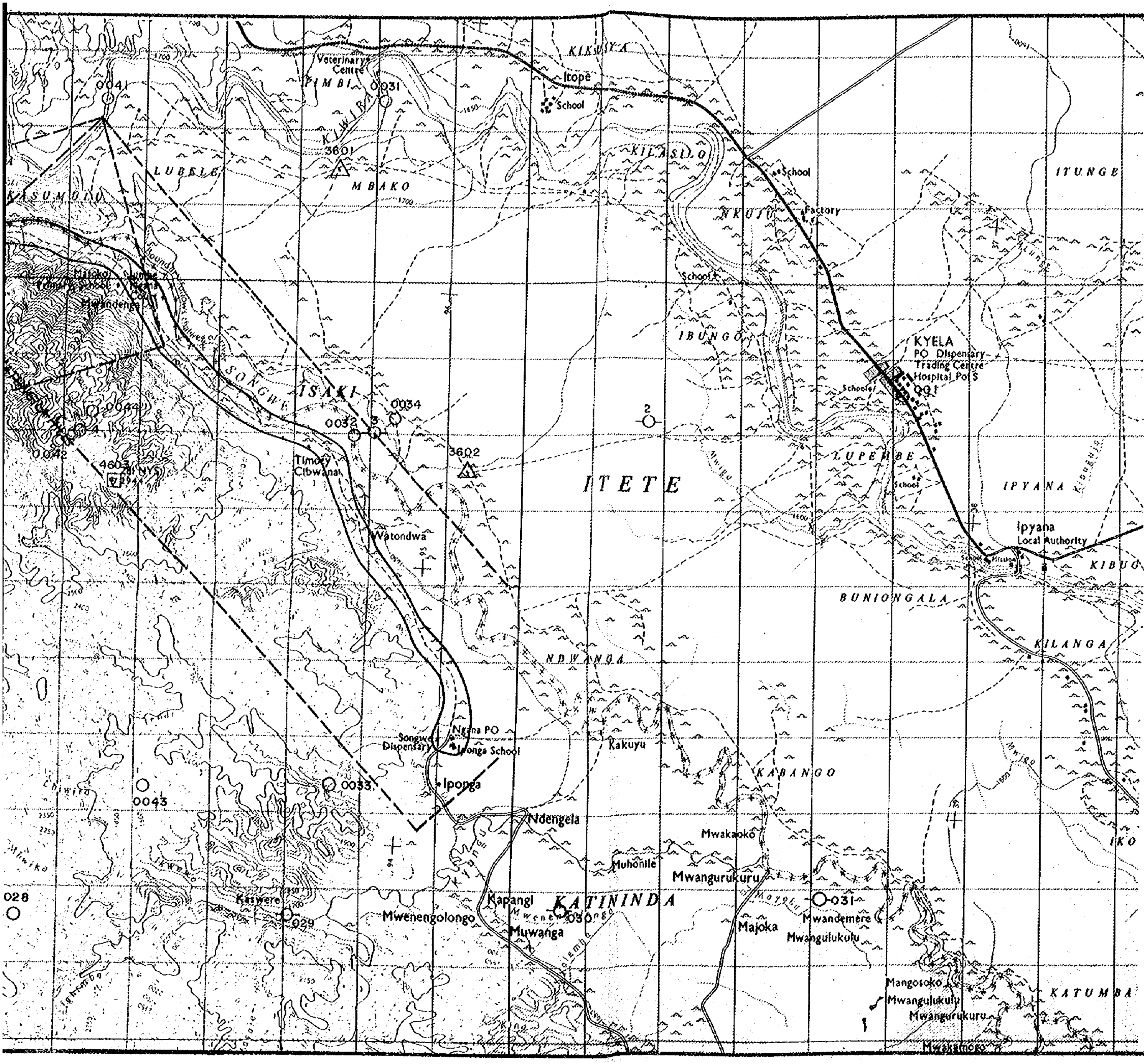


Fig No.1

Republic of Malawi

Ngana Coalfield Airphoto Mapping

Base Map 1 : 50.000

Legend

1 : 5.000 — Sheet line; Mapping area

1 : 10.000 — Sheet line; Mapping area

○ Pass point

△ Horizontal Control point

⊡ Elevation point

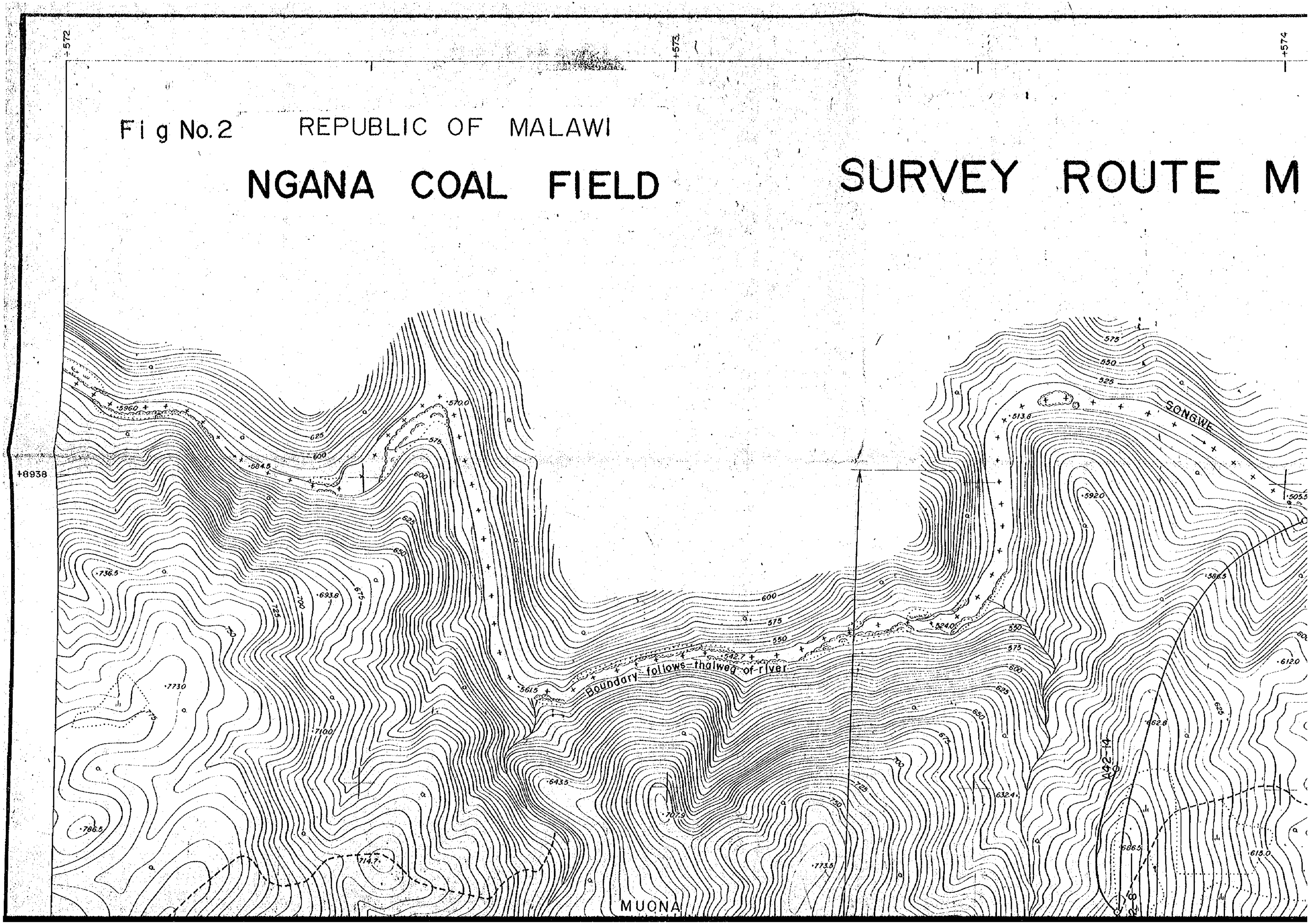
◎ Tie point

-○- Airphoto No.

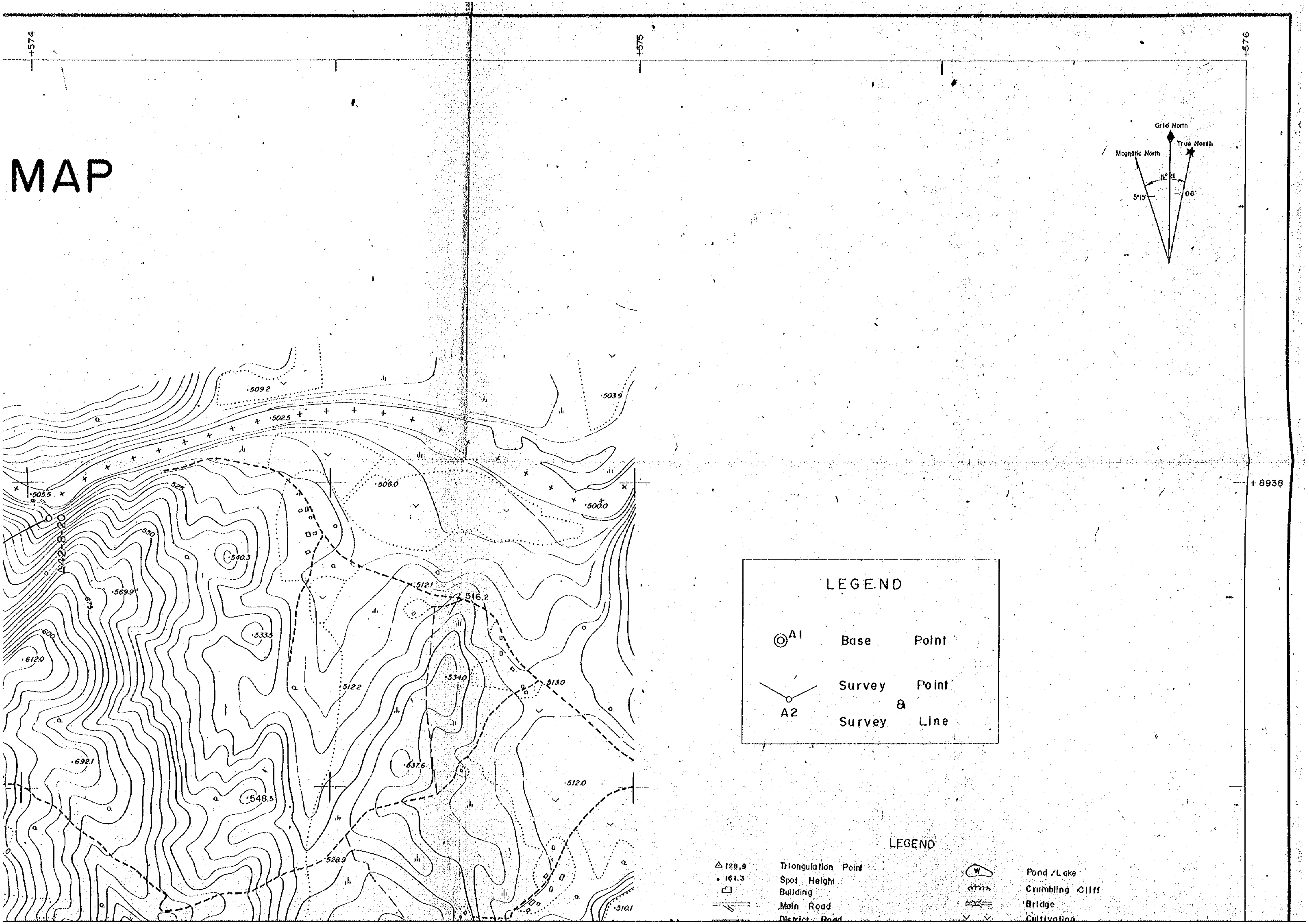
Fig No.2 REPUBLIC OF MALAWI

NGANA COAL FIELD

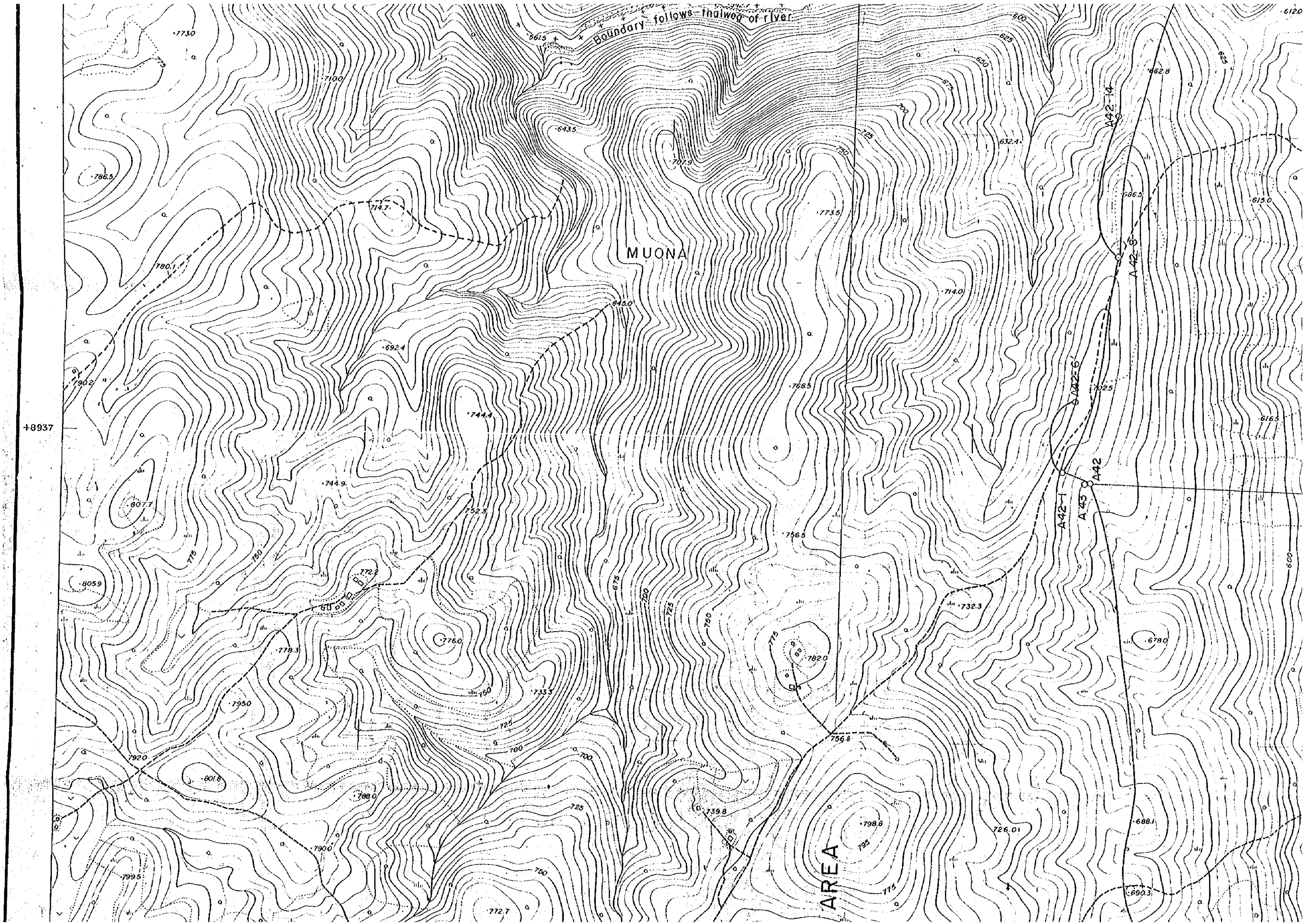
SURVEY ROUTE M

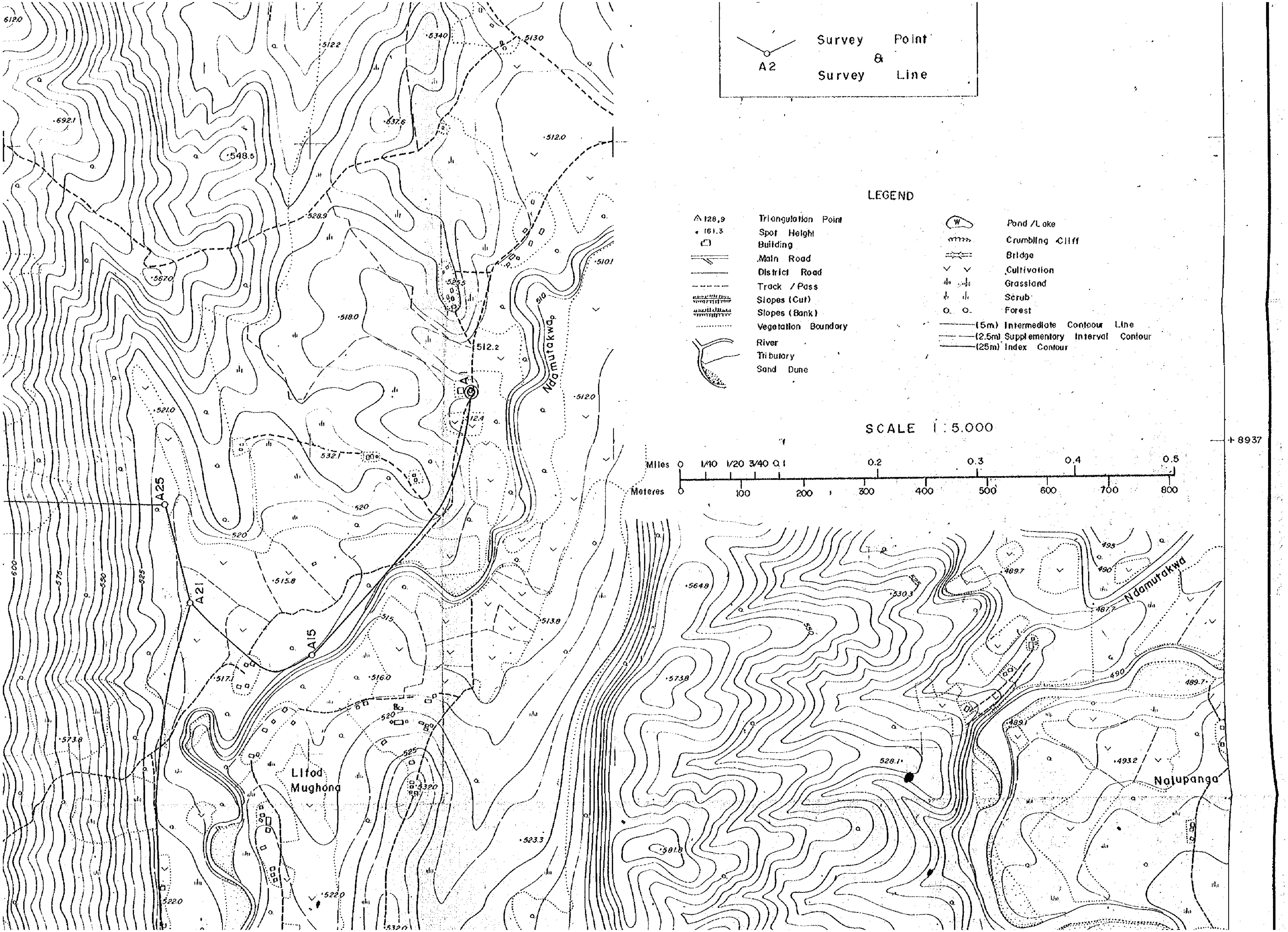


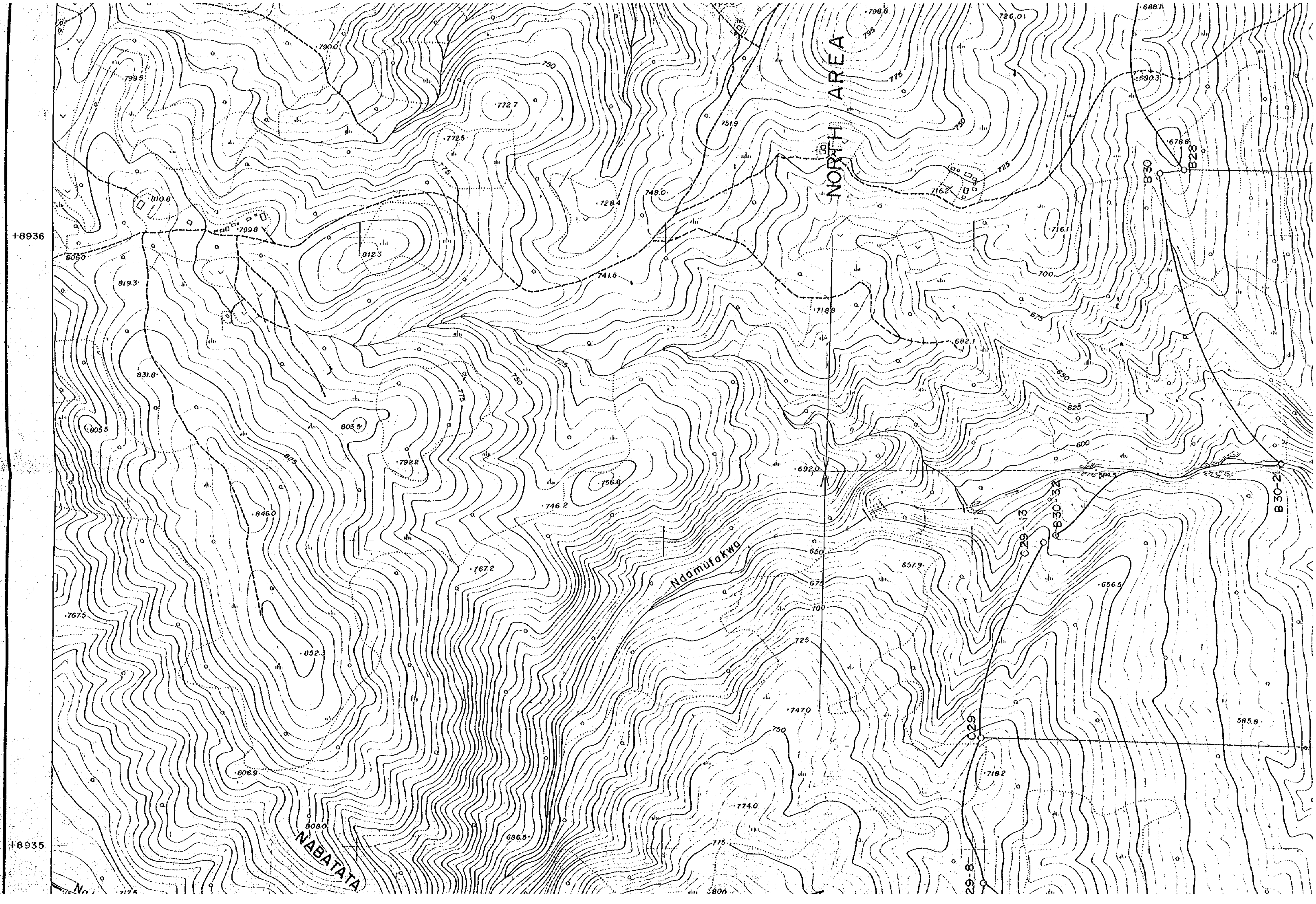
MAP



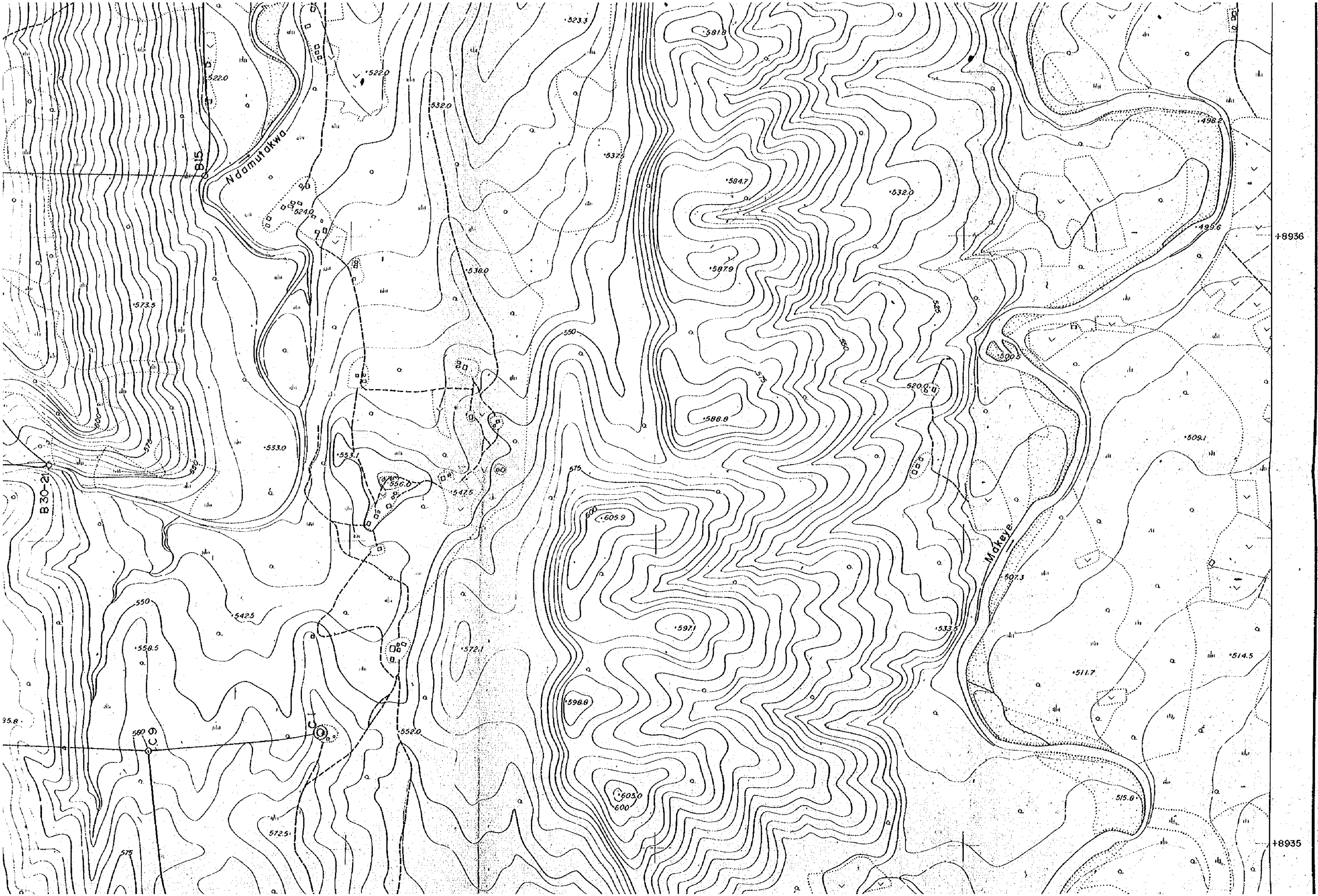
574
575
576
8938
Grid North
True North
Magnetic North
LEGEND
A1 Base Point
A2 Survey Point & Survey Line
A42-8-20
509.2
503.9
502.5
505.5
506.0
500.0
525
550
540.3
569.9
512.1
516.2
533.5
600
612.0
534.0
512.2
513.0
692.1
637.6
548.5
512.0
528.9
510.1
LEGEND
128,9 Triangulation Point
161.3 Spot Height
Building
Main Road
Pond / Lake
Crumbling Cliff
Bridge


Boundary follows thalweg of river
MUONA
AREA
A42-14
A42-8
A42-6'
A42
A42-1
A43
+8937
714.7
643.5
707.9
773.5
714.0
645.0
692.4
744.4
744.9
752.3
768.5
756.5
732.3
772.2
776.0
778.3
733.3
782.0
756.8
739.8
798.8
726.01
772.7
807.7
805.9
795.0
792.0
801.8
790.0
799.5
788.0
780.1
786.5
790.2
773.0
632.4
686.5
615.0
616.5
678.0
688.1
690.3
612.0
662.8

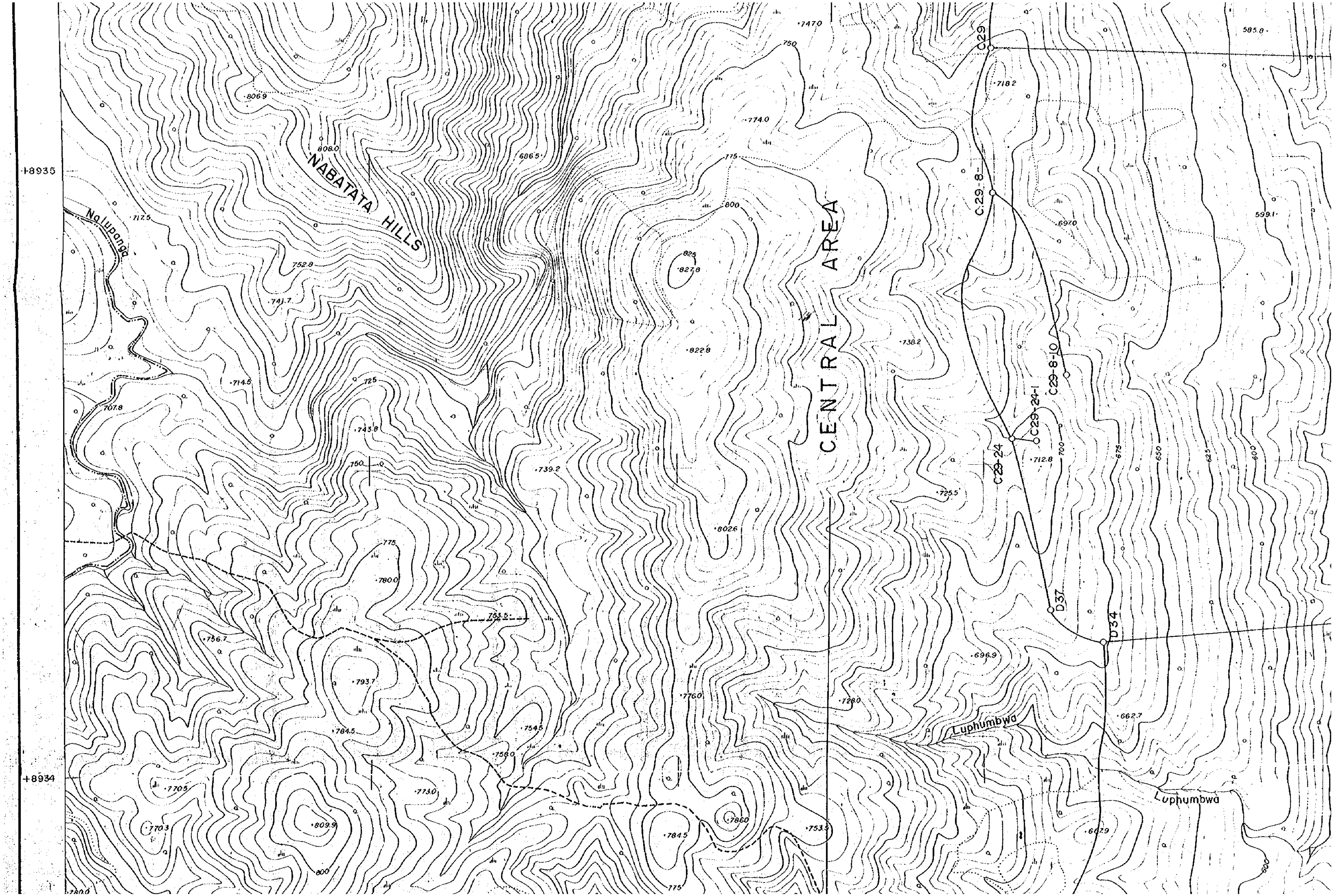

Survey Point & Survey Line
A2
LEGEND
Triangulation Point
Spot Height
Building
Main Road
District Road
Track / Pass
Slopes (Cut)
Slopes (Bank)
Vegetation Boundary
River
Tributary
Sand Dune
Pond / Lake
Crumbling Cliff
Bridge
Cultivation
Grassland
Scrub
Forest
(5m) Intermediate Contour Line
(2.5m) Supplementary Interval Contour
(25m) Index Contour
SCALE 1:5.000
Miles 0 1/40 1/20 3/40 0.1 0.2 0.3 0.4 0.5
Meteres 0 100 200 300 400 500 600 700 800
8937
Ndamutakwa
Lifod Mughona
Nalupanga
A1
A15
A21
A25



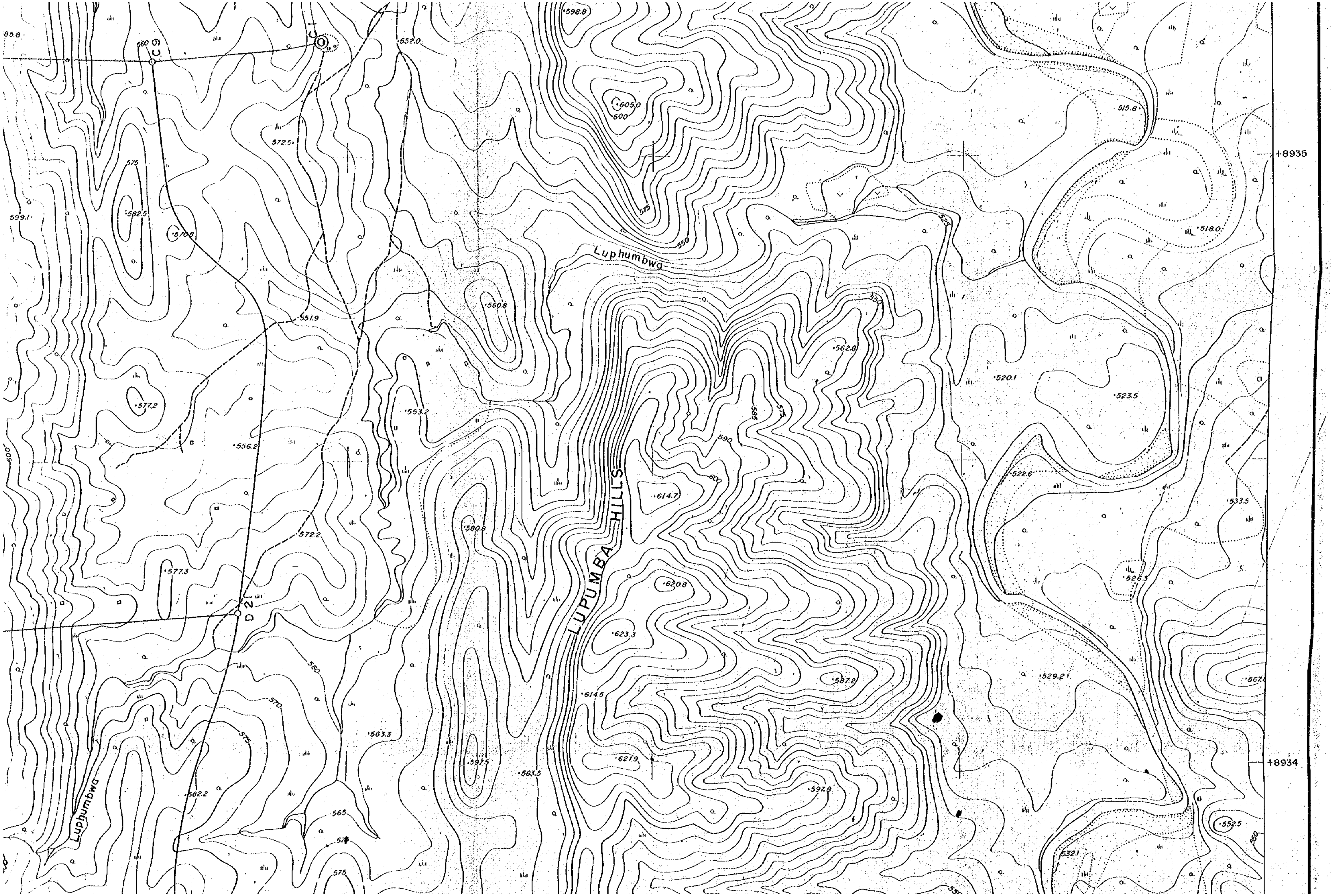
NORTH AREA
Ndamutakwa
NABATATA
+8936
+8935
B30
B28
B30-21
B30-32
C29-13
C29
812.3
846.0
852.3
831.8
792.2
756.8
692.0
657.9
656.5
585.8
747.0
774.0
718.2
806.9
808.0
686.5
767.2
746.2



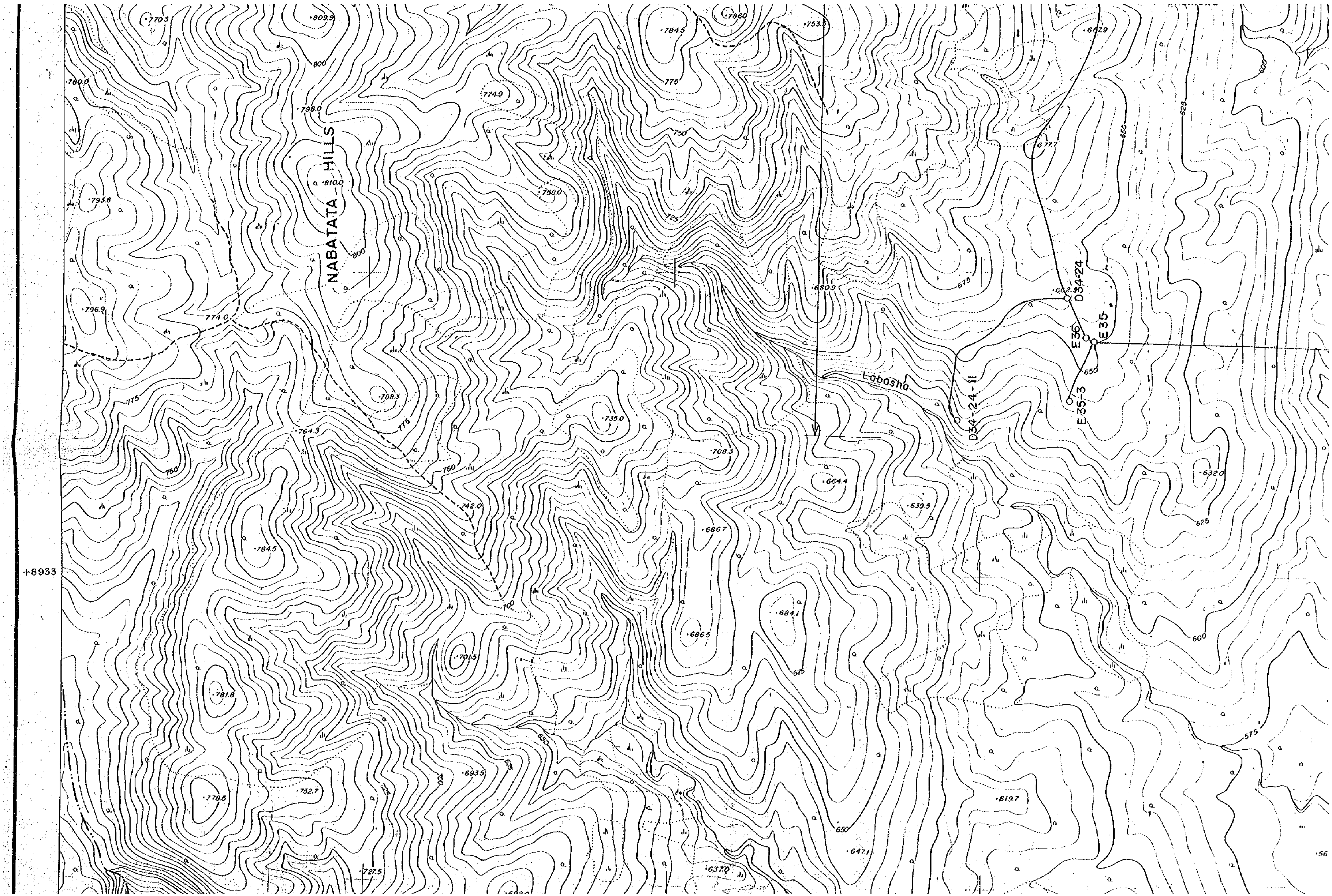
523.3
581.8
522.0
532.0
537.5
584.7
532.0
498.2
495.6
+8936
Ndamutakwa
B15
524.0
587.9
536.0
573.5
550
550
525
500.5
575
520.0
588.8
533.0
553.1
509.1
B30-2
556.0
547.5
575
605.9
600
Makeye
507.3
550
542.5
597.1
533.5
558.5
572.1
514.5
511.7
598.8
C1
C9
552.0
605.0
600
515.8
572.5
575
+8935



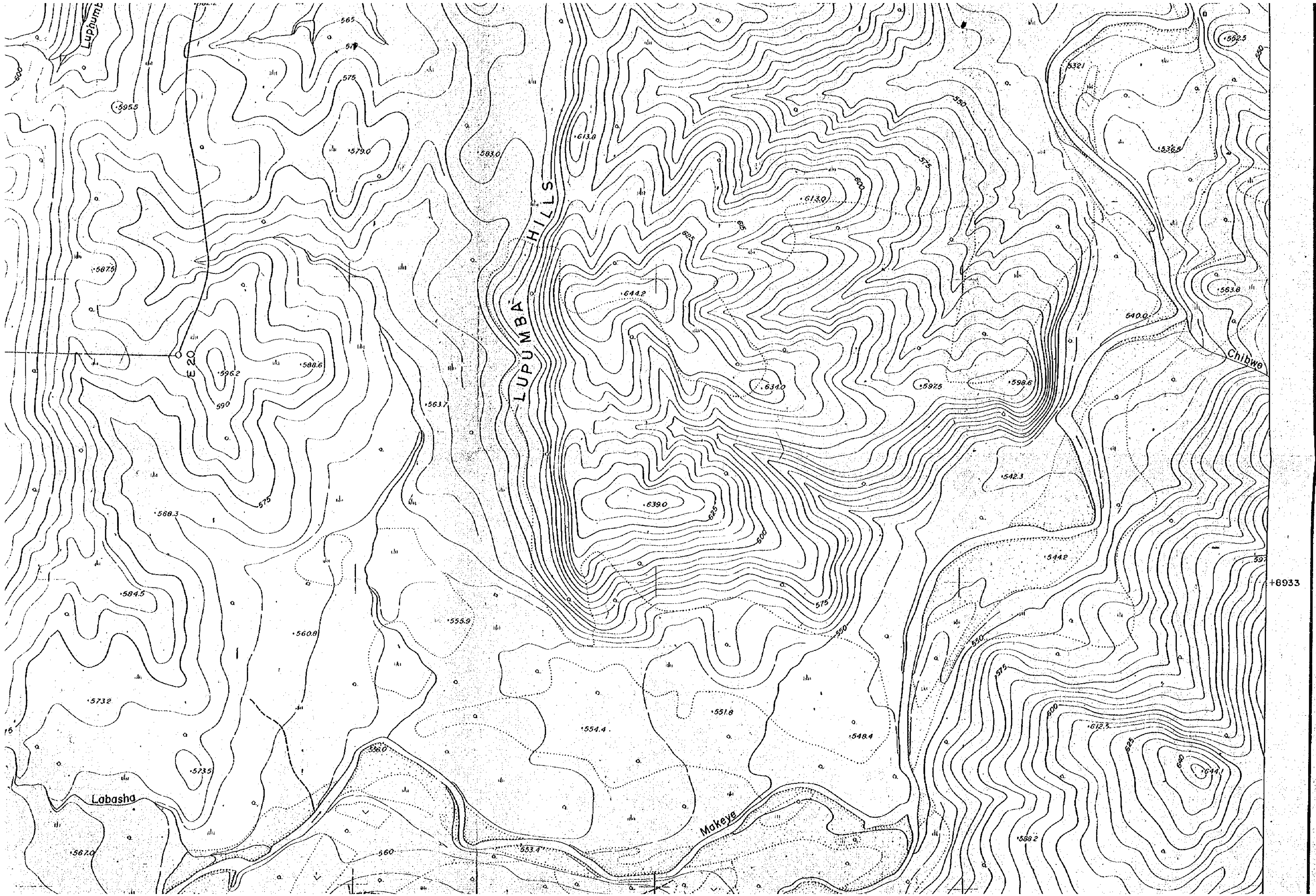
NABATATA HILLS
CENTRAL AREA
Nalupanga
Luphumbwa
Luphumbwa
C29
C.29-8
C29-8-10
C29-24-1
C29-24
D37
D34
+8935
+8934
747.0
750
806.9
808.0
686.5
774.0
775
800
825
827.8
822.8
717.5
752.8
741.7
714.5
707.8
725
743.8
750
739.2
802.6
736.2
725.5
718.2
697.0
712.8
700
675
650
625
600
585.0
599.1
775
780.0
753.5
756.7
793.7
784.5
754.5
756.0
776.0
728.0
696.9
662.7
770.5
773.0
770.3
809.9
786.0
784.5
753.5
667.9
800
775
780.0

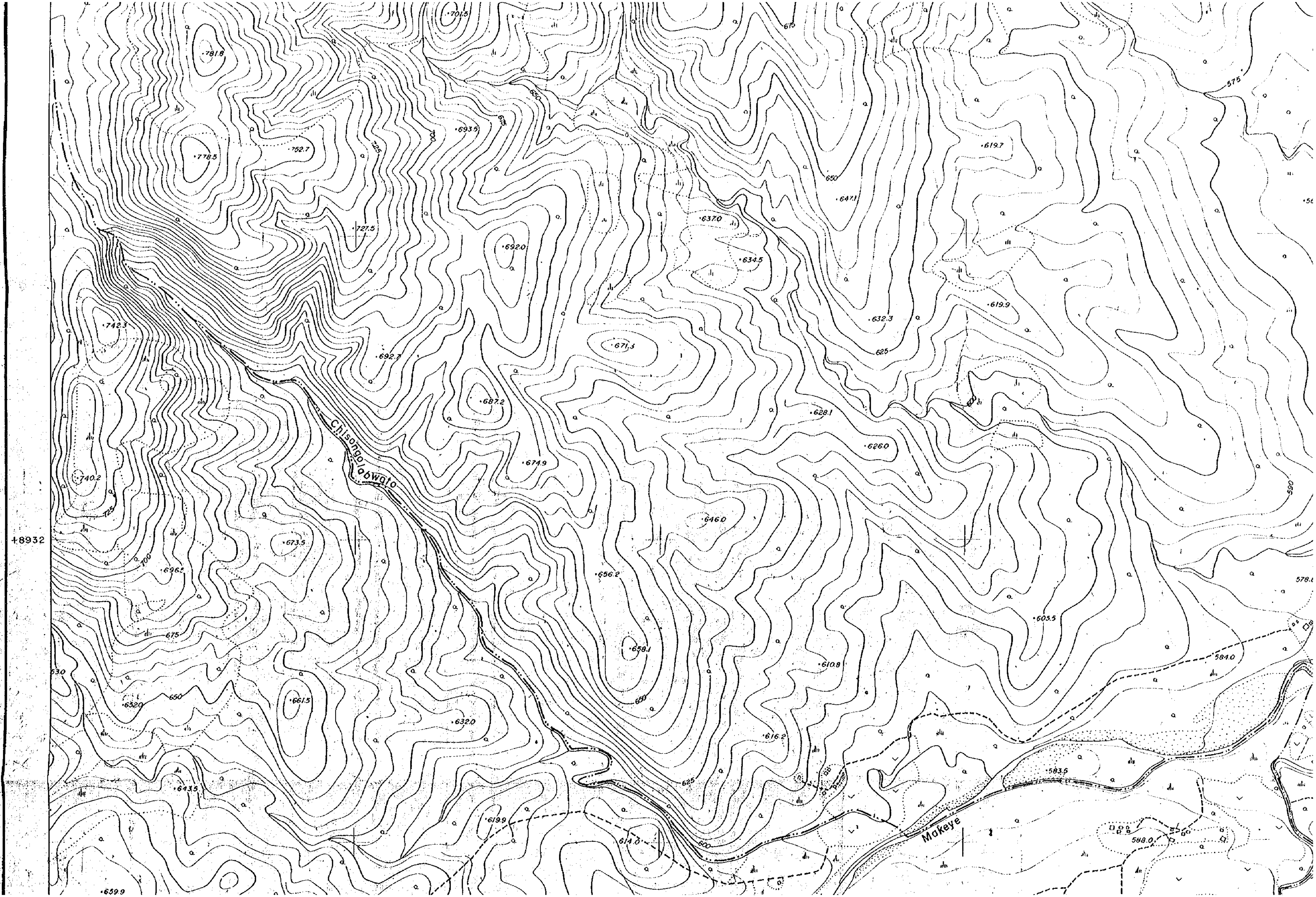


C 9
C 1
D 21
Luphumbwa
LUPUMBA HILLS
Luphumbwa
+8935
+8934
598.8
605.0
600
552.0
572.5
575
582.5
570.8
599.1
551.9
560.8
515.8
518.0
562.8
520.1
523.5
577.2
553.2
556.2
585
590
600
614.7
522.6
533.5
580.8
572.2
577.3
620.8
526.3
623.3
587.2
529.2
614.5
563.3
597.5
563.5
621.9
597.8
562.2
552.5
532.1
565
575
560
570
550

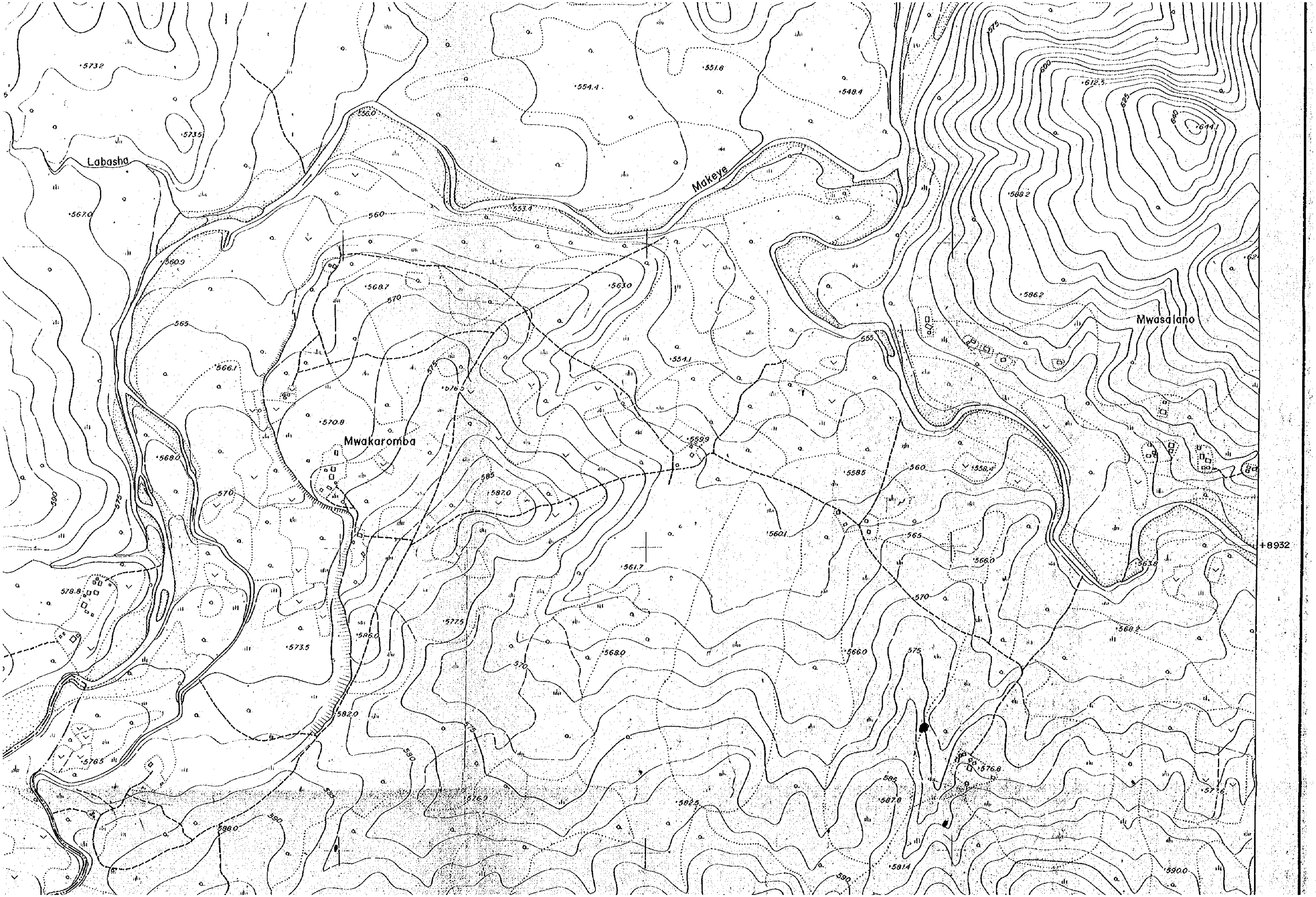


NABATATA HILLS
Labosha
D34-24
E36
E35
E35-3
D34-24-11
+8933

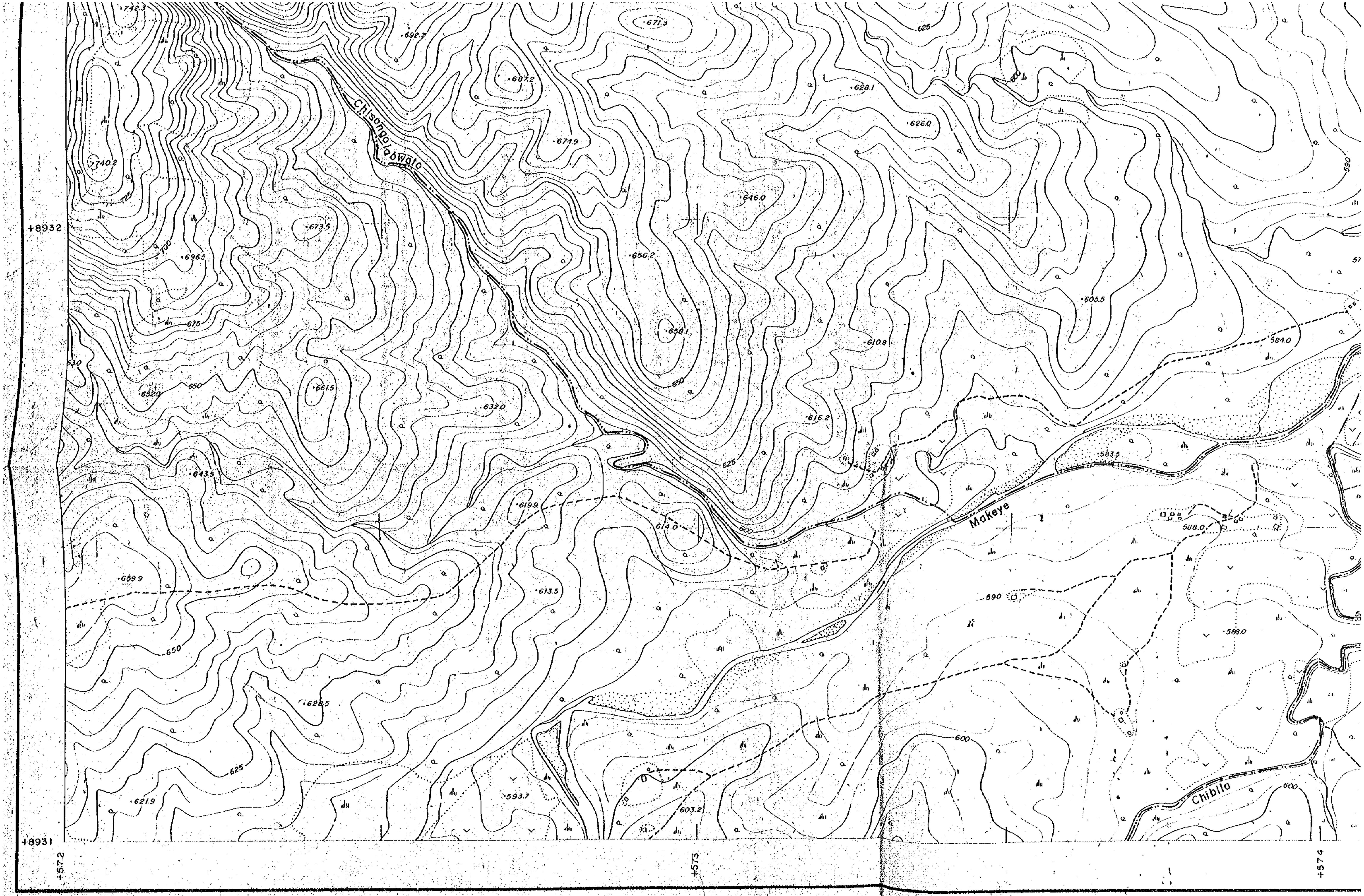

Lupumba
595.5
579.0
583.0
613.8
LUPUMBA HILLS
E 20
596.2
588.6
590
587.5
575
568.3
584.5
560.8
573.2
573.5
Labasha
567.0
556.0
560
553.4
Makeye
555.9
554.4
551.8
548.4
563.7
644.2
639.0
634.0
613.0
597.5
598.6
542.3
544.2
640.0
Chibwe
563.8
536.5
532.1
562.5
550
600
625
612.3
644.1
588.2
+8933



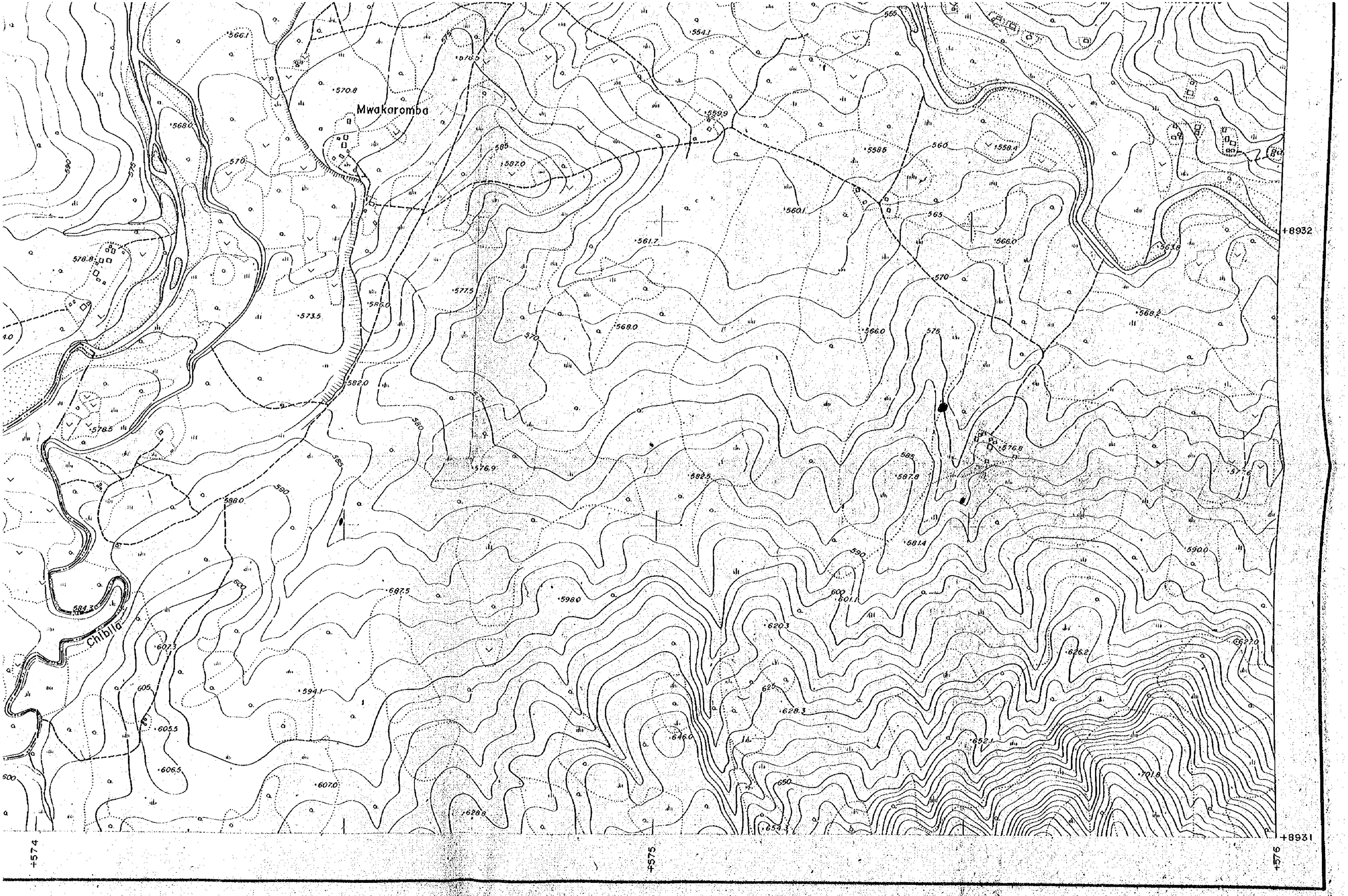
Chisongolobwato
Mokeye
+8932
701.5
781.8
778.5
752.7
693.5
727.5
692.0
742.3
740.2
692.7
687.2
674.9
671.3
637.0
634.5
647.1
632.3
619.7
619.9
628.1
626.0
646.0
656.2
673.5
696.5
658.1
661.5
632.0
652.0
643.5
619.9
614.0
659.9
610.8
616.2
605.5
584.0
583.5
588.0
578.0
575
650
625
600
675
700
725
590



Labasha
Makeye
Mwakaromba
Mwasalano
+8932
573.2
573.5
567.0
560.0
553.4
554.4
551.6
548.4
612.5
644.1
568.2
586.2
560.9
568.7
563.0
566.1
570.8
576.5
554.1
559.9
558.5
558.4
568.0
587.0
560.1
561.7
566.0
563.6
578.8
573.5
577.5
586.0
568.0
566.0
568.2
582.0
576.5
576.9
582.5
587.8
576.8
588.0
581.4
590.0



+8932
+8931
+57.2
+573
+574
Makeye
Chibila
742.3
692.7
671.3
687.2
628.1
626.0
740.2
674.9
646.0
673.5
696.5
656.2
605.5
658.1
610.8
584.0
661.5
652.0
632.0
616.2
643.5
583.5
619.9
614.0
588.0
659.9
613.5
590
588.0
628.5
593.7
603.2
621.9


Mwakaromba
Chibila
+8932
+8931
+574
+575
+576