REPORT

ON

THE COOPERATIVE MINERAL EXPLORATION

IN

THE [illegible] AREA

REPUBLIC OF ZAMBIA

PHASE [illegible]

FEBRUARY 19[illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE CHAMBISHI SOUTHEAST AREA, THE REPUBLIC OF ZAMBIA

PHASE II

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PREFACE

In response to the request of the Government of the Republic of Zambia, the Japanese Government decided to conduct a Mineral Exploration Project consisting of drilling exploration, data compilation and other relevant work in the Chambishi Southeast area to clarify the potential of mineral resources, and entrusted the survey to Japan International Cooperation Agency (JICA). The JICA entrusted the survey to Metal Mining Agency of Japan, because contents of the survey belongs to a field of mineral exploration. The survey conducted during this fiscal year is the second-phase of a three-phase project to be compiled in 1996, MMAJ sent a survey team headed by Mr. Masaaki SUGAWARA to the Republic of Zambia from August 4, 1994 to December 22, 1994.

The field survey was completed on schedule with the cooperation of the Government of Republic of Zambia and Zambia Consolidated Copper Mines Limited.

Results of the second-phase survey are summarized in this report which constitutes a part of the final report.

We wish to express our deep appreciation to the persons concerned of the Government of the Republic of Zambia, the Ministry of Foreign Affairs, the Ministry of International Trade and Industry, the Embassy of Japan in Zambia and the authorities concerned for the close cooperation extended to the team.

February 1995

Kimio FUJITA
President
Japan International Cooperation Agency

Takashi ISHIKAWA
President
Metal Mining Agency of Japan

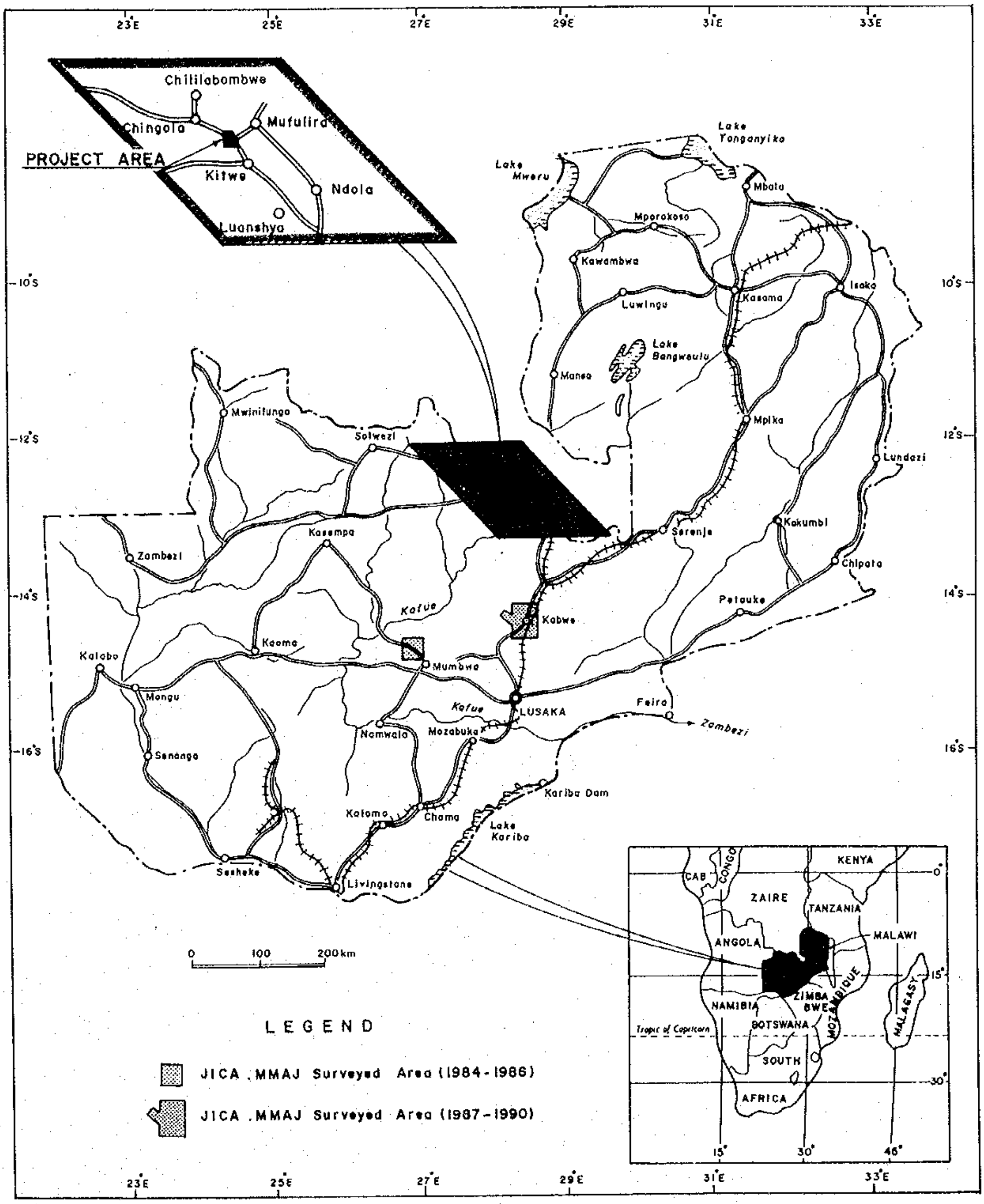

Fig.1-1 Index Map of the Project Area

S U M M A R Y

Drilling was carried out during the second-phase of the Chambishi Southeast area mineral exploration. All five boreholes drilled during this phase attained their objectives by penetrating the ore horizon. The four boreholes designed to obtain basement data reached the basement. The geology and mineralization of the vicinity of known deposits were thus clarified.

MJZC-5 drilled in the northwestern part of this area encountered relatively good ore (width 3.10m T-Cu 1.93% T-Co 0.03%, width 2.64m T-Cu 2.32% T-Co 0.03%). This orebody is believed to be the northwestern extension of the Northern Area Shoot which is the major ore shoot of this area. From this, extension of the northern part of the Northern Area Shoot in the west-northwest direction has become a possibility to be considered seriously.

MJZC-6 and MJZC-7 drilled to the west-northwest of MJZC-5 have encountered relatively low grade ores and they are considered to be located near the palaeo-basement high at the time of ore deposition. The ore shoot confirmed by NN-75 located between these two boreholes is inferred to be developed in the local depression to the south of NN-75, MJZC-6 and MJZC-7, namely on the southern limb of the palaeo-basement high.

MJZC-1 drilled in the southern part of the area encountered relatively low-grade ore. This mineralization, however, is developed immediately below the "Ore Shale" and is believed to be of the same type as that of the currently operating Chibuluma mine. To the east of MJZC-1, MJZC-2 confirmed relatively high-grade ore last year. This brings out the possibility that ore shoot may exist in the unexplored areas to the south of the above two boreholes.

MJZC-8 drilled in the southeastern part of the Northern Area Shoot encountered only weakly mineralized zone. This is most likely located at the crest of the palaeo-basement high and is considered to be barren.

It is thus recommended that drilling be carried out with high priority for the search for new deposits and that the ore reserves of this area be accurately evaluated by integrated study of the drilling results.

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PART I OVERVIEW

Chapter 1 Introduction

1-1 Background and Objective of the Survey

In response to the request of the Government of the Republic of Zambia, the Government of Japan decided to conduct mineral exploration survey in the Chambishi Southeast area. The survey was entrusted to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ). The Scope of Work was signed by the representatives of JICA, MMAJ and the Zambia Consolidated Copper Mines Limited (ZCCM) on 28 June 1993.

This survey is planned to last three years from 1993 in an area encompassing approximately 60 km^2.

The major objective of the survey is to explore and evaluate the mineral potential of the survey area by study of existing data, drilling and geological assessment of the drilling results.

The first phase of this project was carried out in fiscal 1993. The survey of that phase comprised drilling (3 holes, 2,666m), and compilation of existing data.

It was recommended on the basis of the conclusion of the first phase that the drilling in order to discover new ore deposits in the periphery of the deposits, and the drilling in order to clarify the areal extent of the deposit, be undertaken for the second phase survey.

The second phase of this project was carried out in fiscal 1994. The survey of that phase comprised drilling (5 holes, 4,241m).

1-2 Conclusions and Recommendations for the Second Phase

1-2-1 Conclusions of the First Phase

The first-phase survey of the Chambishi Southeast area comprised drilling, and compilation and interpretation of existing data. The following conclusions were obtained from the above.

1. The three holes drilled this year all confirmed the existence of shale-type copper deposits which is typical of the Copperbelt. Also, these holes were drilled to the basement or the proximity, and revealed relevant new information regarding the geology and mineralization of the project area.

2. MJZC-2 was drilled in the southern part of the area and confirmed relatively high-grade ores (width 3.14 m, T-Cu 2.21 %, T-Co 0.21 %). This indicates the possibility of a new ore shoot in this area.

3. It is inferred from distribution of the bioherm and thickness of the Footwall Formation that there was a palaeo-basement high at the ore-forming time in this area. The Northern Area Shoot which is the most important deposit of the area occurs in the depressions of the basement. And the horizon above the palaeo-basement high is of low grade or barren. This is inferred to be the result of the formation of environment favorable for deposition and preservation of sulfides in these submarine depressions by accumulation of heavy-metal-bearing dense solutions and formation of reduced biogenic sulfur in the stagnant sea water in these local troughs.

4. There are two types of present basement highs, namely those which coincide with the palaeo-basement highs and those which were formed by the apparent rise of the basement by folding after the deposition of the ores. Rich ore could occur higher than the top of the latter type highs.

5. The following is inferred from the gravity contour maps, geological maps, and drilling data. (1) Parts of the high gravity anomalies reflect the gabbroic bodies in shallow subsurface zones. (2) Parts of the gravity high anomalies reflect the basement highs such as the relative rise by folding and palaeo-basement highs. (3) High-grade ores most probably do not exist at gravity highs which coincide with thick gabbroic bodies. (4) The relatively thin and low-grade orebodies deposited over the tops and limbs of the palaeo-basement highs may turn out to be rich orebodies under relatively thin gabbroic bodies.

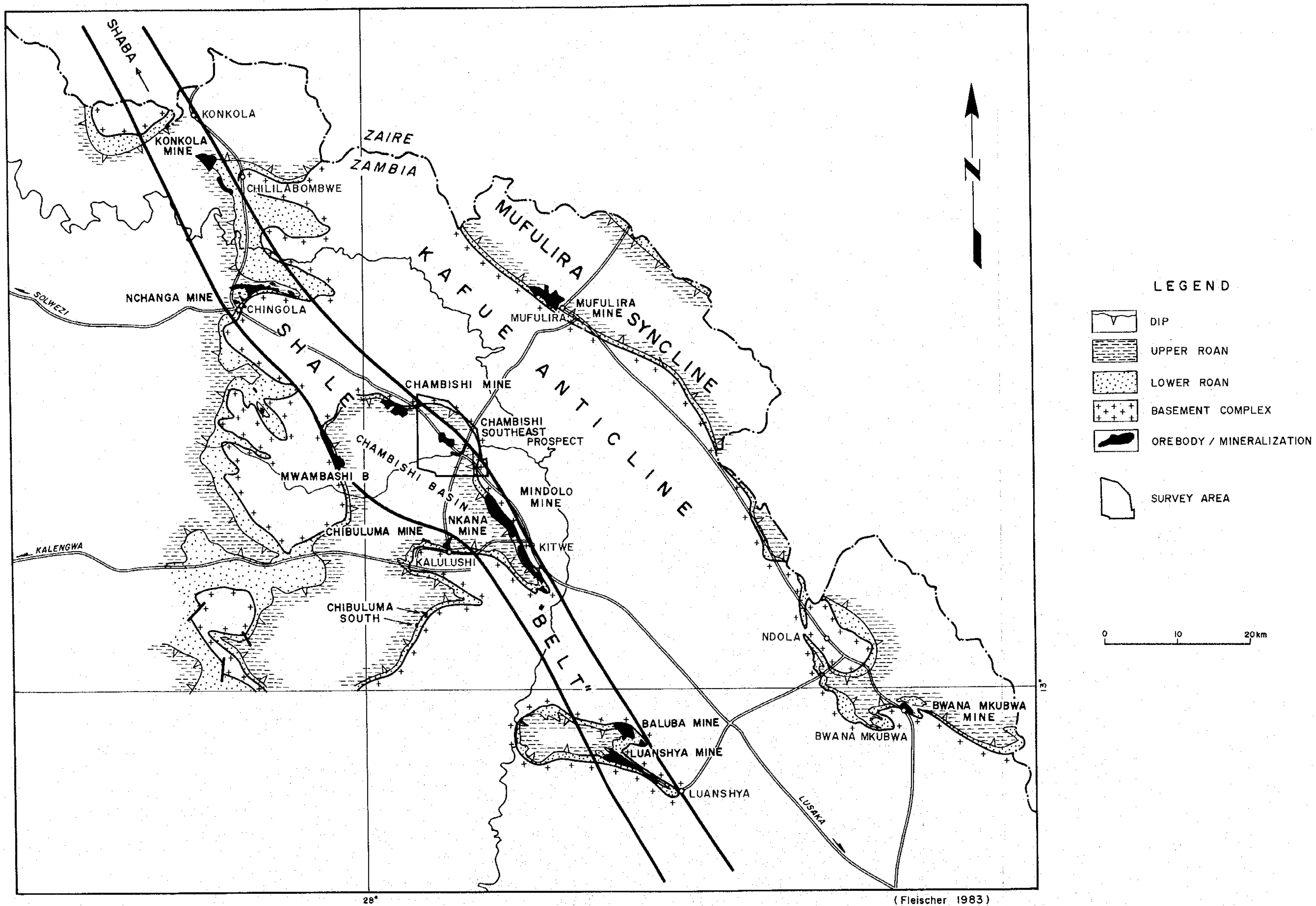


Fig.1-2 Copperbelt Index Plan

6. The mode of occurrence of the rich orebodies indicate that diagenesis and metamorphism played important roles in the formation of ore shoots. Structures similar to dehydration structures of Kuroko (sulfide) deposits occur in these orebodies and the minute grain-sized sulfide proto-ore definitely migrated in conjunction with dehydration during the compaction after deposition.

1-2-2 Recommendations for Second Phase Survey

It is concluded from the results of the drilling reported hitherto that the promising areas for further mineral exploration are; the area northwest of the Northern Area Shoot, and the area from the south to the west of MJZC-2.

The Northern Area Shoot, the most important deposit of the project area, however, has not been prospected sufficiently and drilling along the periphery of the deposit is necessary to clarify the areal extent of this deposit. With the above consideration, drilling as shown in the figure is recommended for the work of second and third phases. The project area is divided into two zones, which are the Northern Area Shoot and the northwest, and the south, and each zone is prioritized. The drilling depth will be, as a rule, to the basement complex, but where the basement depth is already known, to the Footwall of the ore horizon would be sufficient.

It is recommended that confirmation of the northwestern extension of the Northern Area Shoot, the major orebody of this area, and thereby enlarging the ore reserves be the priority activity of the second phase (fiscal 1994) of this project and that drilling be carried out in accordance with this priority.

1-3 Outline of the Second Phase Survey

1-3-1 Survey Area

There is an arc-shaped zone extending in the NW-SE to E-W (12°15'S to 13°15') direction in south-central Africa which is very rich in copper. It is called the "Copperbelt" and many copper deposits are concentrated in this zone. The survey area (Chambishi Southeast) is located near the centre of the Copperbelt between the Chambishi and Mindola mines and approximately

305 km north of the capital Lusaka as the crow flies (Fig. 1-1).

Kitwe, the third largest city of Zambia, has the Nkana deposit within its jurisdiction and is located about 10 km to the south-southeast of the area; Kalulushi where the Technical Directorate of ZCCM and the Chibuluma mine are located is 10 km to the south; the Chambishi mine (suspended) is 10 km to the northwest; the mining town Chingola where the largest deposit of the Belt, the Nchanga mine, occurs is 30 km to the northwest; and the mining town Mufulira is 20 km to the northeast (Fig. 1-2).

The survey area (60 km2)lies in the vicinity of the main tarmac road, joining Chingola and Kitwe (Fig. 1-3).

It is one hour flight from Lusaka to Kitwe and four hours by car.

1-3-2 Objective of the Survey

The objective of the second-phase survey is to discover new ore deposits through the understanding of the metallic mineralization and the geology of the Chambishi Southeast area, and to pursue technology transfer to the Zambian counterpart personnel. And also, the main objective of drilling is to confirm the extension of known ore deposits, and clarify the state of mineralization, and thereby enlarge the ore reserves in the survey area.

1-3-3 Survey Methods

The method of the second-phase survey is drilling exploration. The contents are as follows.

(1) Localities of Holes and Details

Details of the drill holes shown in Figure 1-3 are as follows.

Hole No.	Hole Length (m)	Inclination (°)	Azimuth
MJZC-1	650.85	-90	-
MJZC-5	1,100.15	-90	-
MJZC-6	1,014.96	-90	-
MJZC-7	985.00	-90	-
MJZC-8	490.26	-90	-
Total	4,241.22		

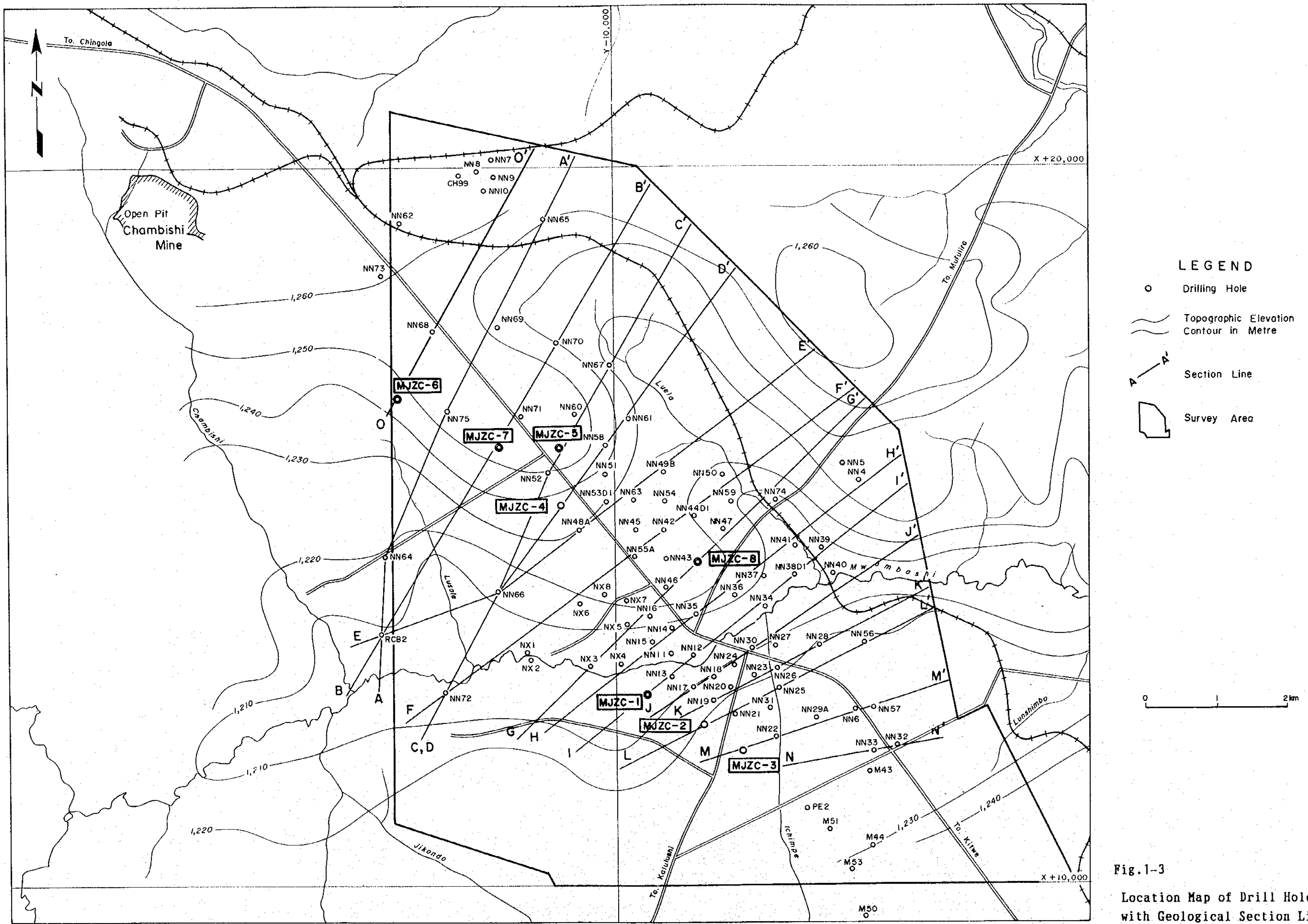


Fig.1-3

Location Map of Drill Holes with Geological Section Lines

(2) Methods

Drilling work was done by DRILLING EXPLORATION AND EQUIPMENT LTD., (D.E.E.) incorporated in Zambia. D.E.E. has sister companies in South Africa, Zimbabwe and Botswana.

From the surface to about 190m, non-core drilling was made by 212mm to 114mm percussion bit or 117mm tricone bit, and 165mm, HW and NW casing pipes were inserted. For deeper parts, wire-line method was used with NQ(79mm) and CHD(78mm) bits. The encountered rocks were generally hard, however, soft parts with lost circulation occurred sometimes. Regarding these soft parts, extension of the casing pipe, cementing and injection of Drillprops or bentonite prevented collapses and lost circulation.

(3) Machinery

The specifications for the drilling rig, and other machinery are listed in Table 1-1, the conditions of the diamond bits in Table 1-2 and the used consumables in Table 1-3.

(4) Operations

Construction, moving, and withdrawal were done by single shift per day, while drilling was carried out by two twelve-hour shifts. Each shift consisted of one Zambian or Botswanian or South African drilling operator and five Zambian workers. And one South African superintendent, one South African engineer and two Japanese engineers supervised all work sites. Operators and workers camped by the site, while both South African and Japanese engineers commuted by car from the accommodations in Kitwe. Working time analysis of the drilling operation is shown in Table 1-4.

(5) Transportation of machinery

Machinery and material sent from South Africa and Botswana were stored in the D.E.E. workshop of Kitwe after passing the customs inspection in Livingstone, and were transported from the workshop to each site by a truck with crane.

(6) Drilling water

Waters from streams were pumped up into a tanker, and the tanker was transported to each site except MJZC-1 by a tractor. The transported distance was about 2.5 to 7 km. Stream water was pumped up and piped for a distance of about 300m to the MJZC-1 site.

Table 1-1 Drilling Machine and Equipment

Drilling Machine Model "L-44", "Strata"	L-44 (2 set)	Strata (1 set)	
Specifications:			
Capacity	1,500m(BQ-WL)	2,500m(BQ-WL)	
Dimensions L × W× H	2,375mm×1,500mm×1,750mm	3,000mm×2,000mm×2,500mm	
Hoisting capacity	4,500kg	8,250kg	
Spindle speed	Forward 50~900rpm	500~800rpm	
Engine Model "DEUTZ"	6 cylinder-624	6 cylinder	
Drilling Machine Model "Rock Giant"	1 set		
Specifications:			
Capacity	200m(percussion drilling)		
Dimensions L × W× H	8m×1.75m×2.6m		
Hoisting capacity	5,000kg		
Spindle speed	3rpm		
Engine Model "DEUTZ"	4 cylinder		
Drilling Pump Model "BEAN ROYAL-35"	3 set		
Specifications:			
Piston diameter	40mm		
Stroke	70mm		
Capacity	Discharge capacity 210 liter /min		
Dimensions L × W× H	2,500mm×1,200mm×1,500mm		
Engine Model "HATZ"	12.5ps/800rpm (2 cylinder)		
Wire-line Hoist	L-44 (2 set)	Strata (1 set)	
Specifications:			
Rope Capacity	1,000m	2,500m	
Hoisting speed	8~105rpm/min	80m/min	
Engine Model "HATZ"	12.5ps/800rpm	Hydraulic	
Generator Model	3 set		
Specifications:			
Capacity	2.8KW, 50Hz, 220V		
Water supply pump model "HONDA"	4 set		
Specifications:			
Capacity	Discharge capacity 50 liter /min		
Dimensions L × W× H	500mm×450mm×450mm		
Engine Model "HONDA"	4.5ps/2000rpm		
Derrick	L-44 (1 set)	L-44 (1 set)	Strata (1 set)
Specifications:	(skid)	(truck mounted)	(trailer mounted)
Capacity	12m-pull	9m-pull	12m-pull
Max load capacity	10,000kg	8,000kg	10,000kg
Tractor Model "188ps M.F."	4 set		
Specifications:			
Water tanker	4 set		
Capacity	4,500		
Drilling tools			
Drilling rod : NDBR(CHD) 6.0m	633 pcs		
Casing pipe : HW 6.0m	29 pcs		
NW 6.0m	75 pcs		
NXC 6.0m	34 pcs		

Table 1-2 Drilling Meterage of Diamond Bit Used

Item	Size	Bit No.	Drilling Meterage by Unit:Meter					Total(m)
			MJZC-1	MJZC-5	MJZC-6	MJZC-7	MJZC-8	
Diamond bit	NQ-WL	9264	195.75					195.75
		21377	20.62					20.62
		21639	294.00					294.00
		26088	106.70					106.70
		2113.1		287.10				287.10
		3783-1		20.61				20.61
		7653		45.36				45.36
		7659		23.37				23.37
		7660		57.89				57.89
		8340		205.16				205.16
		21377-2		132.00				132.00
		21377-5		76.14				76.14
		21377-9		68.52				68.52
		416			131.52			131.52
		2491.1			27.96			27.96
		7276			94.02			94.02
		DC7276			203.46			203.46
		7657			12.97			12.97
		7665			87.26			87.26
		8335			64.40			64.40
		8337			88.53			88.53
		21086			48.01			48.01
		33832			66.95			66.95
		A2113				111.57		111.57
		7652				64.88		64.88
		7654				61.45		61.45
		7658				40.36		40.36
		7663				50.91		50.91
		8331				213.74		213.74
		8334				3.20		3.20
		8340				83.23		83.23
		213777				104.02		104.02
		213776				120.04		120.04
		37M					171.04	171.04
		17182					52.23	52.23
		21039					126.84	126.84
		21377					67.26	67.26
	NX-C	A1801					7.00	7.00
		A2114					4.89	4.89
		Total	617.07	916.15	825.08	853.40	429.26	3640.96
			Drilling length / bit (3640.96m / 39 pcs)					93.36

Table 1-3 Consumables Used

Description	Specifications	Unit	Quantity					Total
			MJZC-1	MJZC-5	MJZC-6	MJZC-7	MJZC-8	
Light oil		liter	1,800	11,645	11,260	8,015	3,150	35,870
Hydraulic oil		liter	45	20	440	250	195	950
Engine oil		liter	41	167	112	149	46	515
Gear oil		liter	36	53	130	108	36	363
Grease		liter	12	62	67	5	22	168
Drillprop		liter	75	37	59	60	22	253
Rod grease		kg	4	201	80	56	45	386
Cutting oil		liter	230	465	645	335	280	1,955
Cement	50kg/sx	kg		2,350		725		3,075
Accelerator		kg		250		54		304
Bentonite		kg					80	80
Percussion bit	212mm	pc		1	1	1	1	4
Percussion bit	152mm	pc					1	1
Percussion bit	114mm	pc		3	1	1		5
Tricone bit	117mm	pc	1					1
Diamond bit	NQ	pc	4	10	11	10	4	39
Diamond shoe bit	NX	pc					3	3
Diamond shoe bit	NW	pc				3		3
Diamond reamer	NQ	pc	1	3	2	1	1	8
Core barrel Ass'y	NQ-WL	set	(1)	1	1	1	(1)	3
Inner tube Ass'y	NQ-WL	set	(1)	1	1	1	(1)	3
Inner tube	NQ-WL	pc	(1)	1	1	1	(1)	3
Locking coupling	NQ-WL	pc	2	2	2	2	2	10
Adapter coupling	NQ-WL	pc	2	2	2	2	2	10
Landing ring	NQ-WL	pc	3	3	3	3	3	15
Core lifter case	NQ-WL	pc	5	6	5	5	5	26
Core lifter	NQ-WL	pc	5	6	5	5	5	26
Stop ring	NQ-WL	pc	2	2	2	2	2	10
Thrust ball bearing	NQ-WL	pc	1	1	1	1	1	5
Hanger bearing	NQ-WL	pc	1	1	1	1	1	5
Inner tube stabilizer	NQ-WL	pc	2	2	2	2	2	10
Hoisting wire rope	21mm×35m	roll		1	1	1		3
Wire line rope	6mm×1,500m	roll		1	1	1		3
Waste		kg	8	10	10	10	7	45

Table 1-4 Working Time Analysis of the Drilling Operation

Hole No.	Bit Size	Drilling: Drilling length (m)	Drilling: Core length (m)	Shift: Drilling (shift)	Shift: Total (shift)	Man Working: Engineer (man)	Man Working: Worker (man)	Working Time: Drilling (h)	Other work (h)	Recover-ing (h)	Sub total (h)	Reassem-blage (h)	Dismant-lement (h)	Road con-struction (h)	Transpor-tation (h)	Water supply (h)	Grand total (h)
MJZC-1	117mm	33.78	N/C	1.00	6.00	14.00	34.00	10.00	14.00	0.00	24.00	24.00	0.00		18.00	7.00	73.00
	NQ	617.07	602.32	34.00	40.00	78.00	219.00	231.00	173.00	38.00	442.00	0.00	20.00		12.00	161.70	635.70
	Total	650.85	602.32	35.00	46.00	92.00	253.00	241.00	187.00	38.00	466.00	24.00	20.00		30.00	168.70	708.70
MJZC-5	212mm	37.00	N/C	1.00	6.00	8.00	48.00	3.00	2.00	0.00	5.00	4.00	0.00	24.00	39.00	0.00	72.00
	114mm	147.00	N/C	8.00	9.00	25.00	45.00	68.00	32.00	0.00	100.00	0.00	2.00	0.00	12.00	0.00	114.00
	NQ	916.15	894.79	123.00	142.00	358.00	746.00	472.00	453.00	721.50	1,647.00	9.00	10.00	0.00	22.00	343.00	2,031.00
	Total	1,100.15	894.79	132.00	157.00	391.00	839.00	543.00	487.00	721.50	1,752.00	13.00	12.00	24.00	73.00	343.00	2,217.00
MJZC-6	212mm	41.00	N/C	0.70	3.00	3.00	21.00	8.00	2.00	0.00	10.00	2.00	0.00	24.00	2.00	0.00	38.00
	114mm	148.88	N/C	6.00	6.00	13.00	33.00	31.00	41.00	0.00	72.00	0.00	2.00	0.00	4.00	0.00	78.00
	NQ	825.08	813.76	81.00	94.00	226.00	464.00	356.50	470.00	247.50	1,074.00	12.00	36.00	0.00	0.00	325.00	1,447.00
	Total	1,014.96	813.76	87.70	103.00	242.00	518.00	395.50	513.00	247.50	1,156.00	14.00	38.00	24.00	6.00	325.00	1,563.00
MJZC-7	212mm	49.00	N/C	0.67	3.00	4.00	21.00	6.00	2.00	0.00	8.00	2.00	0.00	24.00	2.00	0.00	36.00
	114mm	82.60	N/C	2.00	2.50	4.00	15.00	11.00	11.00	0.00	22.00	0.00	2.00	0.00	4.00	0.00	28.00
	NQ	853.40	828.75	115.00	131.00	259.00	657.00	528.00	589.50	358.50	1,476.00	18.00	24.00	0.00	52.00	522.00	2,092.00
	Total	985.00	828.75	117.67	136.50	267.00	693.00	545.00	602.50	358.50	1,506.00	20.00	26.00	24.00	58.00	522.00	2,156.00
MJZC-8	212mm	44.27	N/C	0.80	1.00	3.00	6.00	7.00	3.00	0.00	10.00	2.00	0.00		0.00	0.00	12.00
	152mm	16.73	N/C	0.00	2.00	6.00	14.00	0.00	0.00	0.00	0.00	6.00	0.00		18.00	0.00	24.00
	HQ	11.89	9.46	6.00	6.00	12.00	29.00	15.00	47.00	0.00	62.00	5.00	0.00		5.00	24.00	96.00
	NQ	417.37	385.53	36.00	40.00	75.00	181.00	243.00	184.00	24.00	451.00	0.00	9.00		20.00	179.50	659.50
	Total	490.26	394.99	42.80	49.00	96.00	230.00	265.00	234.00	24.00	523.00	13.00	9.00		43.00	203.50	791.50
Grand total		4,241.22	3,534.61	415.17	491.50	1,088.00	2,533.00	1,989.50	2,023.50	1,389.50	5,403.00	84.00	105.00	72.00	210.00	1,562.20	7,436.20

(7) Withdrawal

After the completion of the survey, all equipments were transported to the D.E.E. workshop in Kitwe by truck, and stored.

(8) Measurement of borehole deviation

Borehole deviation was measured every 100 m for each hole.

(9) Surveying and analysis of cores

a) Cores and cuttings were studied in detail, and geologic logs at scale of 1:200 were made.

b) Microscopic studies of core were made whenever necessary.

c) Each ore and/or mineralized parts of cores were assayed by ZCCM.

d) The numbers of samples studied in the laboratory are as follows.

Laboratory Work	Particulars
Thin section microscopy	10 sections
Polished thin section microscopy	20 sections
Electron probe microanalysis (quantitative)	5 samples
Chemical analysis of ore samples	381 samples

1-3-4 Participants of the Second Phase Survey

Field supervisor

Youichi Okuizumi (Metal Mining Agency of Japan)

Survey Team

Zambian member (Zambia Consolidated Copper Mines Limited)

J. H. D. Patterson (Technical director)
R. J. H. Naish (Consulting geologist)
C. C. Tomkins (Acting consulting geologist)
A. C. Kaunda (Project manager, geological survey)
F. A. Siddiqui (Geological services)
W. J. Silondwa (Geological survey)

Japanese member (Nikko Exploration & Development Co.,Ltd.)

Masaaki Sugawara (Team leader, Geological Survey, Drilling)

Masaya Wakamatsu (Drilling)

1-3-5 Duration

Field survey (Drilling)
8 August 1994 to 19 December 1994
Laboratory work, report preparation
15 November 1994 to 25 February 1995

Chapter 2 Geography of the Survey Area

2-1 Topography and Drainage

2-1-1 Topography

The topography of the survey area and the vicinity is in a relatively flat plateau of 1,200 to 1,300 m in elevation. In general, the elevation gradually rises toward the Chambishi mine to the northwest of the survey area.

As the topography along rivers is more or less flat, they become swampy (called Dambo) during the rainy season.

2-1-2 Drainage

The drainage of the survey area belongs to the Kafue system which is a tributary of the Zambezi system, the large river flowing into the Indian Ocean. The Kafue river flows southward approximately 8 km northeast of the survey area. The Mwambashi stream, a tributary of Kafue, flows eastward in the southern part of the area. NW-SE trending streams are developed to the north of the Mwambashi stream.

2-2 Climate and Vegetation

2-2-1 Climate

The survey area belongs to the savanna climatic zone. The climate largely comprises cold and dry (April to July), hot and dry (August to mid-November) and rainy (mid-November to March) seasons. It rains only once or twice a month during May to September, but it is very humid during September to October, and it rains several times a month. During January to February, precipitation is the largest, heavy rains with thunder occurs almost every day and cold cloudy days are frequent.

Average annual temperature is about 20°C, the maximum temperature 30 to 35°C and the annual precipitation is 1,000 to 1,500 mm.

The monthly mean precipitation observed at Kalulushi, where the ZCCM Technical Service is located, over 13 years (1981-1993) are as follows.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
1981	243.8	277.0	253.8	49.0	15.0	-	-	-	2.0	2.0	176.5	168.0	1187.1
1982	463.0	196.5	63.0	92.6	19.0	-	-	-	1.0	83.5	318.5	210.0	1447.1
1983	299.5	190.5	125.5	122.0	2.5	-	-	-	0.0	38.5	124.0	342.5	1245.0
1984	251.0	252.5	175.5	17.5	62.0	-	-	-	2.5	52.5	114.0	495.5	1423.0
1985	304.5	185.5	192.0	51.0	42.0	-	-	-	3.5	34.5	80.5	287.5	1181.0
1986	343.5	253.5	308.0	191.5	0.0	-	-	-	0.0	104.0	355.0	178.5	1734.0
1987	347.0	266.5	100.2	12.0	0.0	-	-	-	4.0	25.0	49.8	218.0	1022.5
1988	475.0	217.5	272.1	10.7	0.0	-	-	-	3.2	75.0	101.2	215.0	1369.7
1989	264.1	202.8	168.7	67.0	8.5	-	-	-	0.0	0.0	57.5	285.5	1054.1
1990	202.0	226.5	178.0	53.5	42.0	-	-	-	0.0	0.0	85.0	296.0	1083.0
1991	569.5	117.5	296.5	36.5	2.5	-	-	-	98.6	100.9	205.0	201.6	1628.6
1992	97.1	300.9	17.9	0.0	0.0	-	-	-	0.0	11.6	92.8	364.9	885.2
1993	285.9	439.8	239.9	101.1	0.0	-	-	-	0.0	0.5	192.8	157.9	1417.9

(mm)

The monthly mean temperature and precipitation observed at Kabwe in central Zambia over 16 years (1961-1976) and 14 years (1962-1975), respectively, are shown in below.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Average (°C) Temperature	21.0	20.7	20.7	19.8	17.5	16.0	15.8	18.2	21.8	24.0	22.6	21.0	19.9
Average (mm) Precipitation	263.9	204.9	108.3	18.4	4.3	0.0	0.0	0.1	1.0	22.6	84.7	259.1	967.3

2-2-2 Vegetation

The vegetation of the area comprises forests with relatively tall trees of 15 m in height within smaller bushes, and savanna with sparsely distributed trees within grass. The forests are in areas of argillite and dolomite where soil is developed into deeper zones, while the savanna occurs in areas of hard rocks such as quartzite and basement complex where the soil is relatively shallow.

Chapter 3 General Geology

3-1 Geology and Mineralization of the Zambian Copperbelt

The present survey area belongs to the so-called Copperbelt of Africa. This belt extends for approximately 500 km in an arc from the border of Zambia and the southern end of Zaire in the east to the border of Zambia and Angola in the west. This constitutes a metallogenic province of about 80 km in width.

The geology of this belt mainly comprises early to middle Precambrian basement complex and late Precambrian Katangan Supergroup.

The basement of the Zambian Copperbelt comprises the early Precambrian Lufubu Supergroup consisting mainly of schist and gneiss, granitic bodies (1975 Ma) intruded into the Lufubu Supergroup, and the middle Precambrian Muva Supergroup consisting mainly of quartzite (Figs. 1-2 and 1-4). Widespread low-grade copper mineralization is known in these granitic bodies.

The basement complex is overlain by the Katangan Supergroup with marked unconformity. The Supergroup is divided into the Lower Roan Group consisting mainly of conglomerate, sandstone and mudstone with talus and aeolian deposits at the base, the Upper Roan Group consisting mainly of dolomite and dolomitic mudstone including anhydrite, the Mwashia Group consisting mainly of dolomite and shale, and the Kundelungu Group containing glacier deposits, the every Group being conformable to each other. The ore deposits occur as platy bodies within the mudstone and sandstone near the boundary of Upper and Lower Roan Groups (Fig. 1-4).

The Lower Roan Group is further divided into three formations, namely, the Footwall, Ore and Hangingwall Formations. The Footwall Formation is the basal conglomerate unit, and mainly comprises conglomerate and arkosic sandstone. The Ore Formation consists mainly of shale, siltstone, quartzose sandstone and feldspathic sandstone with intercalations of dolomite and conglomerate. The Hangingwall Formation consists mainly of siltstone, quartzose sandstone and arkosic sandstone with intercalations of dolomite.

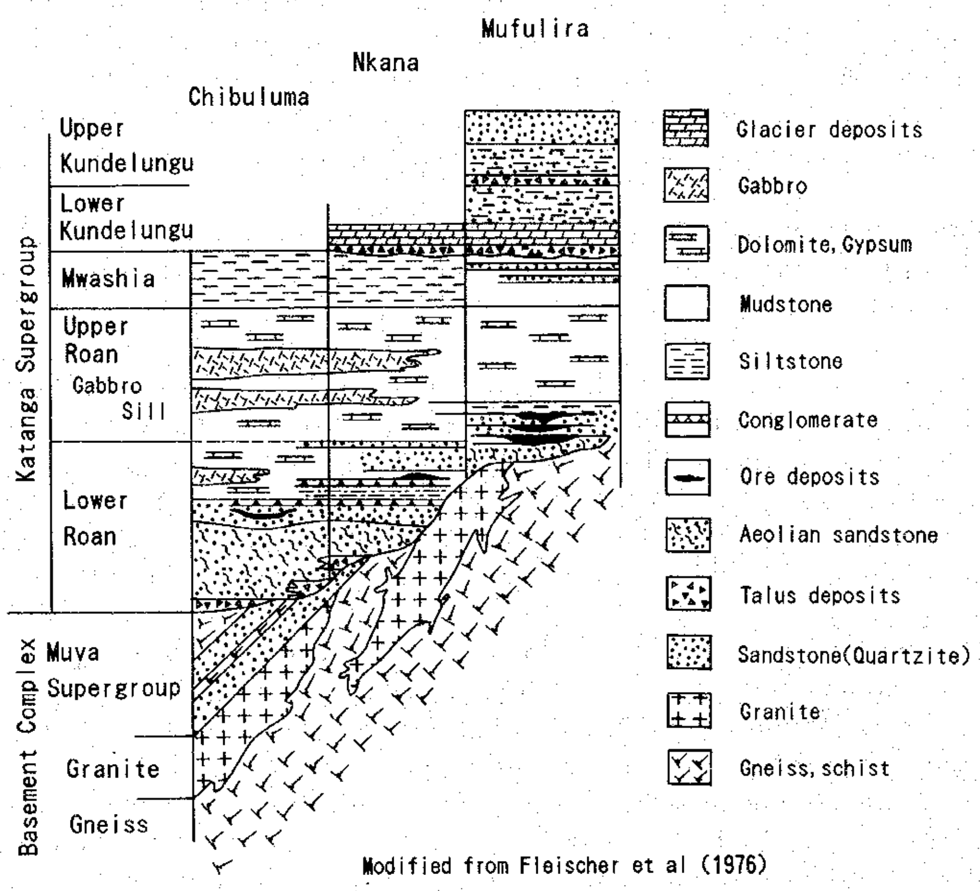


Fig.1-4 Schematic Stratigraphic Columns of the Zambian Copperbelt

The Katangan Supergroup is distributed in an orogenic zone which is developed in an arc in northwest Zambia and extending into Zaire and Angola. Folds, klippe and thrust faults are developed in this zone, and it is called the Lufilian Arc. The geologic units of the Copperbelt were strongly folded with axis in the E-W to NW-SE direction by the late-middle Kundelungu (840 to 465 Ma) Lufilian Orogeny.

The Kafue Anticline trending in the NW-SE direction occur in the Zambian Copper Belt (Fig. 1-2). On the western side of this anticline, ore deposits such as Luanshya, Baluba, Nkana, Chambishi, Nchanga and Konkola occur in pelitic Ore Formation (Ore Shale), but also in footwall quartzite of the Ore Formation (Chibuluma, Nkana). On the other hand, on the eastern side, ore deposits such as Mufulira and Bwana Mkubwa occur in quartzites of the Mufulira Syncline and the Ore Shale Formation is not recognized. Therefore, the complete stratigraphic correlation of orebodies is not possible. There are two theories regarding the ore-bearing horizon, namely in the Lower Roan Group and in the Upper Roan Group.

Characteristics of ore deposits in the Zambian Copperbelt are summarized as follows.

(1) Ore horizon: Most of ore deposits occur in the Ore Formation of the Lower Roan Group, and are clearly stratigraphically controlled.

(2) Shape of ore deposit: Ore deposits including the intensely folded ones in the Chambishi and Roan-Muliashi Basins are stratiform, and conformable with the host rocks. Size of ore deposits is 5 to 55 m in thickness, several kilometers in length and several hundred metres in width. Most of the ore deposits have one ore horizon while those of Nchanga have two and Mufulira and Bwana Mkubwa ore deposits have three ore horizons.

(3) Host rocks: The mineralization in the area west of the Kafue Anticline is hosted in argillite, sandstone or impure dolomite. On the other hand, those in the area east of the Anticline are hosted in sericitic quartzite or graywacke.

(4) Alteration of host rocks: Biotitization, sericitization and silicification are reported. However, the relation between

these alteration and mineralization is not clear.

(5) Ore minerals: Pyrite, chalcopyrite, bornite and chalcocite occur as major primary ore minerals. These are accompanied by minor primary minerals such as pyrrhotite, covelline, digenite, carrollite, linnaeite, Cu-bearing pyrite, molybdenite, scheelite, wolframite, uraninite. Of these, linnaeite and carrollite occur in the Chambishi, Nchanga, Nkana and Baluba ore deposits, and uraninite in the Nkana-Mindola ore deposit.

Malachite, chrysocolla, azurite, cuprite, tenorite, chalcocite, bornite, covelline, native copper, asbolite and heterogenite are present as secondary ore minerals.

(6) Gangue minerals: Biotite, sericite, quartz, feldspar, dolomite, calcite, scapolite and anhydrite occur as major gangue minerals. Chlorite, carbonaceous material, tourmaline, apatite, rutile, tremolite, talc, sphene, epidote, zircon and hematite occur as subordinate gangue minerals.

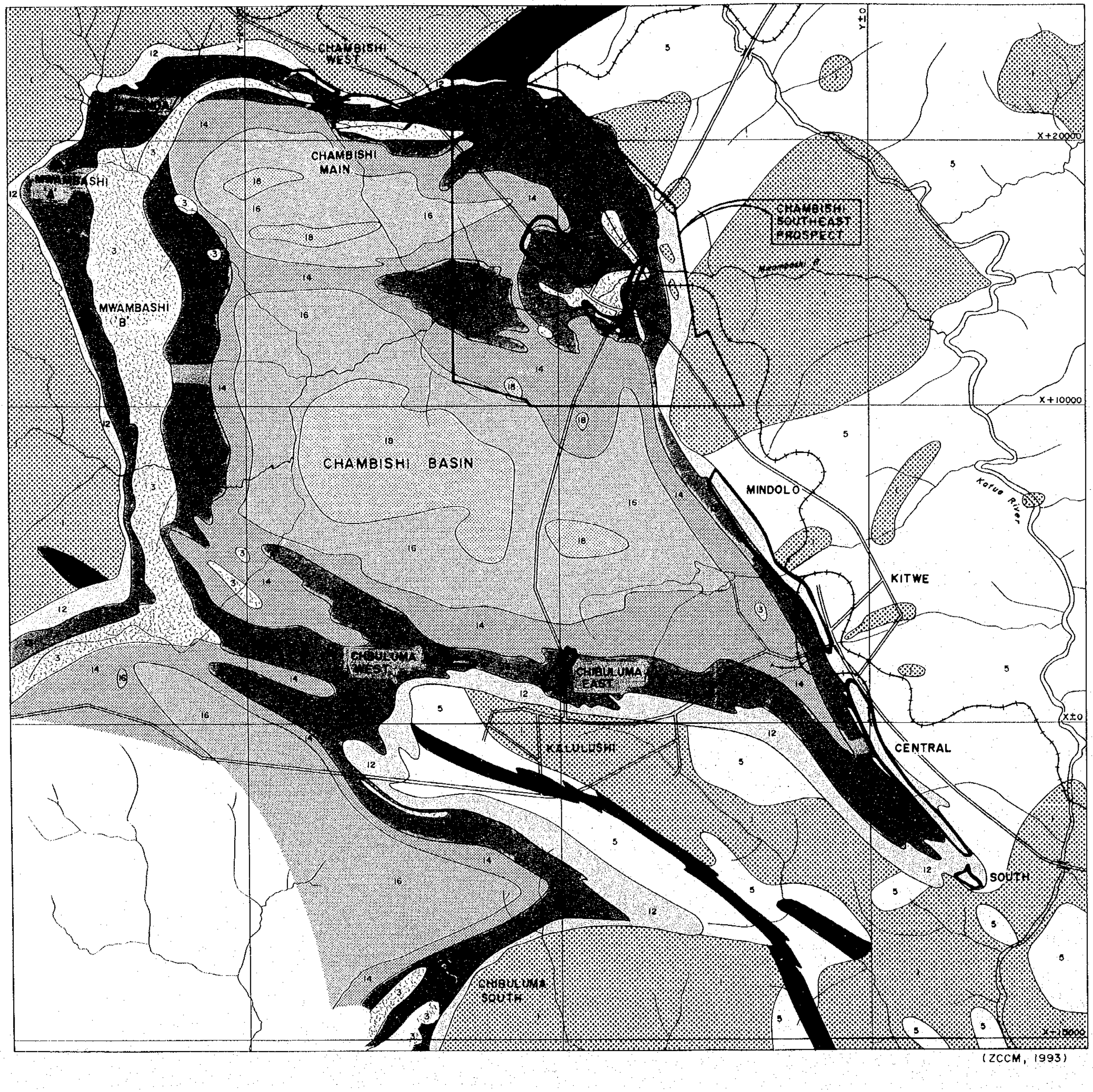
(7) Zorning of sulfide minerals: A horizontal zoning is recognized at most of the ore deposits, and have a nearly constant tendency, i.e., ore deposits distributed in the Ore Shale show the zoning of barren zone chalcocite bornite chalcopyrite pyrite from northeast southwestward (away from the basement areas). Ore deposits in quartzite show a zoning consisting of pyrite at the central part and chalcopyrite and bornite at the periphery. A vertical zoning is also recognized at most of ore deposits.

(8) Occurrence of ore: Depositional structures such as cross-bedding and slumping are observed in ore. In the ore deposits of the Ore Shale, there is a relation between lithofacies change and copper grade, namely, the grade decreases from argillite to sandstone to conglomerate.

3-2 Geology and Mineralization of the Survey Area

The following discussion is based on Fleischer (1983), ZCCM data and results of this survey.

Geological map, generalized columnar section and geological sections are shown in Figures 1-5, 1-6 and 1-7, respectively.



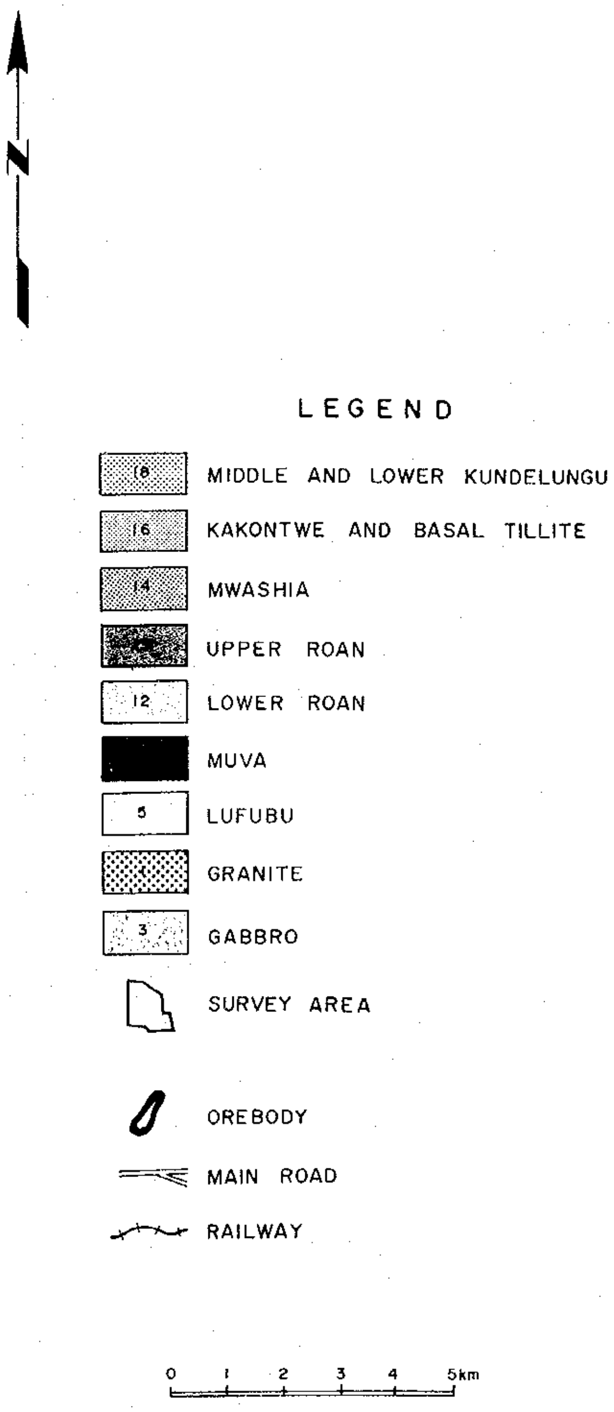
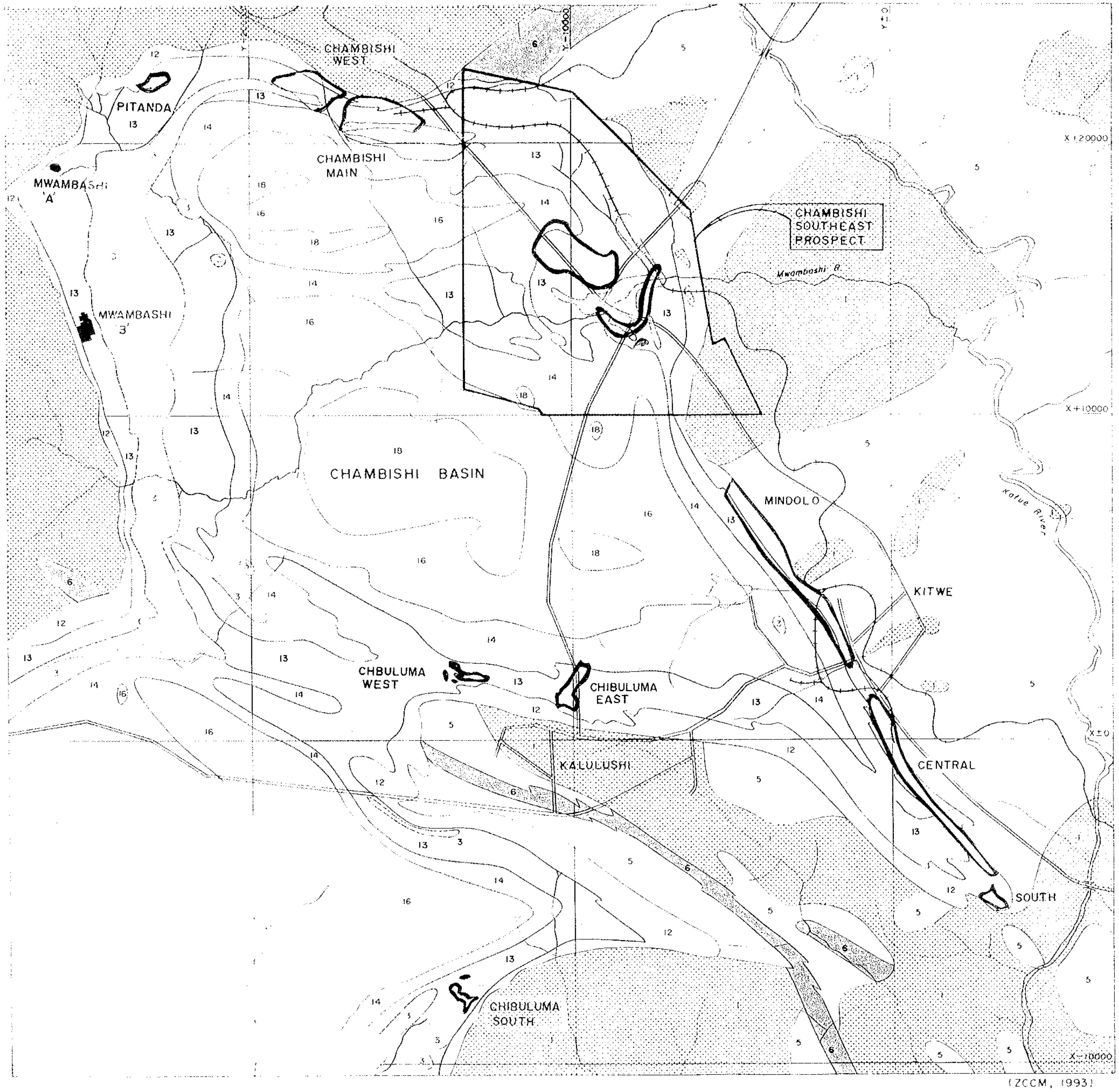


Fig.1-5 Geological Map of the Chambishi Southeast Area



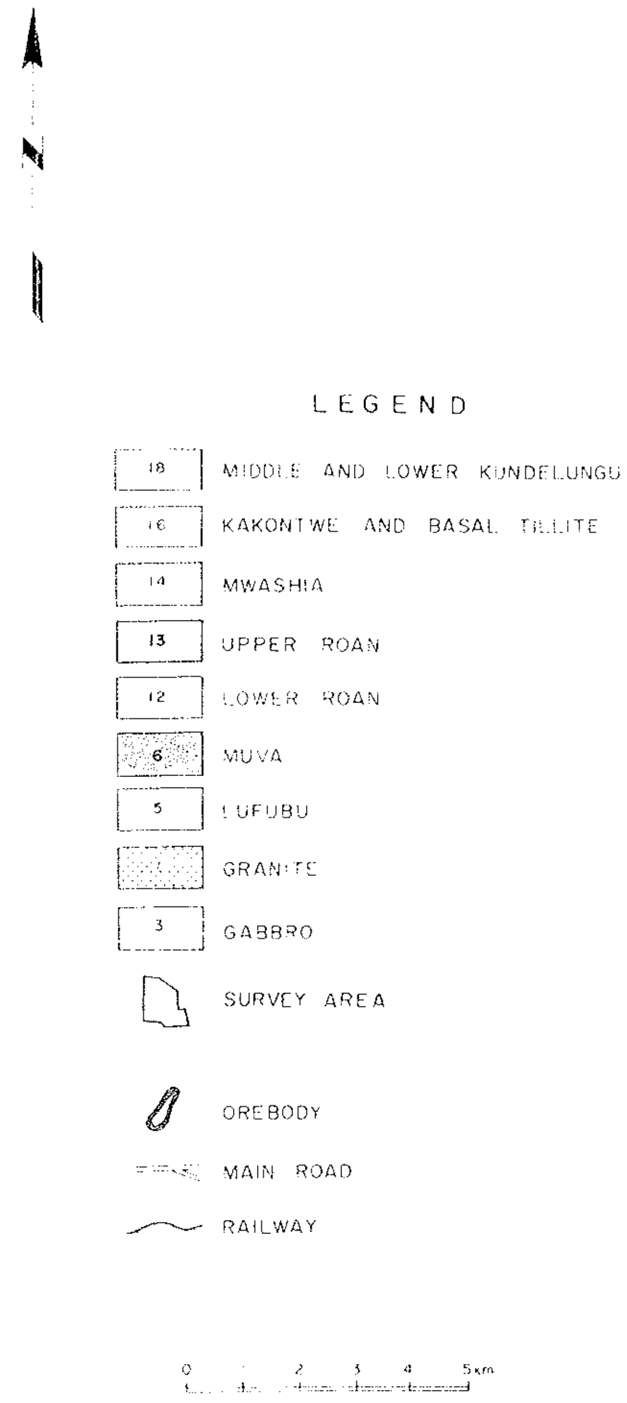


Fig.1-5 Geological Map of the Chambishi Southeast Area

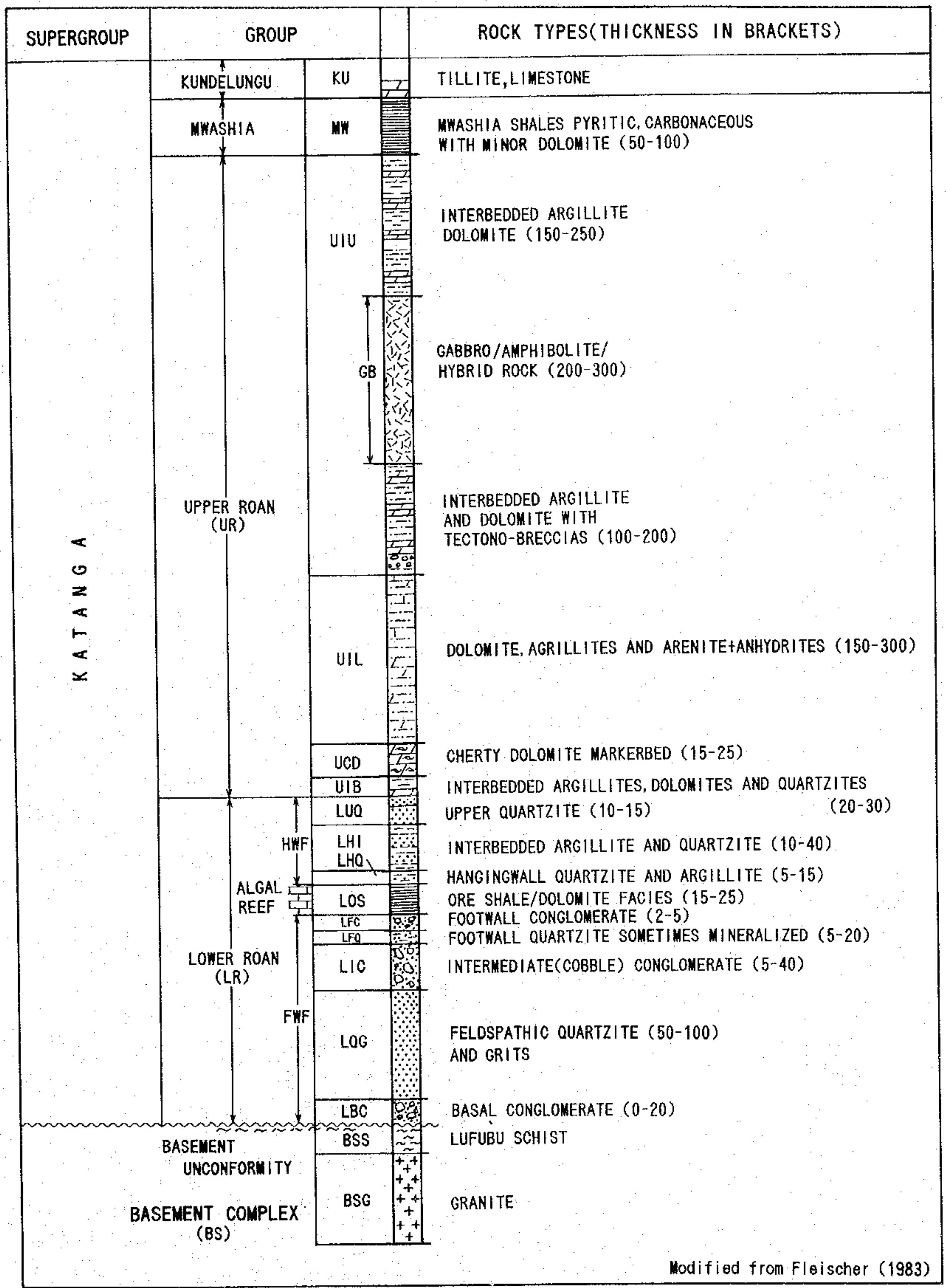


Fig.1-6 Generalized Stratigraphic Section through Chambishi Southeast

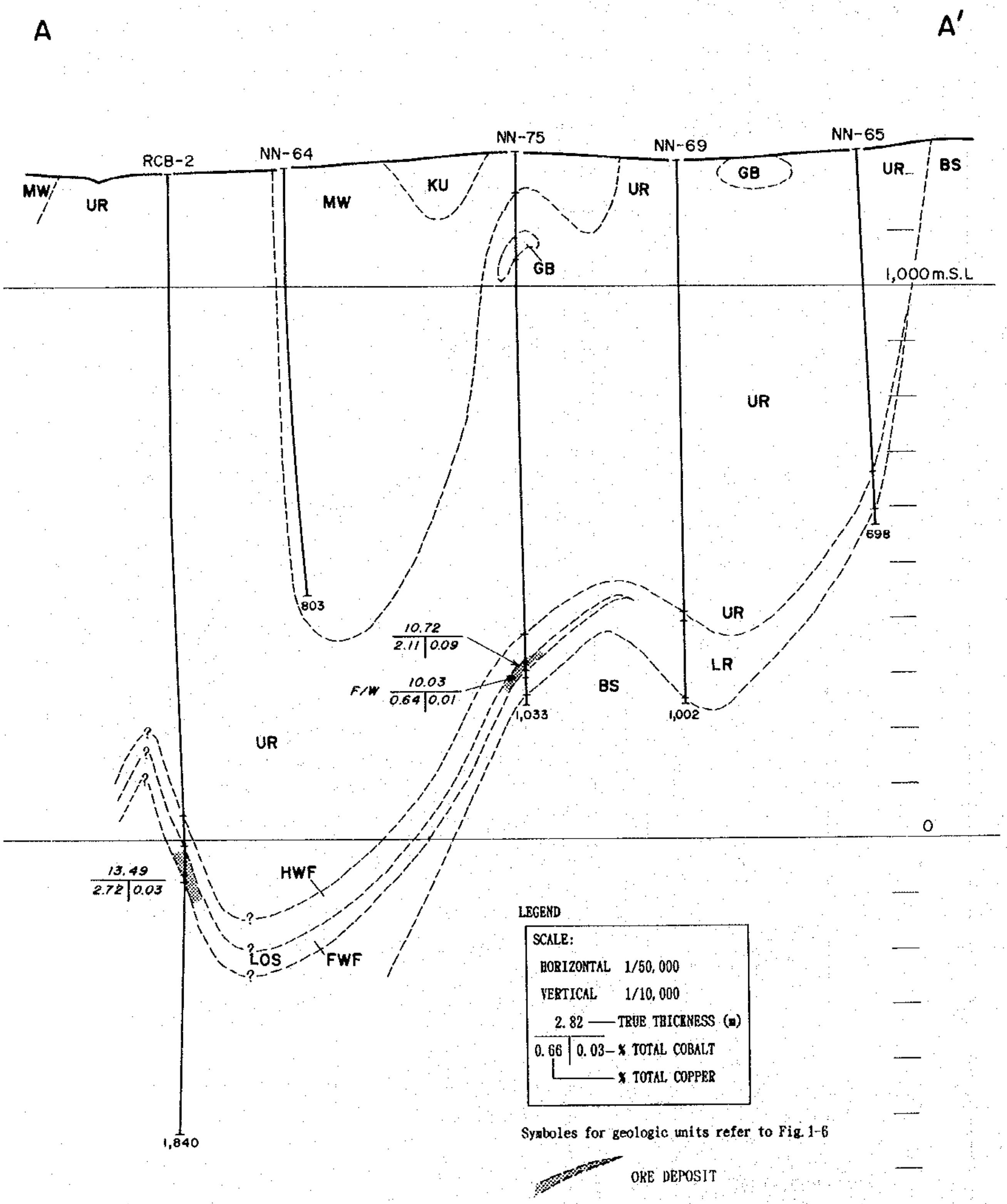


Fig.1-7 Geological Profiles of the Chambishi Southeast Area (1)

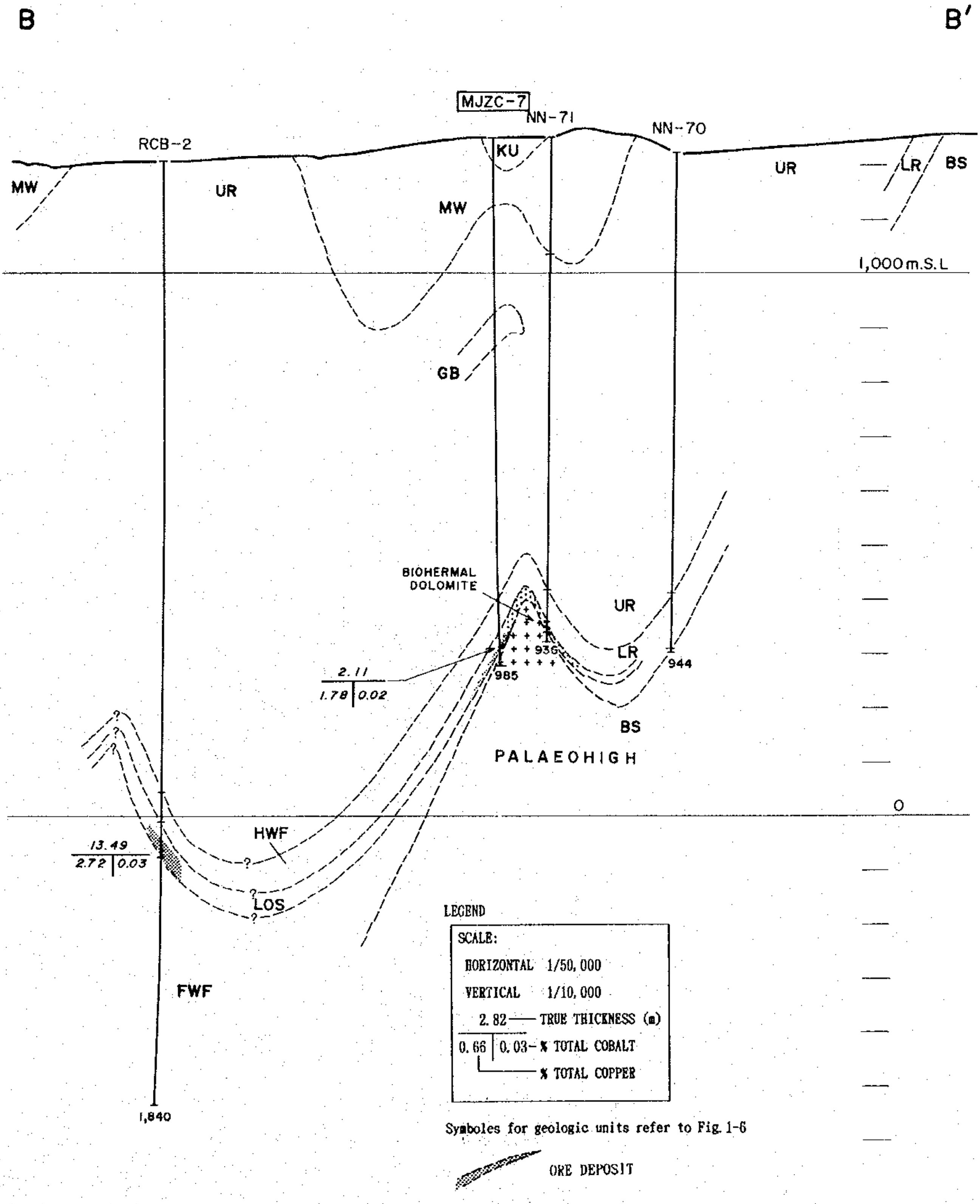


Fig.1-7 Geological Profiles of the Chambishi Southeast Area (2)

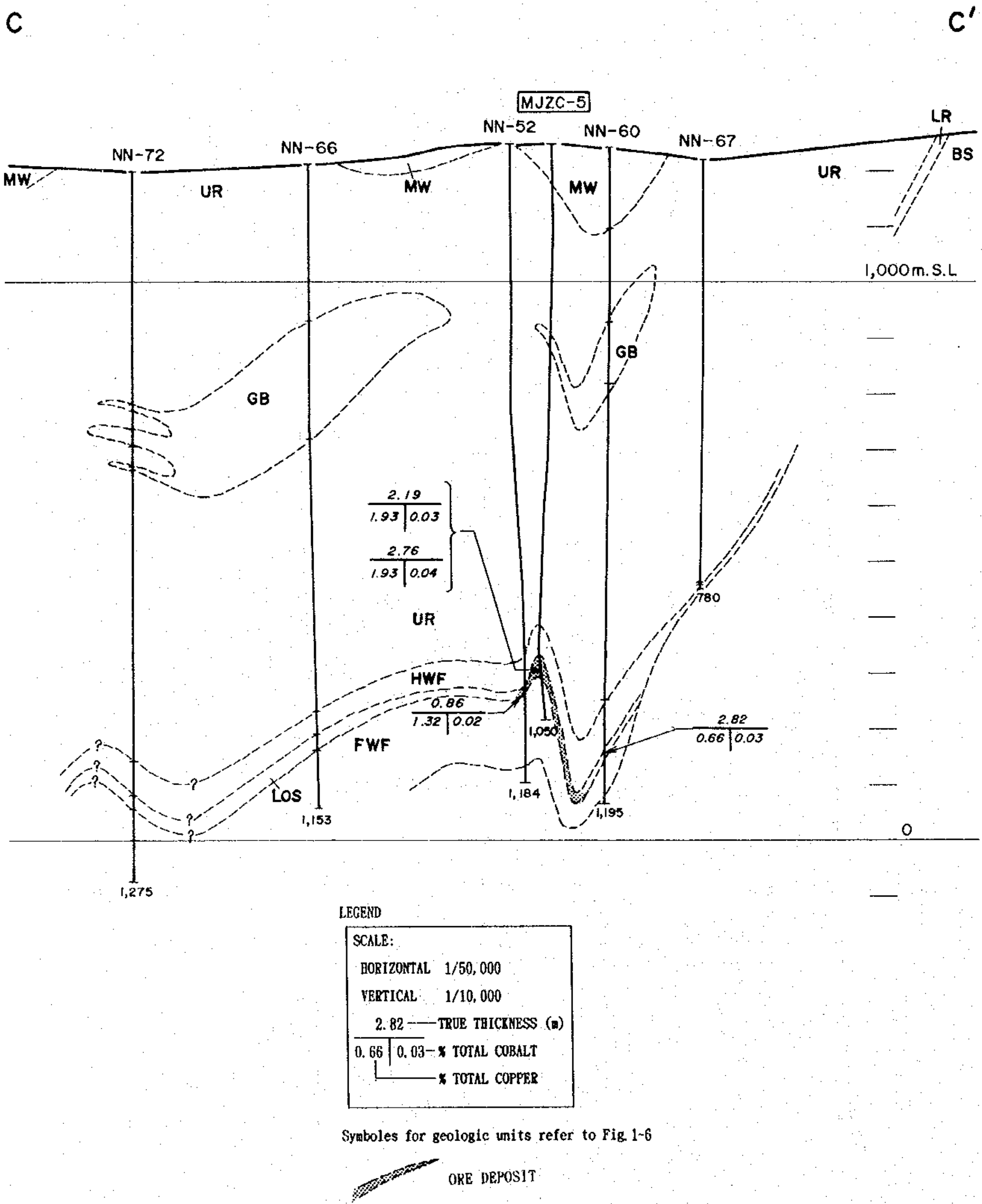


Fig.1-7 Geological Profiles of the Chambishi Southeast Area (3)

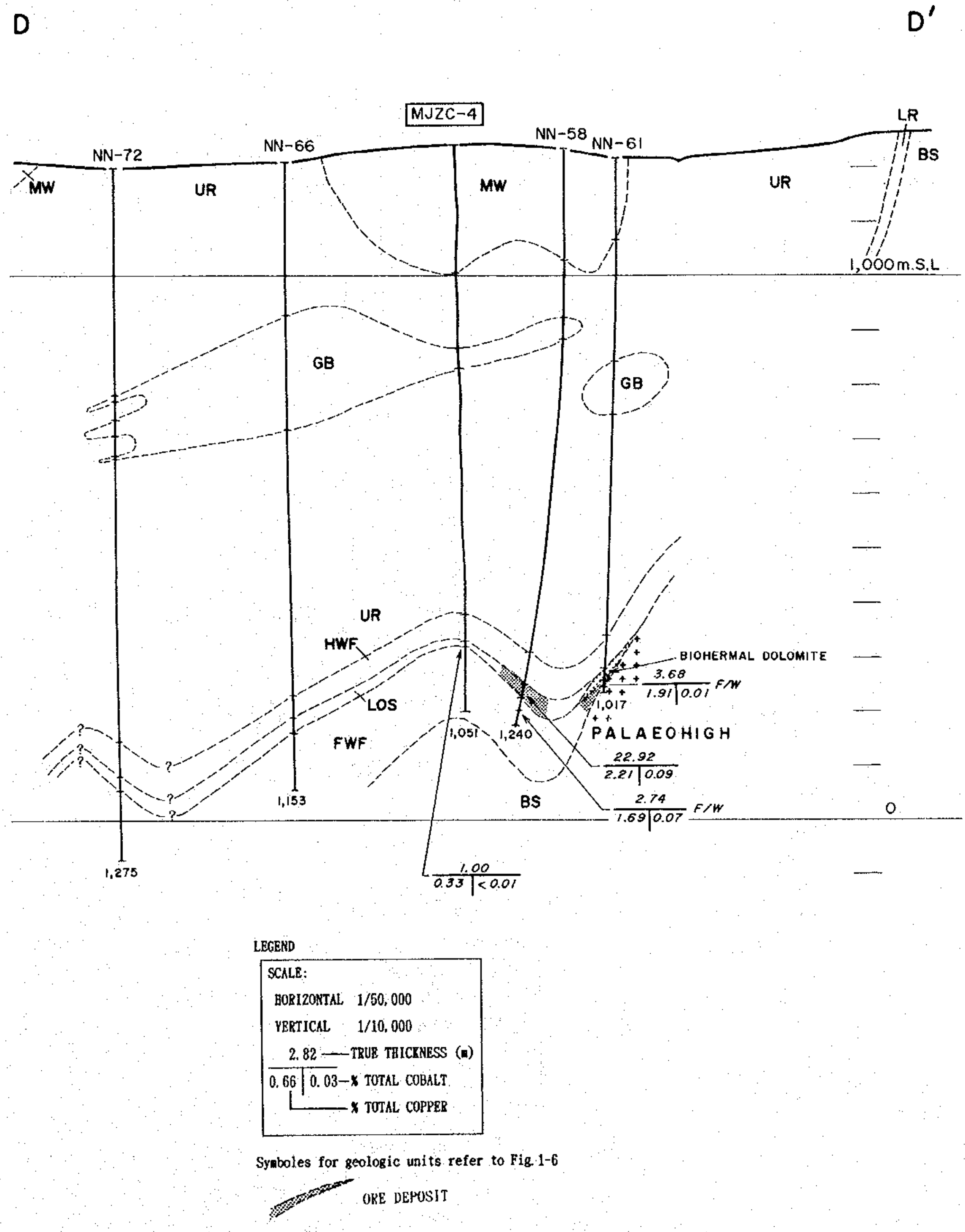


Fig.1-7 Geological Profiles of the Chambishi Southeast Area (4)

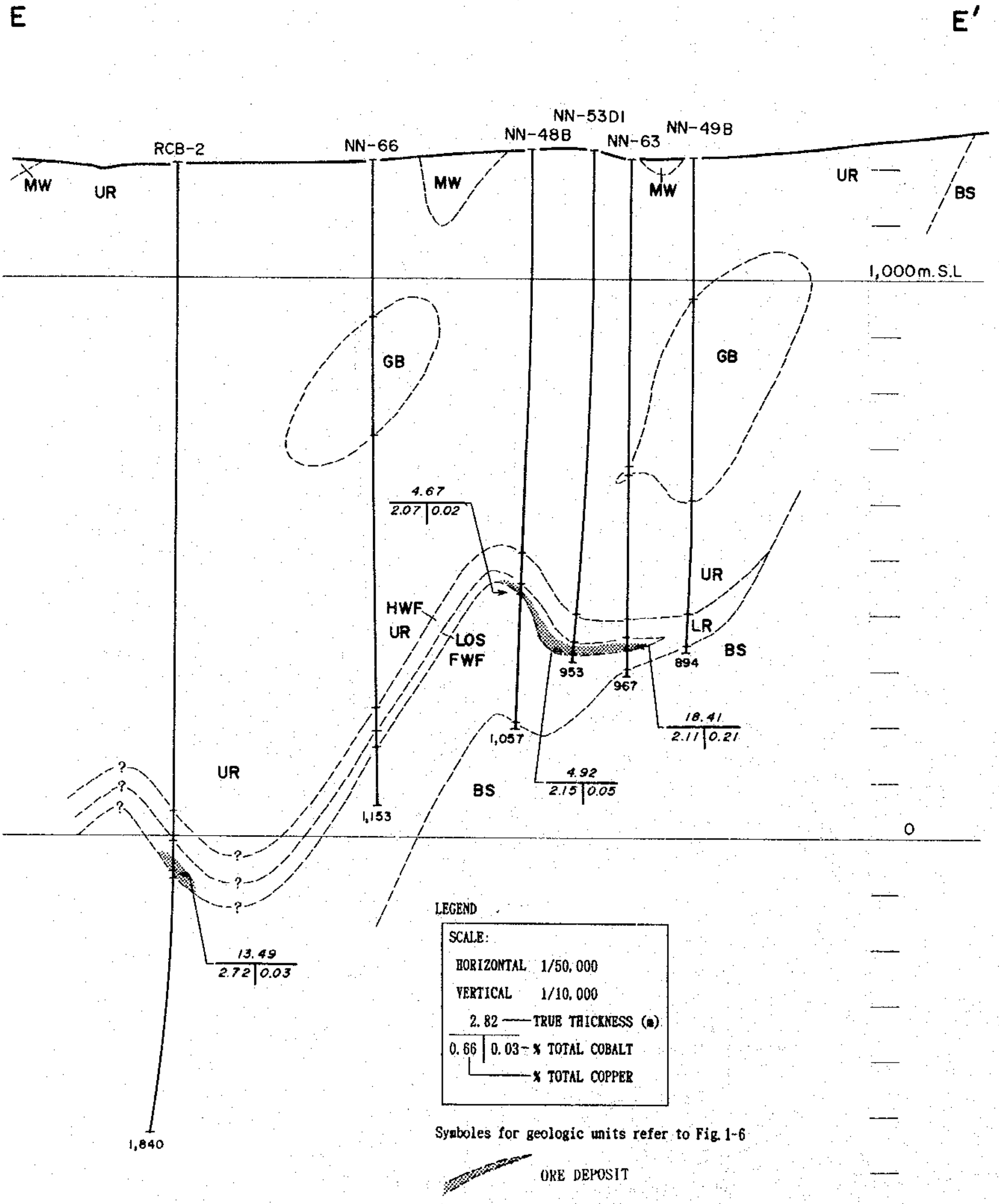


Fig.1-7 Geological Profiles of the Chambishi Southeast Area (5)

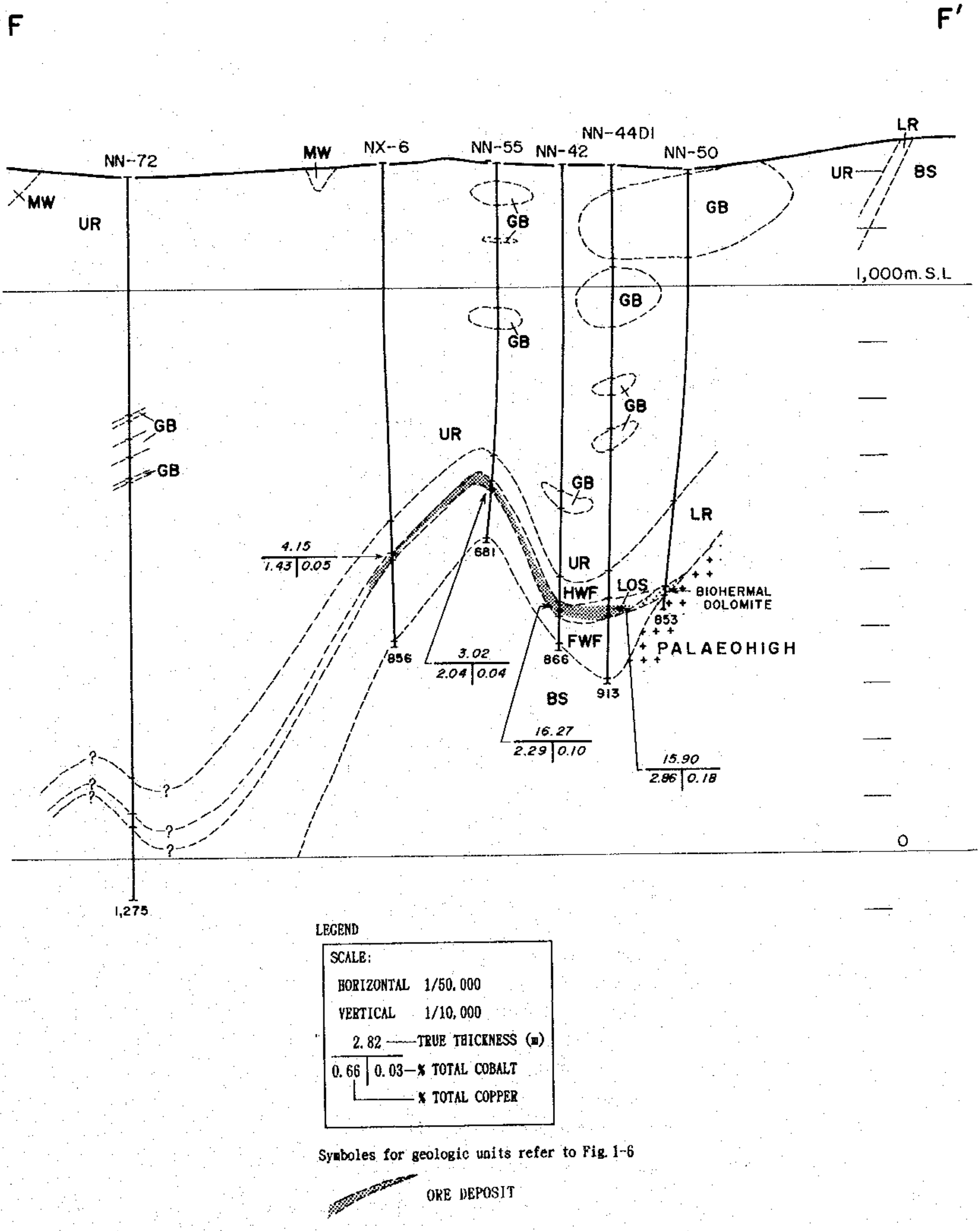
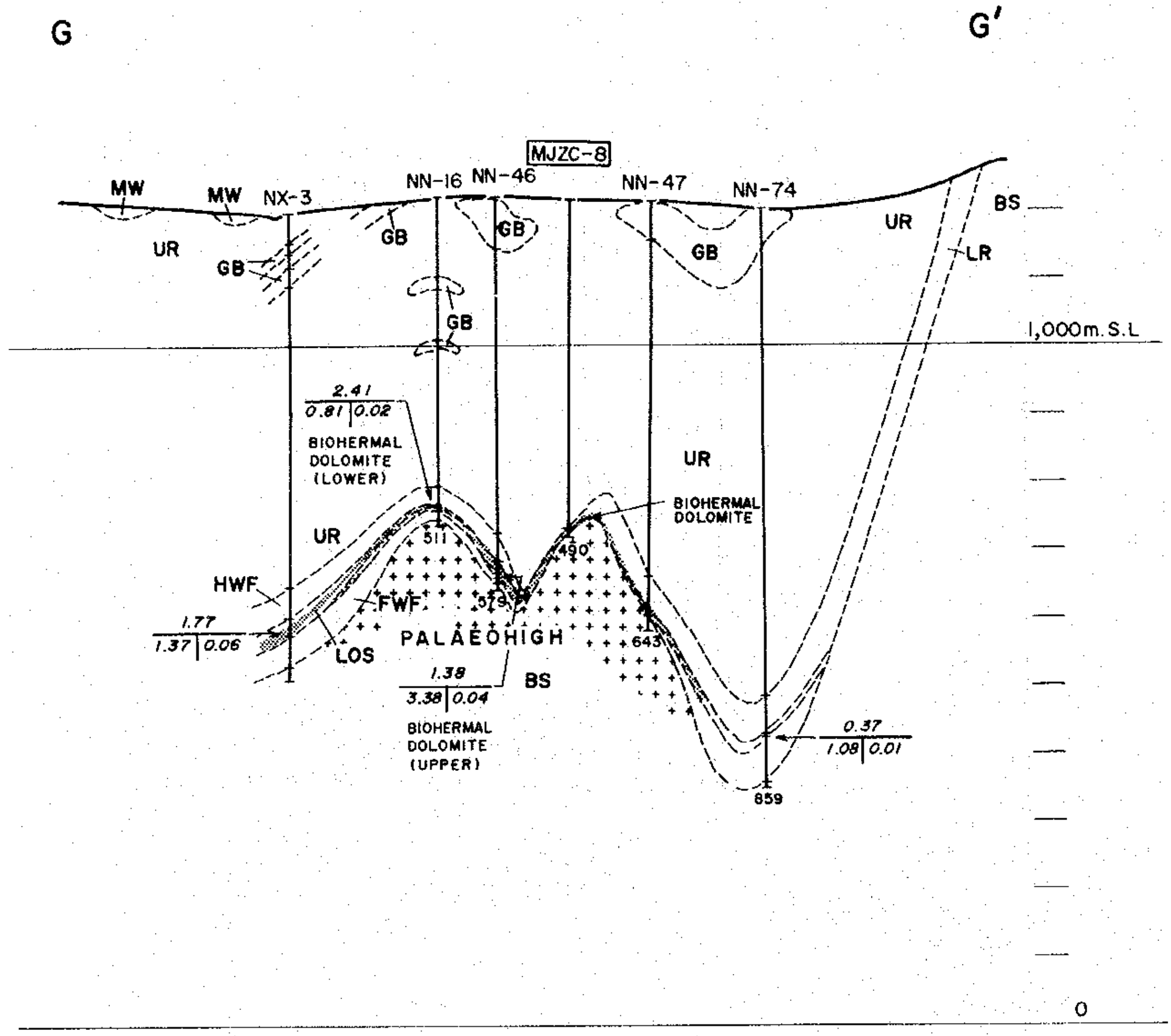


Fig. 1-7 Geological Profiles of the Chambishi Southeast Area (6)



LEGEND

SCALE:

HORIZONTAL 1/50,000

VERTICAL 1/10,000

2.82 —— TRUE THICKNESS (m)

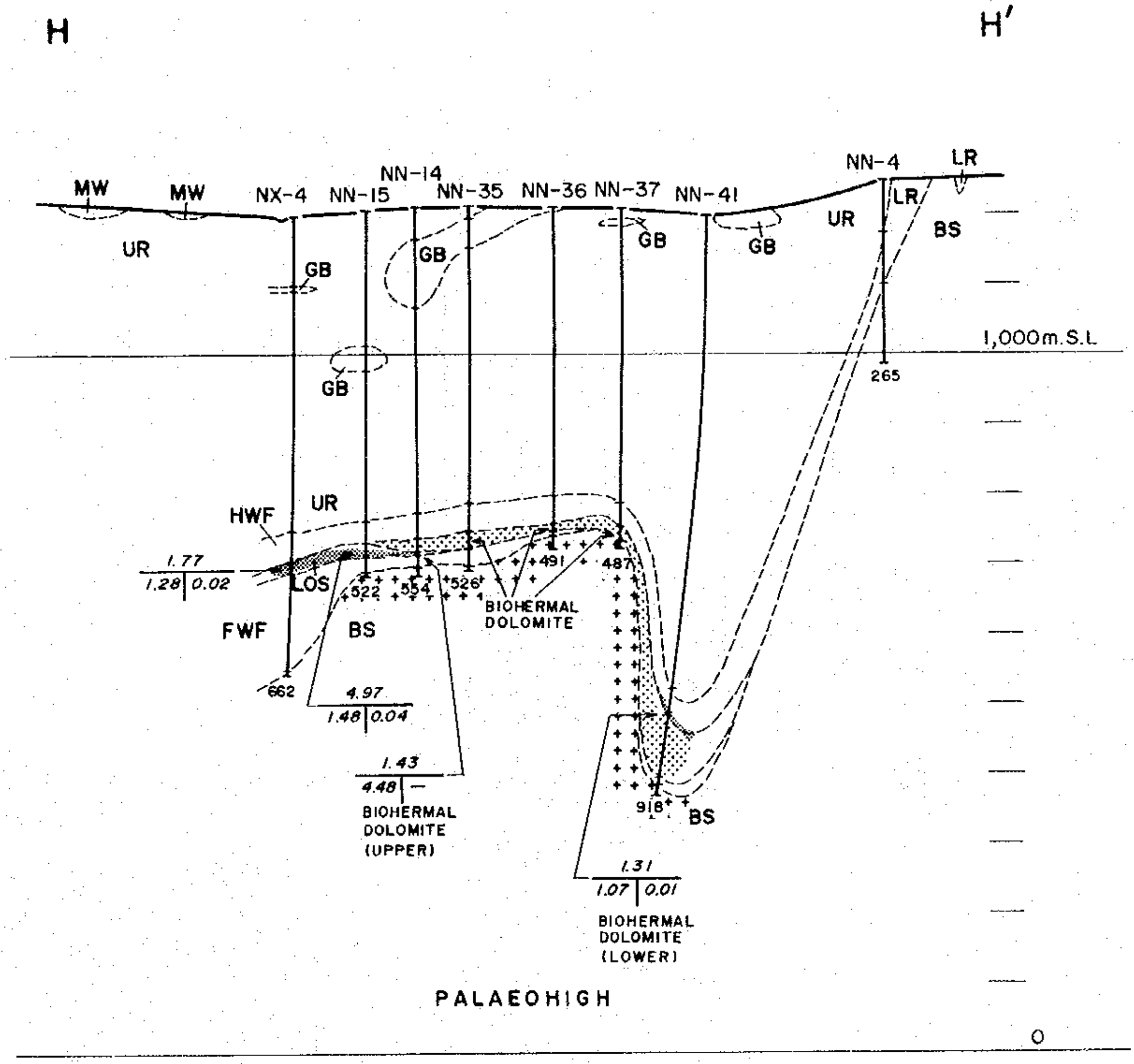
0.66 | 0.03 — % TOTAL COBALT

└—— % TOTAL COPPER

Symboles for geologic units refer to Fig.1-6

ORE DEPOSIT

Fig.1-7 Geological Profiles of the Chambishi Southeast Area (7)



LEGEND

SCALE:

HORIZONTAL 1/50,000

VERTICAL 1/10,000

2.82 —— TRUE THICKNESS (m)

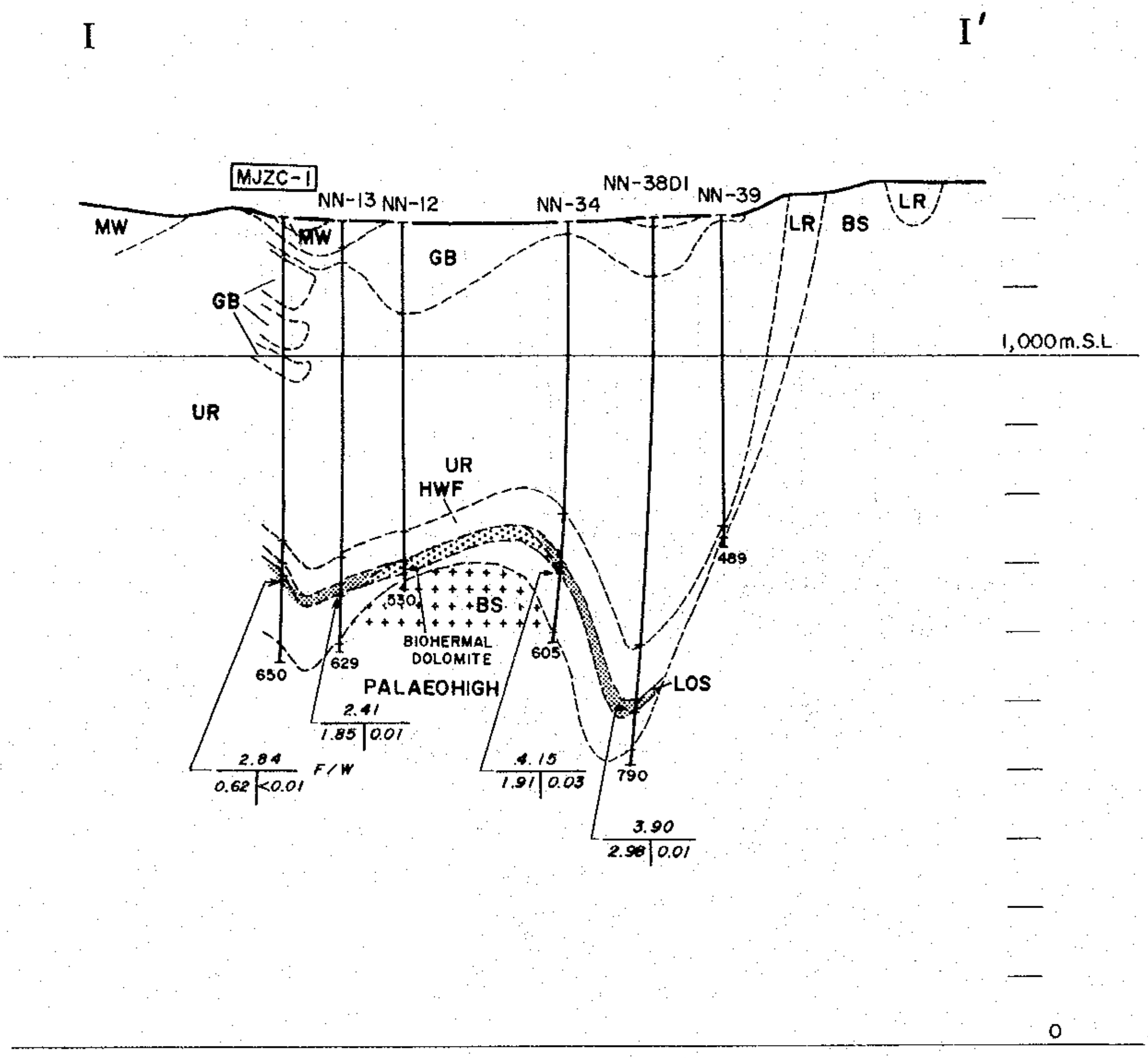
0.66 | 0.03 —% TOTAL COBALT

—— % TOTAL COPPER

Symboles for geologic units refer to Fig.1-6

ORE DEPOSIT

Fig.1-7 Geological Profiles of the Chambishi Southeast Area (8)



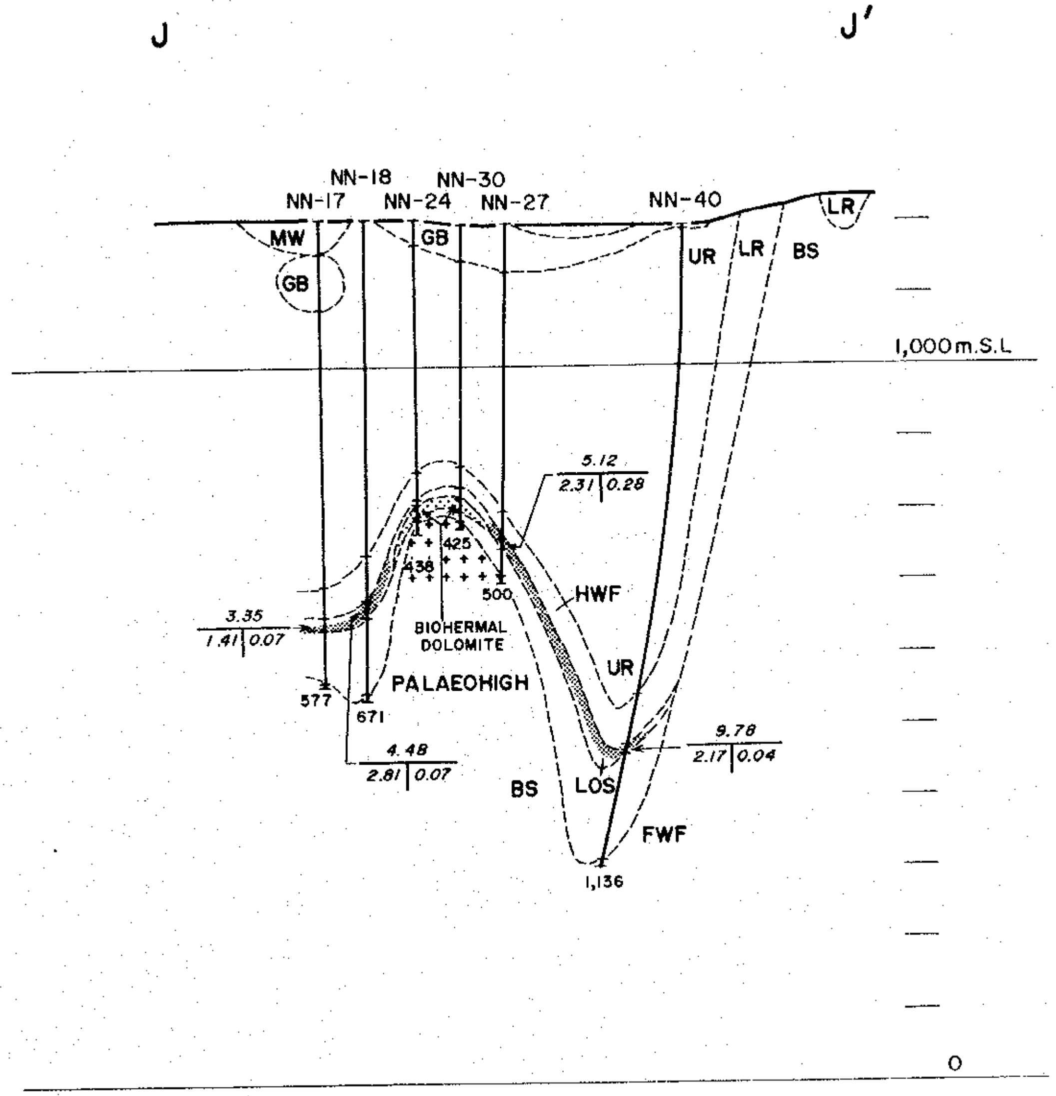
LEGEND

SCALE:	
HORIZONTAL	1/50,000
VERTICAL	1/10,000
2.82	TRUE THICKNESS (m)
0.66 | 0.03	% TOTAL COBALT
	% TOTAL COPPER

Symboles for geologic units refer to Fig.1-6

ORE DEPOSIT

Fig.1-7 Geological Profiles of the Chambishi Southeast Area (9)



LEGEND

SCALE:

HORIZONTAL 1/50,000

VERTICAL 1/10,000

2.82 — TRUE THICKNESS (m)

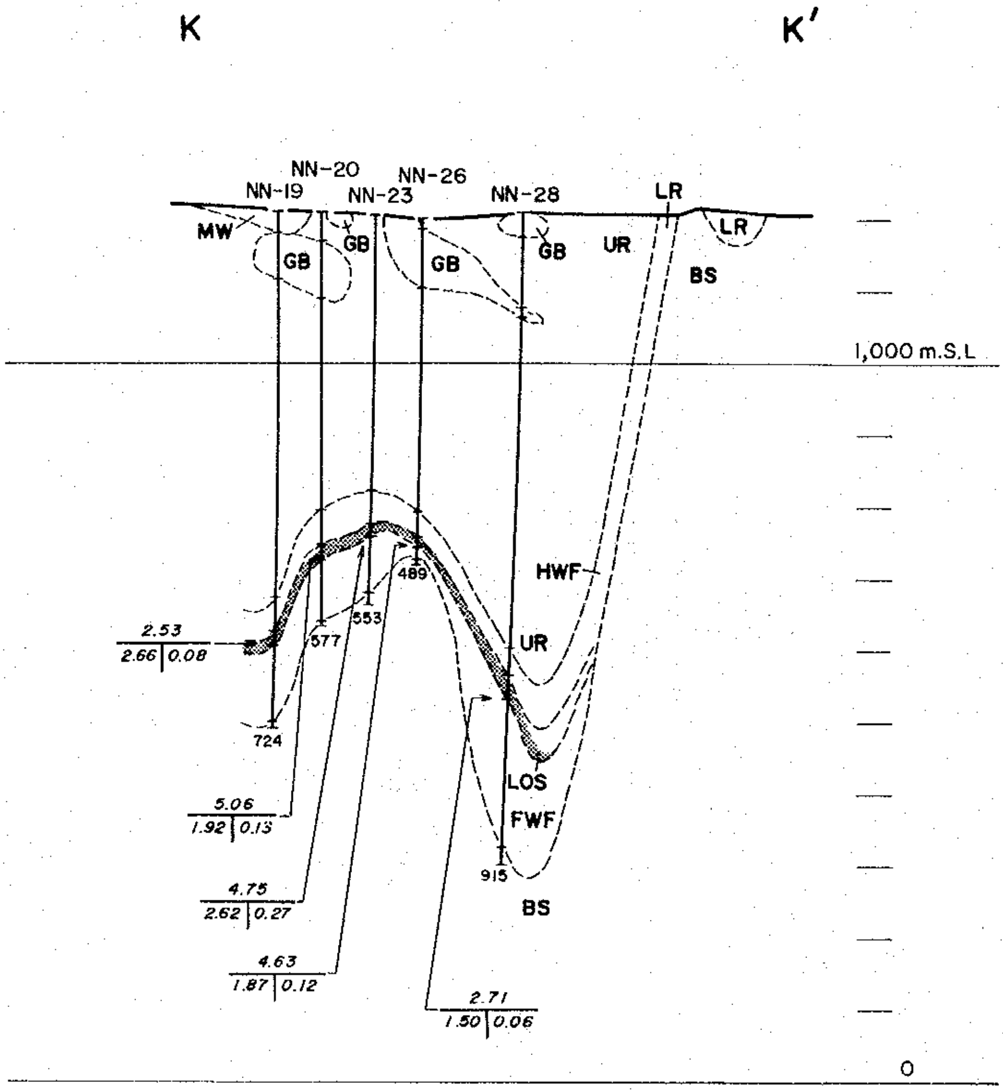
0.66 | 0.03 — % TOTAL COBALT

└── % TOTAL COPPER

Symboles for geologic units refer to Fig.1-6

ORE DEPOSIT

Fig.1-7 Geological Profiles of the Chambishi Southeast Area (10)



LEGEND

SCALE:

HORIZONTAL 1/50,000

VERTICAL 1/10,000

2.82 —— TRUE THICKNESS (m)

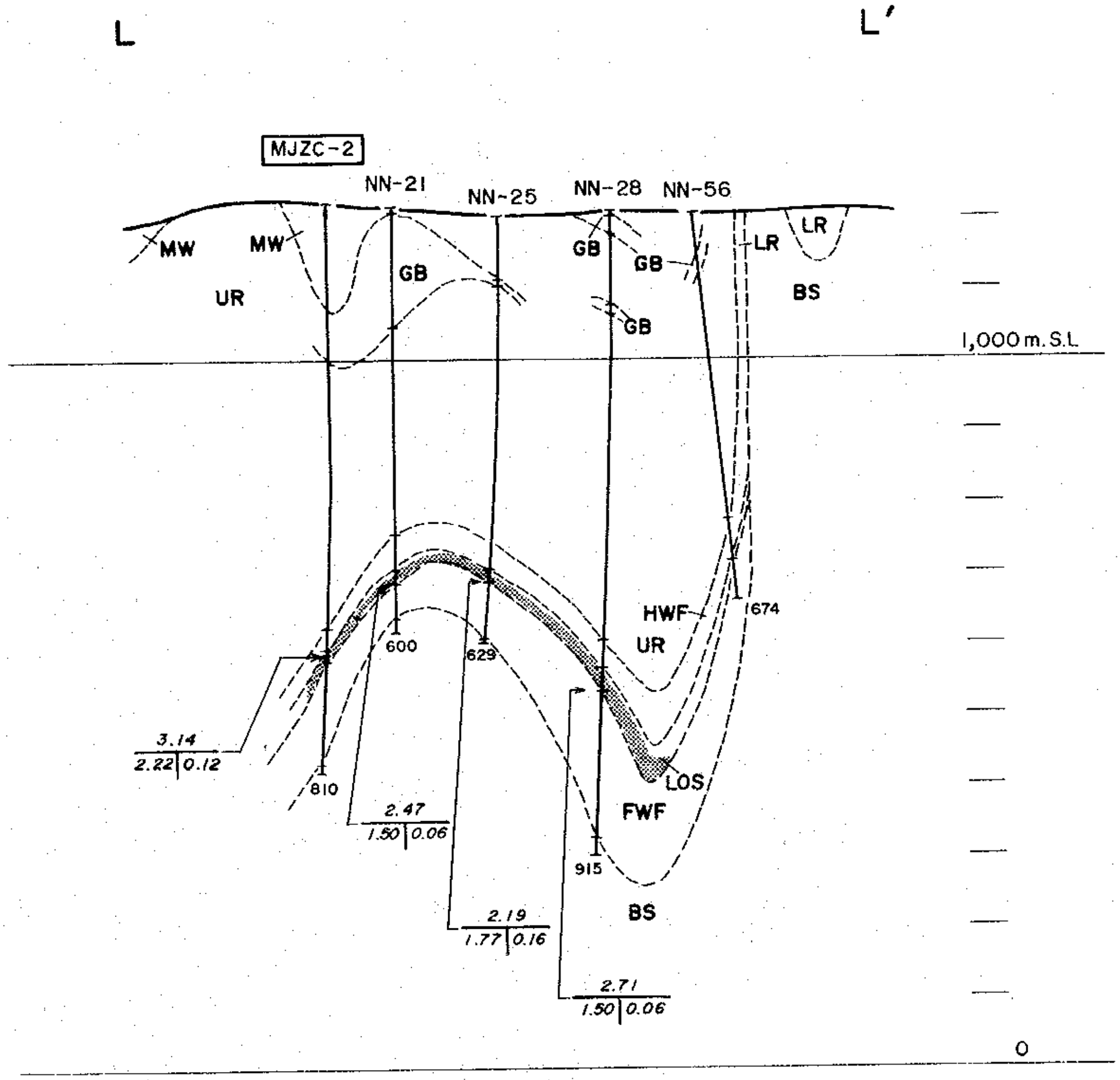
0.66 | 0.03 — % TOTAL COBALT

└—— % TOTAL COPPER

Symboles for geologic units refer to Fig. 1-6

ORE DEPOSIT

Fig.1-7 Geological Profiles of the Chambishi Southeast Area (11)



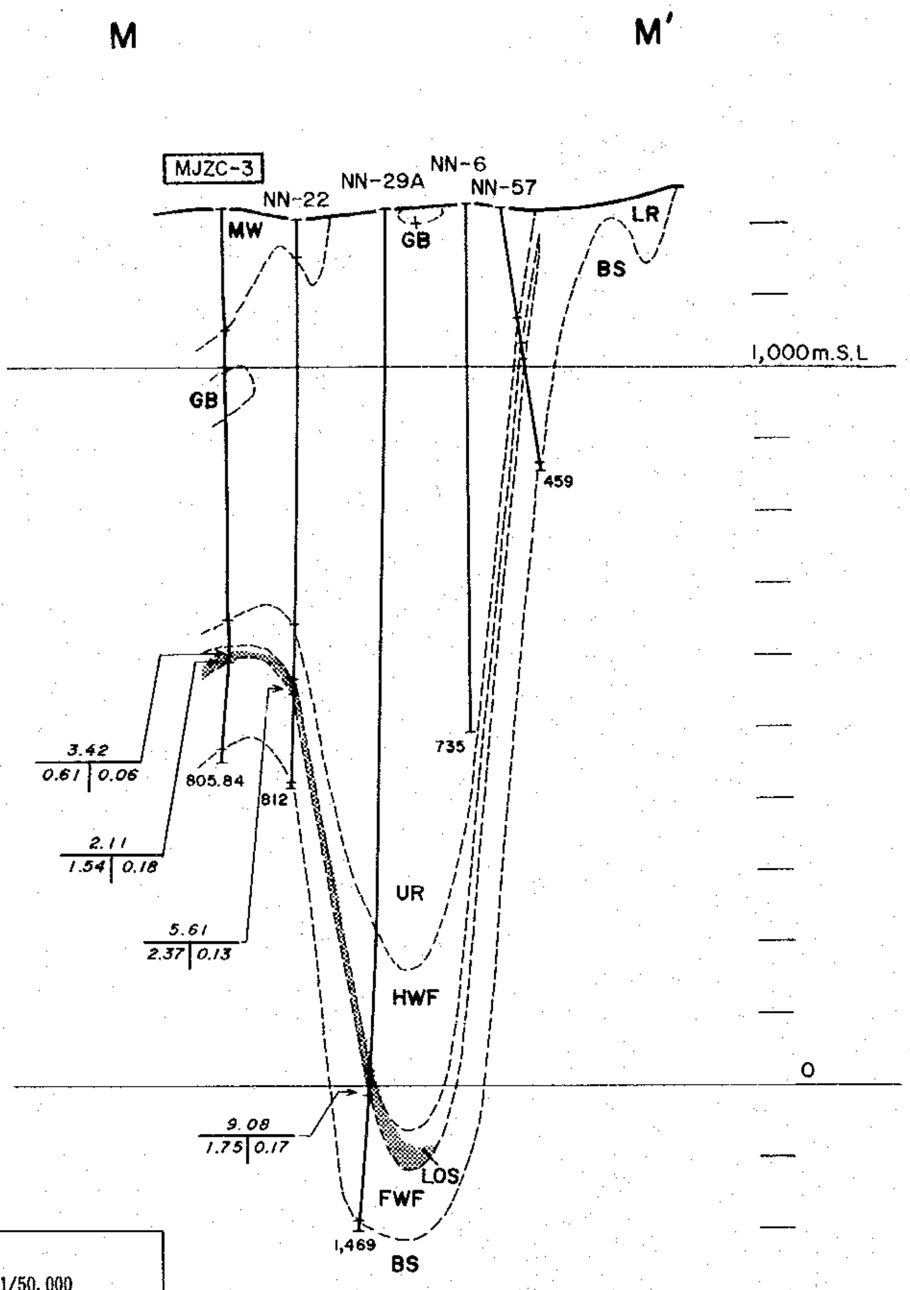
LEGEND

SCALE:
HORIZONTAL 1/50,000
VERTICAL 1/10,000
2.82 —— TRUE THICKNESS (m)
0.66 | 0.03 — % TOTAL COBALT
└—— % TOTAL COPPER

Symboles for geologic units refer to Fig.1-6

ORE DEPOSIT

Fig.1-7 Geological Profiles of the Chambishi Southeast Area (12)



LEGEND

SCALE:
HORIZONTAL 1/50,000
VERTICAL 1/10,000
2.82 —— TRUE THICKNESS (m)
0.66 | 0.03 — % TOTAL COBALT
└—— % TOTAL COPPER

ORE DEPOSIT

Symboles for geologic units refer to Fig.1-6

Fig.1-7 Geological Profiles of the Chambishi Southeast Area (13)

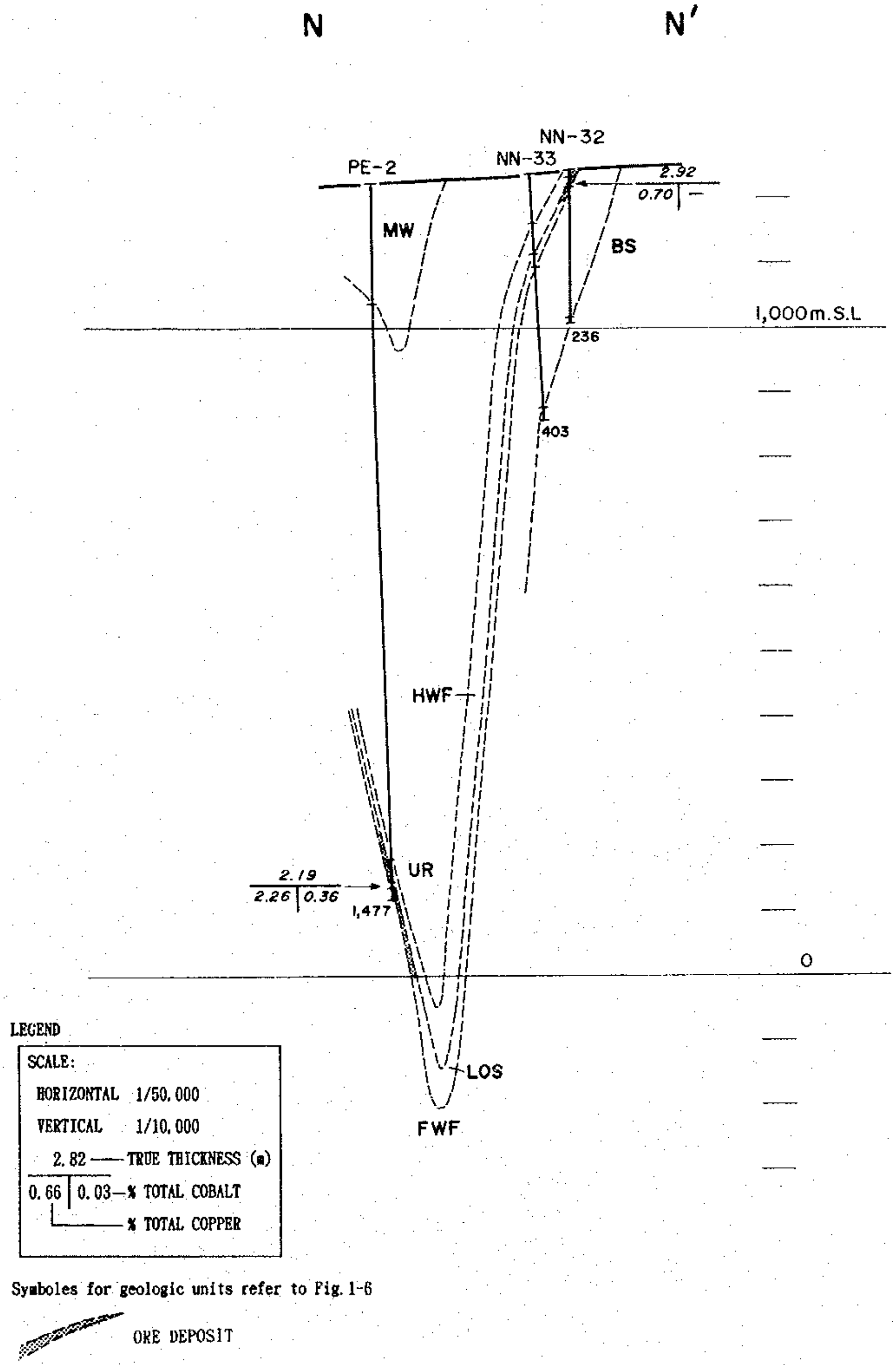


Fig.1-7 Geological Profiles of the Chambishi Southeast Area (14)

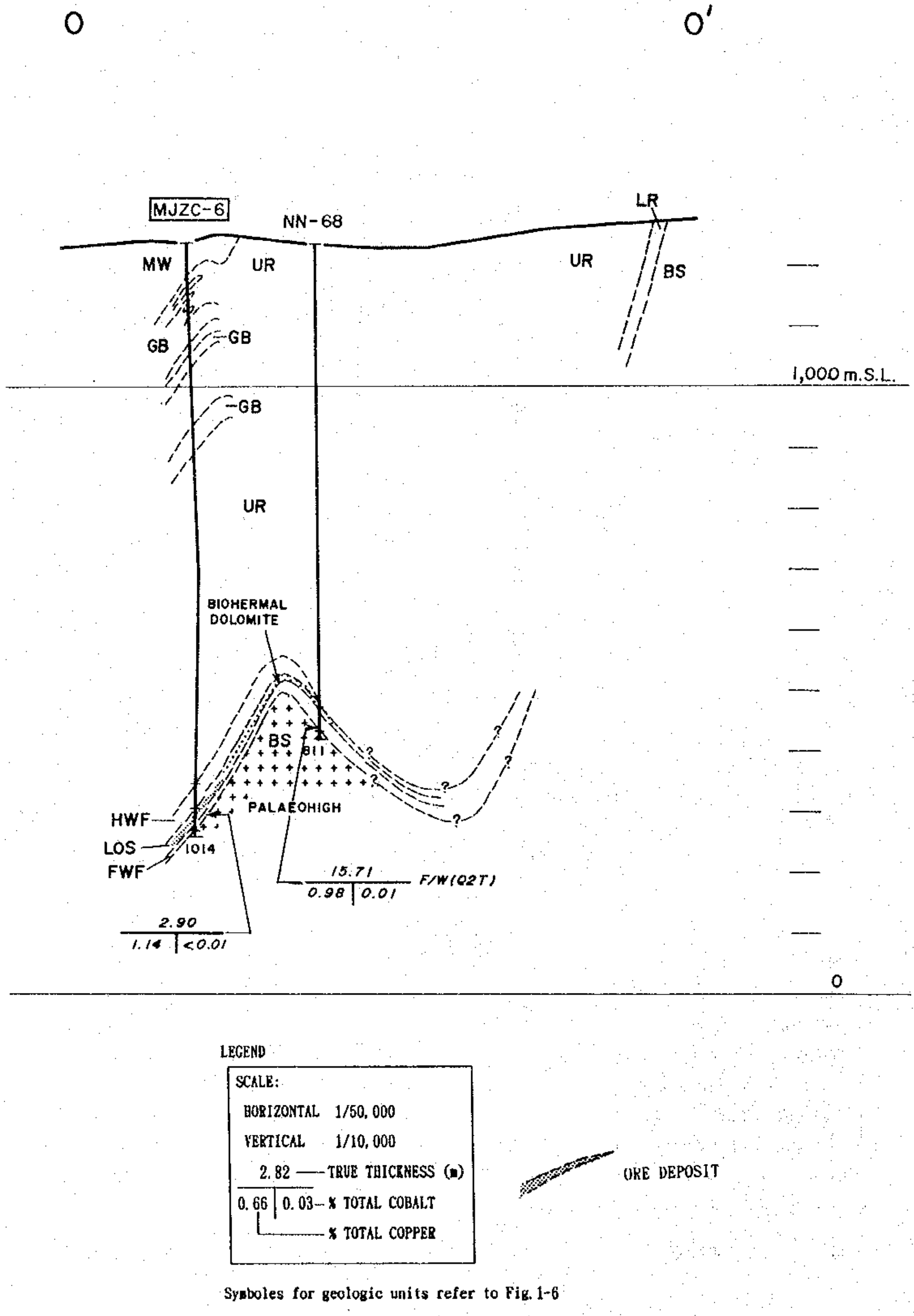
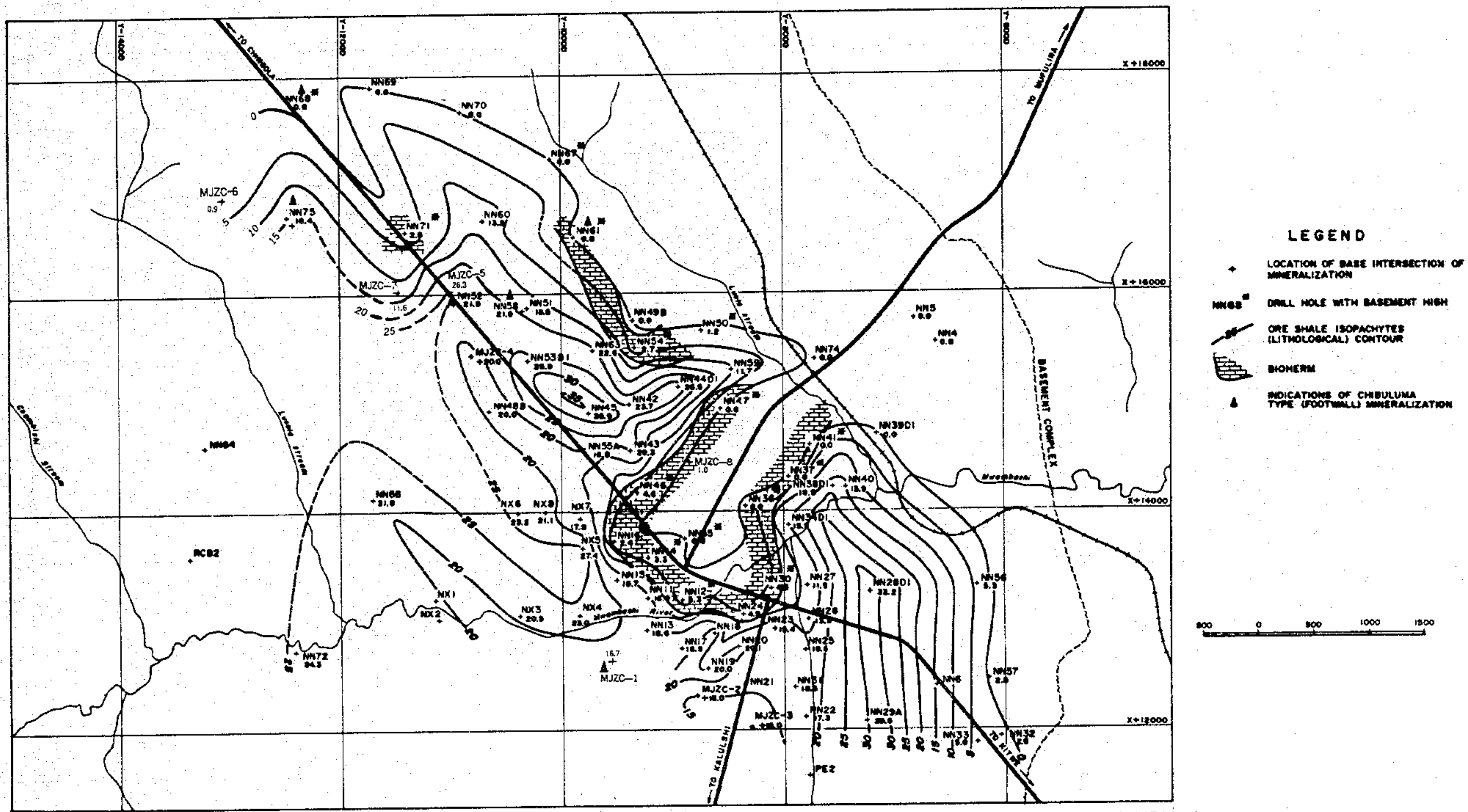


Fig. 1-7 Geological Profiles of the Chambishi Southeast Area (15)



Modified from Fleischer (1983)

Fig.1-8 Ore Shale Isopach Map

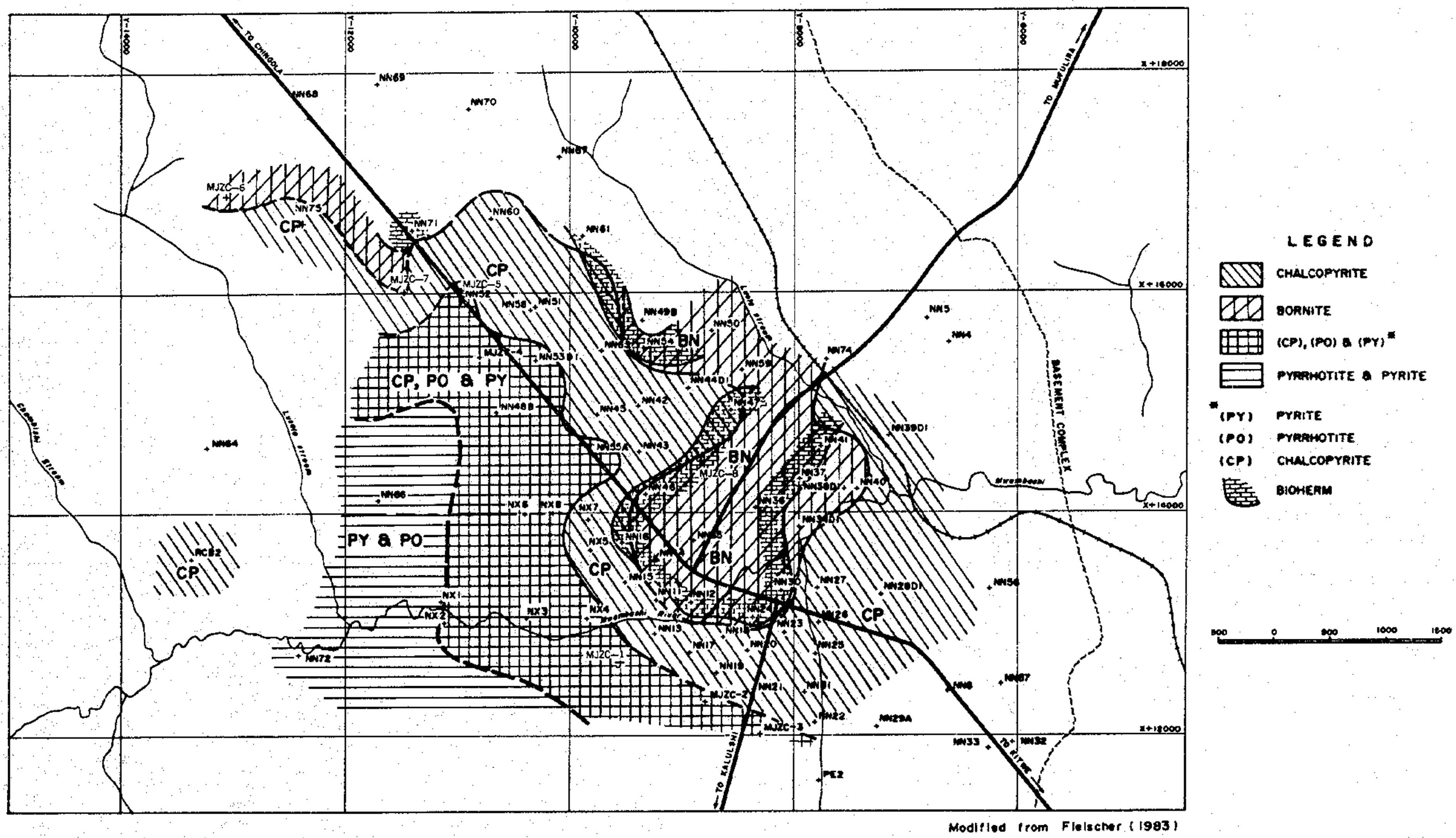


Fig.1-9 Sulphide Mineral Zoning

Geology of the survey area is composed of the Basement Complex and the Katangan Supergroup.

The Basement Complex consists of the Lufubu Schist consisting of schist and gneiss, granites intruded in the Schist, and quartzite of the Muva Supergroup. Schist, gneiss and quartzite are mainly composed of quartz and biotite with subordinate feldspar and chlorite. The granites are mainly composed of quartz, feldspar and biotite.

The Katangan Supergroup is divided into the Lower Roan, Upper Roan, Mwashia and Kundelungu Groups in ascending order and gabbroic sill, the every Group being conformable to each other.

The Lower Roan Group unconformably overlies the Basement Complex, and comprises "Basal Conglomerate", "Feldspatic Quartzite and Grits", "Intermediate Conglomerate", "Footwall Quartzite", "Footwall Conglomerate", "Ore Shale Horizon", "Hangingwall Quartzite and Argillite", "Interbedded Argillite and Quartzite" and "Upper Quartzite" in ascending order. Of these, units lower than the "Ore Shale Horizon", the Horizon itself and units higher than the Horizon are called the "Footwall", "Ore" and "Hangingwall" Formations, respectively.

"Ore Shale Horizon" is made up of argillite and/or dolomite. Because of the presence of stromatolite in the dolomite, the dolomite-dominated part has been considered to be bioherm.

The Upper Roan Group is divided into "Interbedded Argillite, Dolomite and Quartzite", "Cherty Dolomite", "Arenite, Argillite and Dolomite with Anhydrite" and "Interbedded Argillite and Dolomite with Tectono-Breccias" in ascending order. Of these, "Cherty Dolomite" has an intercalation of argillite (Marker bed), and is treated as a key bed.

The Mwashia Group is mainly composed of black shale, green argillite and dolomite.

The Kundelungu Group consists of tillite comprising many kinds of erratic boulders (mainly argillite, dolomite and quartzite; rarely granite and quartz vein) at the basal part, and the upper limestone. It is correlated to the Lower Kundelungu Group.

Gabbro is usually present as sill in the Upper Roan Group, and is considered to have been intruded at the early stages of the Lufilian Orogeny (Mendelshon, 1961). Most of the gabbroic bodies in this area are called amphibolite because of the lack of pyroxene and olivine, and are mainly composed of plagioclase, hornblende, quartz and scapolite (in part) with subordinate epidote, apatite, sphene, biotite and chlorite. By the intrusion of the gabbro, argillite and dolomite were metamorphosed to hornfels and also to chloritized and silicified rocks (called "Hybrid Rocks"). On the other hand, typical skarn minerals do not occur in the carbonate rocks near the gabbroic bodies.

The Katangan Supergroup and Basement Complex in the survey area were regionally metamorphosed to greenschist facies. The metamorphism is considered to have occurred during the Lufilian Orogeny. The Lufubu Schist of the Basement Complex has been metamorphosed to a higher degree than the Katangan Supergroup, and its major constituents are biotite and sericite. Banded structure has been developed in this unit. Metamorphic minerals generally observed in the Katangan Supergroup are biotite, chlorite, tremolite, talc, sericite and albite.

The survey area is located in the northeastern margin of the Chambishi Basin on the southwestern limb of the Kafue Anticline. The strata of the Basin are folded and, on the whole, they tilt gently toward the centre of the Basin with an overall angle of about 10°. Folded structure with E-W trending axis occurs in the western part of the survey area, and WNW-ESE to NNW-SSE trending folds in the southern part.

In the Basin, the Basement Complex which forms the Kafue Anticline, is generally tilted to the southwestern side. But the Complex is partly undulating, and basement highs occur in the central part (around the junction of the Chingola-Kitwe main road and the Mufulira road) and the northwestern part of the survey area. In parts between these basement highs, local basins extending in the NW-SE direction are formed. A trough extending in an N-S direction is present to the east of the central basement high (Figs. 1-7 and 1-10).

Dolomite-dominated zones (bioherm) in the Ore Shale Horizon occur on the above basement highs and on local basins and troughs formed at the limbs of the basement highs (Fig. 1-7).

The formations of the Lower Roan and Upper Roan Groups above the basement have folded structures harmonious with relief of the basement, but they abut on the basement at the limbs of the Kafue Anticline in the northeastern part of the survey area, and also at the sides of the basement highs in the Chambishi Basin (Fig. 1-7).

The thick parts of argillite in the Ore Shale Horizon coincide with the above local basins and troughs on the basement (Fig. 1-8).

Ore deposits confirmed by drilling in the survey area, are shale-type copper deposits, typical of the Copperbelt. Occurrence of the ore deposits is as follows.

(1) Shape of ore deposit: One deposit (Northern Area Shoot) occurs on the northwestern limb of the basement high located in the central part of the survey area, two deposits (Southern Area Shoot-I and II) are on the southeastern limb, and two holes (NN-75 and RCB-2) caught high-grade ores in the western part of the survey area (Fig. 1-3). The deposits are bedded and occur in the Ore Shale Horizon. These are folded conformably to the host rocks. Size of the Northern Area Shoot is 5 to 23 m in thickness, over 2.5km along strike and about 1.5 km along dip. Size of the Southern Area Shoot-I is 5 to 10 m in thickness, about 1.5 km along strike and about 0.5 to 1.3 km along dip. Size the Southern Area Shoot-II is 5 to 9 m in thickness, over 0.5 km along strike and about 1.5 km along dip. These ore deposits have one ore horizon, but chalcopyrite-mineralized zones are present in the Footwall Quartzite at NN-58, NN-61, NN-63 and NN-68 of the Northern Area Shoot and its vicinity, and under the basal part of the Ore Shale at NN-75.

(2) Host rocks: Argillite and dolomite.

(3) Alteration of host rocks: Biotitization, sericitization and silicification are recognized. However, relation between these alteration and mineralization is not clear.

(4) Ore minerals: Pyrite, chalcopyrite, bornite, chalcocite, pyrrhotite, carrollite and cobalt pentlandite occurs as major primary minerals. Cobaltian pyrite, linnaeite and cattierite

occurs as rare primary minerals. Most of copper are from chalcopyrite, but fair amount of bornite also exists. Most of cobalt are from carrollite, but cobalt pentlandite cannot be ignored.

(5) Gangue minerals: Dolomite, calcite, mica, quartz, feldspar and tourmaline are present as gangue minerals. Large amount of tourmaline is characteristic of this belt. The increase of sulfur in "Ore Shale horizon" and the presence of organic carbons after deposition of the Ore Shale are noted.

(6) Zoning of sulfide minerals: The following transition of mineral assemblage can be seen from the northeast to the southwest (away from basement areas); bornite chalcopyrite chalcopyrite-pyrrhotite-pyrite pyrite-pyrrhotite. The occurrence of bornite coincides roughly with that of bioherm (Fig. 1-9).

(7) Occurrence of ore: The ores of the survey area have the typical characteristics of the Zambian Copperbelt deposits. The Fe-Cu-Co sulfide minerals are concentrated along bedding planes. Main occurrences of ore minerals are as follows.

- Thin concretion along bedding plans.
- Segregation parallel to bedding planes.
- Dissemination in host rocks.
- Rim of spotted dolomitic concretions.
- Inclusions in siliceous and dolomitic lenticular concretions.
- Irregular veinlets.

Breccia dike and convoluted lamination formed by liquefaction are observed in these ores, and the former is accompanied by chalcopyrite-spotted ores. Also dolomite, anhydrite, quartz and feldspar veins are present in the orebodies.

In addition to the above main mineralization, the following mineralization is recognized.

- Dissemination of chalcopyrite and pyrite in "Interbedded Argillite and Quartzite" of the Hangingwall Formation.
- Molybdenite at the basal part of "Cherty Dolomite" of the Upper Roan Group (NN-30).
- Micro-spotted chalcopyrite parallel to the bedding planes of "Cherty Dolomite".
- Chalcopyrite-pyrite-mica-dolomite-quartz veinlets and chalcopyrite dissemination developed partly in argillites of "Arenite, Argillite and Dolomite with Anhydrite" of the Upper