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

CONSOLIDATED REPORT

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METAL MINING AGENCY OF JAPAN

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P R E F A C E

The Government of Japan in response to the request extended by the Government of the Republic of Zambia, agreed to conduct a metallic exploration survey in the Chambishi Southeast Area, and commissioned its implementation to the Japan International Cooperation Agency.

The agency, taking into consideration the importance of the technical nature of the survey work, sought the cooperation of the Metal Mining Agency of Japan to accomplish the task.

The Government of the Republic of Zambia appointed the Zambia Consolidated Copper Mines Limited (ZCCM) to execute the survey as a counterpart to the Japanese team. The survey has been carried out jointly by experts of both Governments.

The collaboration survey for metallic mineral, which lasted three years, consists of drilling exploration, data compilation and other relevant work. This consolidated report hereby submitted summarizes results of the said survey.

We wish to take this opportunity to express our gratitude to all sides concerned in the execution of the survey.

February 1996

Kimio FUJITA
President
Japan International Cooperation Agency

Shozaburo KIYOTAKI
President
Metal Mining Agency of Japan

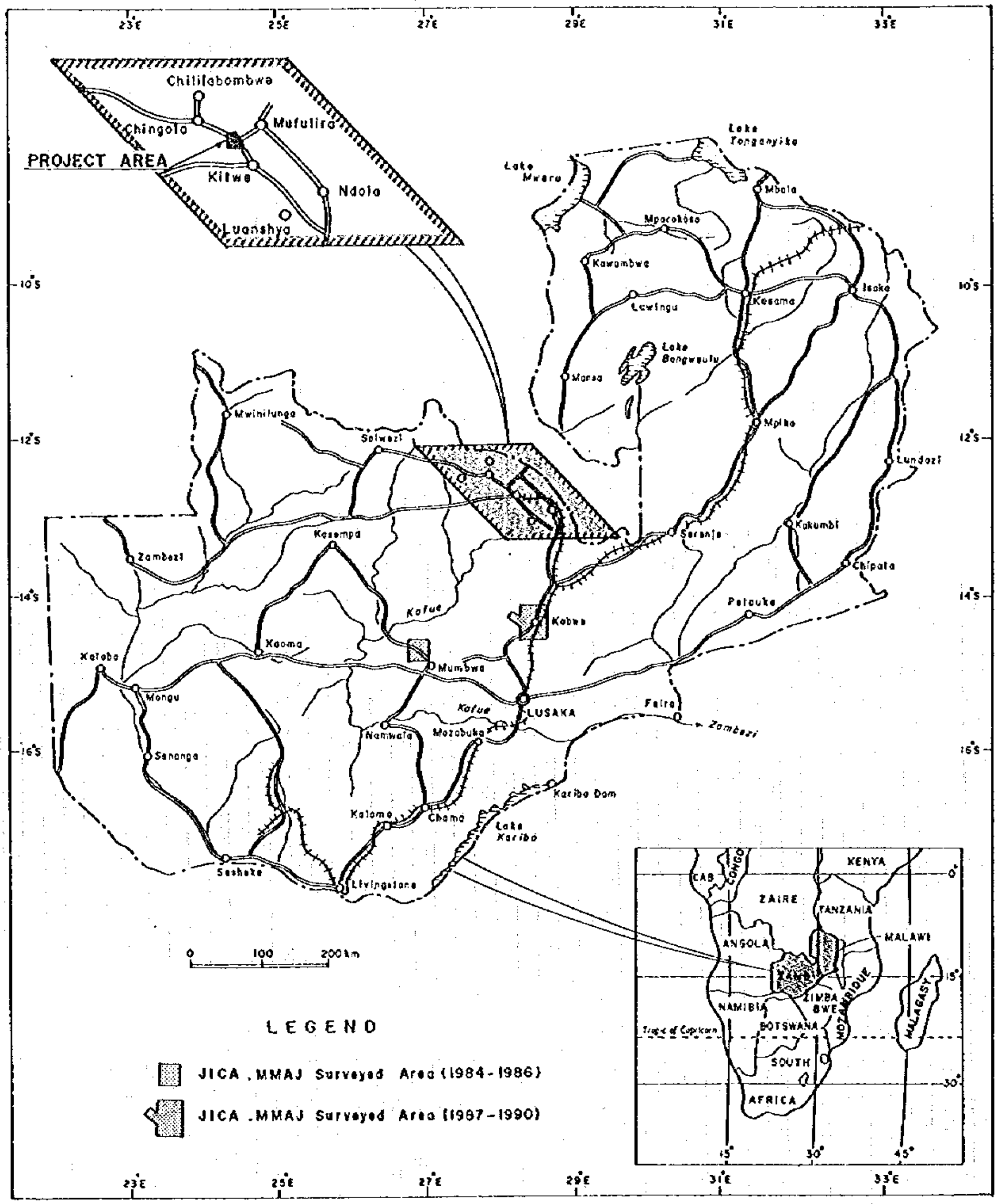

Fig. 1-1 Index Map of the Project Area

S U M M A R Y

During the course of the three year period of Fiscal 1993 to 1995 of the Chambishi Southeast area mineral exploration, drilling, and compilation and interpretation of existing data were carried out. The results are summarized below.

All twelve boreholes drilled during this survey attained their objectives by penetrating the ore horizon. The nine boreholes reached the basement. The geology and mineralization of the survey area were thus clarified.

MJZC-9 drilled in the western part of the area confirmed the existence of high-grade ores (i. width 5.90m, grade T-Cu 3.12%, T-Co 0.08%; ii. width 2.58m, grade T-Cu 2.29%, T-Co <0.01%). These ores are considered to be continuous to the shoot confirmed to the north of this hole (NN-75). Thus it is now clear that an ore shoot of considerable scale exists in this area. It is inferred that this ore shoot is emplaced over a basement depression which is elongated in the NE-SW direction and it is deemed possible that this shoot is developed further southward or westward.

The known areal extent of the Northern Area Shoot, which is the most important ore deposit of this area, expanded northwestward by the confirmation of ores by MJZC-5 (i. width 3.10m, grade T-Cu 1.93%, T-Co 0.03%; ii. width 2.64m, grade T-Cu 2.32%, T-Co 0.03%), while it shrank in the western and southeastern parts by the confirmation of low-grade ores of MJZC-4 and barren zone of MJZC-8.

The five boreholes drilled in the southern part of this area (MJZC-2, -3, -11, -12) were located in relatively raised basement areas, and they showed that many of the mineralized zones consisted of low-grade copper ores belonging to the pyrrhotite-pyrite-chalcopyrite zone. But in some parts, small bornite zone in the lowermost part of the "Ore Shale" (MJZC-12), chalcopyrite zone in the footwall quartzite (MJZC-1), and local high-grade copper of pyrrhotite-pyrite-chalcopyrite zone (MJZC-2, -3, -12) were confirmed. In this area, the occurrence of ore shoots is limited only to the lowermost part of the "Ore Shale", and thus it is inferred that ore deposition occurred in relatively short period of time, thereby limiting the size of

the ore deposits. If, however, deep local depression existed on the seafloor at the time of copper deposition, relatively large ore shoots could have been formed.

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.

In almost all of the boreholes, stratigraphic zonal arrangement of the sulfide minerals is observed in the mineralized zones. The depth of the sea probably increased after the deposition of the "Ore Shale", because the Fe/Cu ratio generally increases upward from near the lowermost part of the "Ore Shale Horizon". Most of the ore shoots in this zone belong to the chalcopyrite zone, but the high cobalt zones exist not only in the chalcopyrite, but also in the pyrrhotite and pyrite zones. It is inferred that the chalcopyrite zone was formed within a narrow sea depth zone. Therefore, we believe that the conditions for the formation of copper ore shoots would be; the continuation of the optimum depth range of the sea, and the existence of depressions suitable for the deposition and preservation of copper minerals.

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.

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.

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

Ore reserve calculation was carried out in order to asses the mineral potential of the survey area with the following results.

Northern Area Shoot: 54.79 million tons, 2.70% T-Cu, 0.13% T-Co
Southern Area Shoot: 14.93 million tons, 2.19% T-Cu, 0.13% T-Cu
Subeconomic Zone : 107.91 million tons, 1.83% T-Cu, 0.03% T-Cu

Significant amounts of ore were confirmed in this survey area by drilling during the period hitherto reported. In order to develop this deposit, however, it is necessary to further increase the ore reserves. The western and southern parts of the survey area have not been explored and the potential is considered to be promising.

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PART I OVERVIEW

Chapter 1 Outline of Project

1-1 Areas and Objectives

In response to the request by the Government of the Republic of Zambia to conduct mineral exploration, the Government of Japan dispatched a mission to discuss the details of the project. And as a result of the consultations between the Zambia Consolidated Copper Mines Limited (ZCCM), and the Metal Mining Agency of Japan (MMAJ), an agreement was reached for cooperative exploration of the Chambishi Southeast Area. The "Scope of Work"(SW) was signed by the representatives of both governments in June 1993. The objective of this project is to assess the mineral potential of the area (areal extent $60km^2$) through drilling exploration during the three year period of Fiscal 1993 to 1995.

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.

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

The third phase of this project was carried out in fiscal 1995. The survey of that phase comprised drilling (4 holes, 3,789m), and ore reserve calculation.

The major objective of the survey of each phase was to discover new ore deposits through the understanding of the metallic mineralization and the geology of the survey area, and to pursue technology transfer to the Zambian counterpart personnel.

1-2 Methods and Contents

The methods employed during the course of this project are; compilation of existing data, drilling, various laboratory work and ore reserve estimation. The methods used each year and the amount of work carried out are laid out in Table 1-1.

Flowsheet-Survey

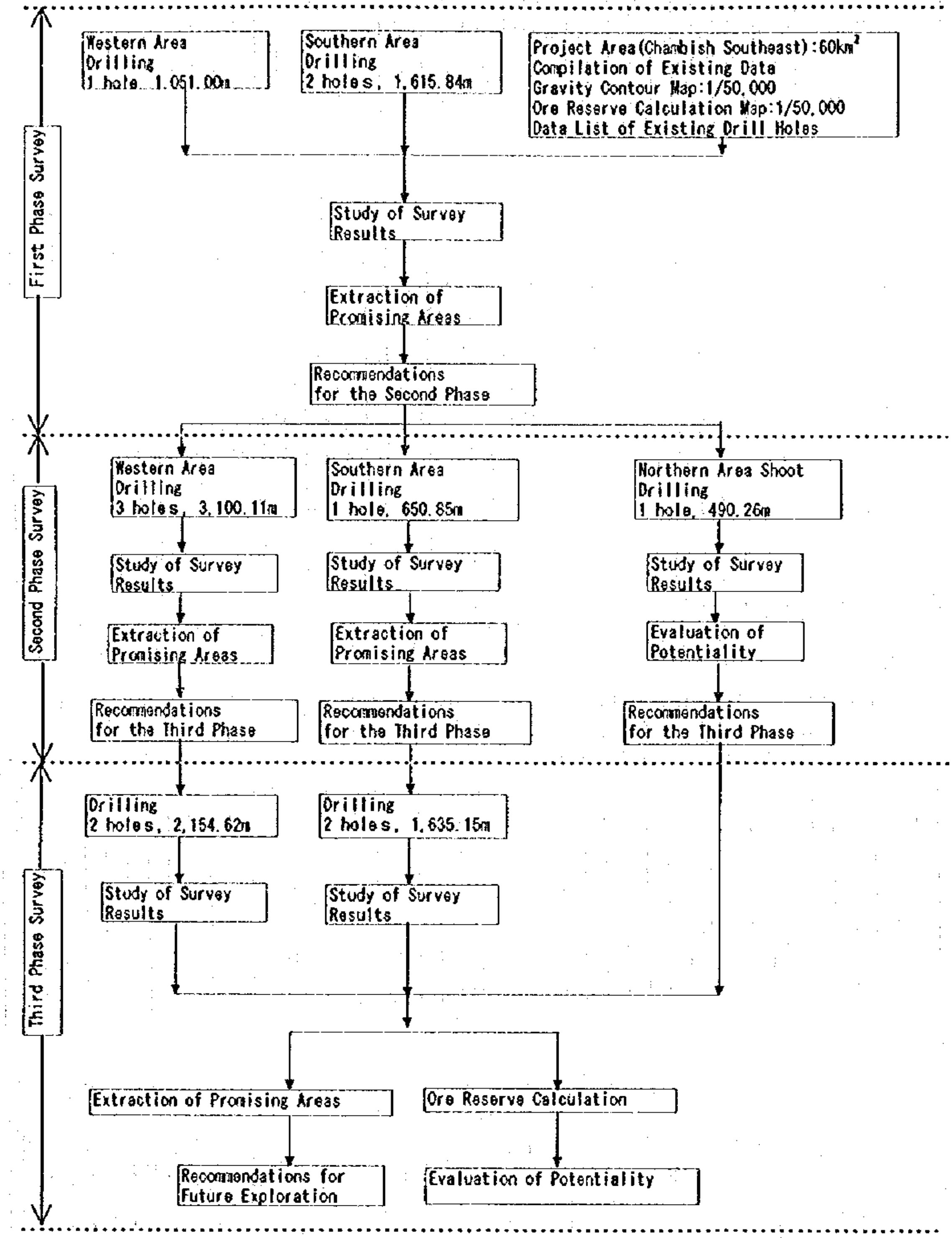


Fig. 1-2 Flowsheet of Survey

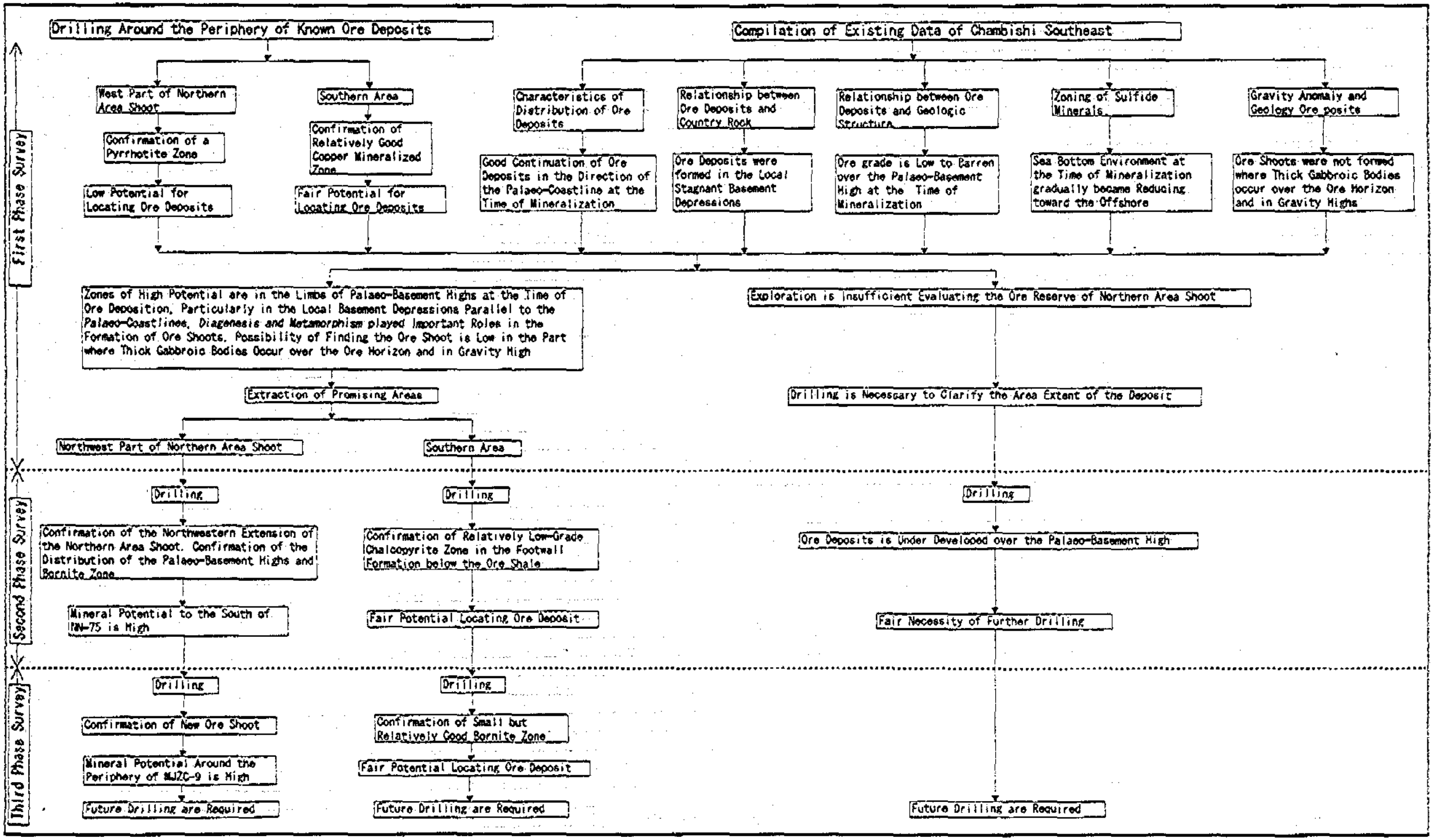


Fig. 1-3 Exploration Flowsheet-Chambishi Southeast

Table 1-1 Amount of Work

Phase	Survey Method	Area	Amount	
First	Compilation of Existing Data	Chambishi Southeast	Areal extent	60 km^2
	Drilling	Chambishi Southeast	Number of drill holes	3
			Total length drilled	2,666.84 m
			Laboratory work	
			Thin section microscopy	14 sections
			Polished section microscopy	12 sections
			X-ray diffraction analysis	31 samples
			Ore assay (Cu,Co,Ni,Zn)	106 samples
			Ore assay (Cu,Co)	48 samples
Second	Drilling	Chambishi Southeast	Number of drill holes	5
			Total length drilled	4,241.22 m
			Laboratory work	
			Thin section microscopy	10 sections
			Polished section microscopy	20 sections
			X-ray diffraction analysis	5 samples
			Ore assay (Cu,Co)	388 samples
Third	Drilling	Chambishi Southeast	Number of drill holes	4
			Total length drilled	3,789.77 m
			Laboratory work	
			Thin section microscopy	10 sections
			Polished section microscopy	20 sections
			X-ray diffraction analysis	6 samples
			Ore assay (Cu,Co)	285 samples
			Ore assay (Au,Ag)	400 samples
	Ore Reserve Calculation	Chambishi Southeast	Areal extent	60 km^2

1-3 Duration and Participants

The duration and the members of the survey team are listed in Table 1-2.

Table 1-2 Duration of Survey and Participants

Phase	Contents	Duration	Japanese Members	Zambian Members
First	Project Finding and Scope of Work Consultation	1993, 6.21 -- 1993, 7. 4	Y. Noguchi [2] T. Tsujimoto [2] Y. Igarashi [2] K. Edo [1] N. Masuda [2]	E. Shamutete [4] E. M. Koloko [4] J. H. D. Patterson [4] R. J. H. Naish [4] A. C. Kaunda [4] S. M. Searstone [4]
	Field Supervisor		T. Tsujimoto [2]	
	Drilling, Compilation of Existing Data	1993, 11.18 -- 1994, 2.15	M. Sugawara [3]	J. H. D. Patterson [4] R. J. H. Naish [4] A. C. Kaunda [4] F. A. Siddiqui [4] W. J. Silondwa [4]
Second	Field Supervisor		Y. Okuizumi [2]	
	Drilling	1994, 8. 8 -- 1994, 12.19	M. Sugawara [3] M. Wakamatsu [3]	J. H. D. Patterson [4] R. J. H. Naish [4] C. C. Tomkins [4] A. C. Kaunda [4] F. A. Siddiqui [4] W. J. Silondwa [4]
Third	Drilling	1995, 7. 6 -- 1995, 12. 2	M. Sugawara [3] M. Wakamatsu [3]	J. H. D. Patterson [4] C. C. Tomkins [4] A. C. Kaunda [4] W. J. Silondwa [4] P. N. Mubuyaeta [4]
	Ore Reserve Calculation	1995, 6.26 -- 1996, 2.20	M. Sugawara [3]	F. A. Siddiqui [4] A. C. Kaunda [4] S. Haabanyama [4]

(1): Japan International Cooperation Agency (2): Metal Mining Agency of Japan
(3): Nikko Exploration and Development Co., Ltd.
(4): Zambia Consolidated Copper Mines Limited (ZCCM)

Chapter 2 Previous Surveys

Major surveys previously carried out in the area are as follows.

(1) Geological Survey

(a) Duration

1903(?)-1952(?); done alternately by RST (Rhodesia/Roan Selection Trust) and Rhoanglo.

(b) Method of Survey

Aerial photography and Field traversing

(c) Results

Chambishi Mine Orebody outcrop

(2) Pitting

(a) Duration

1927-1929; Pitting and trenching - Chambishi Mine itself

1952-1963; Pitting and trenching by RST at Chambishi Southeast Area.

(b) Method of Survey

Manual by pick, shovel plus a bucket

Pit interval: aprox 200m

(c) Results

Inconclusive due to deep weathering

(3) Geochemical Survey

(a) Duration

1953-1955, 1960; by RST

(b) Method of Survey

Determination of copper metal concentration in the soil

(c) Results

No significant values (The majority of samples contained less than 100ppm)

(4) Gravimetric Survey

(a) 1959-1963; Surveyed by Aero Service (Rhodesia Pvt Ltd)

(b) Method of Survey

Gravity meter type called WARDEN

(c) Results

1/10,000 gravity contour map

(5) Magnetometer Survey

(a) Duration

1960-1962; Surveyed by C.J. Survey Ltd.

(b) Method of Survey

Ground magnetic surveys by magnetometers

(c) Results

Anomaly zones do not correspond with geological map

(6) E. M.

(a) Duration

1956, by Hunting Geophysics Ltd for the UNITED KINGDOM ATOMIC ENERGY AUTHORITY, LONDON

1971, by McPhar of Canada for RST

(b) Method of Survey

Airborne E.M.

(c) Results

1/25,000 E.M. map, Amphibolite/Gabbro distribution coincident with highly anomaly areas.

(7) Radiometric Survey

(a) Duration

1971, by McPhar

(b) Method of survey

Airborne Survey

(c) Results

Most distinctive anomaly was attributed to the presence of Amphibolite/Gabbro bodies.

(8) Drilling

(a) Duration

1950-1982, by RST and later by RCM/ZCCM

(b) Method of Survey

Mainly diamond drilling; 95 holes totaling aprox 62,000 meters.

(c) Results

Geological resource of 289.89 million tons at 1.94% Cu of which 202.37 million contains 1.95% Cu and 0.08% Cobalt.

(9) Ore Resource Calculation

(9-1)

(a) Duration

1981-1983, by ZCCM (M. Hancock, V. D. Fleisher)

(b) Method

Triangulation; >3m true thickness, >2% s-Cu Cut-Off factor (without Co), 2.67t/m^3 tonnage factor, 0.1% Co = 1% Cu, 9 holes of Northern and 11 holes of Southern Zone were used for calculation.

(c) Results

Northern Zone: 38.3 m.t (metric ton), 2.42% T-Cu

Southern Zone: 6.3 m.t (metric ton), 2.23% T-Cu

(9-2)

(a) Duration

1982-1983, by ZCCM (V. D. Fleisher)

(b) Method

Computer assisted calculation, outerlimits of 2% T-Cu and 10m%, 11 holes of Northern Zone were used.

(c) Results

Northern Zone: 64.93 m.t 2.49% T-Cu

(9-3)

(a) Duration

1992-1993, by ZCCM (S. Searston)

(b) Method

Calculation for overall mineral potential of the area (all Chambishi Southeast area including RCB-2, NN-75, Ichimpe), 0.05% Co and 1% T-Cu Cut-Off, no thickness considered.

(c) Results

202.37 m.t, 1.95% Cu, 0.08% Co

(10) Metallurgical Study

(a) Duration

1982, by Crane and Degaleeson/ZCCM

(b) Method

Mineralogical studies of bulk floatation, eight representative boreholes were used.

(c) Results

Copper recoveries of 95% and concentrates of grades ranging from 25% to 42% T-Cu.

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 and quartz mica schist(Figs. 1-4 and 1-6). Widespread low-grade copper mineralization is known to occur 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. 1-6).

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 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. 1-4). 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 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

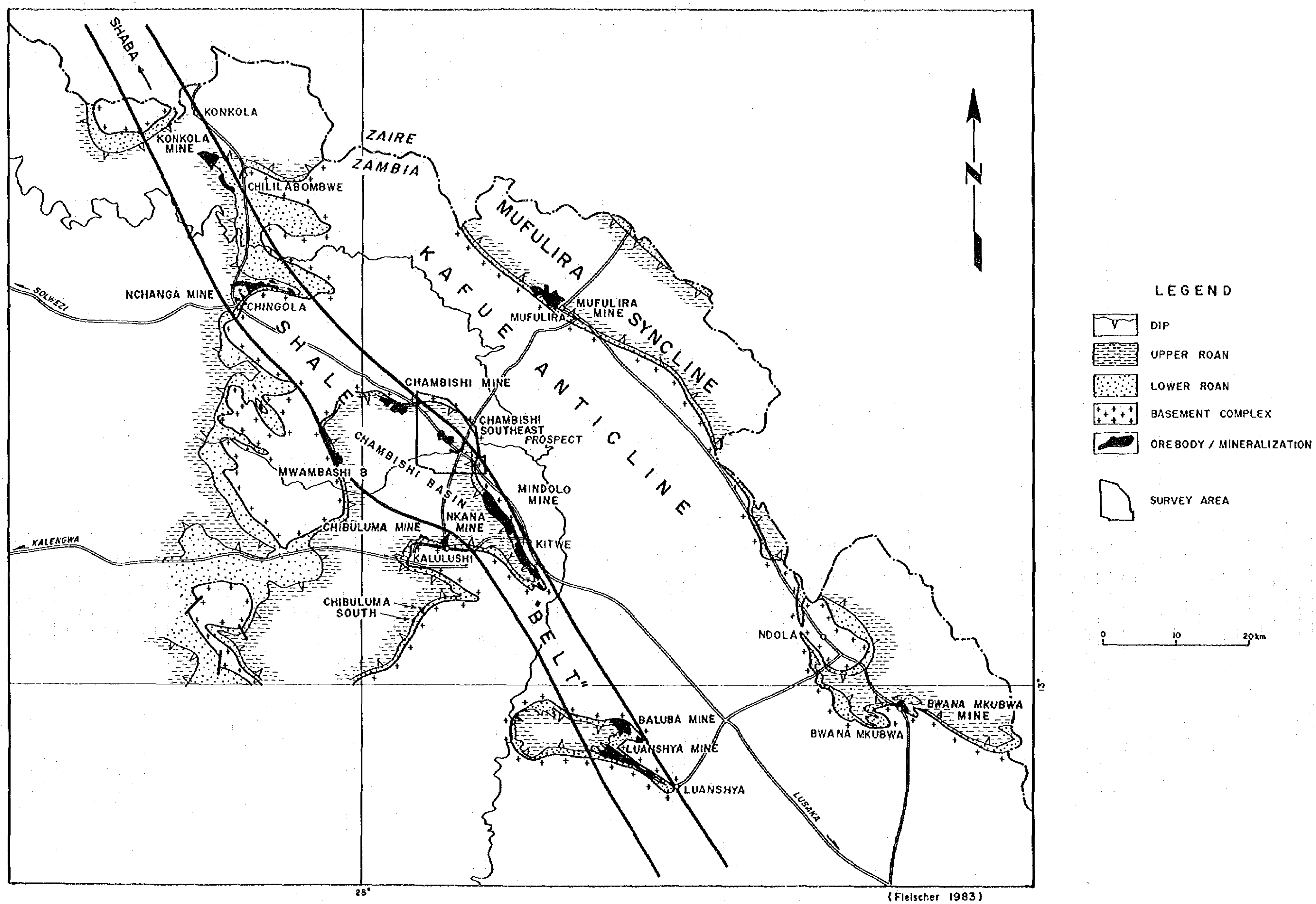


Fig. 1-4 Copperbelt Index Plan

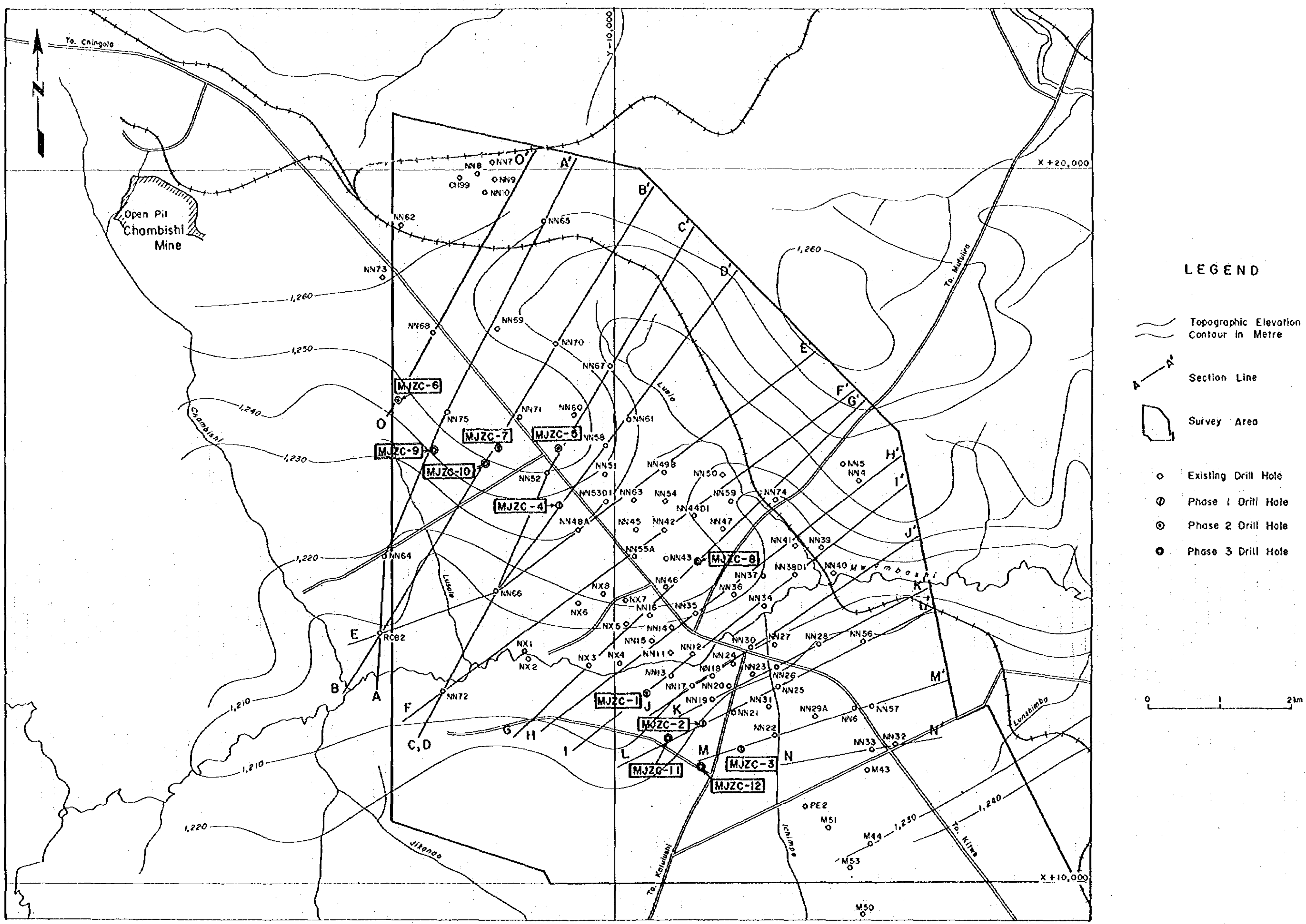


Fig. 1-5 Location Map of Drill Holes with Geological Section Lines

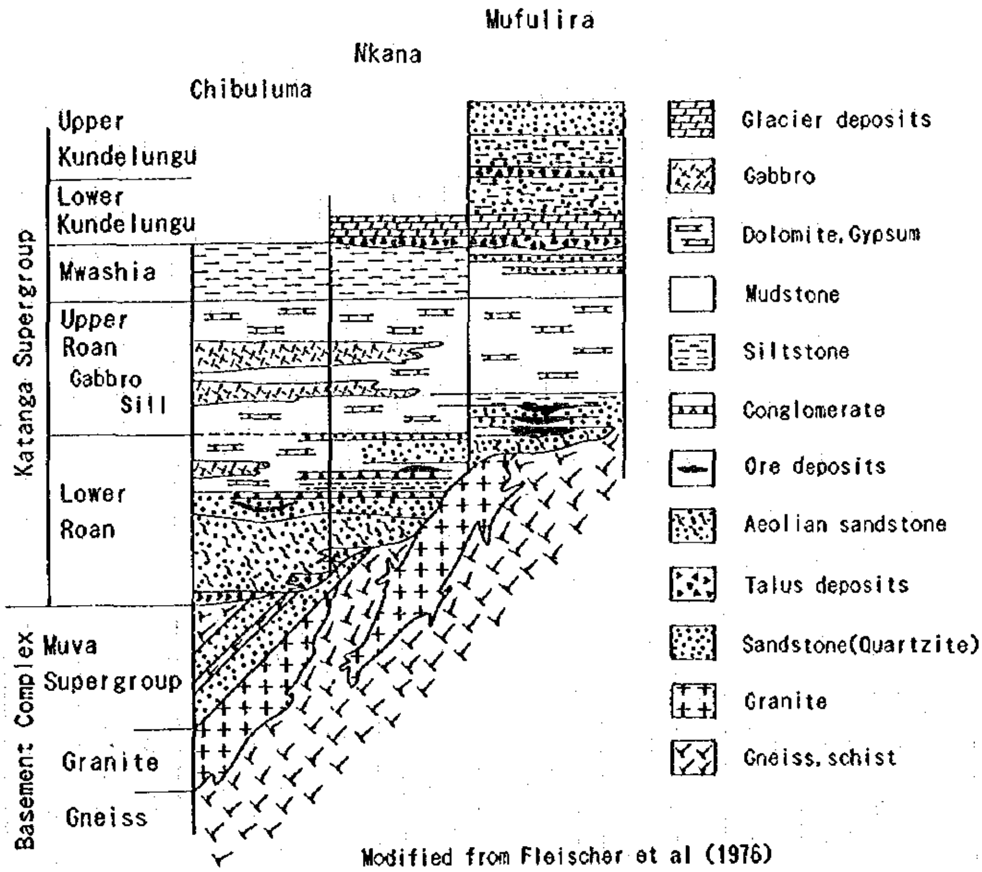


Fig. 1-6 Schematic Stratigraphic Columns of the Zambian Copperbelt

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, cobalt pentlandite, Cu-bearing pyrite, molybdenite, scheelite, wolframite, uraninite. Of these, cobalt minerals 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 the ore deposits.

(8) Occurrence of ore: Depositional structures such as cross-bedding and slumping are observed in ore.

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 1-7, 1-8 and 1-9, 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 and Kundelungu Groups in ascending order and gabbroic sill, and every Group is 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 veins) 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. 1-9 and 1-12).

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. 1-9).

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. 1-9).

The thick parts of argillite in the Ore Shale Horizon coincide with the above local basins and troughs on the basement (Fig.1-10).

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 three holes (NN-75, MJZC-9 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. 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.1-11).

(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

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.

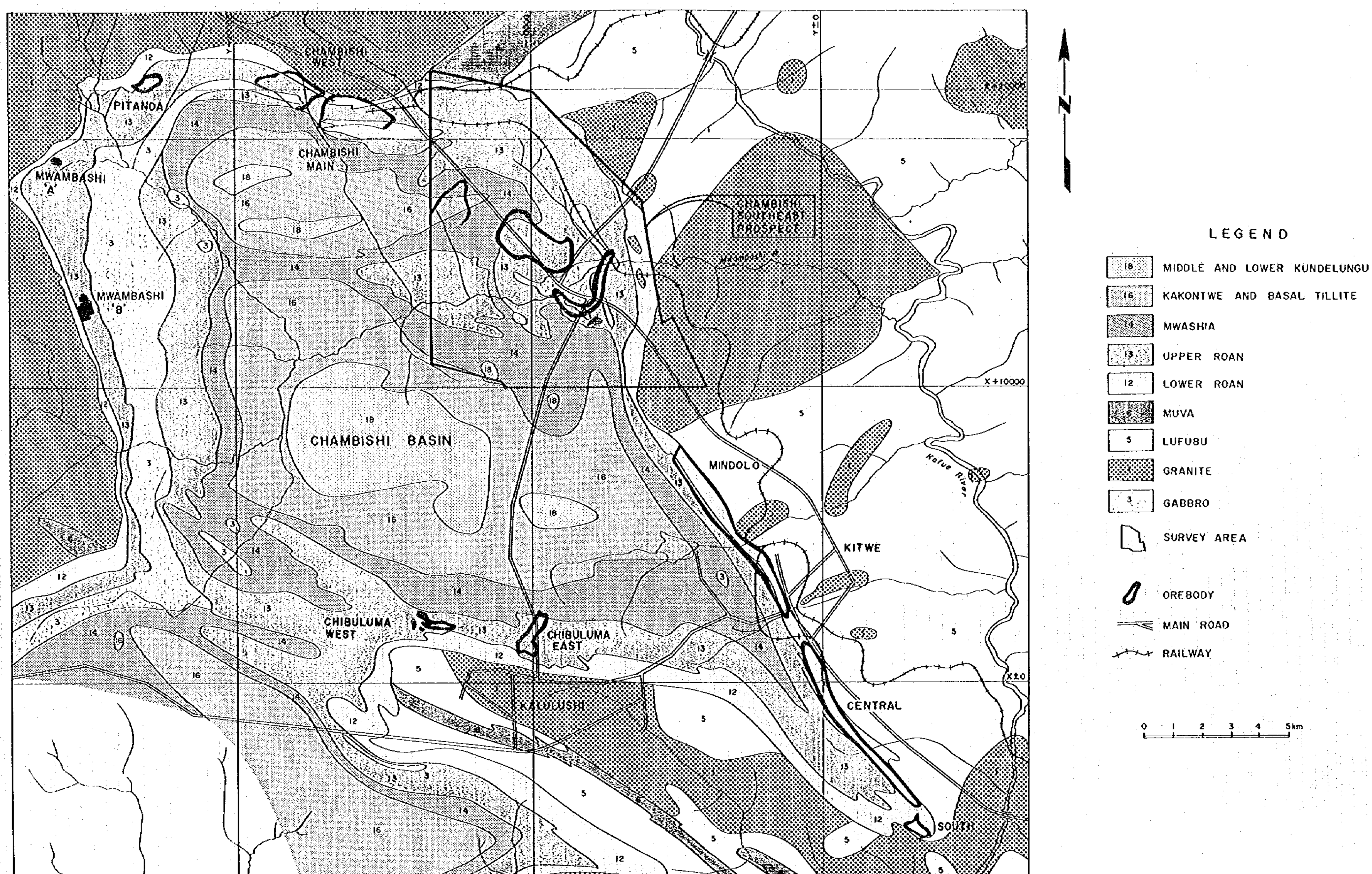
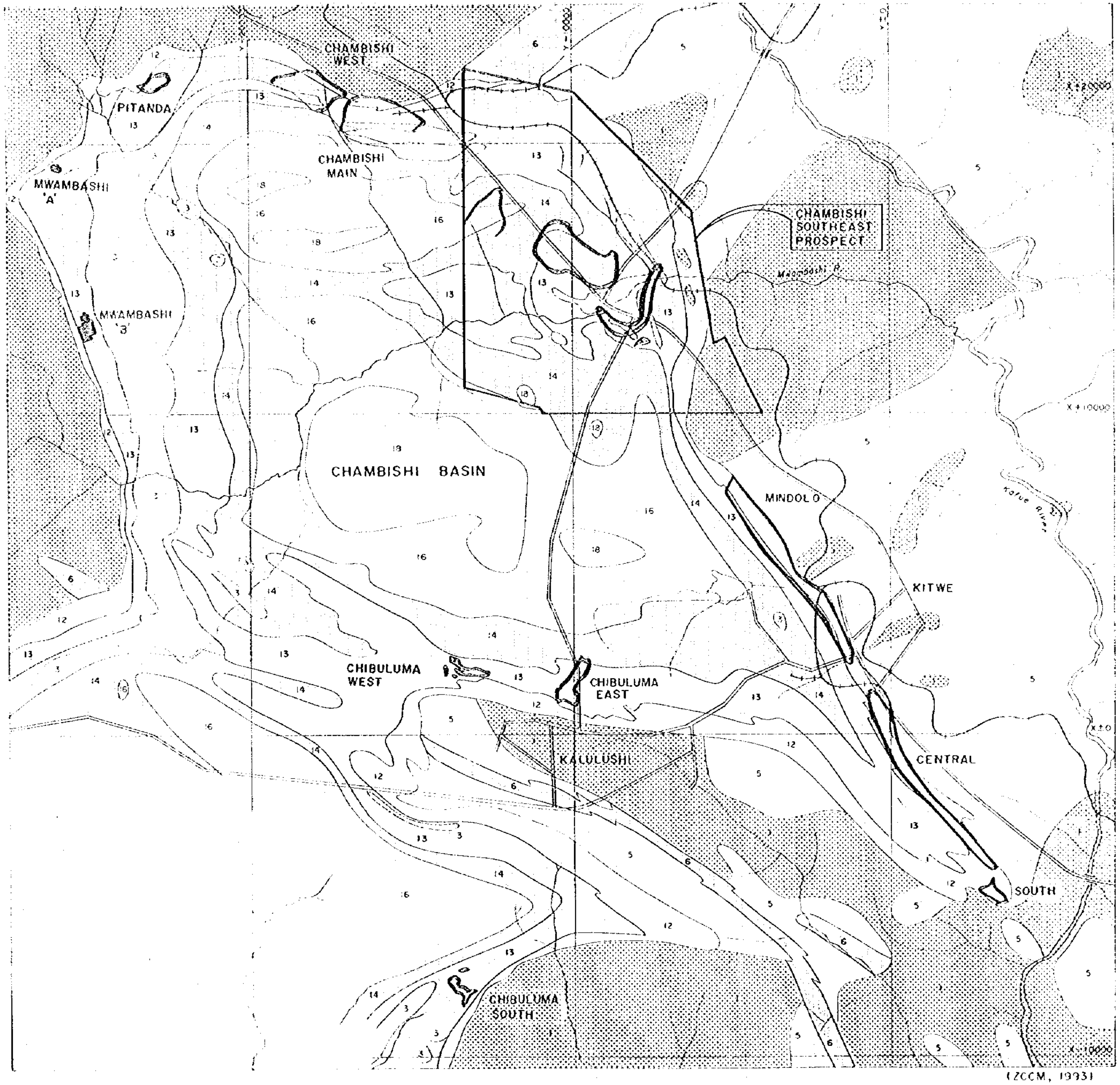


Fig. 1-7 Geological Map of the Chambishi Southeast Area



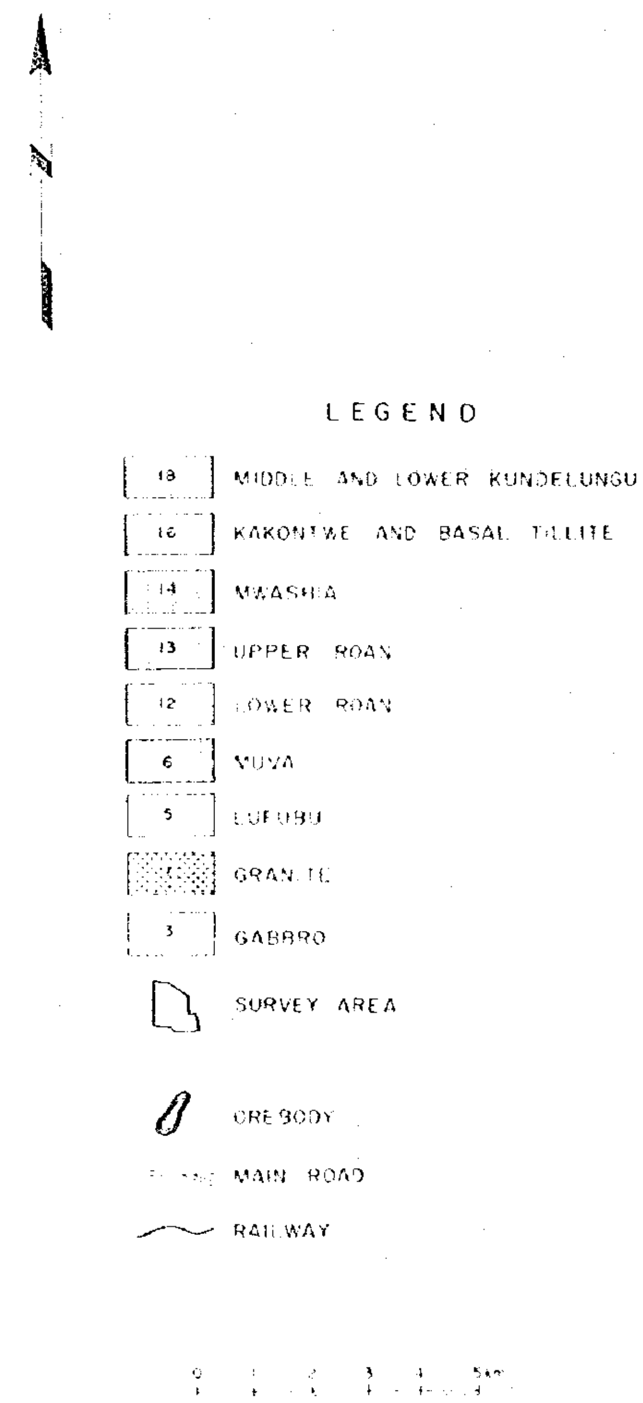


Fig. 1-7 Geological Map of the Chambishi Southeast Area

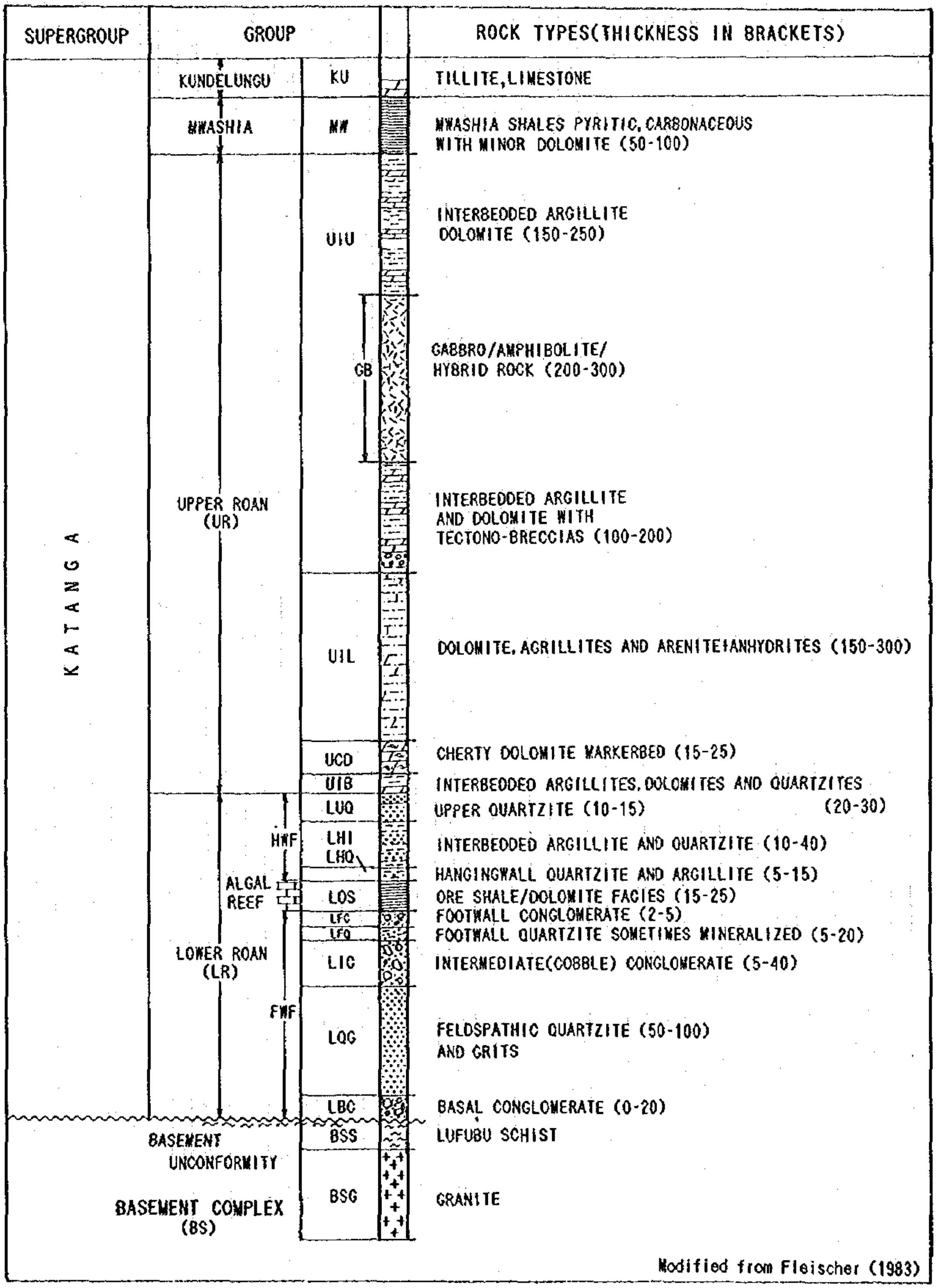


Fig. 1-8 Generalized Stratigraphic Section through Chambishi Southeast

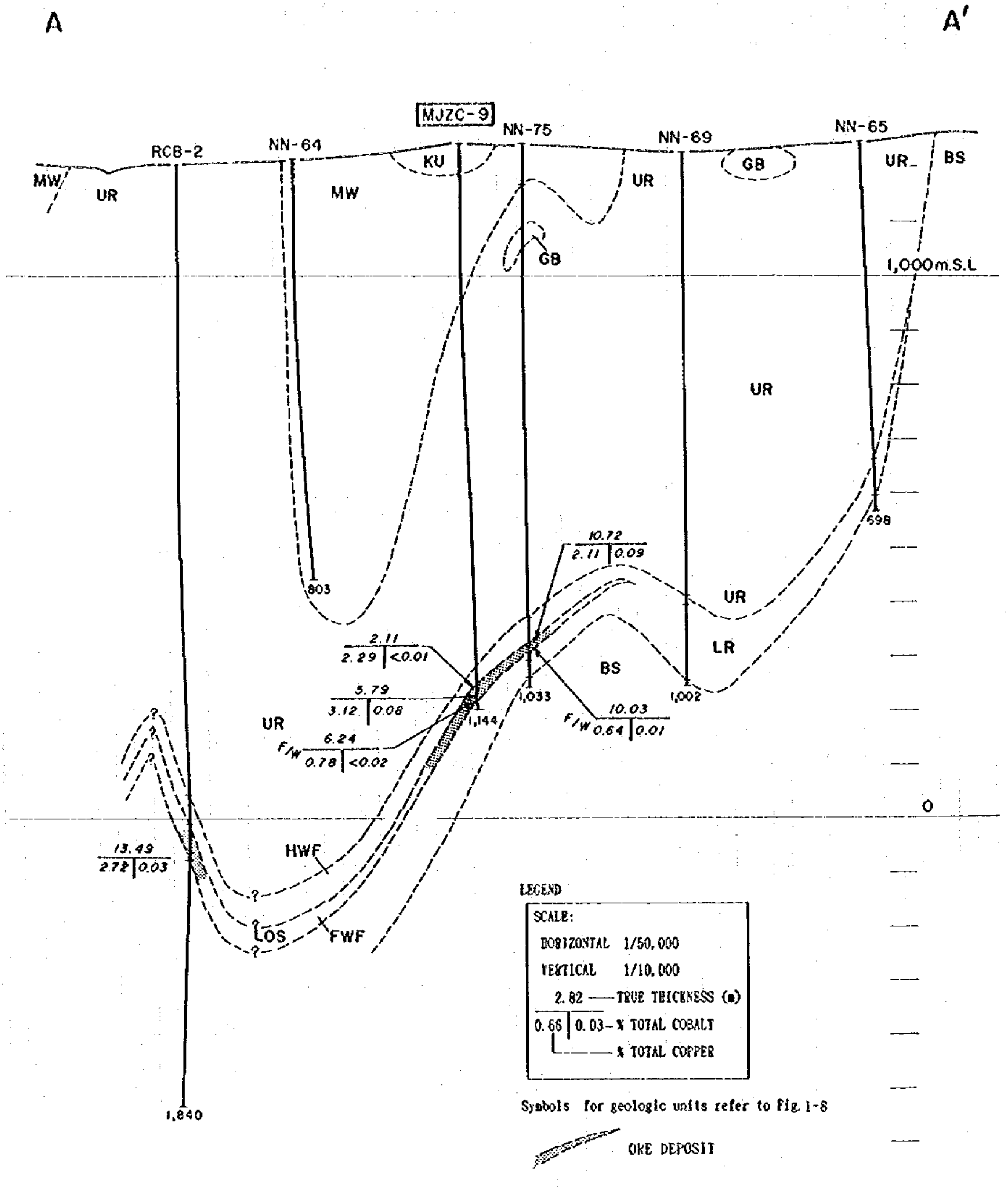


Fig. 1-9 Geological Profiles of the Chambishi Southeast Area(1)

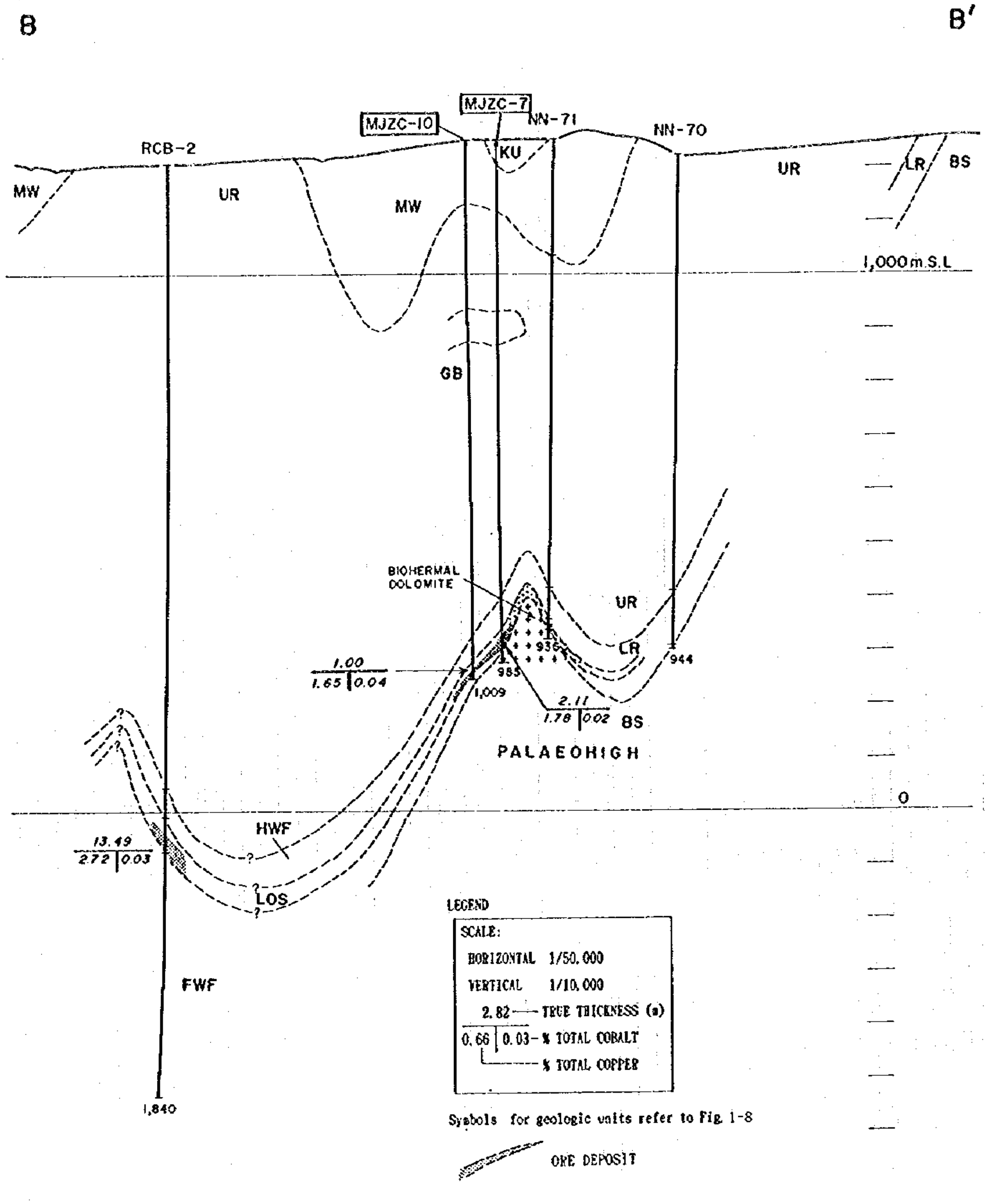
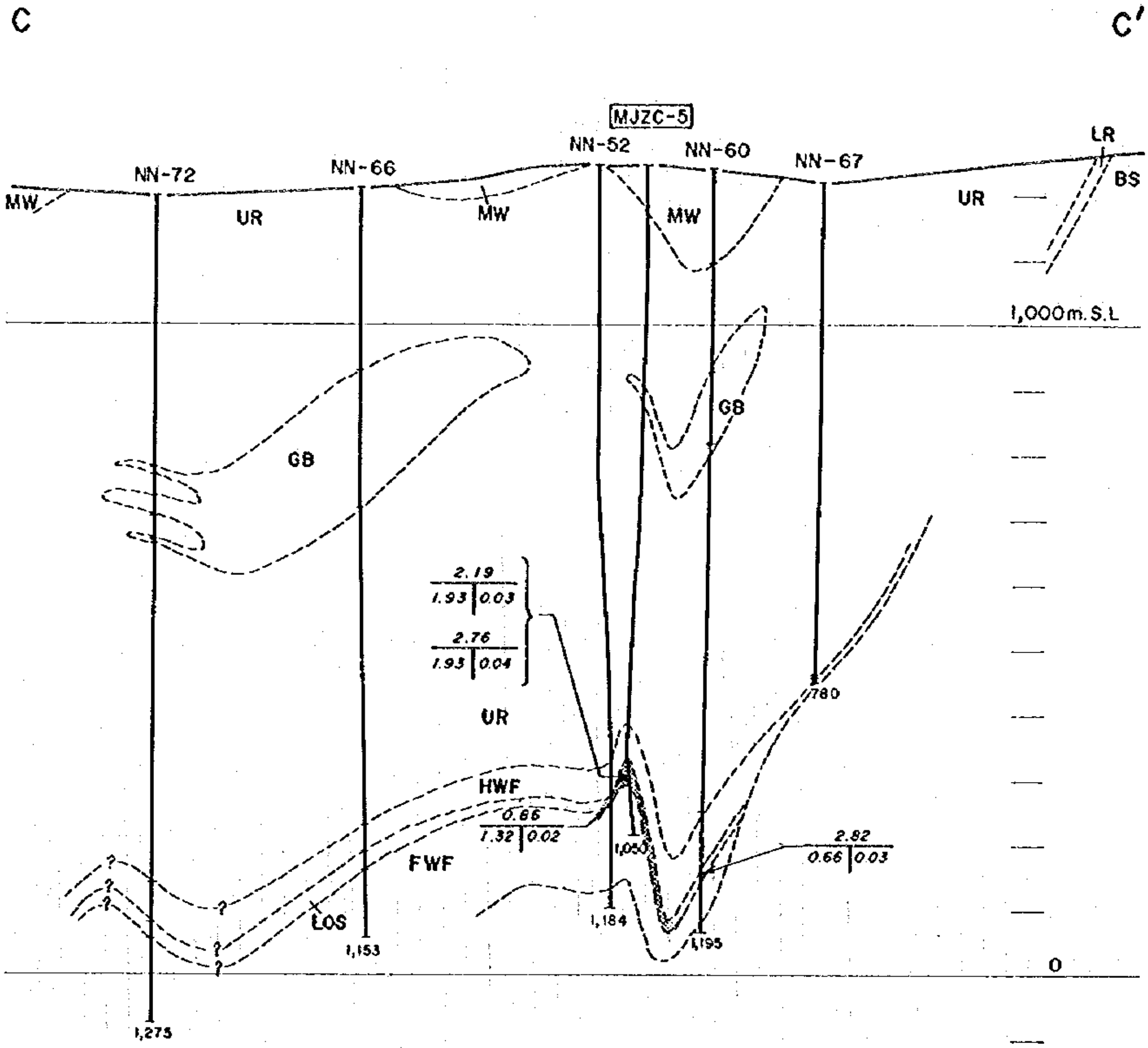


Fig. 1-9 Geological Profiles of the Chambishi Southeast Area (2)



LEGEND

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

Symbols for geologic units refer to Fig.1-8

ORE DEPOSIT

Fig. 1-9 Geological Profiles of the Chambishi Southeast Area(3)

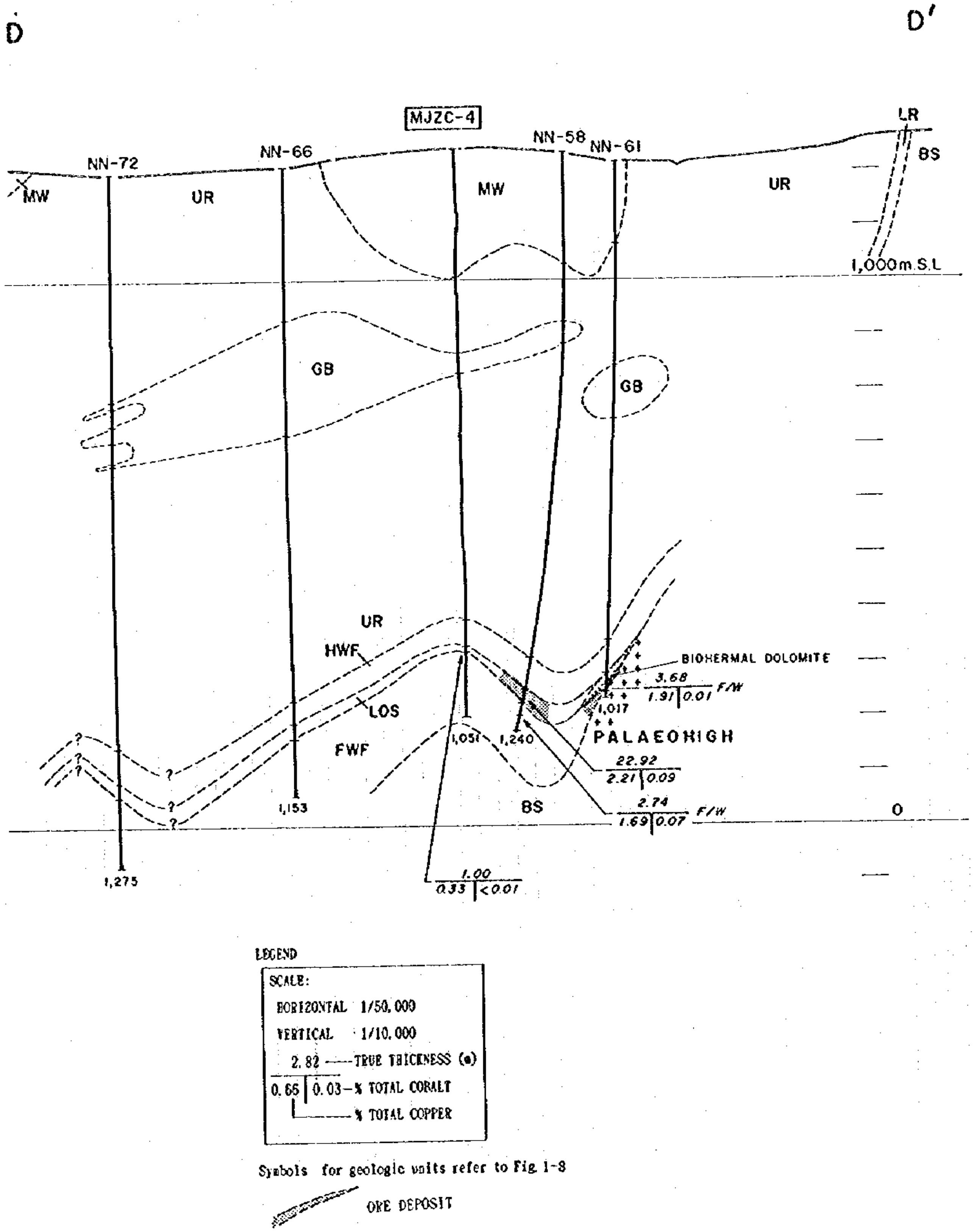


Fig. 1-7 Geological Profiles of the Chambishi Southeast Area (4)

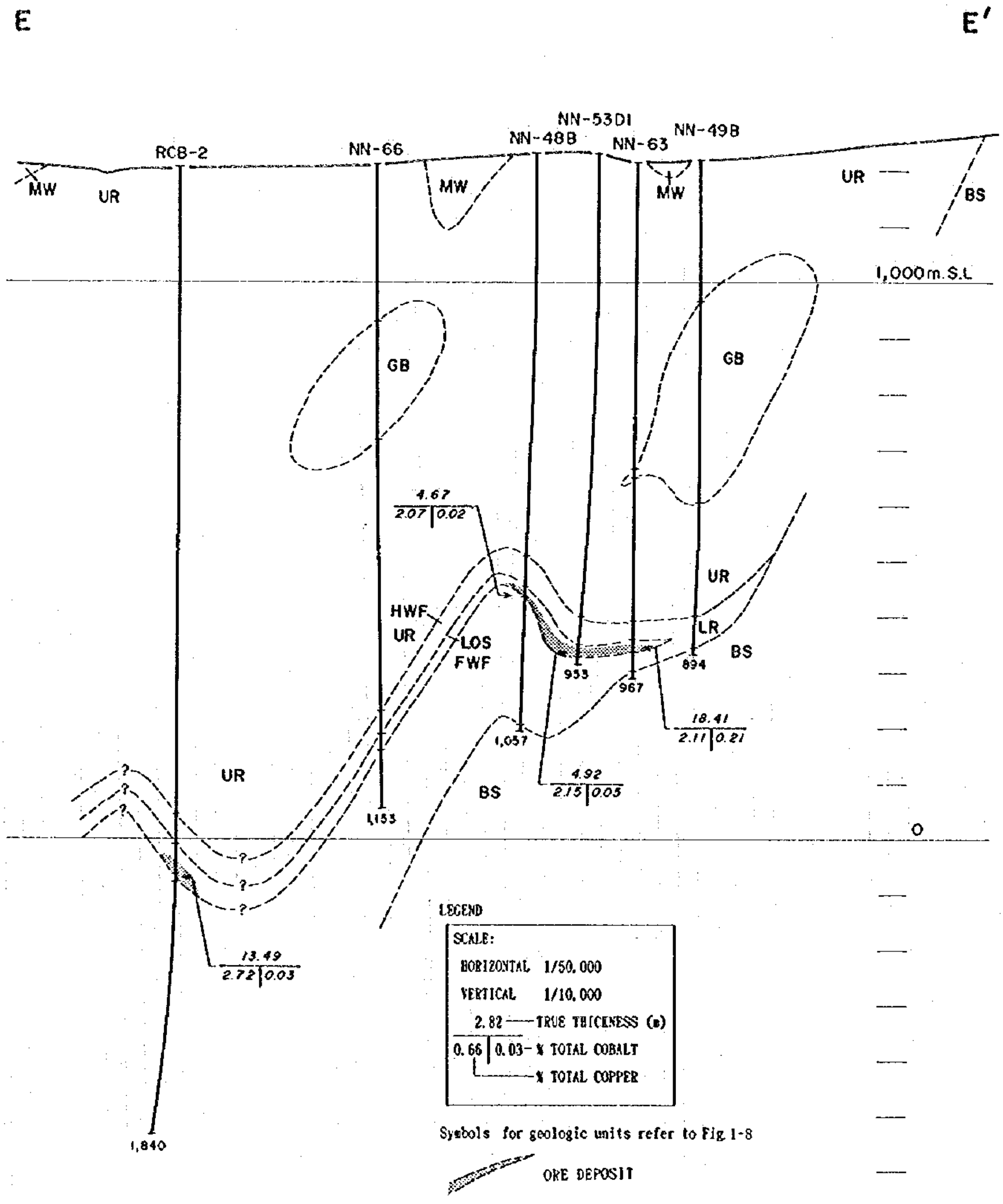


Fig. 1- 9 Geological Profiles of the Chambishi Southeast Area(5)

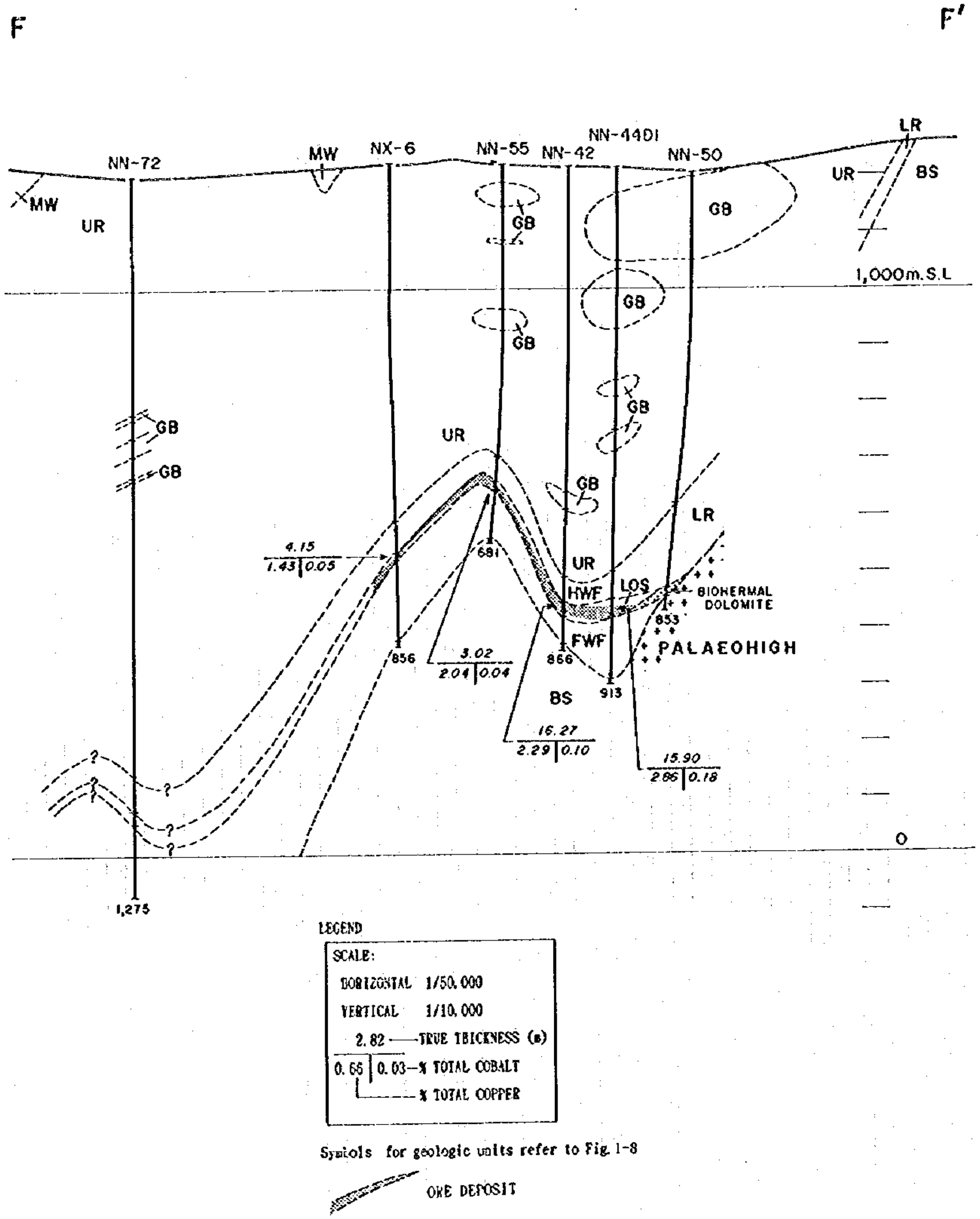
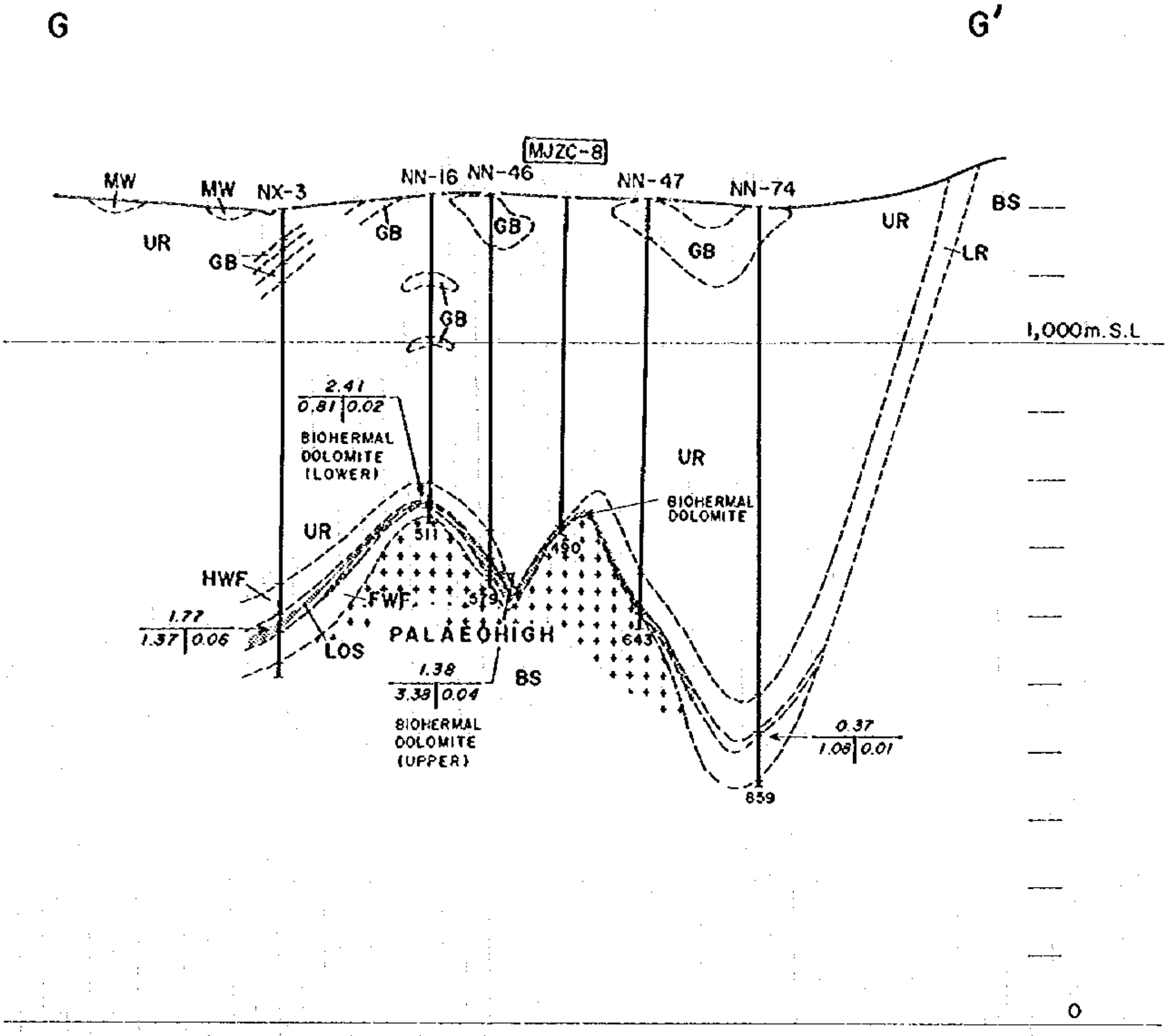


Fig. 1-9 Geological Profiles of the Chambishi Southeast Area (6)



LEGEND

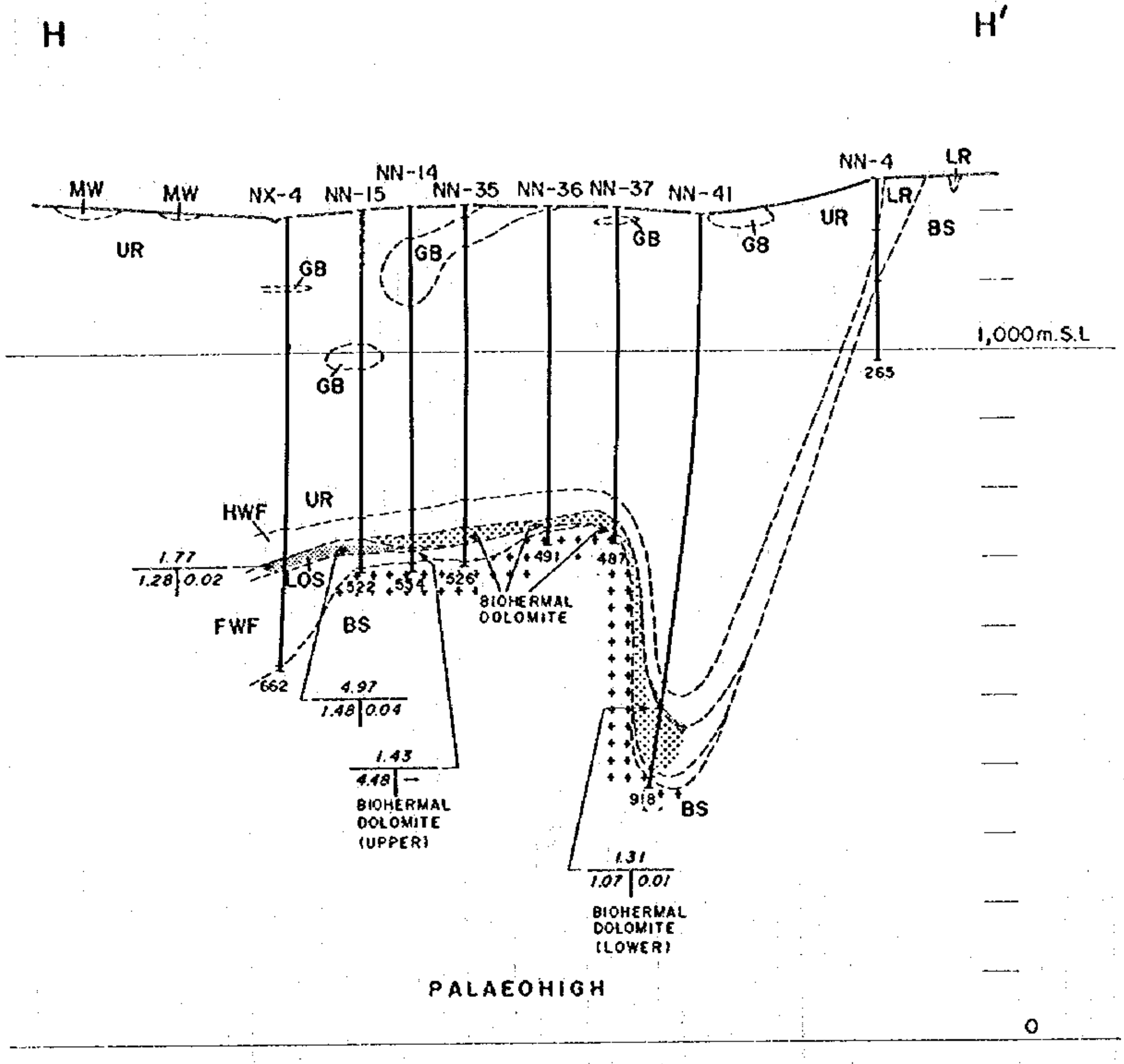
SCALE:
HORIZONTAL 1/50,000
VERTICAL 1/10,000

2.82 --- TRUE THICKNESS (m)
0.66 | 0.03 - % TOTAL COBALT
% TOTAL COPPER

Symbols for geologic units refer to Fig. 1-8

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)

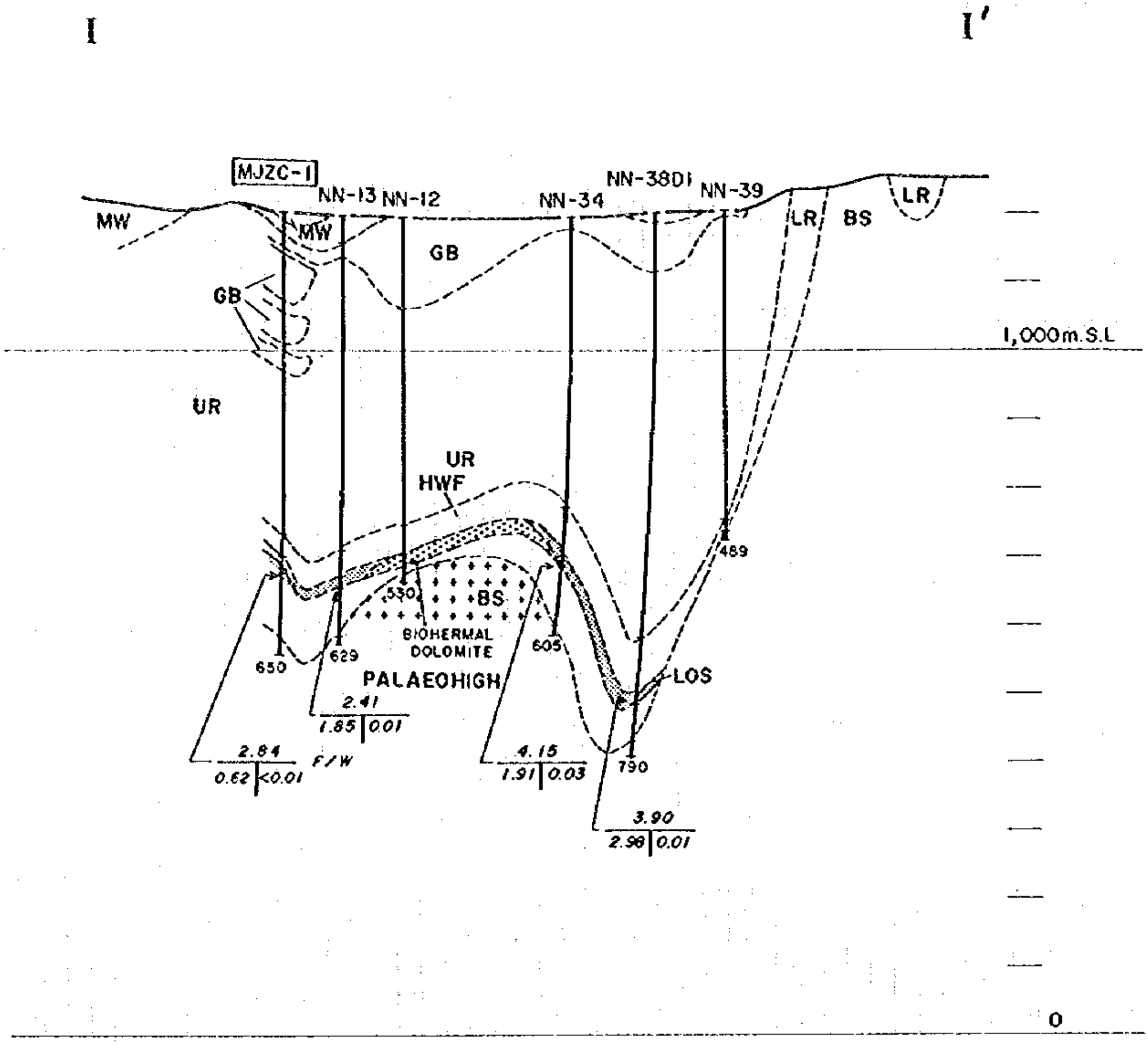
0.66 | 0.03 — % TOTAL COBALT

└—— % TOTAL COPPER

Symbols for geologic units refer to Fig. 1-8

ORE DEPOSIT

Fig. 1-9 Geological Profiles of the Chambishi Southeast Area (8)



LEGEND

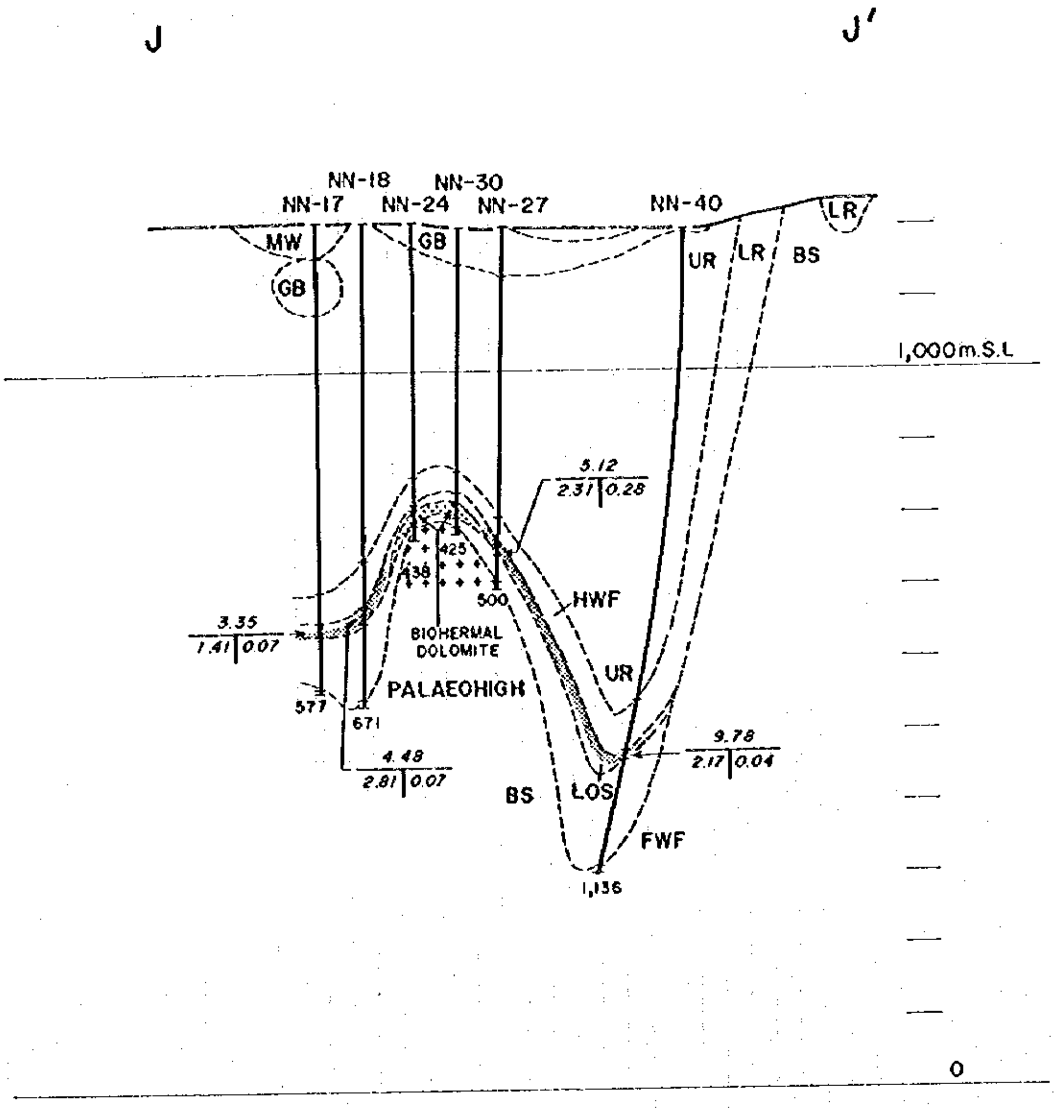
SCALE:
HORIZONTAL 1/50,000
VERTICAL 1/10,000

2.82 —— TRUE THICKNESS (m)
0.66 | 0.03 —— % TOTAL COBALT
└—— % TOTAL COPPER

Symbols for geologic units refer to Fig. 1-8

ORE DEPOSIT

Fig. 1-9 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

Symbols for geologic units refer to Fig. 1-8

ORE DEPOSIT

Fig. 1- 9 Geological Profiles of the Chambishi Southeast Area(10)

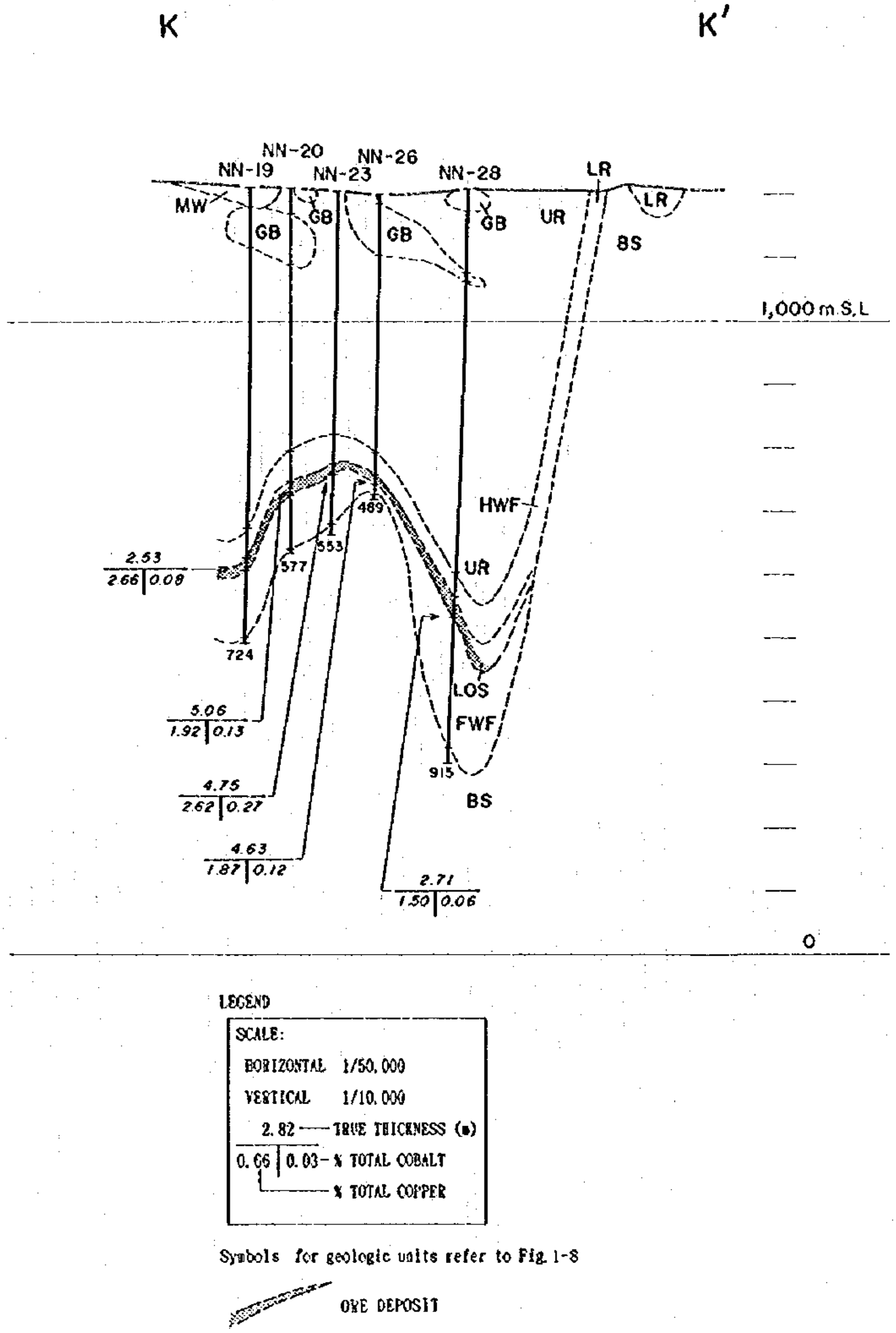
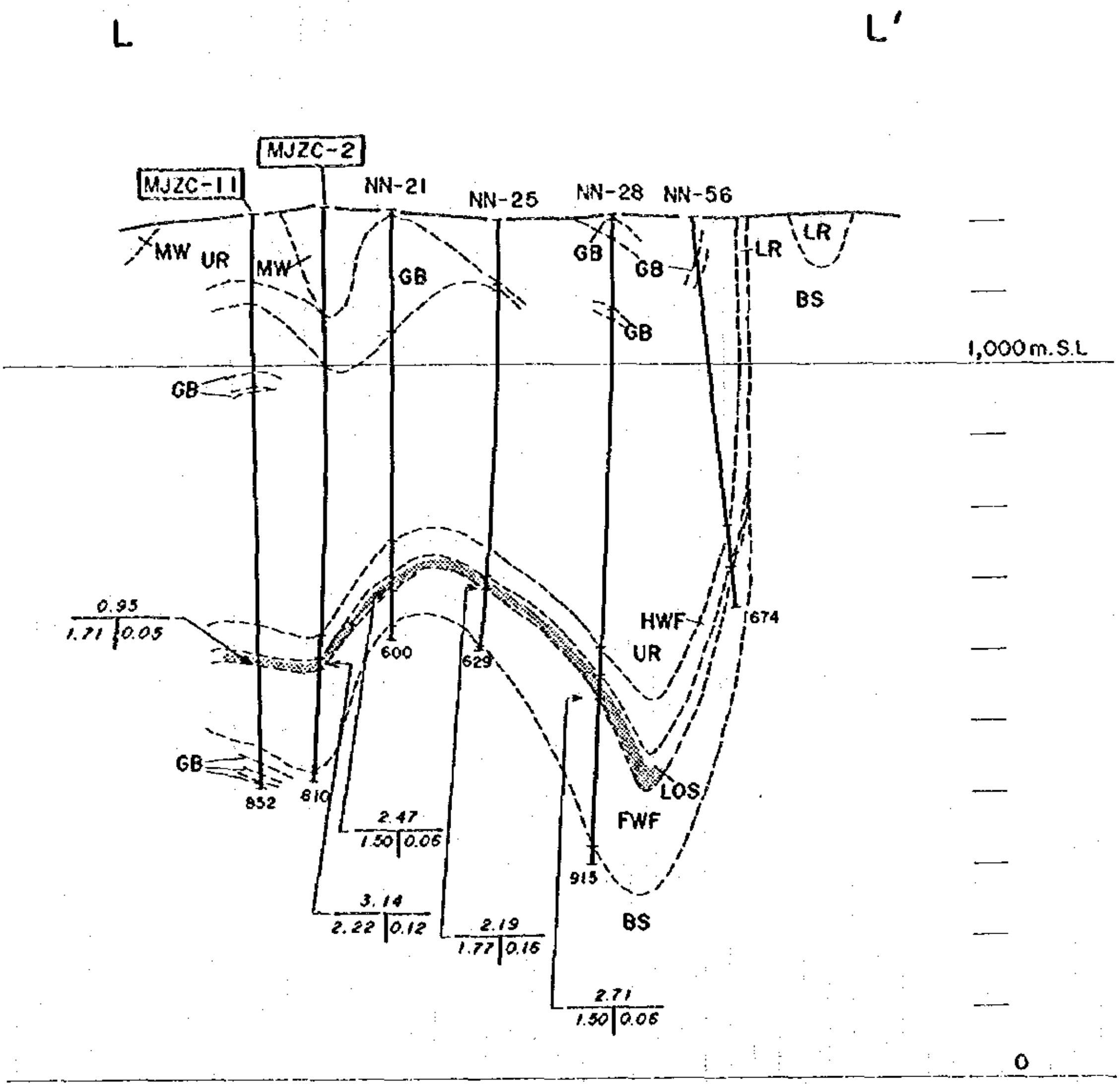


Fig. 1-9 Geological Profiles of the Chambishi Southeast Area(11)



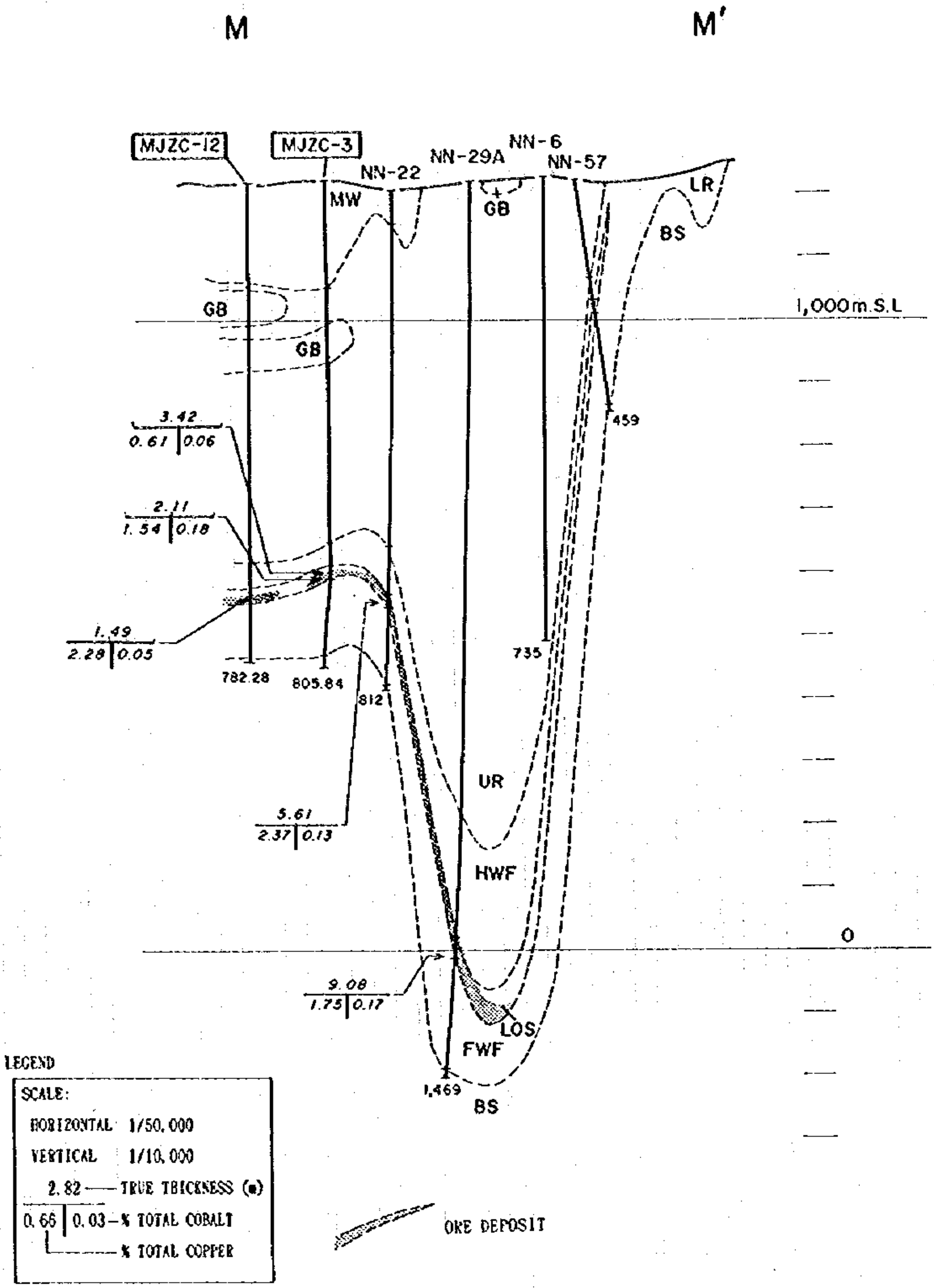
LEGEND

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

Symbols for geologic units refer to Fig. 1-8

ORE DEPOSIT

Fig. 1-9 Geological Profiles of the Chambishi Southeast Area (12)



Symbols for geologic units refer to Fig.1-8

Fig. 1- 9 Geological Profiles of the Chambishi Southeast Area(13)

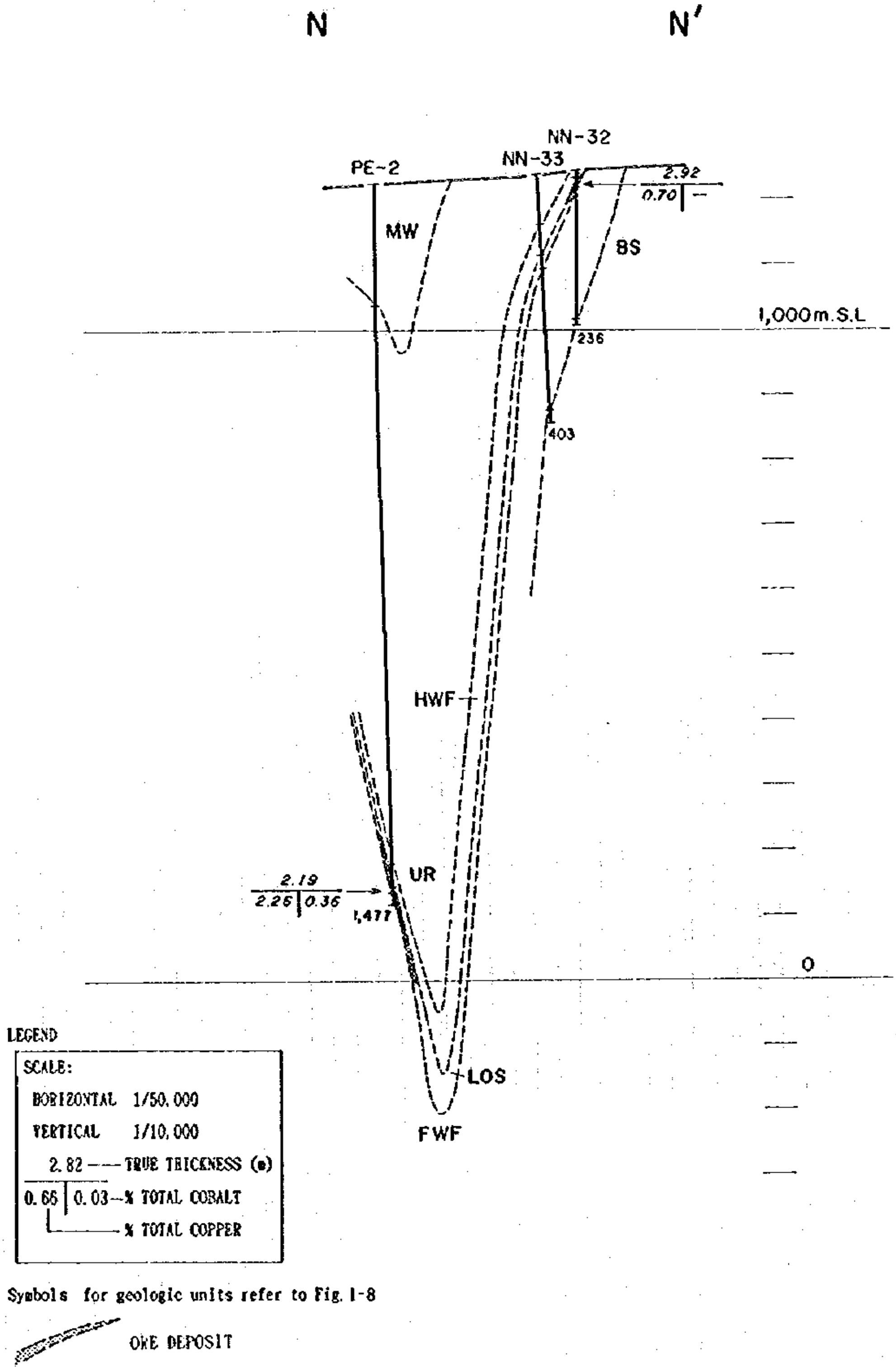


Fig. 1-9 Geological Profiles of the Chambishi Southeast Area(14)

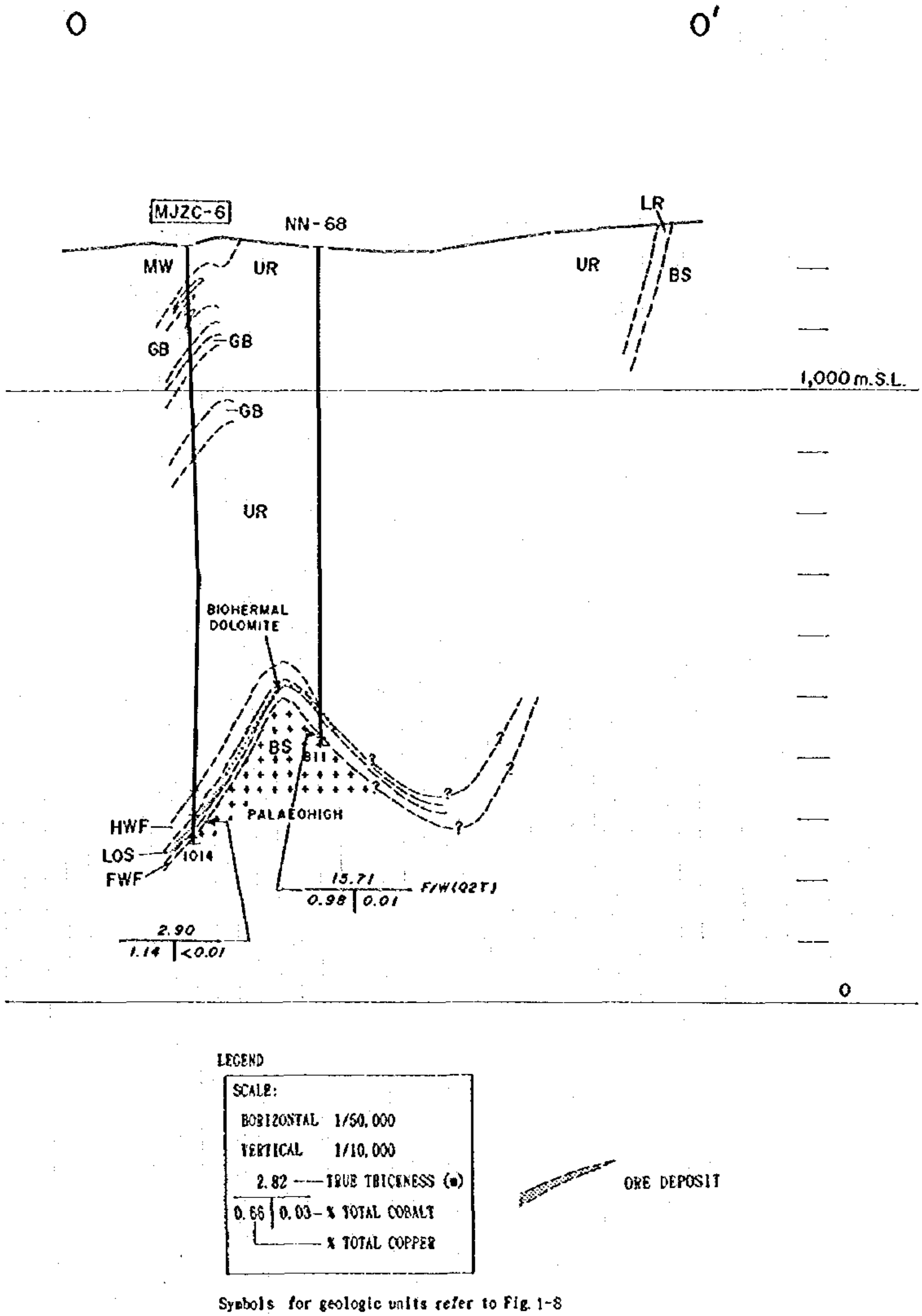


Fig. 1-9 Geological Profiles of the Chambishi Southeast Area(15)

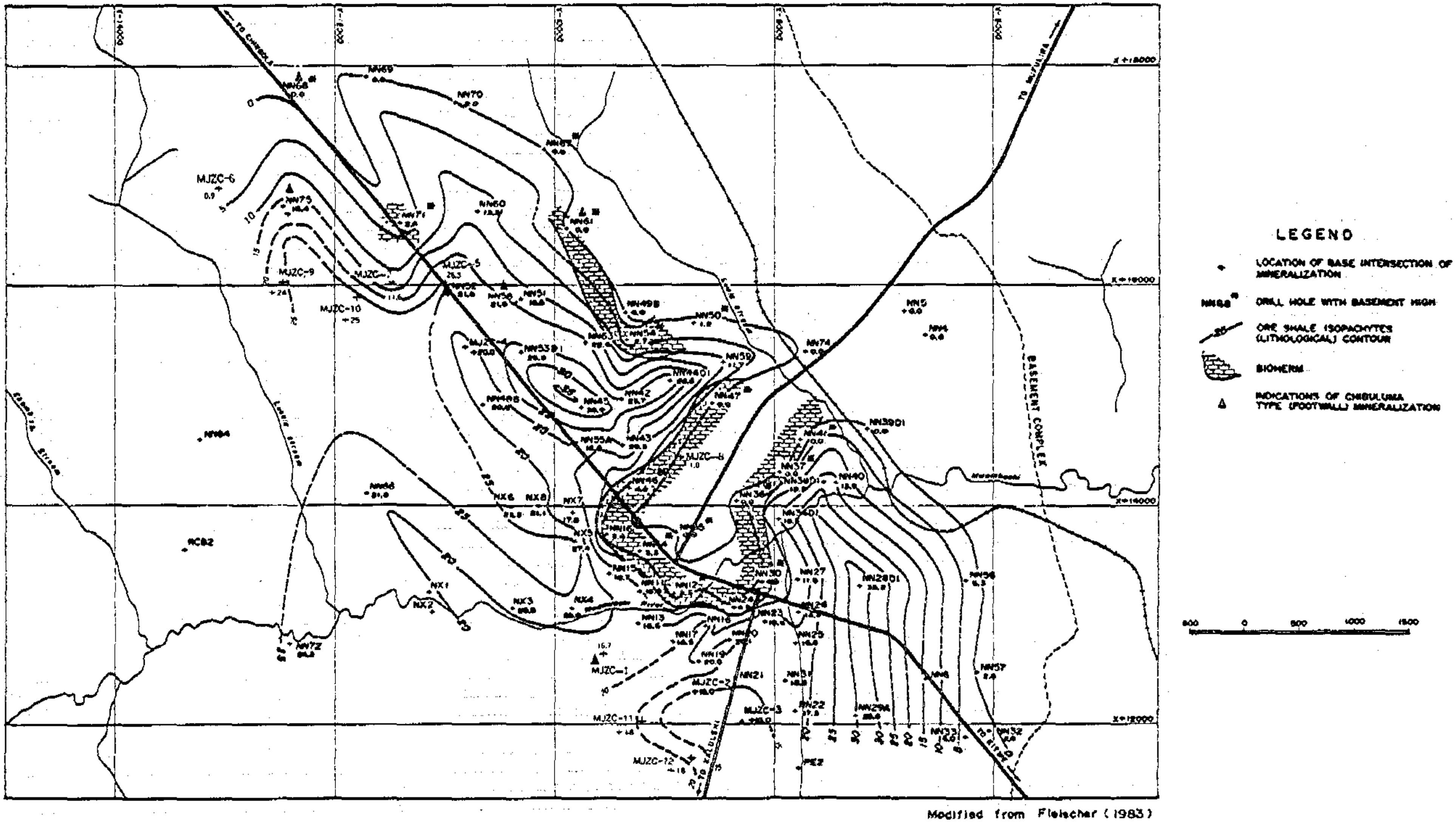
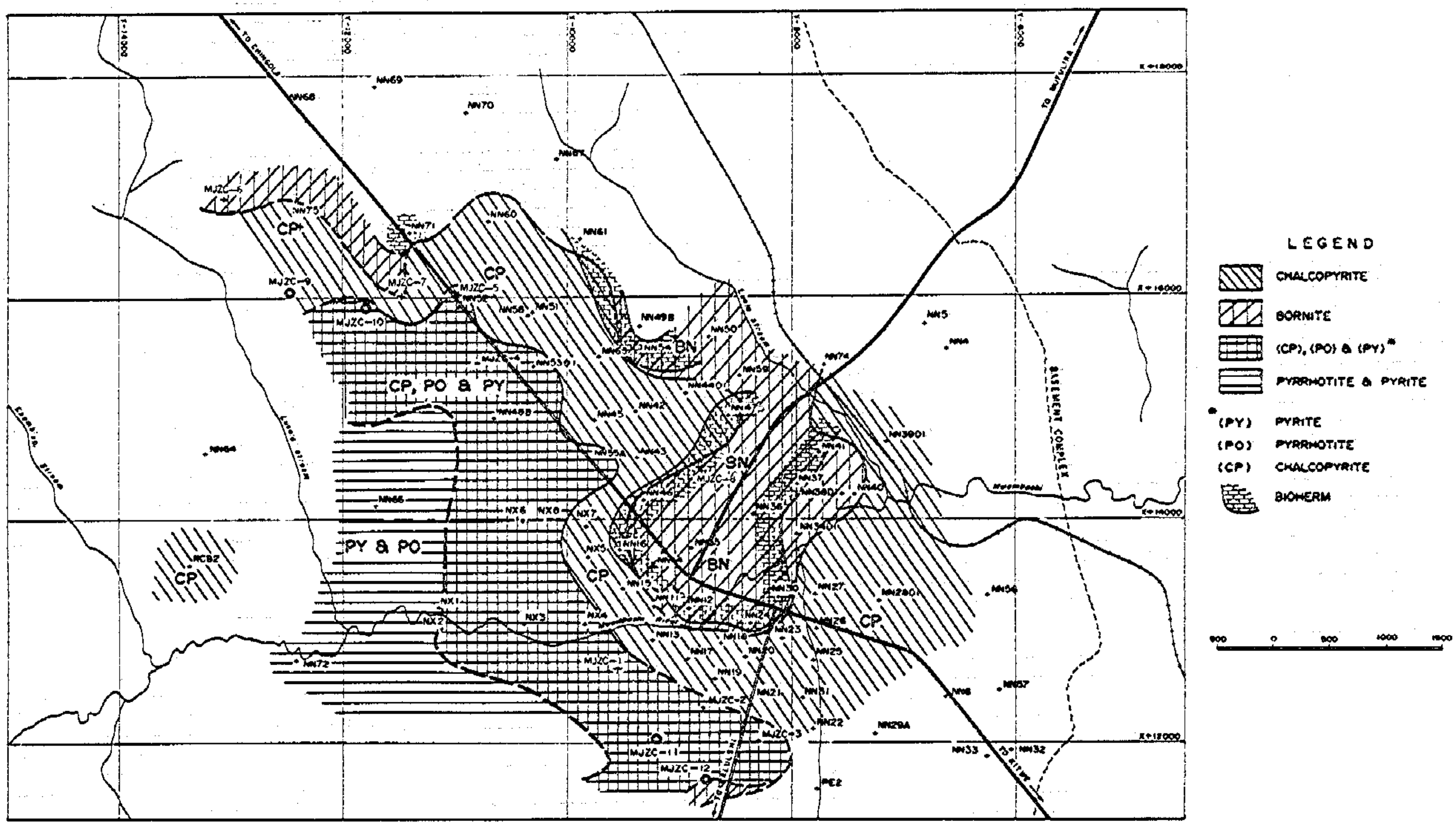


Fig. 1-10 Ore Shale Isopach Map



Modified from Fleischer (1983)

Fig. 1-11 Sulfide Mineral Zoning

Chapter 4 Geography of the Project Area

4-1 Location and Access

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.1-4).

The survey area (60 km2)lies in the vicinity of the main tarmac road, joining Chingola and Kitwe (Fig. 1-5).

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

4-2 Topography, Drainage, Climate and Vegetation

4-2-1 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.

4-2-2 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.

4-2-3 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 (℃) 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

4-2-4 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 5 Conclusions and Recommendations

5-1 Conclusions

During the course of the three year period of Fiscal 1993 to 1995 of the Chambishi Southeast area mineral exploration, drilling, and compilation and interpretation of existing data were carried out with the following conclusions.

1. All twelve boreholes drilled during this survey attained their objectives by penetrating the ore horizon. The nine boreholes reached the basement. The geology and mineralization of the survey area were thus clarified.

2. MJZC-9 drilled in the western part of the area confirmed the existence of high-grade ores (i. width 5.90m, grade T-Cu 3.12%, T-Co 0.08%; ii. width 2.58m, grade T-Cu 2.29%, T-Co <0.01%). These ores are considered to be continuous to the shoot confirmed to the north of this hole (NN-75). Thus it is now clear that an ore shoot of considerable scale exists in this area. It is inferred that this ore shoot is emplaced over a basement depression which is elongated in the NE-SW direction and it is deemed possible that this shoot is developed further southward or westward.

3. The known areal extent of the Northern Area Shoot, which is the most important ore deposit of this area, expanded northwestward by the confirmation of ores by MJZC-5 (i. width 3.10m, grade T-Cu 1.93%, T-Co 0.03%; ii. width 2.64m, grade T-Cu 2.32%, T-Co 0.03%), while it shrank in the western and southeastern parts by the confirmation of low-grade ores of MJZC-4 and barren zone of MJZC-8.

4. The five boreholes drilled in the southern part of this area (MJZC-2, -3, -11, -12) were located in relatively raised basement areas, and they showed that many of the mineralized zones consisted of low-grade copper ores belonging to the pyrrhotite-pyrite-chalcopyrite zone. But in some parts, small bornite zone in the lowermost part of the "Ore Shale" (MJZC-12), chalcopyrite zone in the footwall quartzite (MJZC-1), and local high-grade copper of pyrrhotite-pyrite-chalcopyrite zone (MJZC-2, -3, -12) were confirmed. In this area, the occurrence of ore shoots is limited only to the lowermost part of the "Ore

Shale", and thus it is inferred that ore deposition occurred in relatively short period of time, thereby limiting the size of the ore deposits. If, however, deep local depression existed on the seafloor at the time of copper deposition, relatively large ore shoots could have been formed.

5. 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.

6. In almost all of the boreholes, stratigraphic zonal arrangement of the sulfide mineral are observed in the mineralized zones. The depth of the sea probably increased after the deposition of the "Ore Shale", because the Fe/Cu ratio generally increases upward from near the lowermost part of the "Ore Shale Horizon". Most of the ore shoots in this zone belong to the chalcopyrite zone, but the high cobalt zones exist not only in the chalcopyrite, but also in the pyrrhotite and pyrite zones. It is inferred that the chalcopyrite zone was formed within a narrow sea depth zone. Therefore, we believe that the conditions for the formation of copper ore shoots would be; the continuation of the optimum depth range of the sea, and the existence of depressions suitable for the deposition and preservation of copper minerals.

7. 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.

8. 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.

9. The following is inferred from the gravity contour maps, geological maps, and drilling data. Parts of the high gravity anomalies reflect the gabbroic bodies in shallow subsurface zones. Parts of the gravity high anomalies reflect the basement highs such as the relative rise by folding and palaeo-basement highs. High-grade ores most probably do not exist at gravity highs which coincide with thick gabbroic bodies. 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.

10. Ore reserve estimation was carried out to asses the mineral potential of the survey area with the following results.

POTENTIALLY ECONOMIC MINERALIZATION;
NORTHERN AREA SHOOT: 54,793,000 tons, 2.70% T-Cu, 0.13% T-Co
SOUTHERN AREA SHOOT: 14,934,000 tons, 2.19% T-Cu, 0.13% T-Co
SUBECONOMIC MINERALIZATION :
107,909,000 tons, 1.83% t-Cu, 0.03% T-Co

5-2 Recommendations for Future Exploration

Significant amounts of ore were confirmed in this survey area by drilling during this year. The ore deposits of this area, however, occur in relatively deep zones, the major deposits probably occurs at 550 to 1,050m below the surface. Therefore, in order to develop this deposit, it is necessary to further increase the ore reserves. The western and southern parts of the survey area have not been explored and the potential is considered to be promising.

It is now clear, from the results of the present survey, that a deposit which was hitherto unknown occurs in the western part of the area. Also borehole RCB-2 which confirmed ores is located far south of MJZC-9 which also confirmed ores. From the above it is strongly recommended that efforts be concentrated as follows to confirming new ore reserves and to exploring the vicinity.

First drill at sites where the depth of the ore deposits can be estimated at shallow depths, namely near the two boreholes which encountered ores (MJZC-9, NN-75), then drill at sites where the depth of the ore is considered to become deeper, namely south and west of MJZC-9.

The possibility of ore shoots still remain in the southern part of the area and thus it is recommended that drilling be carried out in the area to the south of MJZC-12.

Also in order to accurately determine the ore reserves of the Northern Area Shoot, the main deposit, drilling should be carried out near the peripheries of the deposit.

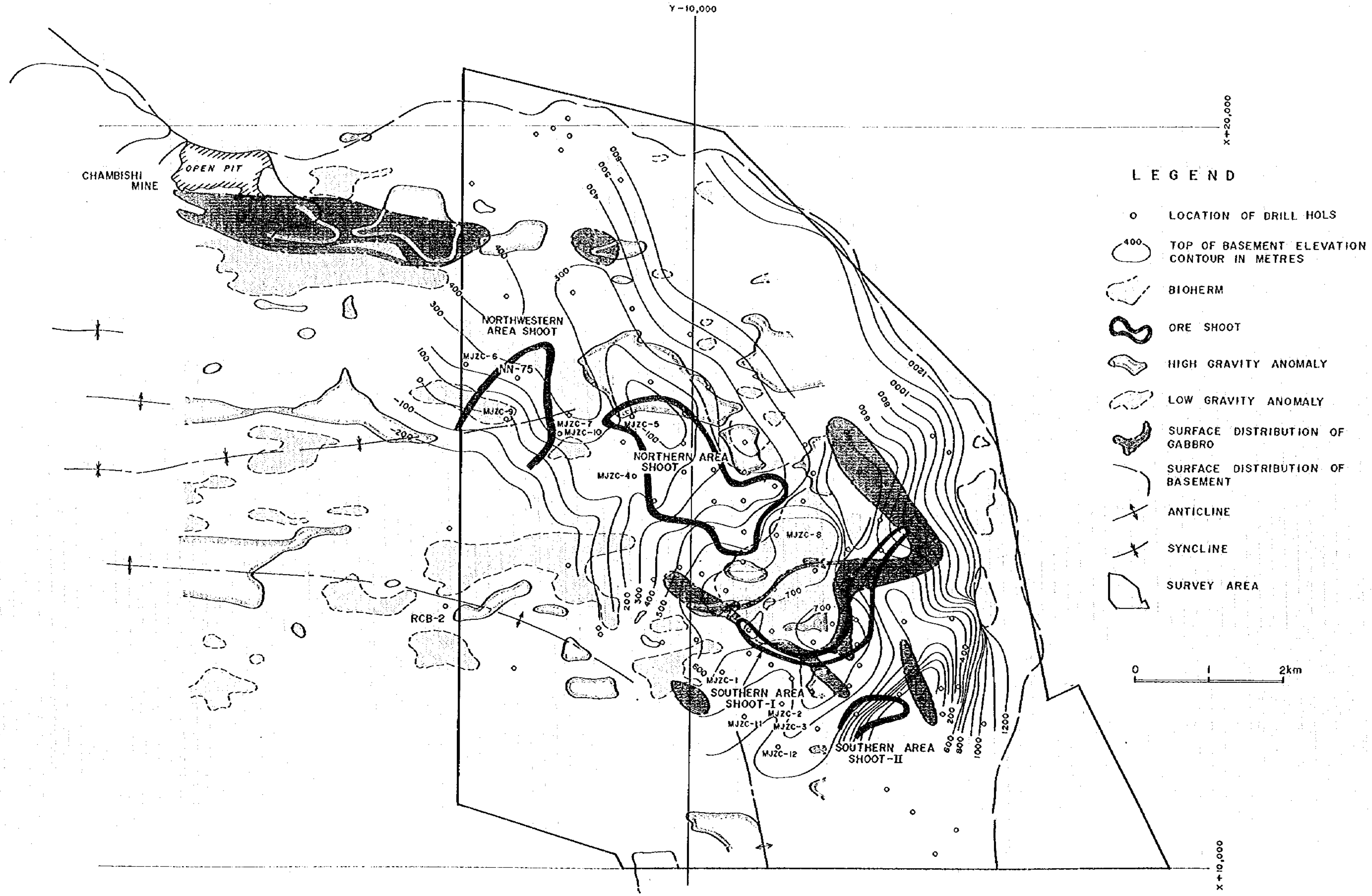


Fig. 1-12 Integrated Interpretation Map

Fig. 1-12 Integrated Interpretation Map

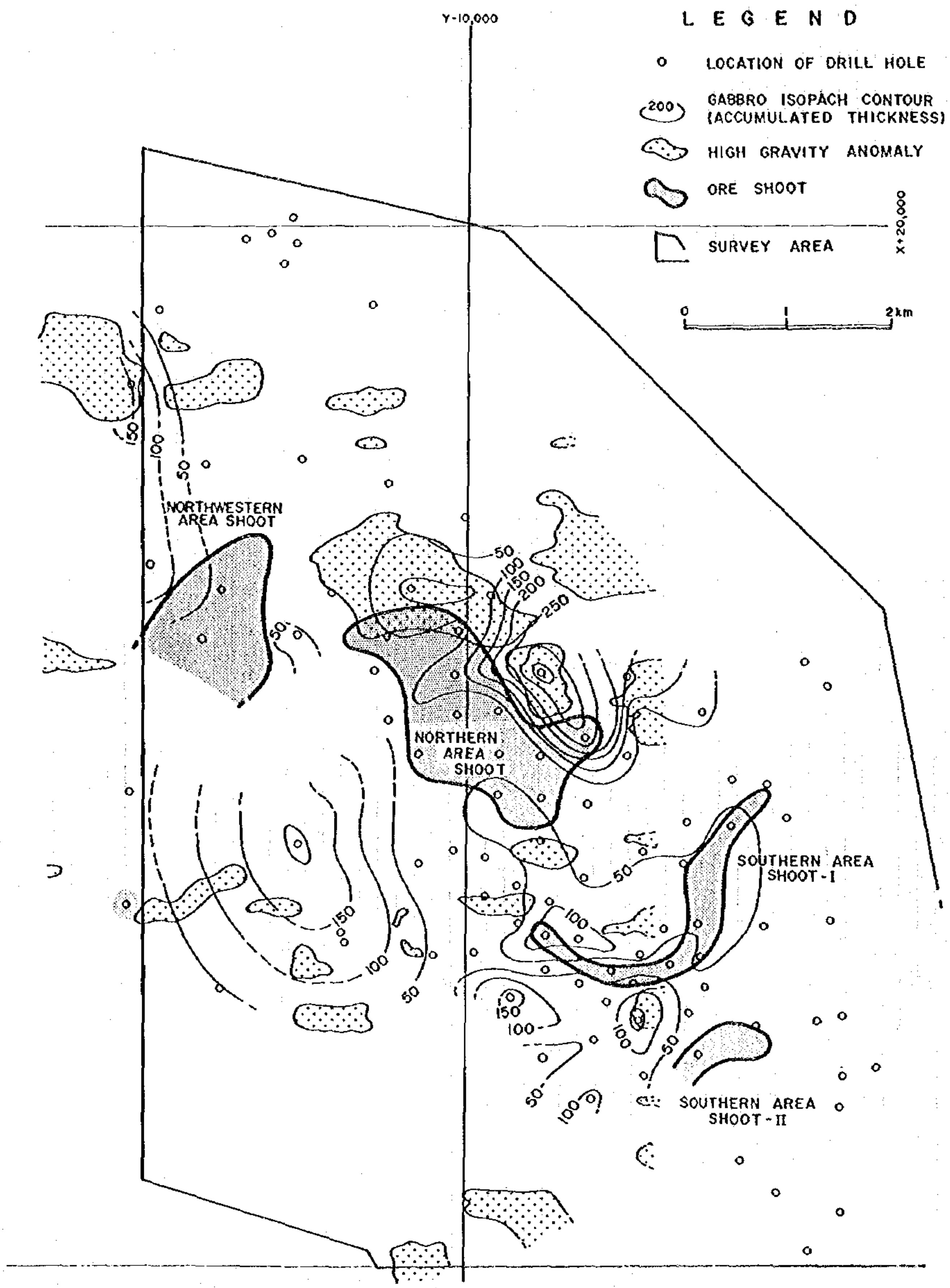


Fig. 1-13 Supplementary Interpretation Map