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

PHASE I

FEBRUARY 1994

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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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 the Japan International Cooperation Agency (JICA). JICA entrusted the survey to the 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 first-phase of a three-phase project to be compiled in 1995, MMAJ sent Mr. Masaaki SUGAWARA, a geologist, to the Republic of Zambia from November 11, 1993 to February 17, 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 first-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 Japanese Embassy in Zambia and the authorities concerned for the close cooperation extended to the team.

February 1994

Kensuke Yanagiya

Kensuke YANAGIYA
President
Japan International Cooperation Agency

Takashi Ishikawa

Takashi ISHIKAWA
President
Metal Mining Agency of Japan

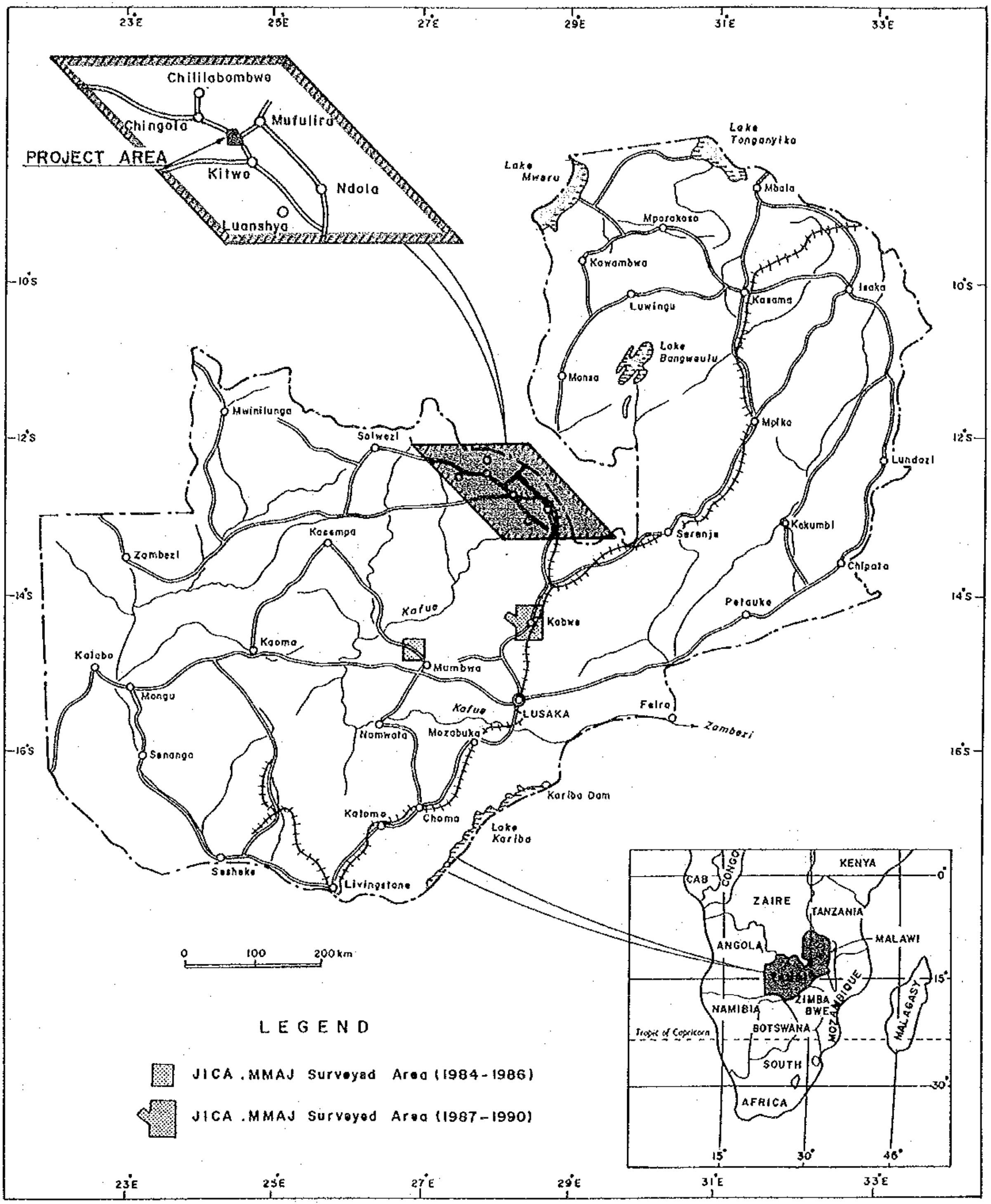

Fig.1-1 Index Map of the Project Area

SUMMARY

The first-phase survey of the Chambishi Southeast area comprised drilling, and compilation 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. Also, these holes were drilled to the basement or its proximity, and revealed relevant new information regarding the geology and mineralization of the project area. Particularly, MJZC-2 drilled in the southern part of the area 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.

2. 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 usually contains low grade ore bodies or is barren. 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.

3. 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 primary orebodies deposited over the tops and limbs of the palaeo-basement highs may turn out to be rich orebodies where the overlying gabbroic bodies are thin.

4. The mode of occurrence of the rich orebodies indicate that diagenesis and metamorphism played important roles in the formation of ore shoots.

5. The localities with possibility of locating new deposits 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, has not been prospected sufficiently, and drilling along the periphery of the deposits is necessary to clarify the areal extent of the deposit.

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.

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PART Ⅰ OVERVIEW

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.

1-2 Outline of the First Phase Survey

1-2-1 Survey Area

There is an arc-shaped zone extending in the NW-SE to E-W (12°15′S to 13°15′S) 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 Copper Belt between the Chambishi and Mindolo 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 km^2)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 three hours by car.

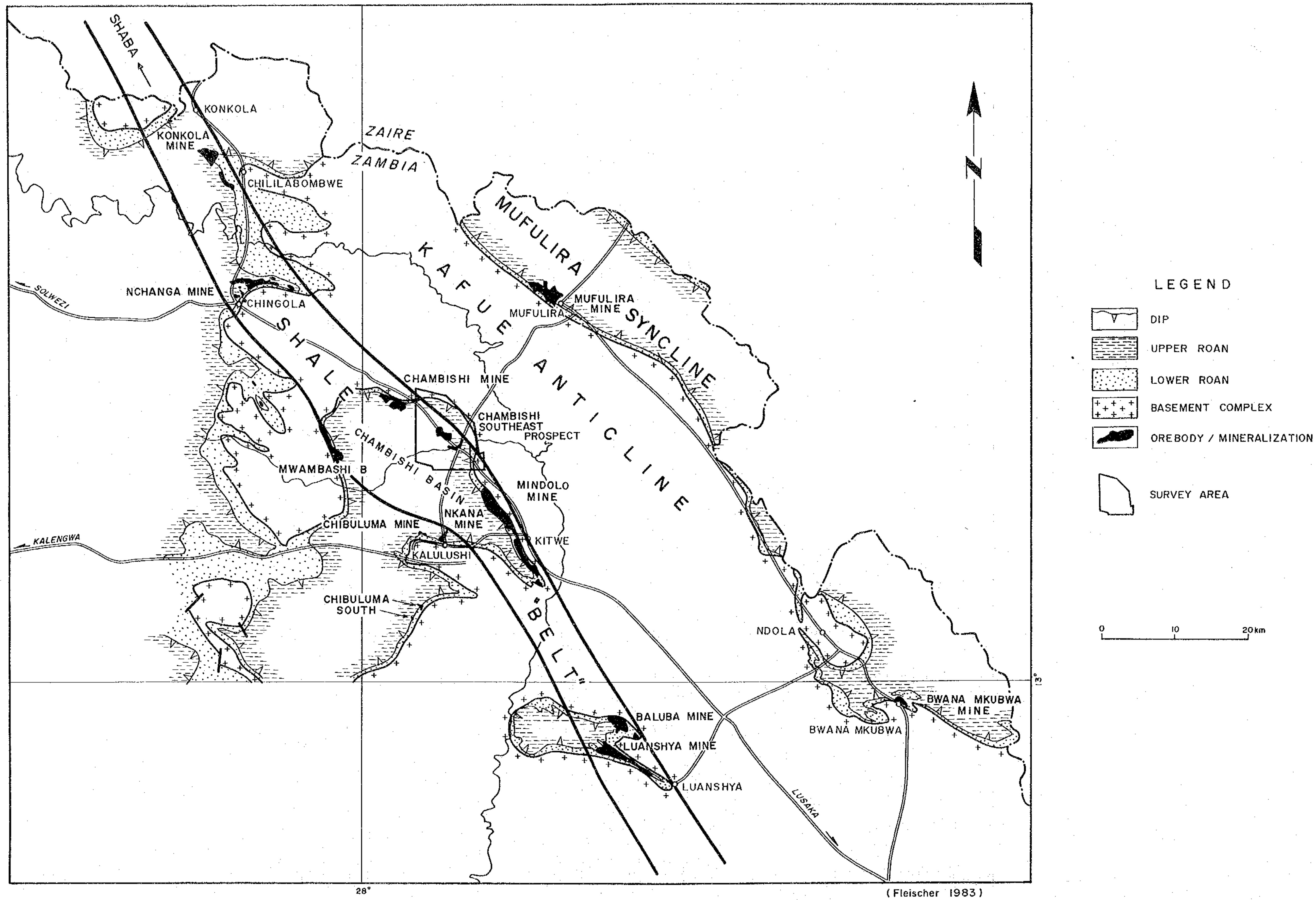


Fig.1-2 Copperbelt Index Plan

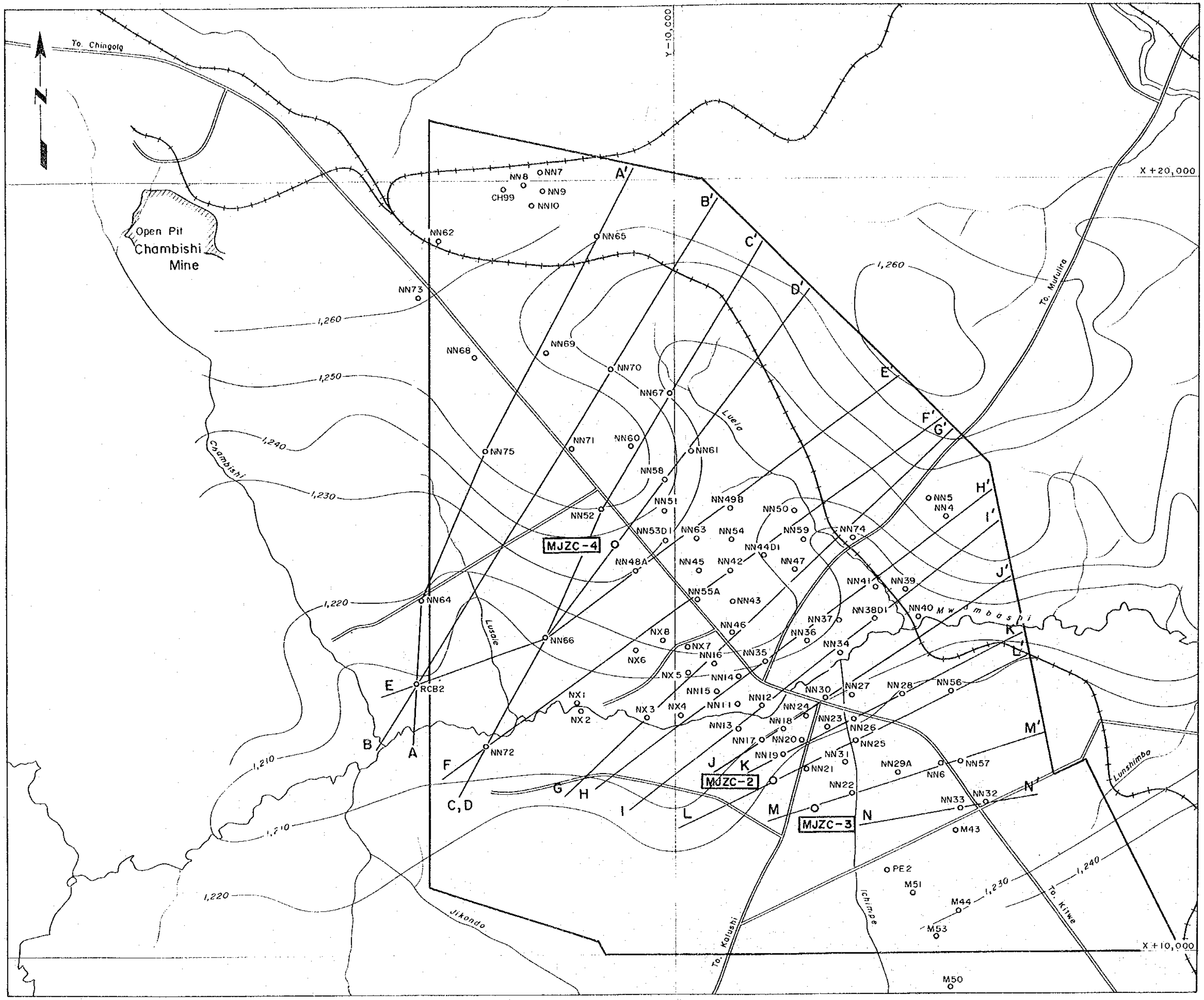


Fig. 1-3

Location Map of Drill Holes with Geological Section Lines

1-2-2 Objective of the Survey

The objective of the first-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.

1-2-3 Survey Methods

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

(1) Main Objective

The main objective is to confirm the extension of known ore deposits and to clarify the state of copper mineralization in the unexplored parts of the survey area.

(2) Localities of Holes and Details

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

Hole No.	Hole Length	Inclination	Azimuth
MJZC-2	810.00 m	-90°	—
MJZC-3	805.84 m	-90°	—
MJZC-4	1,051.00 m	-90°	—
Total	2,666.84 m		

(3) Field Work

1) Drilling machine with capacity in excess for the drilling length planned was used because it could have become necessary to exceed the planned depth.

2) Casing pipe with minimum diameter was prepared for over 60 % of drilling length planned.

3) The minimum diameters of the cores were BQ and BX or over.

4) Deviations of boreholes were measured every 100 m.

5) Coring and core recovery

a) All coring, except the soil, was the norm. But cuttings were collected to the depth of ore horizon within the total limit of 1,300 m in drilling length.

b) Core recovery over 80 % was planned even if full coring was not possible.

Particular effort was made for full core drilling at the mineralized parts, the bottom of the holes and the boundaries of rocks.

6) Handling of cores

a) Cores were preserved in the core boxes marked with the upper and lower sides

b) The depth of cores was indicated inside and outside of the core boxes.

c) Cores were stored in ZCCM facilities in Kalulushi.

7) Surveying and analysis of cores

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

b) Microscopic studies of core was made whenever necessary.

c) Each ore and/or mineralized parts of core was assayed by ZCCM.

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

Laboratory Work	Particulars
Thin section microscopy	14 sections
Polished section microscopy	12 sections
X-ray diffraction	31 samples

The drilling machines and the equipments, the drilling meterages of diamond bits used, the consumables used and the working time analysis of the drilling operation are shown in Tables 1-1, 1-2, 1-3 and 1-4, respectively.

(4) Field Work of the Geologist (Project Director)

The geologist studied the nature and contents of the cores and cuttings, and interpreted the results of the drilling during the drilling operation. Also he collected, compiled, studied and evaluated data and information from previous work on the geology and ore deposits of the area. From the above, the relation between the known deposits and the rise of the basement was clarified, and the extent of the orebodies under exploration was considered.

The existing data and information were handled with care, conferring with ZCCM officials whenever necessary. The result of compilation is annexed to this report.

Table 1-1 Drilling Machine and Equipment Used

Drilling Machine Model "L-44"	2 set	
Specifications:		
Capacity	1,500m(BQ-WL)	
Dimensions L x W x H	2,375mmx1,500mmx1,750mm	
Hoisting capacity	4,500kg	
Spindle speed	Forward 50~900rpm	
Engine Model "DEUTS"	6 cylinder-624	
Drilling Machine Model"Rock Jaint"		1 set
Specifications:		
Capacity	200m(percussion drilling)	
Dimensions L x W x H	8mx1.75mx2.6m	
Hoisting capacity	5,000kg	
Spindle speed	3rpm	
Engine Model "DEUTS"	4 cylinder	
Drilling Pump Model "BEANROYL-35"	2 set	
Specifications:		
Piston diameter	40mm	
Stroke	70mm	
Capacity	discharge capacity 210ℓ/min.	
Dimensions L x W x H	2,500mmx1,200mmx1,500mm	
Engine Model "HATS"	12.5ps/800rpm	
Wire line Hoist	2 set	
Specifications:		
Rope capacity	1,000m	
Hoisting speed	8~105m/min	
Engine Model "HATS"	12.5ps/800rpm	
Generator Model	2 set	
Specifications:		
Capacity	2.8KW 50Hz 220V	
Water supply pump model " HONDA"	2 set	
Specifications:		
Capacity	discharge capacity 50ℓ/min	
Dimensions L x W x H	500x450x450mm	
Engine Model "HONDA"	4.5ps/2000rpm	
Derrick	1 set	1 set
Specifications:	(skid)	(truck mounted)
Height	12m-pull	9m-pull
Max load capacity	10,000kg	8,000kg
Tractor Model "188ps M.F."	3 set	
Specifications:		
Water tanker	2 set	
Capacity	1,000ℓ	
Drilling tools		
Drilling rod NQ-WL 3.0m	546 pcs	
BQ-WL 3.0m	666 pcs	
Casing pipe HW 6.0m	10 pcs	
NW 6.0m	136 pcs	
BX 3.0m	546 pcs	

Table 1-2 Drilling Meterage of Diamond Bit Used

Item	Size	Bit No.	Drilling Meterage by Unit:Meter MJZC-2	MJZC-3	MJZC-4	Total(m)
Diamond bit	NQ-WL	A317/34	276.41			276.41
		HL11A1120	150.90			150.90
		HL6A317/38	89.00			89.00
		HL11A1120/2	39.96			39.96
		3Q31605	81.73			81.73
		3Q31611	19.00			19.00
		16683/9		65.00		65.00
		30151/5		284.00		284.00
		30157/5		17.00		17.00
		31607		66.00		66.00
		40/60			136.00	136.00
		16683/6			17.00	17.00
		TPSI			100.00	100.00
		16683/1/2			89.00	89.00
		303/6/5			78.00	78.00
		Total	657.00	432.00	420.00	1509.00
			Drilling length/bit (1509.00m/15 pcs)			100.60
	BQ-WL	33601		106.00		106.00
		3033513		69.00		69.00
		29217/5HL6		1.00		1.00
		19575/38		80.00		80.00
		29217/5		34.00		34.00
		29217/6		48.84		48.84
		24844/1			7.00	7.00
		14989/29			56.00	56.00
		Huddy BL			106.00	106.00
		29217/7			36.00	36.00
		91131			213.00	213.00
		958016			19.33	19.33
		958017			52.77	52.77
		HL624024/7			45.00	45.00
		125024			50.50	50.50
		19549/60			18.70	18.70
		Total	0	338.84	604.30	943.14
			Drilling length/bit (943.14m/16 pcs)			58.95
	Grand Total		657.00	770.84	1024.30	2452.14

Table 1-3 Consumables Used

Description	Specifications	Unit	Quantity			
			MJZC-2	MJZC-3	MJZC-4	Total
Light oil		ℓ	4,050	5,700	7,050	16,800
Hydraulic oil		ℓ	120	120	205	445
Engine oil		ℓ	120	170	135	425
Gear oil		ℓ	50	60	60	170
Grease		ℓ	50	38	250	338
Drillprop		ℓ	85	100	185	370
Rod grease		kg	90	110	180	380
Cutting oil		ℓ	210	360	440	1,010
Cement	50kg/sx	kg	200	450	500	1,150
Percussion bit	200mm	pc	1			1
Tricone bit	165mm	pc		1	1	2
Tricone bit	150mm	pc	1	1	1	3
Tricone bit	130mm	pc		1	1	2
Diamond bit	NQ	pc	11	4	4	19
Diamond bit	BQ	pc		4	8	12
Diamond reamer	NQ	pc		1	2	3
Core barrel Ass'y	NQ-WL	set	1	1	1	3
Core barrel Ass'y	BQ-WL	set	2	2	2	6
Inner tube Ass'y	NQ-WL	set	1	1	1	3
Inner tube Ass'y	BQ-WL	set	2	2	2	6
Inner tube	NQ-WL	pc	1	1	1	3
Inner tube	BQ-WL	pc	1	1	1	3
Locking coupling	NQ-WL	pc	2	2	2	6
Locking coupling	BQ-WL	pc	2	2	2	6
Adapter coupling	NQ-WL	pc	2	2	2	6
Adapter coupling	BQ-WL	pc	2	2	2	6
Landing ring	NQ-WL	pc	3	3	3	9
Landing ring	BQ-WL	pc	3	3	3	9
Core lifter case	NQ-WL	pc	5	5	5	17
Core lifter case	BQ-WL	pc	3	3	4	10
Core lifter	NQ-WL	pc	5	5	5	15
Core lifter	BQ-WL	pc	5	5	5	15
Stop ring	NQ-WL	pc	2	2	2	6
Stop ring	BQ-WL	pc	2	2	2	6
Thrust ball bearing	NQ-WL	pc	1	1	1	3
Thrust ball bearing	BQ-WL	pc	1	1	1	3
Hanger bearing	NQ-WL	pc	1	1	1	3
Innertube stabilizer	NQ-WL	pc	2	2	2	6
Innertube stabilizer	BQ-WL	pc	2	2	2	6
Hoisting wire rope	21mm x 35m	roll	1	1	1	3
Wire line rope	6mm x 1000m	roll	1	1	1	3
Waste		kg	10	10	10	30

Table 1-4 Working Time Analysis of the Drilling Operation

Hole No.	Drilling			Shift		Working man		Working Time							
	Bit size	Drilling length (m)	Core length (m)	Drilling (shift)	Total (shift)	Engineer (man)	Worker (man)	Drilling (h)	Other working (h)	Recovering (h)	Total (h)	Reassemblage (h)	Dismantlement (h)	Road construction and Transportation (h)	G. Total (h)
MJZC-2	200mm	35.00	N/C	1.0	2.0	2.0	8.0	4°	1°	0°	5°	10°	-	1°	16°
	150mm	118.00	N/C	1.6	1.6	1.6	6.6	14°	5°	1°	20°	-	4°	-	24°
	NQ	657.00	652.02	34.4	50.4	60.4	165.4	180°	232°	68°	480°	96°	48°	52°	676°
	Total	810.00	652.02	37.0	54.0	64.0	180.0	198°	238°	69°	505°	106°	52°	53°	716°
MJZC-3	165mm	4.00	N/C	0.1	9.1	11.0	52.0	2.5°	1°	-	3.5°	40°	-	1°	44.5°
	150mm	86.00	N/C	3.9	3.9	5.0	12.0	55°	16°	-	71°	-	-	-	71°
	130mm	12.00	N/C	4.0	4.0	6.0	16.0	7.5°	2°	1°	10.5°	-	-	-	10.5°
	NQ	432.00	413.30	29.0	29.0	47.0	120.0	210°	86°	34°	330°	-	-	12°	342°
	BQ	271.84	266.32	31.0	36.0	57.0	158.0	179°	88°	55°	322°	-	48°	164°	534°
	Total	805.84	679.62	68.0	82.0	126.0	358.0	454°	193°	90°	737°	40°	48°	177°	1.002°
MJZC-4	165mm	7.00	N/C	0.1	9.1	20.0	49.0	4°	1°	-	5°	40°	-	2°	47°
	150mm	65.00	N/C	1.9	1.9	2.0	4.0	37°	8°	-	45°	-	-	-	45°
	130mm	12.00	N/C	3.0	3.0	4.0	12.0	7°	1°	2°	10°	-	-	-	10°
	NQ	420.04	406.44	24.0	24.0	37.0	96.0	233°	26°	18°	277°	-	-	6°	283°
	BQ	546.96	538.93	69.0	85.0	143.0	371.0	281°	234°	396°	911°	-	36°	129°	1,076°
	Total	1,051.00	945.37	98.0	123.0	206.0	532.0	562°	270°	416°	1,248°	40°	36°	137°	1.461°
Grand Total		2,666.84	2,277.01	203.0	259.0	396.0	1,070.0	1,214°	701°	575°	2,490°	186°	136°	367°	3.179°

1-2-4 Participants of the First Phase Survey

(1) Mission for Scope of Work Consultation

1) Japanese side

Yasuo NOGUCHI (team leader)	Executive Director, MMAJ
Takafumi TSUJIMOTO (supervise)	Deputy Director,Technical Cooperation Division, Overseas Activities Department, MMAJ
Yoshiaki IGARASHI (arrangement)	Technical Cooperation Division, Overseas Activities Department, MMAJ
Kiyoshi EDO (research)	Mineral Exploration and Industrial Investigation Department, JICA
Nobuyuki MASUDA (research)	Representative, MMAJ Nairobi Office

2) Zambian side

E. Shamutete	President, ZCCM
E. M. Koloko	Director, ZCCM
J. H. D. Patterson	Technical Director, ZCCM Technical Directorate
R. J. H. Nasih	Consulting Geologist, ZCCM Technical Directorate
A. C. Kaunda	Project Manager, ZCCM Technical Services
S. M. Searstone	Project Geologist, ZCCM Technical Directorate

(2) Survey Team

1) Japanese member

Masaaki SUGAWARA (team leader)	Senior Geologist, Nikko Exploration & Development Co. Ltd.

2) Field supervisor

Takafumi TSUJIMOTO	Deputy Director,Technical Cooperation Division, Overseas Activities Department, MMAJ

3) Zambian member

J. H. D. Patterson	Technical Director, ZCCM Technical Directorate
R. J. H. Nasih	Consulting Geologist, ZCCM Technical Directorate
A. C. Kaunda	Project Manager, ZCCM Technical Services
F. A. Siddiqui	Head of Geological Services, ZCCM Technical Services
W. J. Silondwa	Senior Geologist, ZCCM Nkana Division

1-2-5 Duration

(1) Scope of Work Consultation

21 June 1993 to 4 July 1993

(2) Drilling Exploration

10 November 1993 to 28 February 1994

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 Zambeshi 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(mm)	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

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 (℃) 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	22.0
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 Geology and Mineralization of the Survey Area and the Vicinity

3-1 Geology and Mineralization of the Vicinity

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 Angora 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.

The Katangan Supergroup is distributed in an orogenic zone which is developed in an arc in northwest Zambia and extending into Zaire and Angora. 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

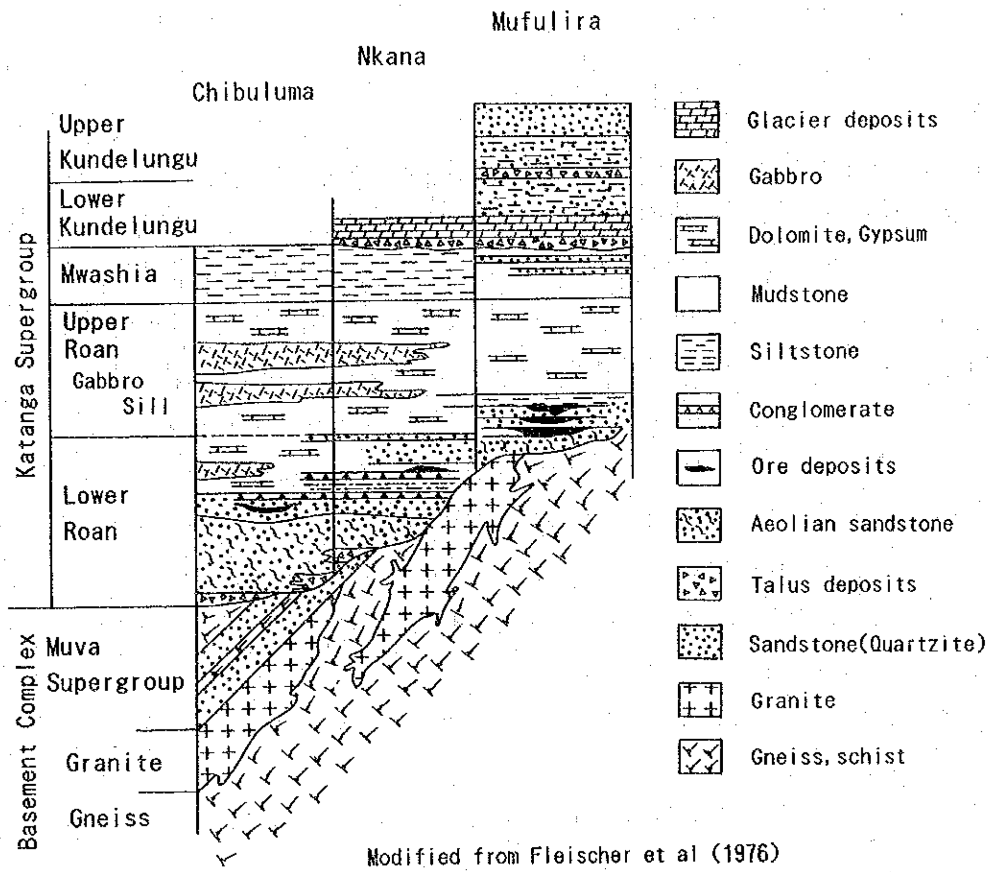


Fig.1-4 Schematic Stratigraphic Columns of the Zambian Copperbelt

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 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-Muriashi 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 meters 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-Mindolo 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 Geologic Setting of the Survey Area

The geology and ore deposits of the survey area have been studied by Fleischer (1983) in detail. Results of compilation of existing data this year are shown in Appendices 2 to 5. 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.

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

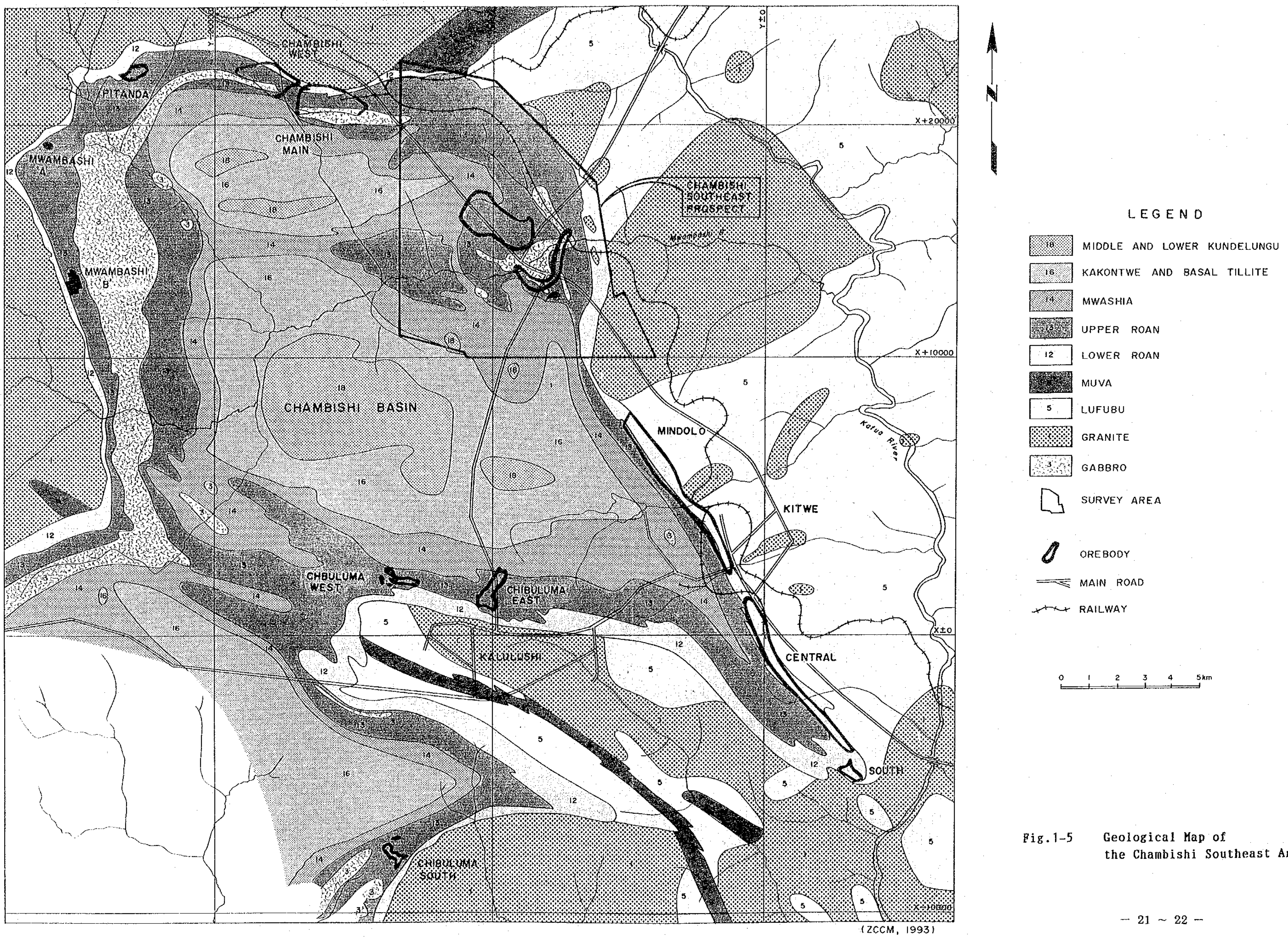


Fig.1-5 Geological Map of the Chambishi Southeast Area

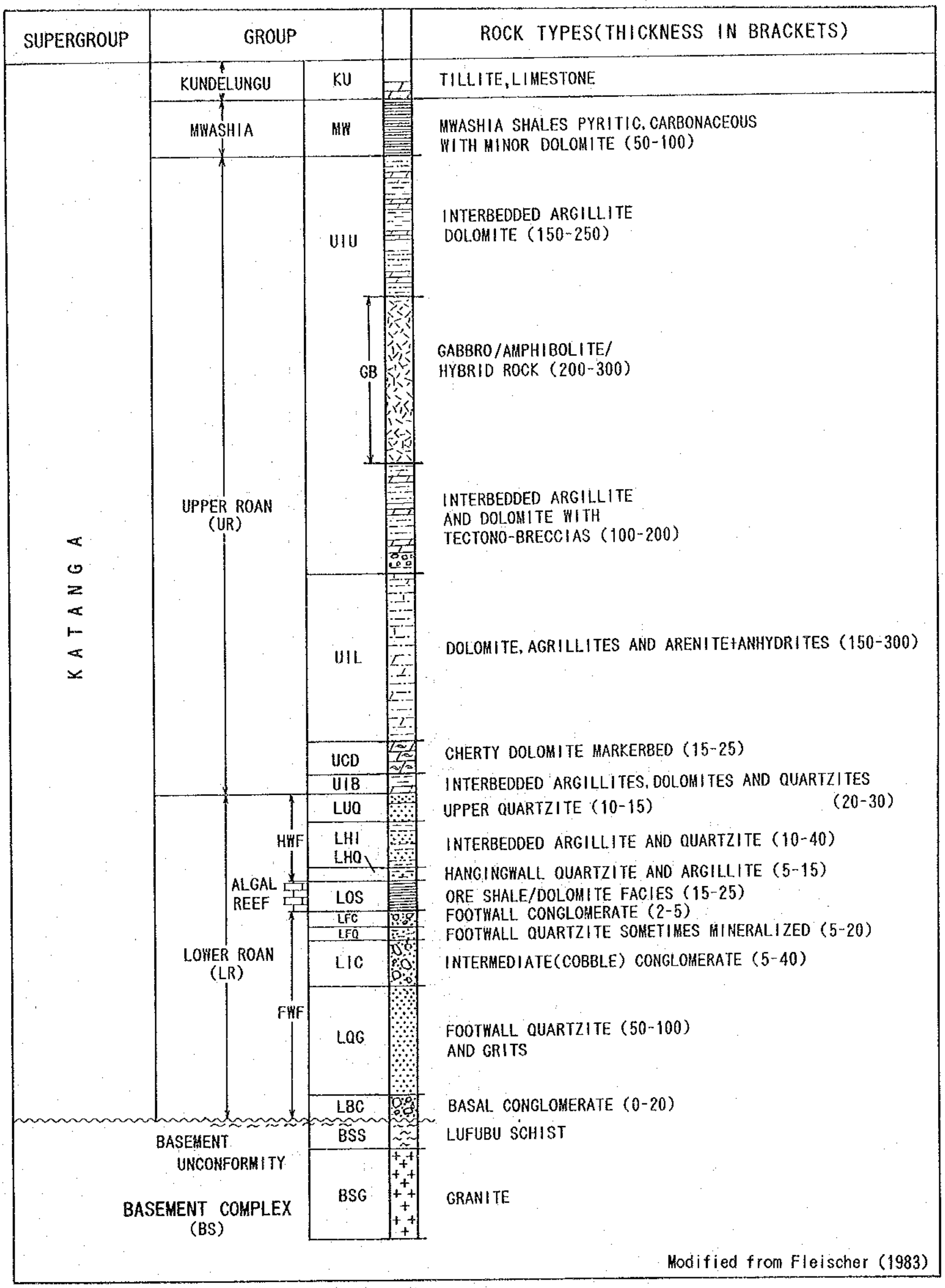


Fig.1-6 Generalized Stratigraphic Section through Chambishi Southeast

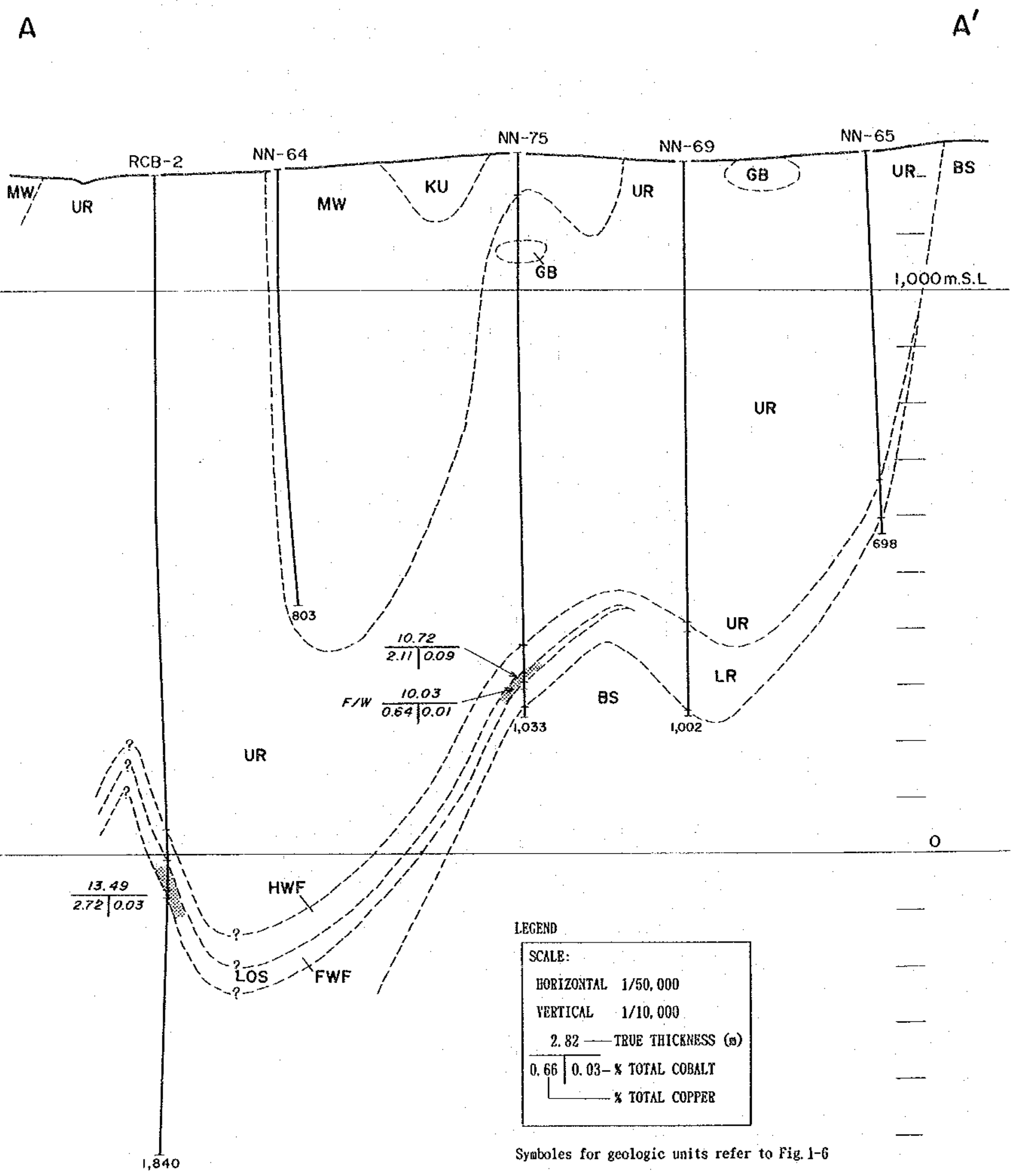


Fig.1-7 Geological Profiles of the Chambishi Southeast Area (1)

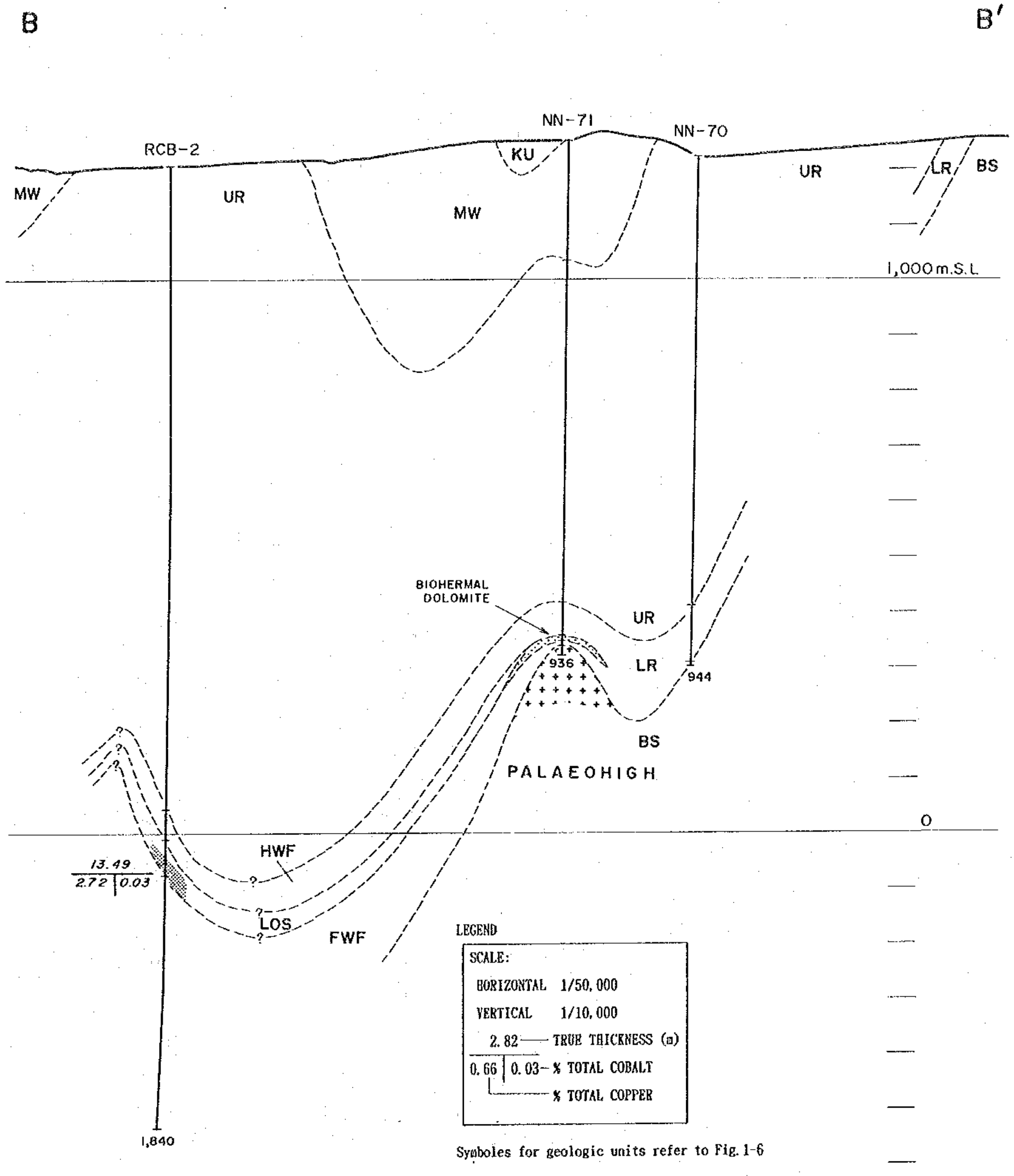
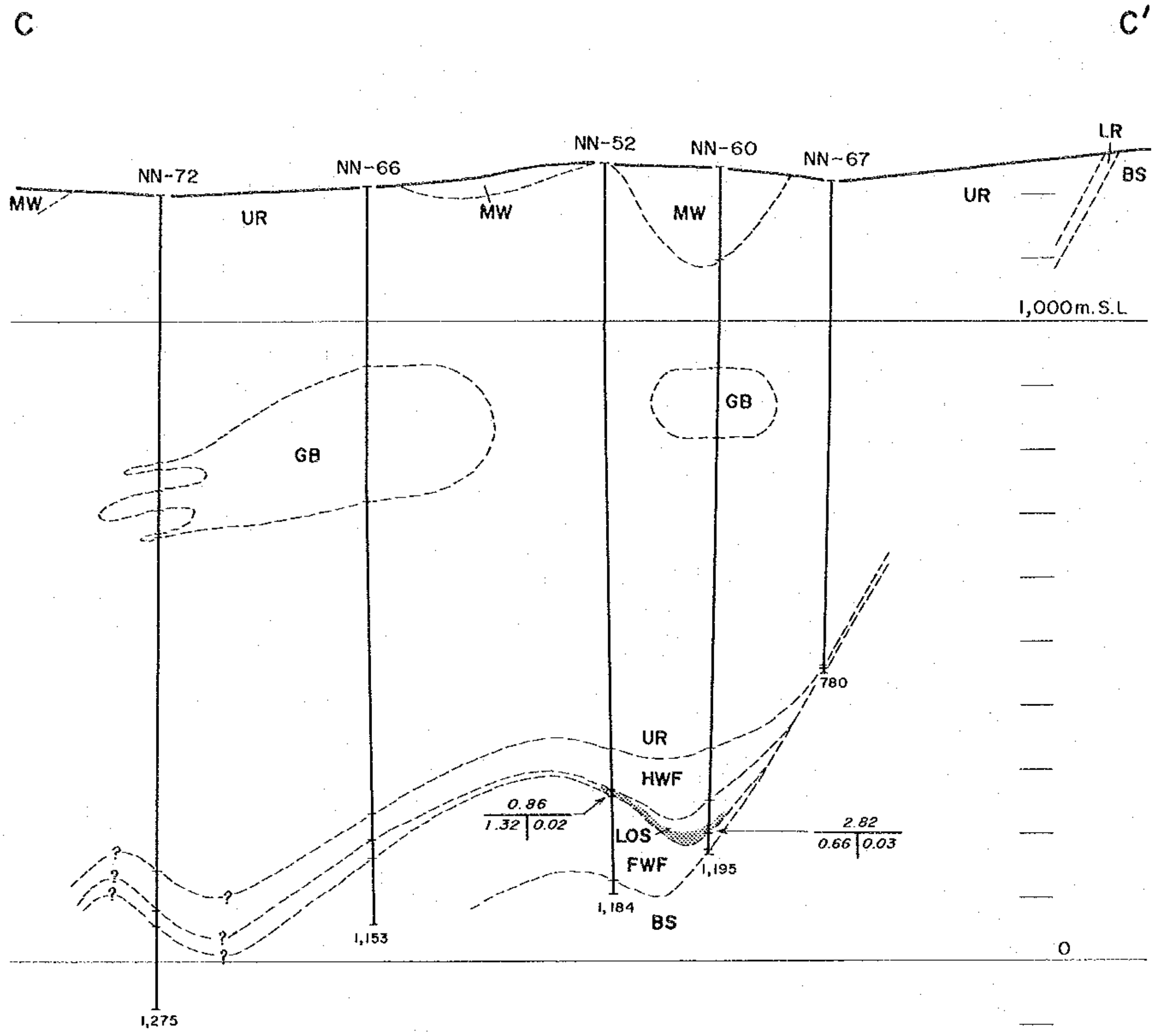


Fig.1-7 Geological Profiles of the Chambishi Southeast Area (2)



LEGEND

SCALE:	
HORIZONTAL	1/50,000
VERTICAL	1/10,000

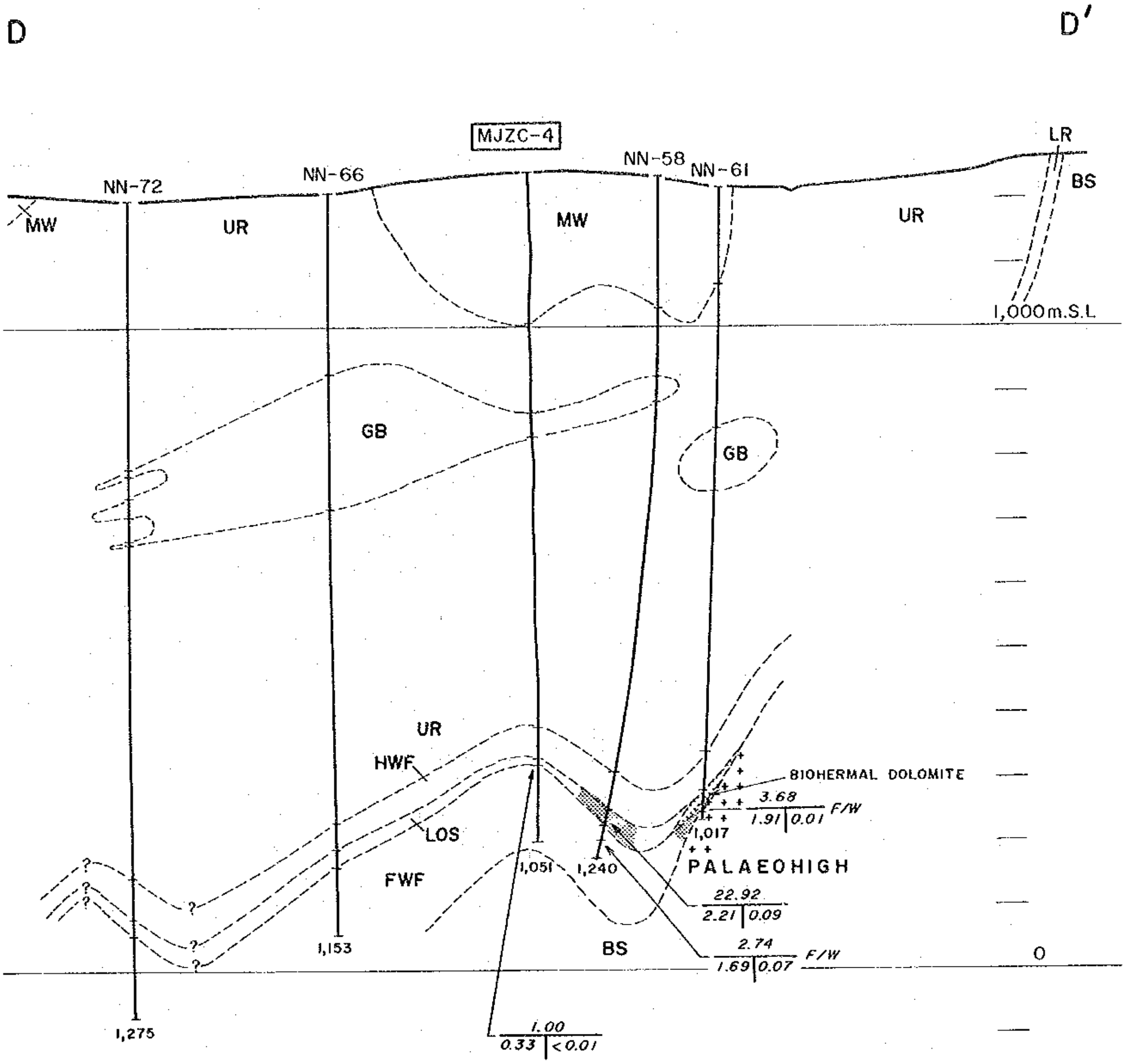
2.82 —— TRUE THICKNESS (m)

0.66 | 0.03 — % TOTAL COBALT

└—— % TOTAL COPPER

Symboles for geologic units refer to Fig. 1-6

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



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

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

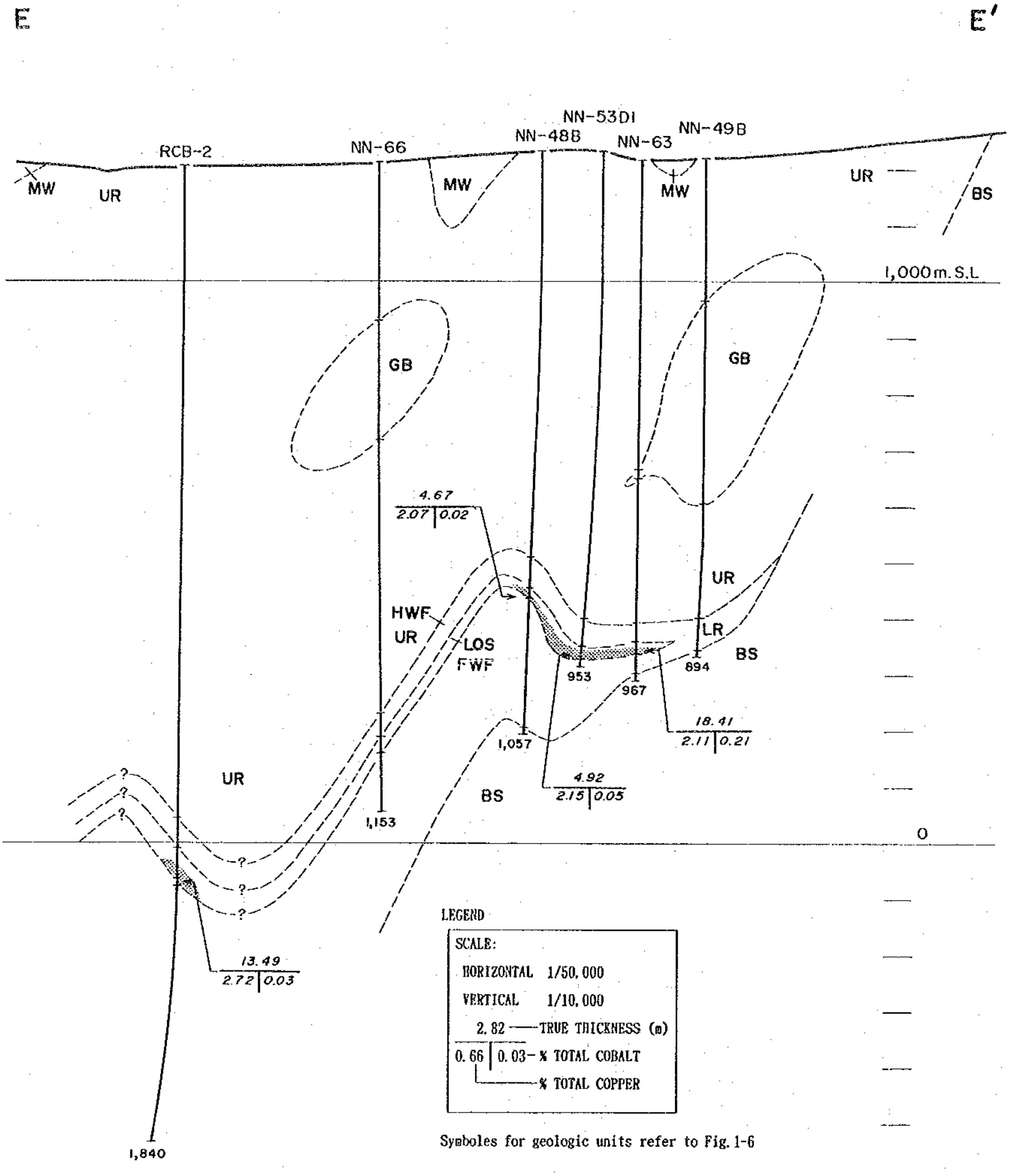
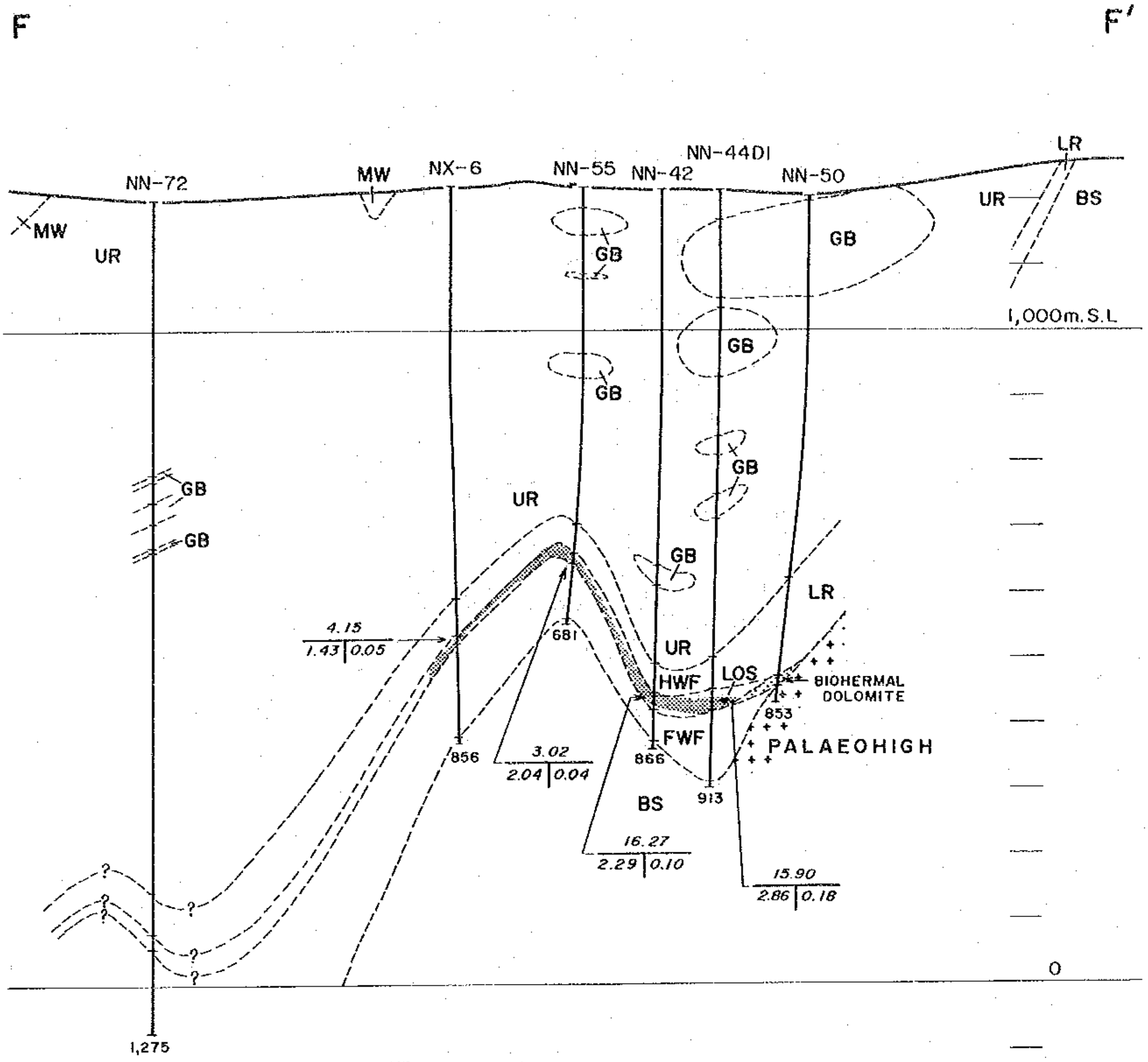


Fig.1-7 Geological Profiles of the Chambishi Southeast Area (5)



LEGEND

SCALE:

HORIZONTAL 1/50,000

VERTICAL 1/10,000

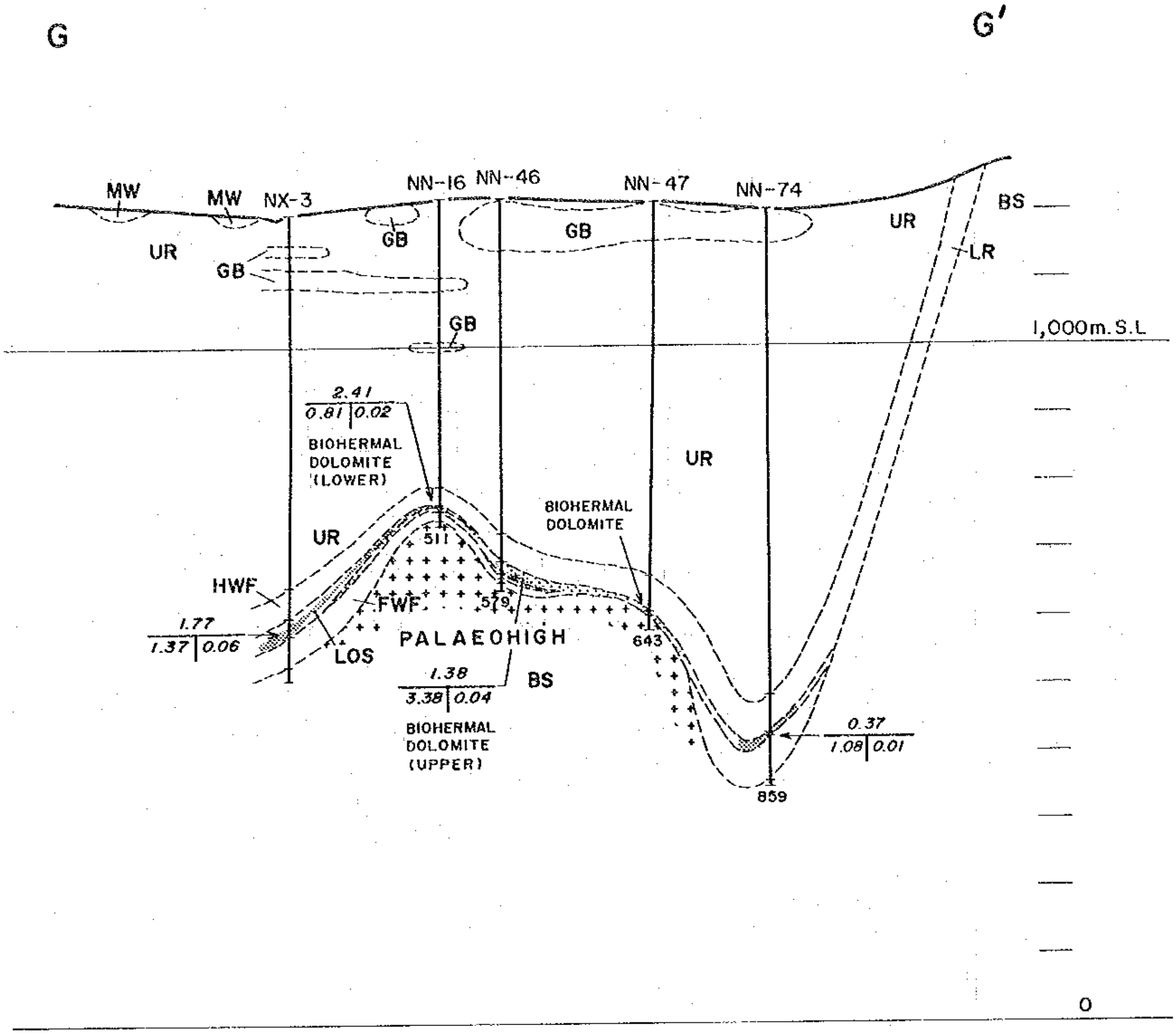
2.82 —— TRUE THICKNESS (m)

0.66 | 0.03 — % TOTAL COBALT

└—— % TOTAL COPPER

Symboles for geologic units refer to Fig.1-6

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



LEGEND

SCALE:

HORIZONTAL 1/50,000

VERTICAL 1/10,000

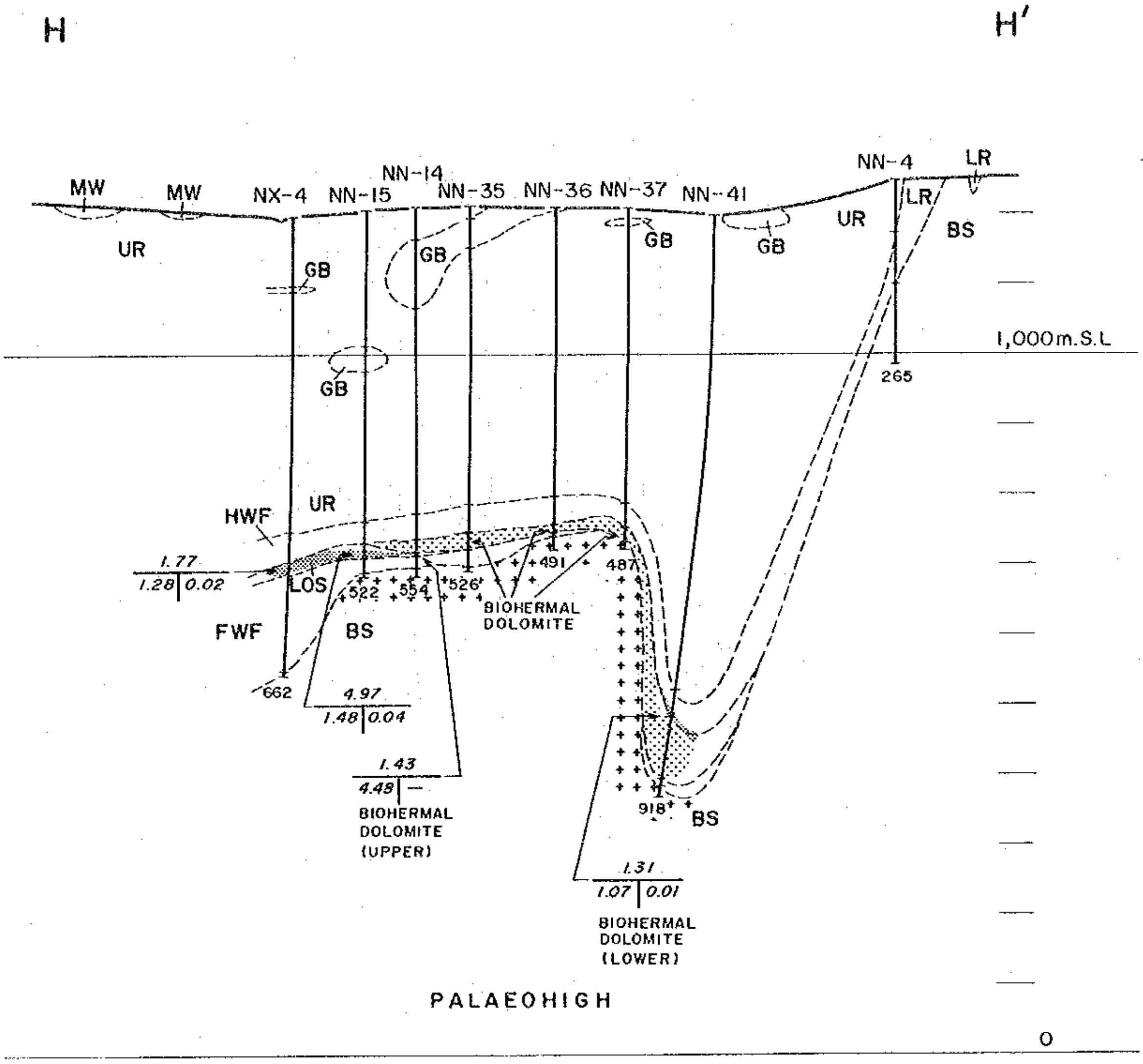
2.82 —— TRUE THICKNESS (m)

0.66 | 0.03 — % TOTAL COBALT

└—— % TOTAL COPPER

Symboles for geologic units refer to Fig. 1-6

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

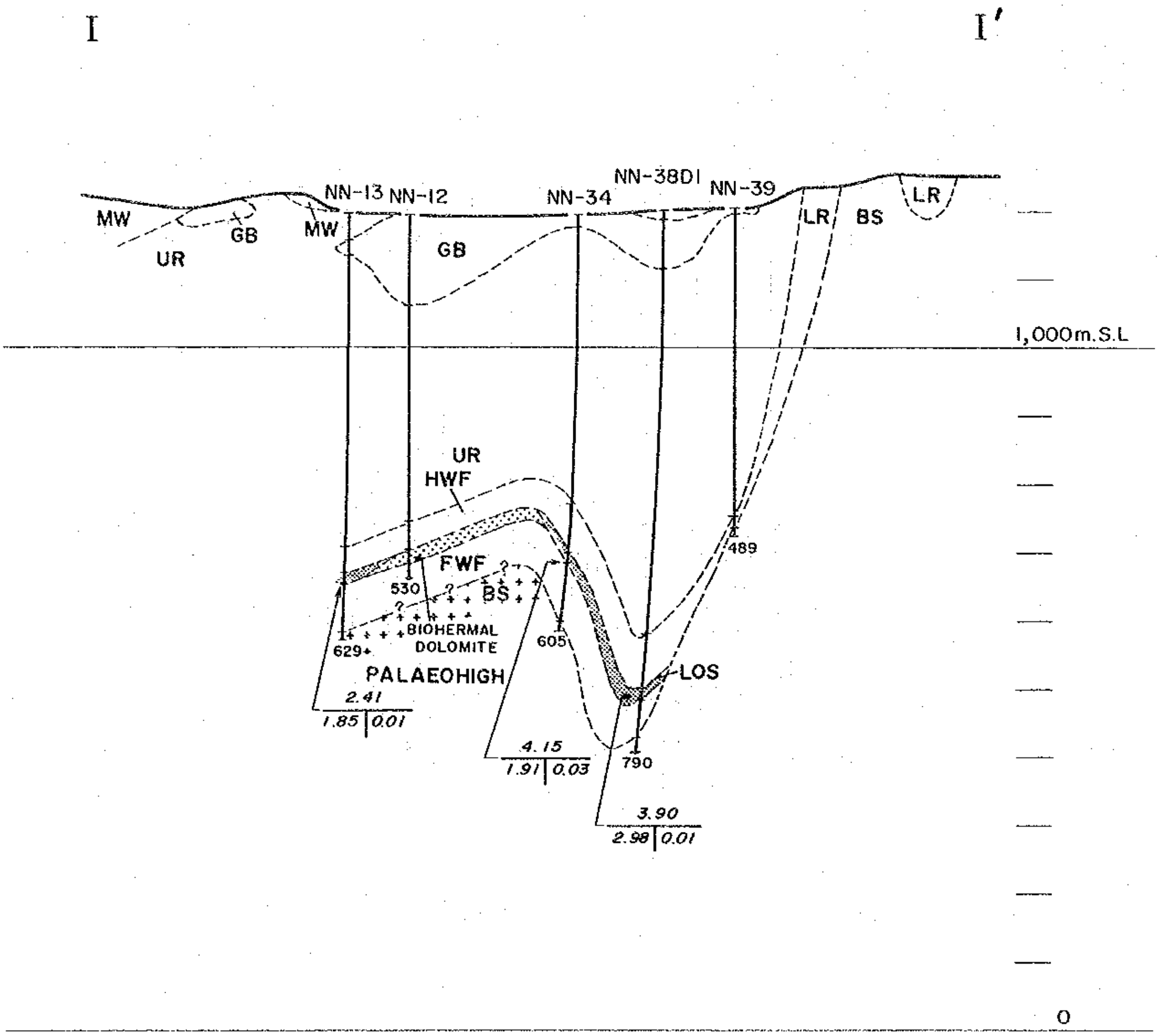


LEGEND

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

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



LEGEND

SCALE:
HORIZONTAL 1/50,000
VERTICAL 1/10,000

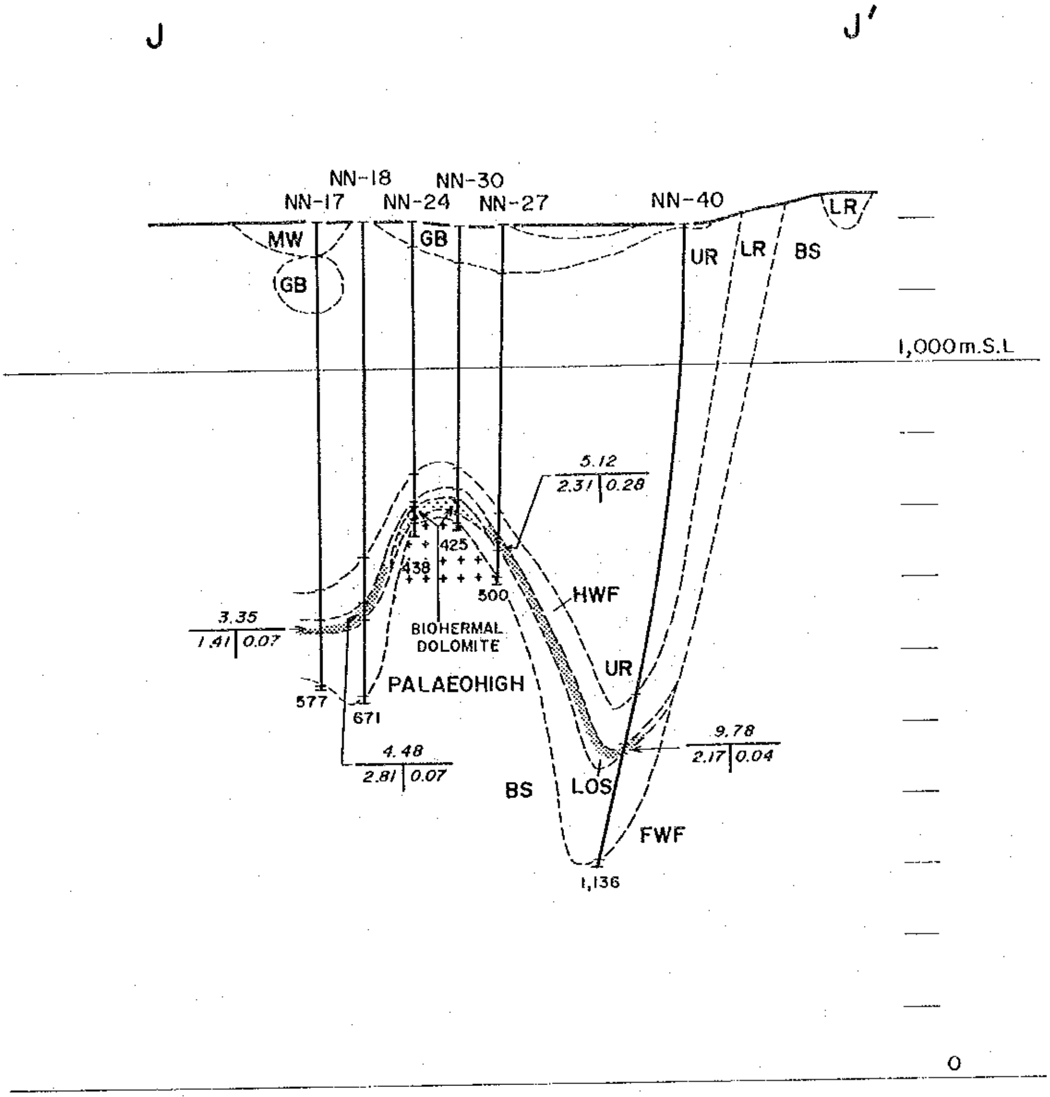
2.82 —— TRUE THICKNESS (m)

0.66 | 0.03 —— % TOTAL COBALT

└—— % TOTAL COPPER

Symboles for geologic units refer to Fig. 1-6

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



LEGEND

SCALE:

HORIZONTAL 1/50,000

VERTICAL 1/10,000

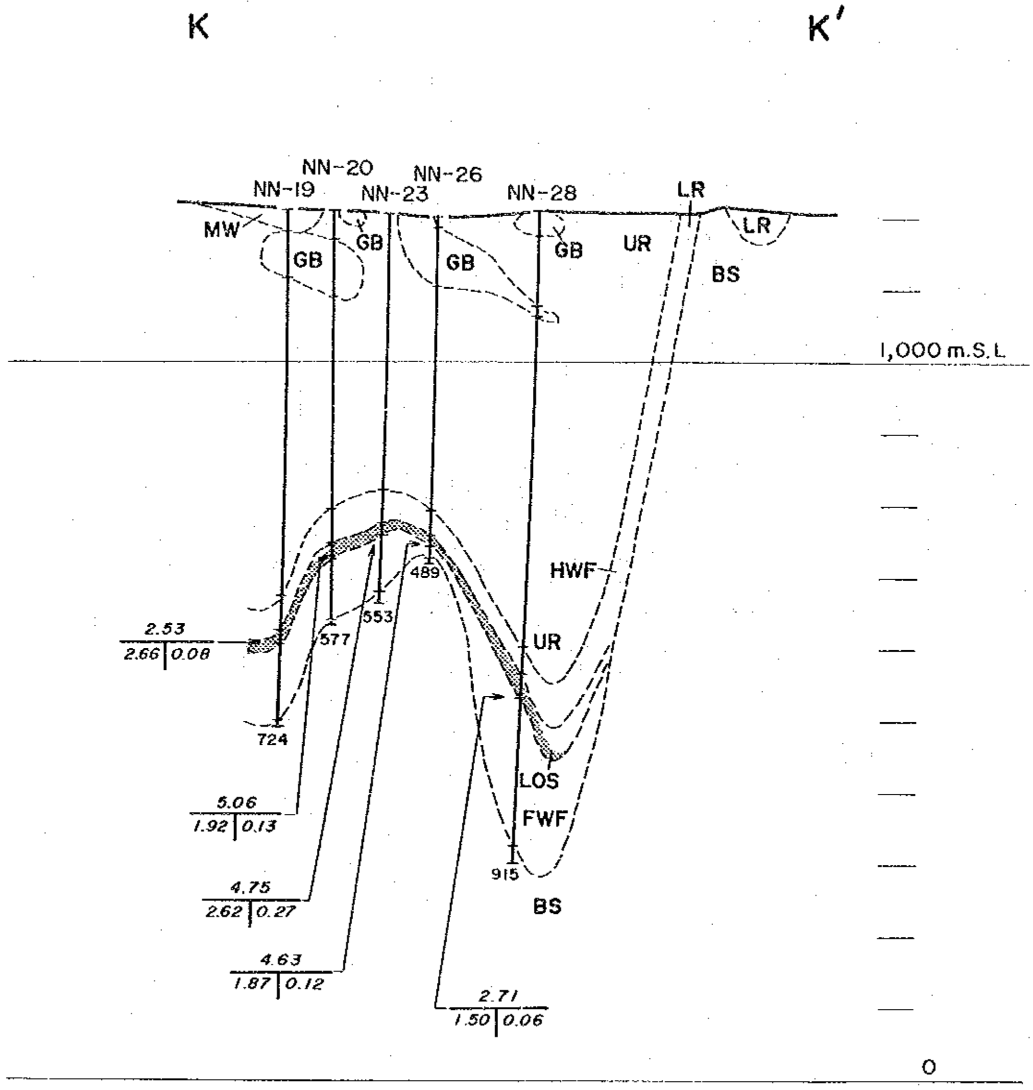
2.82 — TRUE THICKNESS (m)

0.66 | 0.03 - % TOTAL COBALT

└ % TOTAL COPPER

Symboles for geologic units refer to Fig. 1-6

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



LEGEND

SCALE:

HORIZONTAL 1/50,000

VERTICAL 1/10,000

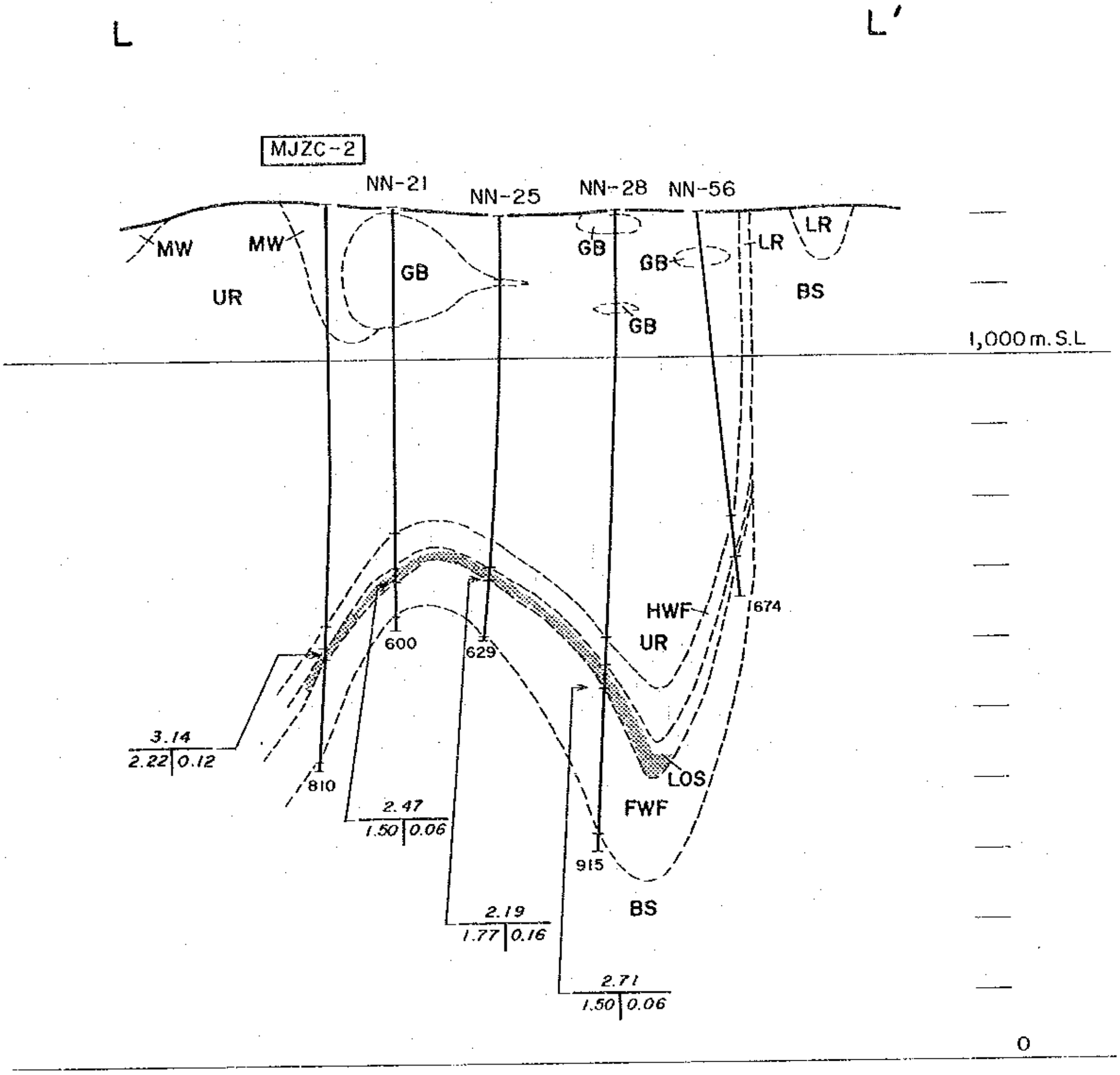
2.82 —— TRUE THICKNESS (m)

0.66 | 0.03 — % TOTAL COBALT

└—— % TOTAL COPPER

Symboles for geologic units refer to Fig.1-6

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



LEGEND

SCALE:

HORIZONTAL 1/50,000

VERTICAL 1/10,000

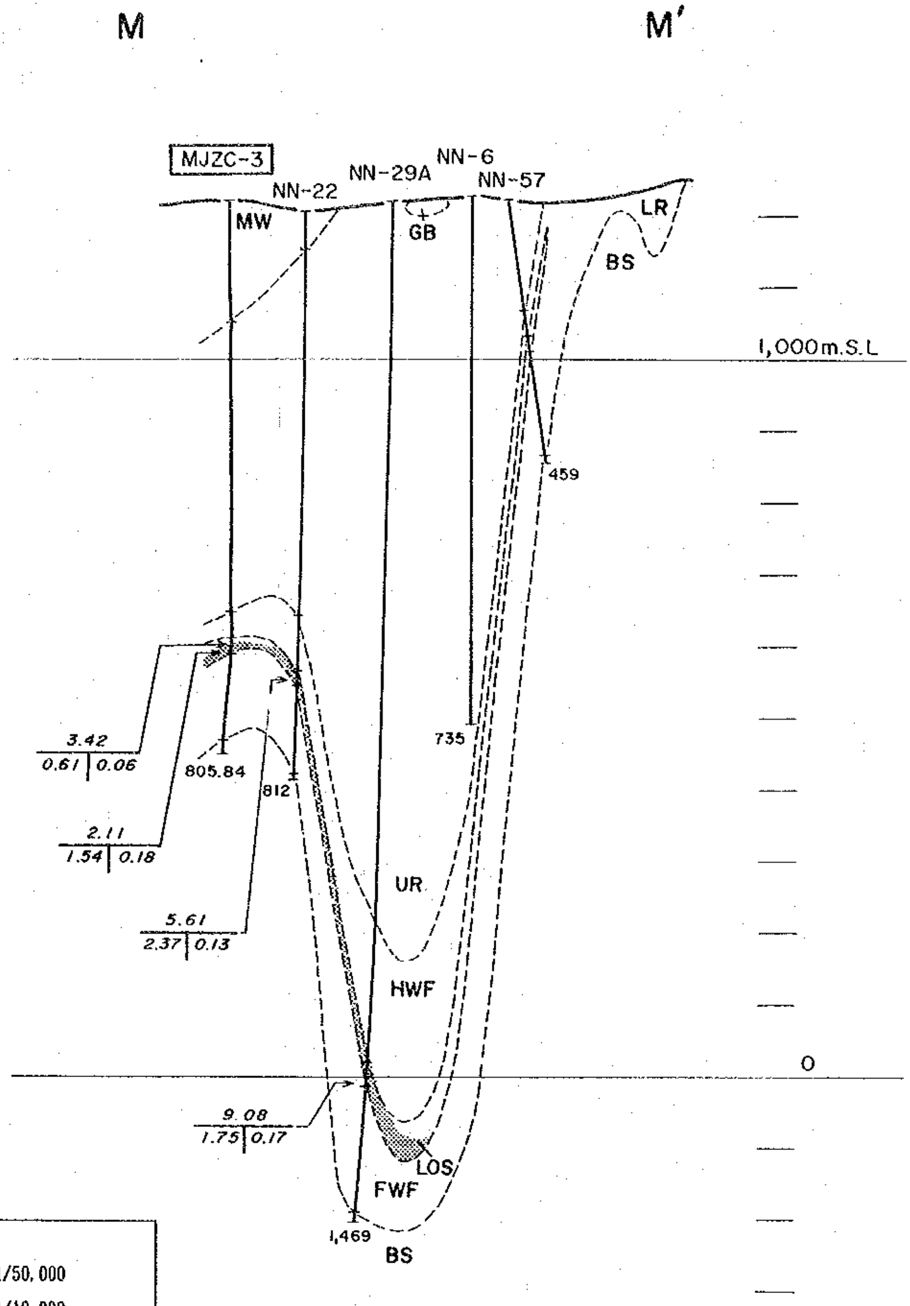
2.82 —— TRUE THICKNESS (m)

0.66 | 0.03 — % TOTAL COBALT

└—— % TOTAL COPPER

Symboles for geologic units refer to Fig.1-6

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

Symboles for geologic units refer to Fig. 1-6

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

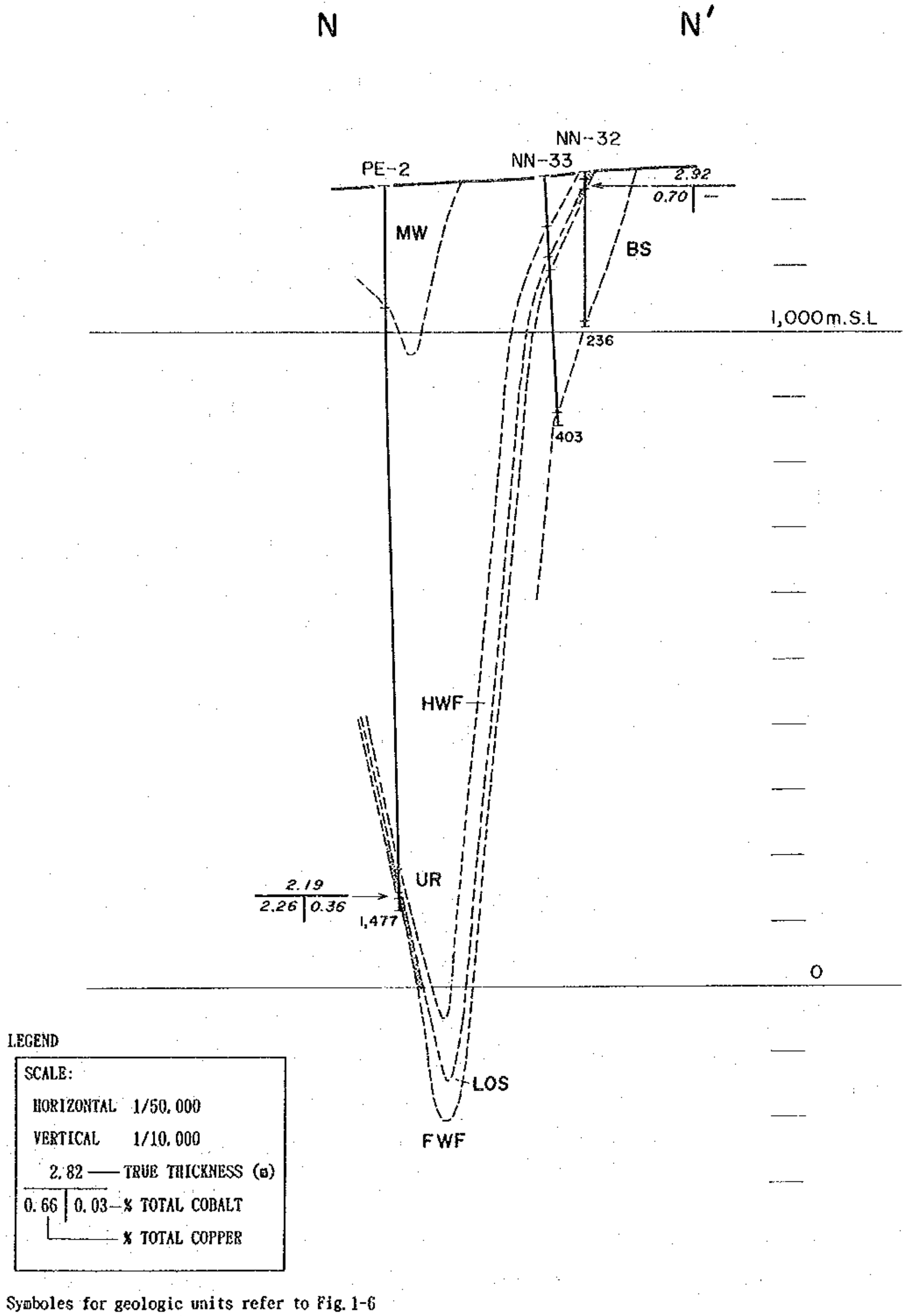


Fig.1-7 Geological Profiles of the Chambishi Southeast Area (14)

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・Grits", "Intermediate Conglomerate", "Footwall Quartzite", "Footwall Conglomerate", "Ore Shale Horizon", "Hangingwall Quartzite・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・Dolomite with Anhydrite" and "Interbedded Argillite and Dolomite with Tectono-Breccias" in ascending order. Of these, "Cherty Dolomite" has an intercalation of argillite (Makerbed), 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 metamotphosed 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 of 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 (Appendix-4). These ore deposits have one ore horizon, but chalcopyrite-mineralized zones are present in the Footwall Quartzite at NN-58 of the Northern Area Shoot and NN-61 in the 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.

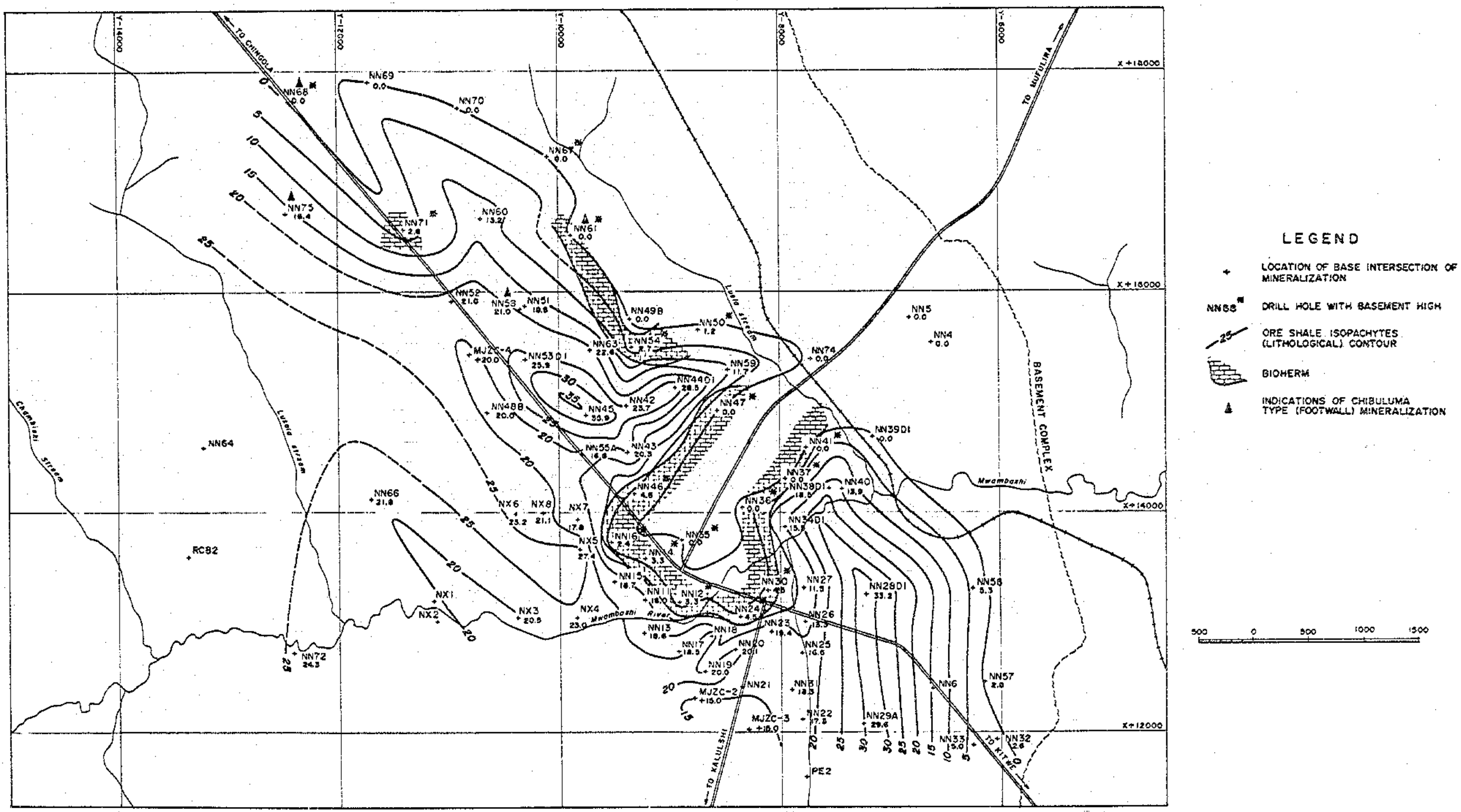
④ Ore minerals: Pyrite, chalcopyrite, bornite, chalcocite, pyrrhotite, carrollite and cobalt pentlandite occurs as major primary minerals. Cobaltian pyrite, linnaeite and cattierite occurs as rare primary minerals. Most of copper are from chalcopyrite, but fair amount of bornite also exists. Most of 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.



Modified from Fleischer (1983)

Fig.1-8 Ore Shale Isopach Map

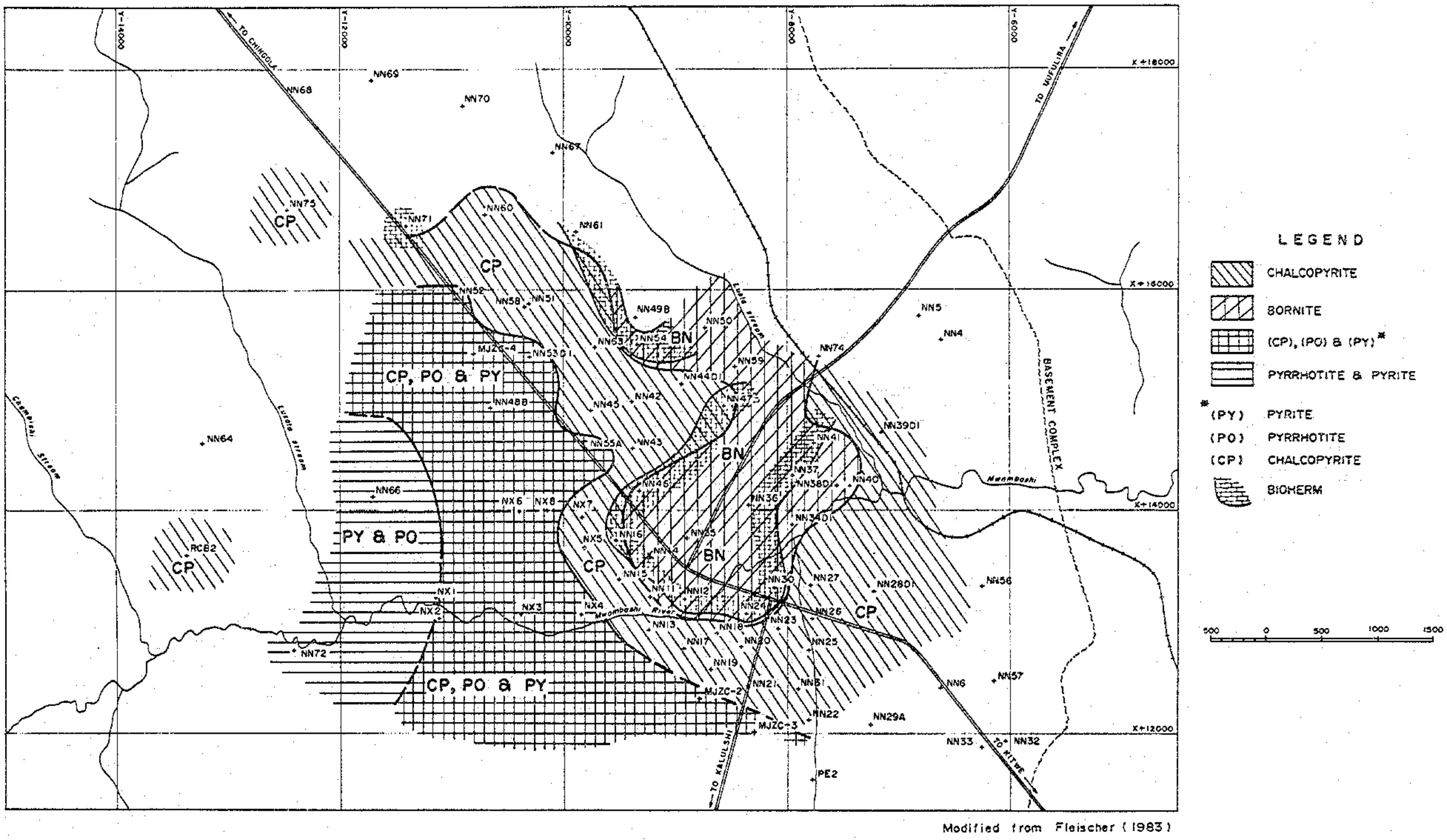


Fig.1-9 Sulphide Mineral Zoning

- 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 Roan Group.
- Pyrrhotite rim of dolomitic lens contained in shales of the Mwashia Group and boudinage or intensely disseminated pyrite in the shales.
- Pyrite-pyrrhotite rim of fragments contained in sedimentary rocks of the Kundelungu Group, and discontinuous thin beds and dissemination of pyrrhotite in the Group.

Chapter 4 Discussions

4-1 Geologic Structure, Characteristics of Mineralization and Mineralization Control

The mineral deposits of the Zambian Copperbelt occur along two NW-SE trending linear zones, namely one along the western limb of the Kafue Anticline and the other along the Mufurlira Syncline, as shown in Figure 1-2. The deposits occur in this belt which continues for several hundred kilometers and extend into Zaire. The mineralized zone of the Chambishi Southeast area occurs in the zone along the western flank of the Kafue Anticline. In the Zambian side, most of the copper deposits occur in the Ore Formation of the Lower Roan Group, and are clearly bounded stratigraphically. The above alignment of the deposits parallel to the Kafue Anticlinal axis is the direction of the strike of the country rock formations which is parallel to the palaeo-coastline at the time of mineralization. The continuation of the individual deposits is several to over ten kilometers in the direction of the above coastline, while that in the direction normal to the coast (toward the central part of the basin) is shorter, in the order of several hundred meters to several kilometers.

In the Chambishi Southeast area, the orebodies occur in argillites and dolomites, and locally the mineralization also occurs in the Footwall Quartzite. It is inferred from the above that the orebodies were deposited under the shallow marine or lagoonal environment near the coast during the early stage of marine transgression. This is the stage which began with the deposition of the conglomerates of the Footwall Formation. The argillites contain large amount of organic carbon which indicates stagnant reducing environment during mineralization. Also the sulfide minerals are distributed zonally from the coast outwards as follows; bornite→ chalcopyrite→ chalcopyrite-pyrrhotite-pyrite→ pyrite-pyrrhotite. This indicates that the sea bottom environment, namely the environment for mineralization, gradually became reducing toward the offshore (Fleischer et al., 1976). The Northern Area Shoot, the most important ore deposit of the area, occurs in the depression of the basement. And the ore grade is low to barren where basement is inferred to have been high at the time of ore deposition. This inference is made from distribution of the bioherm and thickness of the Footwall Formation. This is considered to be the result of stagnant water, retention of mineralizing fluid, biogenic formation of reduced sulfur, formation of heavy metal sulfides, and thus favorable environment for the preservation of metallic sulfide in the local depressions of the basement.

The depositional environment mentioned above has already been reported (Fleischer, 1983), and the conditions are similar throughout the shale-type deposits in the Zambian Copperbelt. The following is some of the features newly clarified during the present survey.

Geological cross sections (Fig. 1-7) were prepared during this project, and contour map of the depth of the upper surface of the basement, which is based on the geological cross sections, was also prepared (Fig. 1-10). Contour maps have also been prepared by ZCCM, but compared to these, the present map shows more clearly the rise of the basement on the southwestern side of the NW-SE trending depression. The Northern Area Shoot occurs in this depression, and it is shown that this depression is closed.

It should be noted, however, that the present morphology of the upper surface of the basement does not necessarily reflect the conditions at the time of ore deposition. There are two types of basement rise; one which coincides with the palaeo-basement highs at the time of ore deposition (Fig. 1-7: G-G', H-H', I-I', J-J') and the other risen by folding after the deposition of the Ore Shale. Parts of the palaeo-basement highs corresponds to the present depressions and the limbs of the depressions (Fig. 1-7: D-D', H-H'). In some parts of the ore horizon, dolomite overlaps with the ore-bearing argillites, and thus it is inferred that the depth of the sea changed by the vertical movement of the basement after the start of ore deposition.

The gravity high and low zones extracted from the gravity contour maps, and the gabbro distribution and fold axes extracted from geological map are shown in Figure 1-10.

The gravity highs near the Chambishi mine coincide well with the distribution of gabbro, and those in the western and southwestern parts of the survey area coincide with the anticlinal axes. There are small-scale gravity highs corresponding to the basement high in the central part of the survey area, but gabbro also occur in this part. The gravity high on the northern side of the Northern Area Shoot occurs in the basement depression. Ore shoot does not occur in the gravity high, and the northern boundary of the Northern Area Shoot coincides very well with the southern boundary of the gravity high to the north. From the above, it is inferred that:

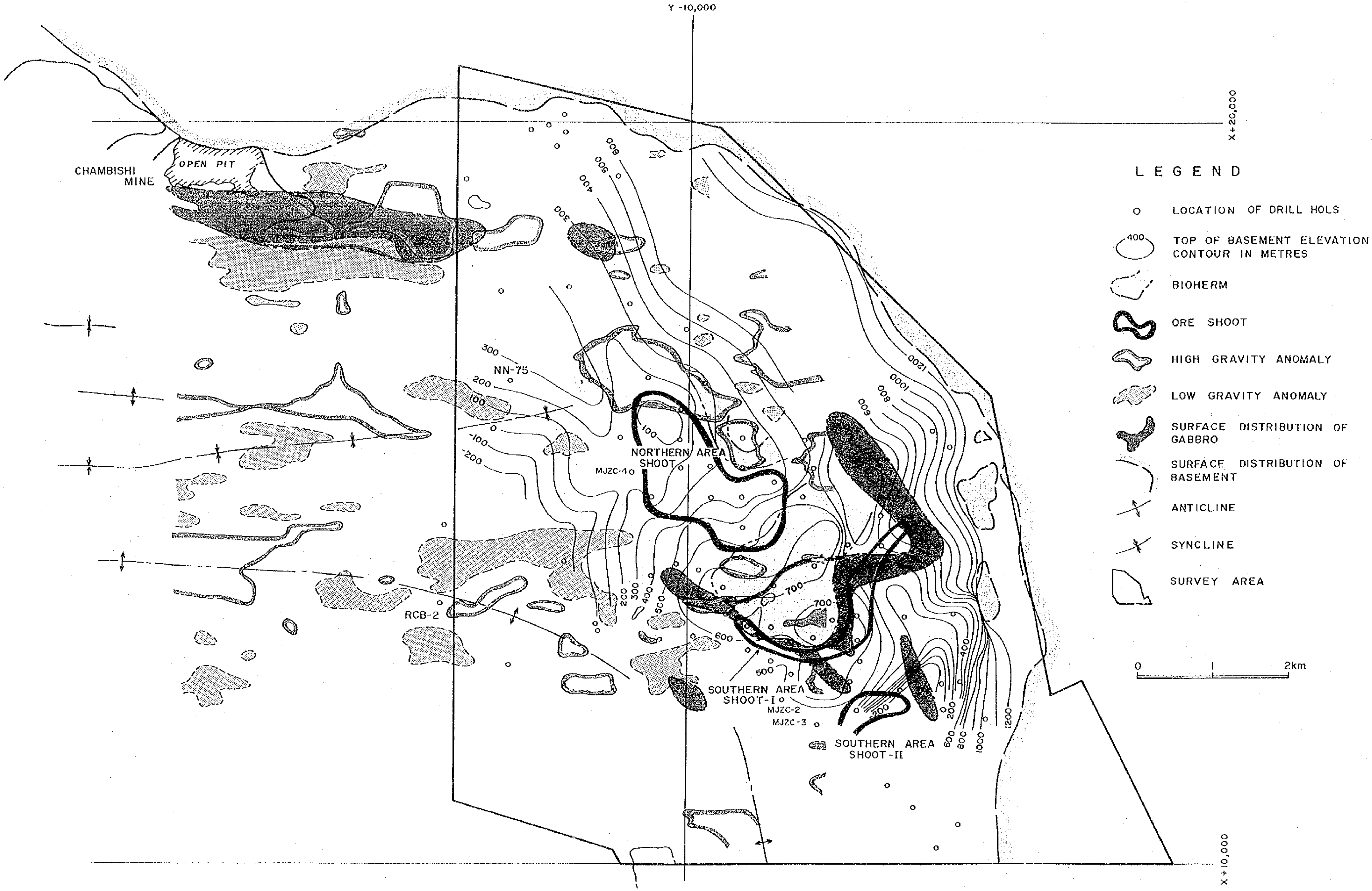


Fig.1-10 Integrated Interpretation Map

① Parts of the gravity highs indicate the occurrence of gabbro in the shallow subsurface zones.

② Parts of the gravity highs indicate the basement highs either formed by folding or palaeo-basement highs which existed before ore deposition.

③ Some kind of relationship possibly exists between the distribution of gravity highs and ore shoots.

An isopach map of subsurface gabbroic bodies (accumulative thickness when there are some bodies) prepared from drilling data and the spatial relation of the gravity highs and the ore shoots are shown in Figure 1-11. It is seen from this map that: the gravity high on the northern side of the Northern Area Shoot coincides very well with the thick part of the gabbroic body; the small-scale gravity highs lying between the Northern Area Shoot and the Southern Area Shoot-I do not correspond to thick gabbro, but to the basement high; the ore shoots are developed where the gabbroic bodies are thin with the exception of the eastern part of the Southern Area Shoot-I . The genetic relation between gabbro and ore shoots is not necessarily clear, but the following is a possibility.

The most probable reason for the lack of association of ore shoots and thick gabbroic bodies is that the heavy load of the gabbroic bodies caused the ore material to migrate to parts with lower load. This migration is inferred to have been greater in zones where the hard compact basement rocks were shallow. The eastern part of the Southern Area Shoot-I remains below gabbro, and this is probably because the basement was deep at this point. The Southern Area Shoot-I may indicate that ore shoots can be formed where the gabbroic bodies are relatively thin by the above mechanism.

As mentioned in 2-3 of PARTII, the mode of occurrence of the ore shoots suggests that diagenesis and metamorphism played important roles in their formation. Although of a different type, the importance of diagenesis for the formation of Kuroko deposits which deposited on the sea floor in Neogene Tertiary has been reported (Sugawara et al., 1982). Water escape structure (Lowe et al., 1974) similar to those in the sulfides of the Kuroko ores is observed in the ores of the present area, and it is certain that the proto-ore consisting of minute sulfide grains migrated during the dehydration caused by compaction after deposition. Also the geologic units of this area have been regionally metamorphosed, and the primary rocks and minerals have all been recrystallized.

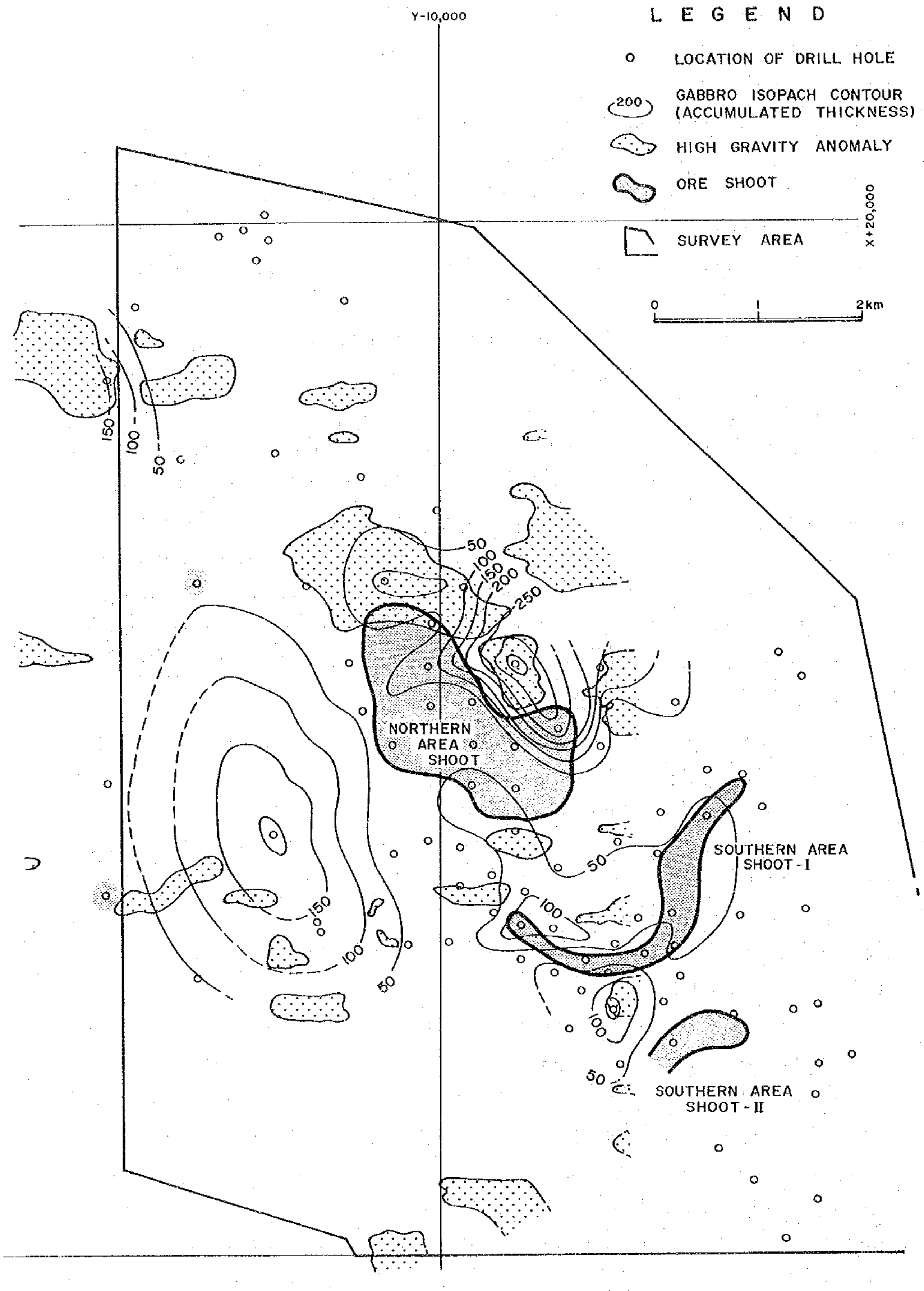


Fig.1-11 Supplementary Interpretation Map

There are two theories regarding the genesis of the gabbroic bodies of this area; namely magmatic intrusion and metamorphic origin. The former genesis is widely believed, but the latter cannot be totally discarded (Mendelsohn, 1961). The basis for the metamorphic origin is that; the chemical composition of the mixture of dolomite and argillite is similar to that of gabbro, the gain-size and texture of the gabbro changes irregularly and abruptly, the gabbro gradually changes to dolomite, typical skarn minerals do not occur in the vicinity of gabbroic bodies, amphibolite formed from pelitic dolomite is similar to that formed by alteration of mafic rocks. Also if gabbroic bodies are of intruded magma origin, the following hydrothermal activities and metamorphism are considered to have took part in the migration of ore materials. However, the orebodies would have been solidified by then, and so the mechanism of migration is difficult to envisage. If the gabbroic bodies are of metamorphic origin, as the distance between the dolomitic rocks and the orebodies is in the order of 500 m, it is considered that the orebodies were still in the stage of diagenesis, and horizontal movement could have been caused by the load of the dolomitic units. The age of the rocks of this area is very old, and it is difficult to clarify the relation between diagenetic, metamorphic, and igneous activities from the recrystallized units.

4-2 Mineral Potential

The orebodies of this area are developed in the limbs of palaeo-basement highs at the time of ore deposition, particularly in the local basement depressions parallel to the palaeo-coastlines. And ore shoots occur at horizons higher than the present basement high risen by folding after the burial of the Ore Shale. Ore shoots were not formed where thick gabbroic bodies occur over the ore horizon and in gravity highs. From the above, the guiding factors for prospecting in this area would be as follows.

Because the basement high which bounds the southwestern side of the Northern Area Shoot was formed after the deposition of orebodies, the vicinity of this basement high is a possible zone for occurrence of rich ores. Therefore, there is a good possibility of the Northern Area Shoot extending to the west of NN-48 and NN-55, and further continuing toward the Chambishi mine through the area between NN-52 and NN-60, and NN-75 which has hit ore.

The present survey indicates a possibility of the Southern Area Shoot-II extending to MJZC-2, and further continuing westward and southward. The basement of this part is relatively shallow, and there is a gap of gravity highs here and is deemed interesting.

NN-66 and NN-72 in the western part of the survey area belong to the pyrite-pyrrhotite zone, and presence of Cu-ore shoot cannot be expected in the vicinity. In the area between NN-66 and MJZC-4 at which pyrrhotite-remarkably dominated ores with lesser chalcopyrite were confirmed during this survey, presence of Cu-ore shoot cannot be expected. The ore shoot of RCB-2 west of the above pyrite-pyrrhotite zone, is considered to have a source different from the ore shoot in the central part of this area.

The priority for prospecting in the northern side of the Northern Area Shoot is lower, because gabbroic bodies and gravity highs are developed, and the Lower Roan Group may abut against the basement in the deeper subsurface zones and the possibility of finding ore horizon is low.

Chapter 5 Conclusions and Recommendations

5-1 Conclusions

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. 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 grade of the horizon above the palaeo-basement high is low 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.

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 water-escape 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.

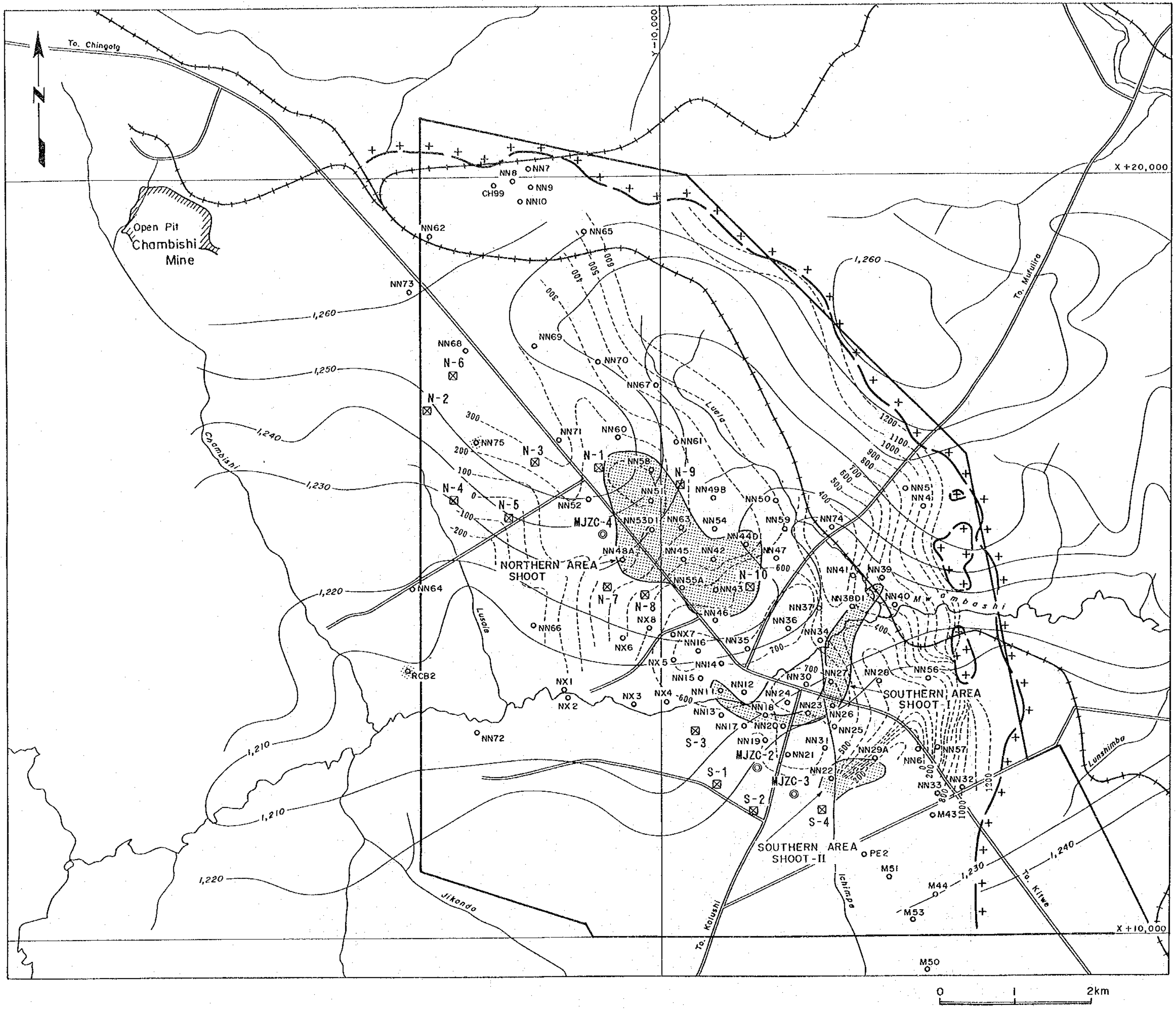
5-2 Recommendations for Second Phase Survey

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 Figure 1-12 is recommended for the work of second and third phases. Namely, the project area are 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, 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.



Northwestern Area

Priority	Drill Hole No	Inclination	Drilling Length(m)
1	N-1	-90	1,100(F)
2	N-2	-90	1,100(B)
3	N-3	-90	1,050(B)
4	N-4	-90	1,350(B)
5	N-5	-90	1,350(B)
6	N-6	-90	950(B)
7	N-7	-90	800(F)
8	N-8	-90	800(B)
9	N-9	-90	1,000(F)
10	N-10	-90	600(B)
	Total		10,100

Southern Area

Priority	Drill Hole No	Inclination	Drilling Length(m)
1	S-1	-90	1,100(B)
2	S-2	-90	1,100(B)
3	S-3	-90	750(B)
4	S-4	-90	1,400(B)
	Total		4,350

B : To the Basement
F : To the footwall of the ore horizon

L E G E N D

- LOCATION OF DRILLHOLES RECOMMENDED
- LOCATION OF EXISTING DRILL HOLES
- 1,250 TOPOGRAPHIC ELEVATION CONTOUR IN METRES
- 300 TOP OF BASEMENT ELEVATION CONTOUR IN METRES
- ORE SHOOT
- SURFACE DISTRIBUTION OF BASEMENT
- SURVEY AREA

Fig.1-12

Drill Holes Recommended for 2nd and 3rd phase exploration

PART II

DETAILED DISCUSSIONS

PART II DETAILED DISCUSSIONS

Chapter 1 MJZC-2

1-1 Progress of Drilling

The location and the collar elevation of MJZC-2 are as follows.

Latitude	Longitude	Co-ordinates		Collar Elevation	Drilling Length	Incli-nation
		X	Y			
12°43′28″S	28°07′03″E	+12,199.51	-8,775.17	1,212.5 m	810.00 m	-90°

Summary of the drilling, record of the drilling operation and the drilling progress are shown in Tables 2-1-1 and 2-1-2, and Figure 2-1-1, respectively.

For the near surface zone to 35.00 m, non-core drilling was made by 200 mm percussion bit, and 200 mm casing pipes were inserted to 35.00 m. At 35.00 to 153.00 m, non-core drilling was made by 150 mm percussion bit, and HW and NW casing pipes were inserted to 153.00 m. From 153.00 m to the bottom depth of 810.00 m, core drilling was made by NQ bit. Cuttings were collected at 1 m interval for non-core drilling.

This drilling operation went smoothly without major loss of circulation.

Borehole deviation was measured every 100 m as shown in Appendix-6. The measurement showed that the borehole deviated northwestward similar to those of previous holes in the vicinity.

1-2 Geology and Mineralization

The geologic log is appended. The geology of the drill hole is similar to that of the survey area, which is described in 3-2 of PART I. Description of the drill hole is as follows.

Basement : 797.20 to 810.00 m. The upper part is white, intensely silicified rock consisting of quartz and mica, and it gradually changes to granite in the lower part. The granite is white or grey, recrystallized holocrystalline, and is composed of quartz and biotite, containing pseudomorph of feldspar replaced by quartz. Anhydrite veinlets are dispersed in the granite.

Table 2-1-1 Summary of the Drilling Operation on MJZC-2

	Survey Period				Total man day	
	Period	Days	Work day	Off day	Engineer	Worker
Operation			days	days	man	man
Preparation	27.12.1993~27.12.1993		0.5			
	18.01.1994~21.01.1994	4.5	4.0	0	10	28
Drilling	27.12.1993~29.12.1993		Drilling 21	3	60	168
	22.01.1994~10.02.1994	24	Recovering 0	0	0	0
Dismantling	11.02.1994~12.02.1994	2	2	0	8	24
Total	27.12.1993~12.02.1994	30.5	27.5	3	78	220

Drilling length			
Length planed	810.00 m	Overburden	12.00 m
Increase or Decrease in length	— m	Core length	652.02 m
Length drilled	810.00 m	Core recovery	99.2 % 652.02 /657.00

Core recovery of 100 m hole		
Depth of hole (m)	Core recovery (%)	Core recovery cumulated (%)
0.00 ~ 100.00	N/C	—
100.00 ~ 200.00	96.2	96.2
200.00 ~ 300.00	98.6	98.3
300.00 ~ 400.00	98.2	98.3
400.00 ~ 500.00	99.9	98.7
500.00 ~ 600.00	100.0	99.0
600.00 ~ 700.00	99.9	99.2
700.00 ~ 800.00	99.5	99.2
800.00 ~ 900.00	100.0	99.2

Working hours	h	%	%
Drilling	198°00′	39.2	26.1
Other working	238°00′	47.1	31.4
Recovering	69°00′	13.7	9.1
Total	505°00′	100.0	66.6
Reassemblage	106°00′		14.0
Dismantlement	52°00′		6.9
Water transportation	42°00′		5.5
Road construction and transportation	53°00′		7.0
G. Total	758.00		100.0

Efficiency of Drilling	
Total m/work period(m/day)	810.00 m/ 24 days (33.75 m/day)
Total m/work shift(m/shift)	810.00m/ 37 shift (21.89 m/shift)

Drilling length/bit (each sized bit)				
Bit size	200mm	150mm	NQ	BQ
Drilled length	35.00m	118.00m	657.00m	— m
Core length	0.00m	0.00m	652.02m	— m

Casing pipe inserted			
Size	Meterage (m)	Meterage/drilling length × 100 (%)	Recovery (%)
200mm	35.00	4.3	0
HW	153.00	18.9	100
NW	153.00	18.9	100

Table 2-1-2 Record of the Drilling Operation on MJZC-2

	Drilling length			Daily Total		Number of Shift		Number of Person	
	shift 1	shift 2	Total Cumulated	Drilling	Core length	Drilling	Total	Engineer	Worker
December	m	m	m	m	m	shift	shift	man	man
26	Day off	Day off	Day off	Day off	Day off	0	0	0	0
27	Tra-Reas	35.00	35.00	35.00	0.00	1	2	2	8
28	60.00	41.00	136.00	101.00	0.00	2	2	2	8
29	17.00	Dismant	153.00	17.00	0.00	1	2	2	8
30	Pds	Day off	153.00	0.00	0.00	0	1	1	4
31	Supension		153.00	0.00	0.00	0	0	0	0
~									
January									
17	Day off	Day off	153.00	0.00	0.00	0	0	0	0
18	Trans	Trans	153.00	0.00	0.00	0	2	1	4
19	Trans	Trans	153.00	0.00	0.00	0	2	1	4
20	Reas	Reas	153.00	0.00	0.00	0	2	3	8
21	Reas	Reas	153.00	0.00	0.00	0	2	3	8
22	Ins C.P	Ins C.P	153.00	0.00	0.00	2	2	3	8
23	Day off	Ins C.P	153.00	0.00	0.00	0	1	2	8
24	19.17	24.60	196.77	43.77	42.75	2	2	3	8
25	38.80	6.50	242.07	45.30	44.54	2	2	3	8
26	32.90	31.57	306.54	64.47	63.84	2	2	3	8
27	33.56	36.87	376.97	70.43	68.62	2	2	3	8
28	52.44	23.80	453.21	76.24	76.18	2	2	3	8
29	34.76	30.00	517.97	64.76	64.70	2	2	3	8
30	Day off	45.25	563.22	45.25	45.25	1	1	2	4
31	17.09	10.54	590.85	27.63	27.63	2	2	3	8
February									
1	19.82	10.20	620.87	30.02	30.02	2	2	3	8
2	9.64	19.56	650.07	29.20	29.09	2	2	3	8
3	35.90	11.10	697.07	47.00	47.00	2	2	3	8
4	12.20	5.00	714.27	17.20	17.20	2	2	3	8
5	3.80	18.90	736.97	22.70	22.70	2	2	3	8
6	Day off	12.00	748.97	12.00	12.00	1	1	2	4
7	4.55	0.00	753.52	4.55	4.55	1	2	3	8
8	27.58	0.00	781.10	27.58	27.30	1	2	3	8
9	9.90	0.00	791.00	9.90	9.65	1	2	3	8
10	18.00	1.00	810.00	19.00	19.00	2	2	3	8
11	Out C.P	Day off	-	-	-	-	1	3	8
12	Dismant	Day off	-	-	-	-	1	3	8
Total	447.11	362.89	810.00	810.00	652.02	37	54	78	220

Abbreviation

Pds : Preparation for drilling site
Trans : Transportation
Tra-Reas : Transportation and Reassemblage
Reassemb : Reassemblage
Dismant : Dismantlement
Main-mac : Maintenance of machines
Ins-C.P : Inserting casing pipe
Out-C.P : Taking out casing pipe
Road-con : Road construction
Repair : Repair work on a road
Tra-pack : Transportation and packing of equipment

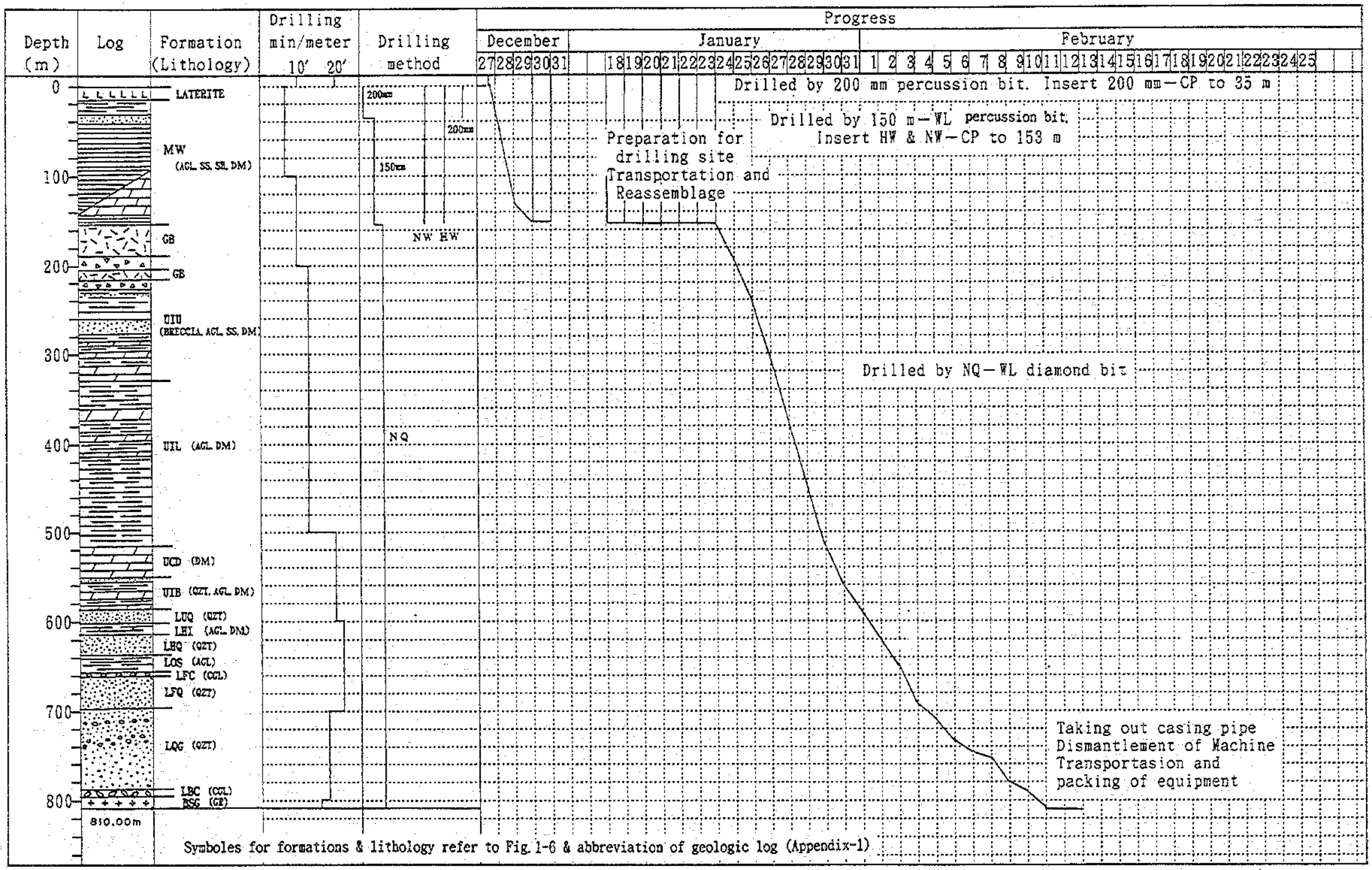


Fig.2-1-1 Drilling Progress of MJZC-2

Lower Roan Group

"Basal Conglomerate": 791.10 to 797.20 m. It is composed of pinkish grey pebbles with granite boulders in part. The pebbles mainly consist of subangular silicified granite with minor amount of angular chert. The matrix mainly consists of biotite and quartz, containing pink and white silicified crystal fragments (feldspar ?).

"Feldspathic Quartzite and Grits": 698.00 to 791.10 m. This unit is composed of grayish white and pinkish gray quartzites with intercalations of conglomerate, pebbly quartzite and argillite lamina. These are intensely silicified in general. Anhydritization and biotitization are recognized.

"Intermediate Conglomerate": 676.30 to 698.00 m. It is composed of intensely silicified gray conglomerates with anhydrite patches. The conglomerates contain various types of pebbles such as chert, granite, quartzite, gneiss and biotitized rock.

"Footwall Quartzite": 660.70 to 676.30 m. It consists of dark gray and pink pelitic quartzites with many intercalations of argillite. The quartzites are rich in biotite.

"Footwall Conglomerate": 658.60 to 660.70 m. This formation is made up of biotite-rich, gray silicified conglomerates. The conglomerates are composed of chert, black sandy rock and granite pebbles and anhydrite matrix.

"Ore Shale Horizon": 638.20 to 658.60 m. It mainly consists of sandy and dolomitic argillites with very thin layers of dark gray and black lamina (1 to 5mm). The basal part of this formation is made up of pelitic dolomites. A interval of 642.90 to 658.60 m is a mineralized zone composed of Cu-bearing sulfide minerals. A interval of 649.20 to 658.60 m of the above interval is a Cu-high grade part at which chalcopyrite and pyrrhotite are disseminated and concentrate in thin lenses parallel to bedding planes, and irregular veinlets of quartz-chalcopyrite-pyrite-pyrrhotite occur. At a depth of 642.90 to 645.60 m, small-spotted dolomitic concretions are contained, and their rims are fringed with pyrite. At 648.10 to 649.30 m, chalcopyrite and pyrrhotite occur in and around concretions of siliceous dolomite. Results of ore assay are shown in Table 2-4-4.

"Hangingwall Quartzite and Argillite": 614.90 to 638.20 m. It consists of dark gray pelitic quartzites with many amounts of argillite band and small amounts of anhydrite-rich dolomite and siliceous dolomite partings. Lenticular and disseminated anhydrites occur in this interval.

"Interbedded Argillite and Quartzite": 602.30 to 614.90 m. It is mainly composed of green sandy argillites with intercalations of siliceous and micaceos dolomites. Disseminated, small patch and lenticular anhydrites are observed.

"Upper Quartzite": 587.70 to 602.30 m. It is composed of pinkish and brownish gray quartzites with many pelitic and micaceous bands.

Upper Roan Group

"Interbedded Argillite, Dolomite and Quartzite": 552.00 to 587.70 m. This unit is divided to upper and lower parts. The former is of sandy rocks such as gray quartzite and gray dolomitic quartzite with intercalations of dark yellowish gray micaceous argillite, white anhydritic dolomite, sandy dolomite, green dolomitic argillite and so on. The latter is of white micaceous and siliceous dolomites with intercalations of quartzite, sandstone, sandy argillite and so on.

"Cherty Dolomite": 517.70 to 552.00 m. It mainly consists of massive white dolomites and locally with spotted silicified parts. In the upper part, a dark green micaceous and sandy argillite (Maker Shale) is intercalated. While, in the lower part, dark gray pelitic dolomite and micaceous argillite are intercalated. Generally, spotted anhydrites are contained. A copper mineralization is recognized at 539.80 to 541.10 m, where very fine-gained chalcopyrite are disseminated in the anhydrites and dolomites.

"Arenite, Argillite and Dolomite with Anhydrite": 329.90 to 517.70 m. This unit is divided to upper and lower parts. The former is of green and dark yellow micaceous and silty argillites with many thin dolomite partings, and the latter of green sandy argillites and alternations of thin argillite and sandstone with thin quartzite partings. In the alternations of argillite and thin sandstone, dish structure, pillar structure, sandstone dike formed by liquefaction and convolute lamination are developed. From about 333 m downward, intense anhydritization (lens, veinlet and spot) is generally observed, and quartz veinlets are dispersed at 453 to 500 m.

"Interbedded Argillite and Dolomite with Tectono-Breccias":189.50 to 329.90m. This unit is divided to upper, middle and lower parts. The upper part is of silicified, dolomitized and micaceous breccias, the middle part of white quartzitic sandstones with intercalations of pale green argillite, dark gray siliceous shale and white dolomite, and the lower part of green sandy argillites and white siliceous or micaceous dolomites. Stylolites are recognized in dolomites at 274 to 293 m. Limonites are attached to vugs broadly observed in dolomites. At 225.80 to 232.20 m, vuggy veinlets composed of limonite and dolomite are developed in argillites.

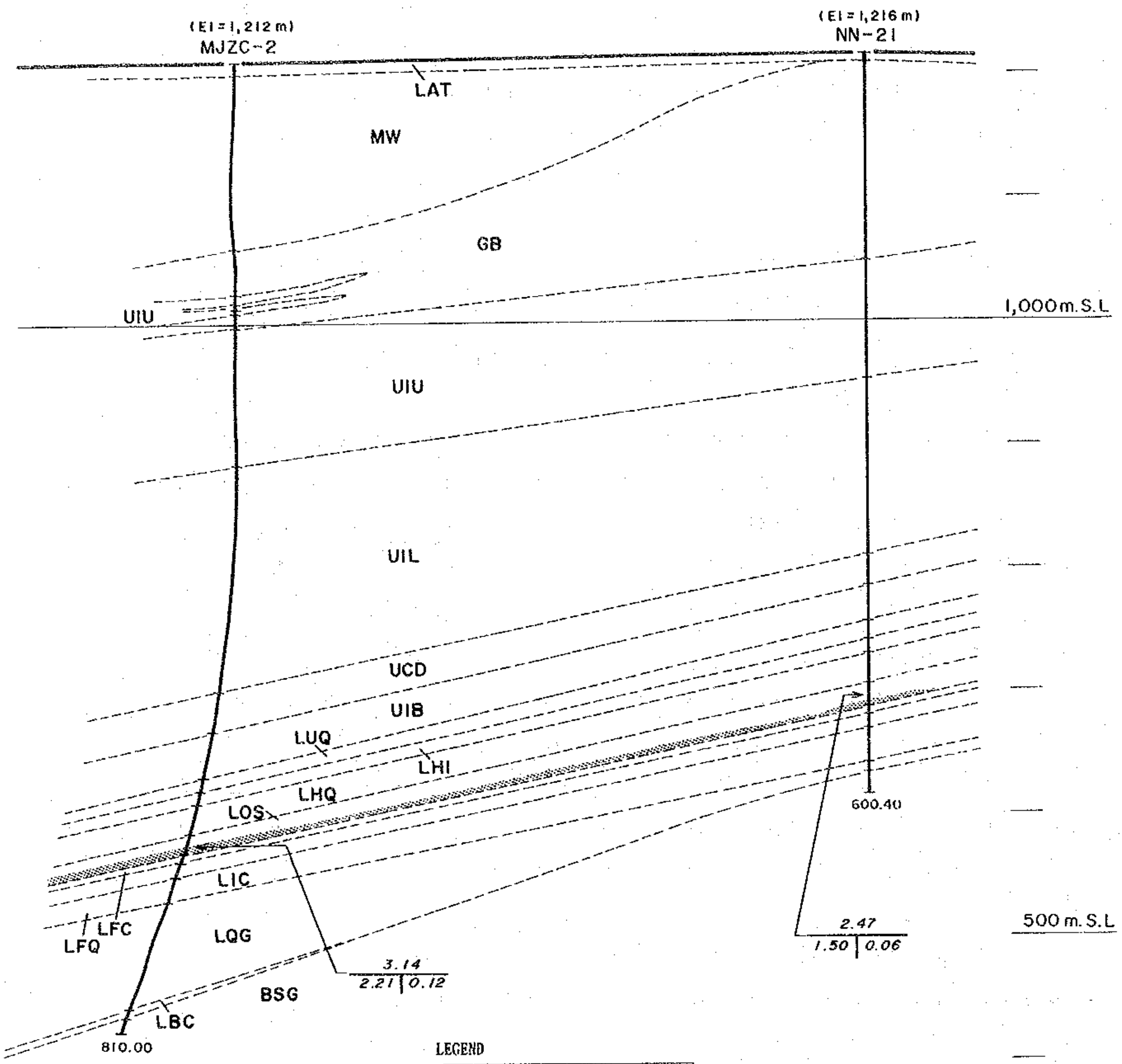
"Mwashia Group": 12.00 to 153.00 m. It consists of black shales with gray dolomites, dark green phyllitic argillites and arkosic sandstones. A densely disseminated pyrite zone is developed in the shales.

"Gabbro": Gabbros occur at many parts in a interval of 153.00 to 216.00 m. These are dark green to gray, altered, biotite-dominant massive rocks with gray intensely silicified rocks. In these gabbroic bodies, silica-dolomite-mica stockworks are developed.

1-3 Discussions

It is seen from the cross sections (Fig. 2-1-2) that the basement is further depressed, and consequently the "Feldspathic Quartzite and Grits" of the Lower Roan Group is thicker in this hole than in NN-21 to the east. Aside from the above and the thin gabbroic body, the geology of this hole is very harmonious to the conditions of NN-21. The mineralized zone in the Ore Shale confirmed in this hole occurs on the western limb of the basement high extending in an N-S direction (Fig. 1-10), and the ore conditions are relatively good. It is very probable that the Southern Area Shoot-II extends westward along the southern projection of the basement limb through the southern side of MJZC-3 and continues to this hole.

The copper-rich part of the Ore Shale of this hole consists of thin lenses, dissemination and veinlets of chalcopyrite, and chalcopyrite-bearing siliceous dolomitic concretions. It indicates the possibility of migration and concentration of copper through diagenesis and metamorphism.



LEGEND

SCALE: 1/5,000
2.82 — TRUE THICKNESS (m)
0.66 | 0.03 - % TOTAL COBALT
% TOTAL COPPER

Symboles for geologic units refer to Fig.1-6

Fig.2-1-2 Geological Profile of Drilling Hole (MJZC-2)