III RE-ASSESSMENT OF DATA

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3.1 Geology and Ore Deposit

3.1.1 Previous Works

The area of the present study has been well known as a southern extension of the Copper Belt. Copper-bearing quartz veins in Sebembere, some 3 km northeast of zinc mineralization at Kabwe West, were first reported at Sebembere in 1902 by T.G. Davey, who discovered outcrops of lead and zinc mineralization of Kabwe in the same year.

In 1953, Rio Tinto commenced prospecting works for copper in the area, using detailed geochemical soil survey and geophysical survey. Anomalies detected by a regional gravity survey were traced by soil sampling with detailed geophysical survey utilizing resistivity and gravitational methods. Between 1955 and 1959, a number of 28 diamond drilling holes were drilled over the area of Sebembere, totalling 10,700 m. As the result, some several million tonnes of ore at 2% Cu were indicated. One of these holes, SB 20, was collared 3 km southwest of copper showings at an angle of -70° and drilled to the depth of 190.63 m.

The hole intersected the mineralized zone of 6.16% Zn in massive dolomite, between 96.08 and 105.23 m of drilling length, but no attention was paid for this intersection.

In 1963, the Mineral Search of Africa, a subsidiary of Rio Tinto, planned additional drillings but the Sebembere Copper Claims were abandoned in 1970. In 1970, Geomin acquired a Prospecting Licence of Sebembere P.L.7 over an area of 11.5 km^2 and drilled three holes with a total depth of 903.1 m. The Licence was converted to an Exploration Licence, E.L.34, and in 1972, six additional holes of 1,725.8 m were sunk.

Ore deposits were estimated to be of some 9.7 million tonnes at 1.62% Cu in three beds totalling 4.7 m thick in quartzite, with a strike length of 1,200 m at a depth ranging from 100 to 500 m. A prospecting shaft commenced to be sunk but due to a high level of underground water, sinking was suspended at a depth of 37 m and the area was reduced to 2.5 km^2 in 1973, and abandoned in 1975.

As described above, prospecting efforts were made only for copper during these days.

In 1976, MINDEX considered the area to be potential of zinc mineralization because of

1) The presence of zinc mineralization in dolomite, intersected by a drill hole SB 20,

2) Being situated on the same dolomite horizon with that of Kabwe Mine at 17 km southeast of the area, and

3) Available data on adjacent areas.

In 1976, soil sampling was started and from its results, a Prospecting Licence was applied and granted as Kabwe West P.L. 142, which covered an area of dolomite of about 170 km^2 and included Sebembere. The work was suspended owing to a financial difficulties and the Licence expired in 1980. In 1981, MINEX acquired a Prospecting Licence P.L. 187 of Kabwe West II over an area of 20 km^2 centering at a zone of zinc mineralization but the Licence was relinquished in 1983 (Fig. 3-1-1).

The previous works are listed in the table shown in the appendices.

3.1.2 Geology

It is not practical to understand the geology of Kabwe West by surface survey due to thick soil cover by strong weathering. However, the geology can be summarized as follows from the information obtained by pitting,

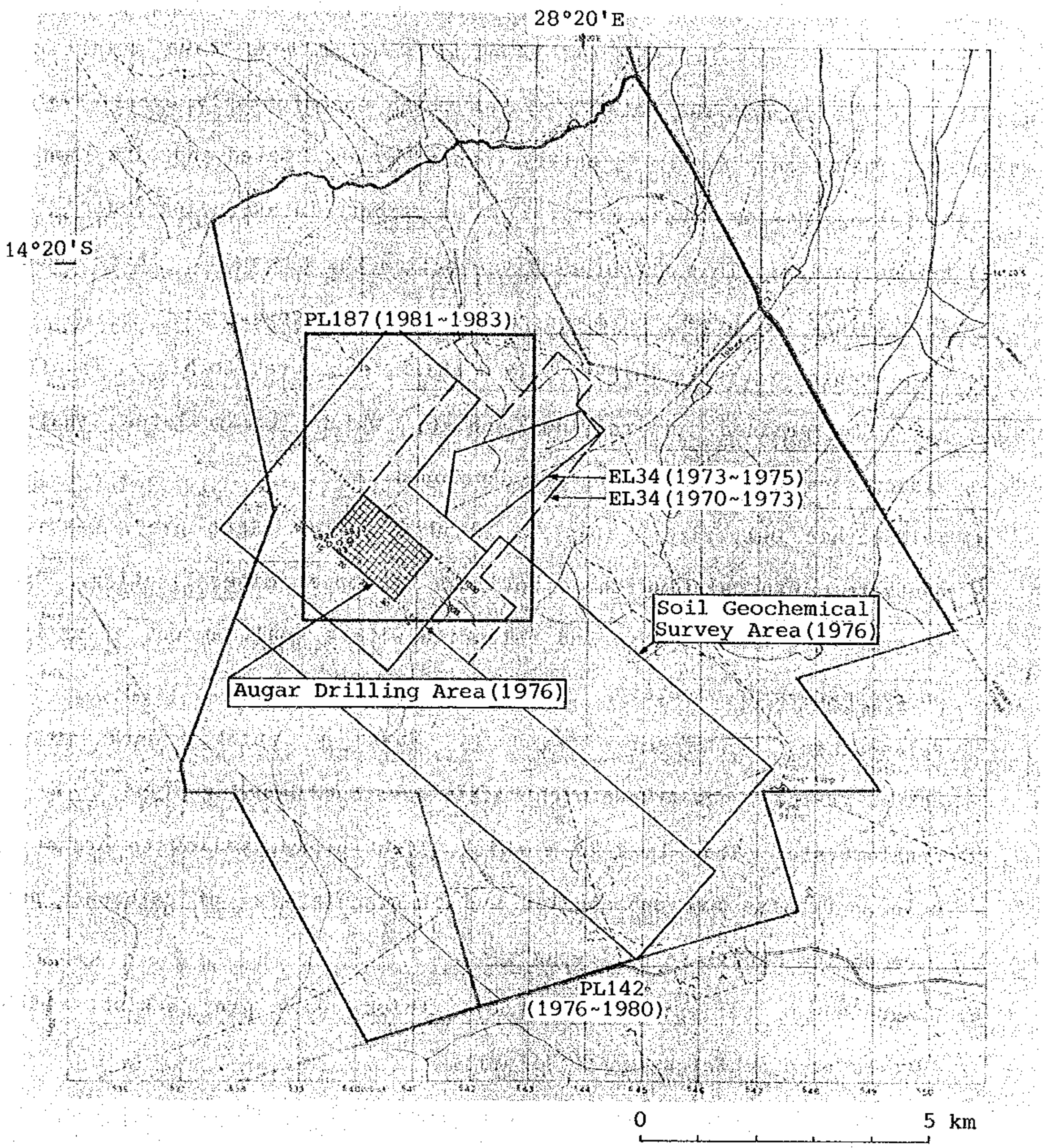


Fig. 3-1-1 Old Licenced Area

trenching, auger drilling and diamond drilling conducted during copper prospecting in the 1950's - 1960's and zinc prospecting in the 1970's.

The area is underlain by the Basement Complex consisting mainly of granite and gneiss and the Katanga System which unconformably overlies the Basement. The Katanga System is partly covered by an altered andesite lava.

The Katanga System consists of following members in ascending order.

1) Arkose Series: This unconformably overlies the Basement. It is about 30 m thick, red brown, hard and coarse-grained arkose.
2) Lower Schist Series: This is 5-15 m thick, dark grey to black, fragile and fine-grained crystalline schist, which intercalates shale. Fissures parallel to bedding are developed.
3) Feldspathic Quartzite: This is 20-50 m thick, light grey, massive quatzite, intercalating three horizons of copper mineralization. Ore minerals are chalcopyrite and calcocite with a small amount of pyrite and copper oxide minerals.
4) Feldspathic Sandstone: This is 5-35 m thick, dark grey, coarse-grained, sub-arkose with fairly developed bedding plane.
5) Conglomerate: This is 2-20 m thick, light cream, yellow to brown in color. Pebbles are sub-angular and of granule size of carbonate and mica schist Matrix is siliceous sand.
6) Upper Schist Series: This 20-60 m thick, dark grey schist, which intercalates schistose white dolomite.
7) Massive Dolomite: This is more than 300 m thick, light grey, homogeneous. It is the host rock of lead and zinc ore deposits at the Kabwe Mine and Kabwe West and in other areas, and is known as Broken Hill Dolomite.
8) Phyllite Series: This is the uppermost bed in the area, more than 90 m thick, consisting of phyllite and argillaceious schist.

The series 1) - 6) are correlative with the Lower Roan Group, 7) with the Upper Roan Group, and 8) with the Mwashia Group respectively in the Copper Belt.

The geological structure of the Kabwe West area was formed by the Lufilian orogeny (615-635 m.y.) which resulted in the synclinal and anticlinal structures. The axis of syncline runs in an ENE-WSW direction and the anticline runs in an E-W direction, both plunging gently toward the west-southwest or west. The Katanga System strikes in a shape of revered 'S', dipping at about 30 - 40° indicated by core correlation. A fault running in a NE-SW direction is inferred at the northern limb of the syncline (Table 3-1-1, Fig. 3-1-2).

3.1.3 Ore Deposits

(1) Exploration before MINEX

Systematic prospecting for zinc ore deposits was first undertaken in 1976 by MINEX, but the following information was available by prior explorations for copper ore deposits.

(a) Diamond drilling by Rio Tinto (1955 - 1959)

i) SB20 (Bearing: N68°E, dip: -70°, length: 190.63 m)

0 - 8 m	:	Surface soil
18 - 96.08 m	:	Dolomite
96.08 - 105.23 m	:	Zinc mineralized zone, 6.16% Zn
105.23 - 190.63 m	:	Dolomite

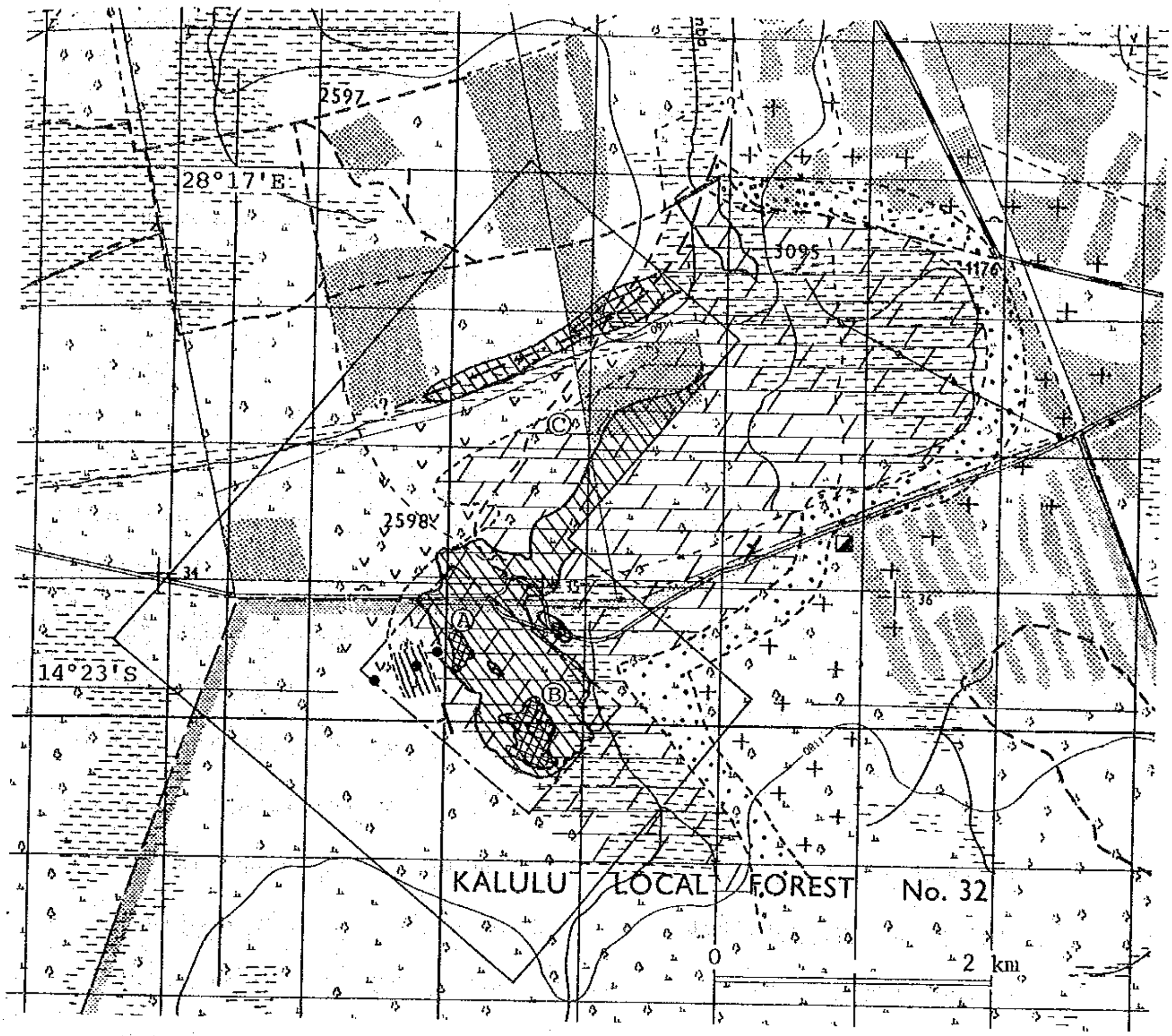
ii) SB21 (Location: 490 m S68°W of SB20, Bearing: N68°E, dip: -50°, length: 387.35 m)

0 - 8 m	:	Surface soil
8 - 284 m	:	Volcanic rock (weak copper mineralization in two places)

Table 3-1-1 Stratigraphic Correlation

	Kabwe West				Copper Belt (Mendelsohn) 1961
	Formation	Columner section	Thick-ness (m)	Lithology	
Katanga System	8) Phyllite Series		90+	Phillite, argillaceous schist	Mwashia Group
	7) Broken Hill Dolomite		300+	Pb•Zn mineralization Massive dolomite	Upper Roan Group
	6) Upper Schist Series		20 ∿ 60	Schist, dolomite	Lower Roan Group
	5) Conglomerate		2 ∿ 20	Pebble cg. (carbonate)	
	4) Feldspathic Sandstone		5 ∿ 35	Sub-arkose	
	3) Feldspathic Quartzite		20 ∿ 50	Quartzite Cu mineralization	
	2) Lower Schist Series		5 ∿ 15	Schist, shale	
	1) Arkose Series		30±	Arkose	
Basement Complex				Crystalline schist, granite, gneiss	Basement Complex

After
A.R.Dawson (1976),
A.Sliwa, M.Podemski (1980) and
T.Cairney & C.D.Kerr (1973)



Legend

V V	Andesitic Lava	◪	Shaft
≡	Phyllite Series	●	Diamond Drilling Hole
///	Dolomite		Geochemical Possible Anomaly (Zn)
∴	Schist, Quartzite etc.		Geochemical Anomaly (Zn)
+ +	Basement Complex		Auger Drilled Area
— —?	Fault (Inferred)	Ⓐ	Geochemical Anomaly Area
	Dip & Strike		

(After A.R. Dawson, 1976 and A. Sliwa, M. Podemski, 1980)

Fig. 3-1-2 Geological Map of Kabwe West Area

284 - 375 m : Schists

375 - 387.35 m : Dolomite

(b) Diamond drilling by Geomin (1972)

R3 (Location: between SB20 and SB21, 155 m from SB20, direction: vertical, length: 387.35 m)

0 - 31 m : Surface soil

31 - 116 m : Schist

116 - 335 m : Dolomite

(2) Exploration by MINEX (1976)

MINEX carried out the following prospecting works.

- Soil geochemical prospecting	: 5,951 samples, covering 45 km^2		
- Pitting	: 3 holes totalling: 20 m		
- Auger drilling	: 403 holes, totalling: 6,418 m		
- Rotary percussion drilling	: 12 holes, totalling: 192 m		
- Diamond drilling	: 4 holes, totalling: 4 m		
- Preliminary geophysical prospecting	: Gravity	:	99 stations
	Resistivity	:	99 stations
	IP	:	21 stations
	SP	:	42 stations

(a) Soil geochemical prospecting

A number of 5,951 samples were collected in an area of about 45 km^2 by a 200 x 50 m grid, or a 100 x 25 m grid and assayed for Cu, Pb, Zn, Ni and statistic analysis was made by the Lepetlier's method (1969), in which assay values were plotted in the logarithmic-normal probability paper on each rock type, taking a 30% value as low background (LBG), a 50% value as high background (HBG), an 84% value as possibly anomaly (PA), and a 97.5% value as anomaly (A). The results of Zn, Pb and Cu are as follows.

Rock type	Zn (ppm)				Pb (ppm)				Cu (ppm)			
	LBG	HBG	PA	A	LBG	HBG	PA	A	LBG	HBG	PA	A
Dolomite	57	93	275	910	32	-	200	500	-	-	120	180
Argillaceous phyllite	90	-	260	900	15	-	96	180	-	68	160	215
Metabasic igneous rocks	-	-	180	300	22	70	140	-	28	-	105	350

Two zones of Anomaly with the highest value of 1,940 ppm Zn have been delineated in the east and southeast of SB20 and are called Area A and B respectively. The Area B has a dimension of 800 m by 1,200 m. The third zone of anomaly has been located 2 to 3 km north of these areas and is named Area C. A Pb anomaly zone with the maximum value of 440 ppm Pb was found only in overlapping on the Area B of zinc anomaly.

Three anomaly zones in copper have been detected. One of them, located near SB21, is considered to reflect the weak copper mineralization in andesite lava found by SB21, the second zone to reflect the southern extension of the copper mineralization at Sebembere, and the third one is a small zone overlapping Zn anomaly of Area B.

The anomaly zones in Co were distributed sporadically, with the exception of small one overlapping Zn anomaly of Area B. No anomaly zone in Ni is observed.

As the result of geochemical prospecting, a follow-up prospecting was considered to be necessary over the areas of Zn anomaly, especially Area A and Area B covering a 1,000 x 1,600 m area in the vicinities of SB20. This area is called the Detailed Prospecting Area.

(b) Detailed prospecting by auger drilling

Pitting and rotary percussion drilling were planned to clarify Zn variation to the depths in the overburden, the subsurface configuration of bed rocks, lithology and mineralization. However, pitting did not exceed a depth of 8 m due to a high level of ground water and percussion drilling encountered the sampling problem.

In stead of these, the auger drilling was introduced and conducted along the soil sampling lines at an interval of 100 m and intermediate of these lines. A sum of 403 holes with a total length of 6,418 m were drilled over the Detailed Prospecting Area with the minimum spacing of 25 m on the sampling lines.

A sum of 253 of these 403 holes encountered the bedrock and a number of 133 holes did not reach the bedrock. The overburden is about 15 m thick on the dolomite area and more thick in the schist area where a maximum depth of 69 m was recorded. The configuration in the subsurface varies with regards of lithology and dolomite seems to give a karst-like topography.

The overburden was sampled every 1 m and assayed for Cu, Pb, Zn and Mn. The Zn value was constantly very low in the schist area, but it often showed an abnormally high value and tended to increase in value with depth in the dolomite area.

Zinc values at the bottom of holes reached up to 30% Zn at 475 NE of Line 19 where gossans with sphalerite were encountered. More than 1% Zn value was recorded in a 200 x 400 m area extending around this hole. This area roughly coincides with the soil anomaly Area A, but soil anomaly seems to have shifted slightly toward the northeast in accordance with an inclined topography. The SB20 is located at the western edge of the anomaly.

In the Area B, however, an area of high grade has not been found at the bottom of holes with exception of a few holes which yielded 1% Zn or more.

A statistical analysis of the data on Zn values at the bottom of 395 holes should an average value of 9,274 ppm with a standard deviation of 25,759 ppm. When the value of 35,033 ppm (3.5%) was taken as the threshold value, anomalous areas in the Area A of 3.5% or more are located in dolomite near the boundary with overlying schists and on zones at a horizontal distance of 50 - 100 m and of 150 m from the boundary. The maximum length is about 400 m. In Zone B, however, no anomaly zones are delineated.

In addition to the auger drilling, diamond drilling was supplemented at the bottom to recover a core by replacing the drill bit when the hole reached to bed rock. Four holes of 1 m each were drilled by this method and one of which was implemented at 475 NE of Line 19 where a value of 30% Zn was recorded, but no details of diamond drilling are known.

(3) Discussion

As a result of the soil geochemical prospecting and auger drilling in the Kabwe West area, the zinc mineralization in dolomite seems to be of high potential.

There have been delineated three anomaly areas of A, B and C. The surface distribution of anomaly is in accord with the geology and also reflects its topographical features.

The southwestern boundary of anomaly of areas A and B almost coincides with the contact between overlying schist and dolomite, and areas A and B are situated immediately on the northeastern side of the contact. The surface topography dips gently to the northeast and areas of anomaly are drifted in that direction. Moreover the anomaly area is situated near the crest of the anticline, of which the axis runs east-westerly in the vicinity of SB20.

The anomaly of Area C seems to extend along a certain horizon in both wings of the synclinal axis which runs in an ENE-WSE direction.

Samples collected at the bottom of holes brought information on lithological distribution in the bedrock.

From the Zn anomaly localities detected by auger drilling, it can be inferred that the zinc mineralization is notable in the dolomite horizon near the contact with the overlying schist. However there is no direct evidence to link the zinc mineralization in SB20 with the anomalies delineated by auger drilling.

The geological setting of Kabwe West is similar to that of the Kabwe Mine. Furthermore considering ore genesis of the Kabwe deposits, the Kabwe West area seems to have a promising potential in finding of zinc mineralization in bedrocks.

Patterns of soil anomaly and delineated mineralization in the overburden give two possibilities of a type of mineralization. One is of disseminated and stratiform type and another is of massive sulphide orebody of Kabwe type (Fig. 3-1-3).

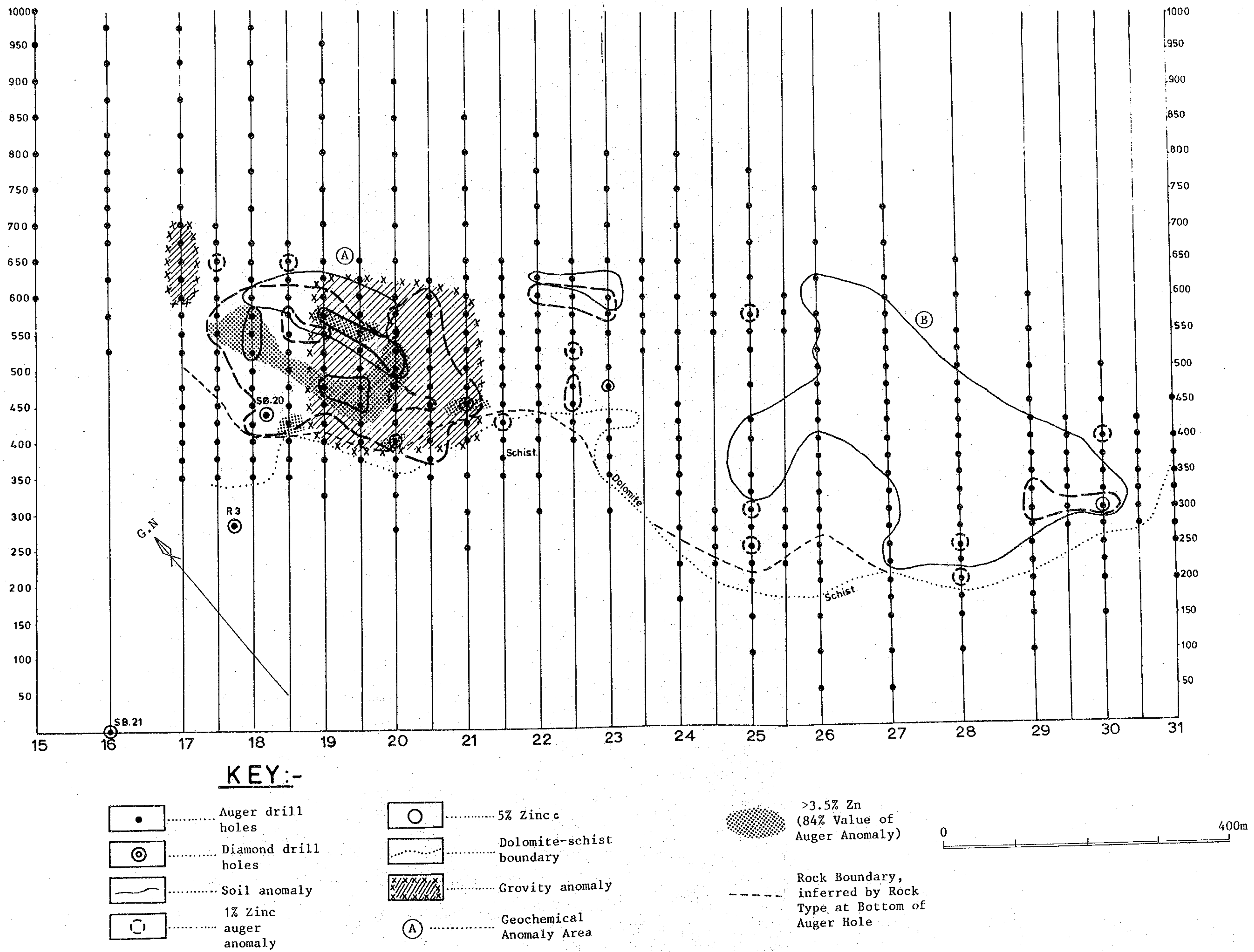


Fig. 3-1-3 Auger Drill, Gravity and Soil Anomaly Map (Original by D.J. Weir, 1977)

3.2 Geophysical Prospecting

The history of geophysical prospecting in the Kabwe area goes far back to the early 1920's (Table 3-2-1).

Ground geophysical prospecting was conducted mainly for direct exploration of ore deposits. The Kabwe area was covered by the airborne magnetic and radiometric survey carried out in 1966 - 1967 (Canadian Aero Service Ltd.) and by the airborne magnetic survey conducted again in 1974 (Geometrics). The scale of those maps was 1/50,000 and traverse spacing of traverse line was set at 1 km in all these surveys.

In 1974, the reconnaissance gravity map of Zambia (the Technical Report of the Geological Survey No. 76) was published, which contained a Bouguer anomaly map drawn on a scale of 1/1,500,000 without terrain correction.

3.2.1 Geophysical Prospecting in the Vicinities of Kabwe Mine

The ore deposits at the Kabwe Mine are pipe-like or vein deposits occuring in massive dolomite, with a core of massive sulphide surrounded by oxidized zone. Massive sulphide comprises mainly sphalerite and galena with a minor amount of pyrite in part. Sphalerite has a low iron content and its electric resistivity is high just as oxidized ore.

Consequently, electric and electromagnetic prospectings were carried out for exploration of conductive sulfides such as galena and pyrite, and gravimetric prospecting was for exploration of massive ore deposits which have a higher density than the host rock.

In 1926 and 1927, a Swedish electric prospecting company carried out an exploration by the electromagnetic method. Details of this method are unknown, but it is reported that the detecting unit was placed in a large horizontal loop and operated at a frequency of 540 Hz. Drilling was conducted on anomaly zones detected in this survey, but no ore deposits were

Table 3-2-1 Chronological Data of Geophysical Prospecting in Kabwe Mine Area

Year	Kabwe Mine and Vicinities	Kabwe West Area	Area Embracing Kabwe Mine
1926 - 1927	Electromagnetic method		
1948	Gravity, resistivity, SP methods		
1955	Radiometric method	(1950 - 1960) Gravity, magnetic, IP, SP, electromagnetic, radiometric methods	
1958	Electromagnetic method		
1966 - 1967	Gravity, magnetic, IP, methods		Airborne magnetic, radiometric methods
1967 - 1968	Residual analysis of gravitational data with a computer		
1971 - 1973			Nation-wide reconnaissance gravity survey
1974			Airbone magnetic method
1976		Magnetic, gravitational, resistivity, IP, SP, electromagnetic (TURAM) methods in Kabwe West area	

discovered. The survey also produced a large number of anomaly zones with low S/N ratios which were attributed to the detection limit and defects of the equipment, geological condition, and artificial noise. The electromagnetic method of this kind is suitable for exploration of conductive massive sulphide existing in the host rock with a high electric resistivity. While the equipment used in those days had an exploration depth of only about 50 m, there are now available far more advanced devices such as a transient electromagnetic method (SIROTEM, etc.), using a horizontal transmitting loop or a multifrequency electromagnetic method using two receiving coils put at a right angle (GEM-8).

Geophysical prospecting in the Kabwe area was suspended for a long time after the said survey by the Swedish company. After World War II, a gravitational prospecting was made in 1948, and the resistivity method and SP method were used to supplement the gravity method.

The Kabwe Mine and its vicinities were covered by this gravitational prospecting, and 10 holes with a total depth of 2,325 m were drilled in 10 anomaly zones detected by the prospecting. Some disseminated zones of lead and zinc were found as a result of this drilling operation, but no pipe-shaped ore bodies were discovered.

Since the gravity map prepared at the time was not made available to the study team, locations of these holes on the map are not known. It is probable, however, that the drilling was conducted to probe into each high anomaly zone.

It is believed that the resistivity and SP methods produced virtually no useful data because the survey area was encountered with noises from the water pipeline and transmission lines of the Kabwe Mine. Nevertheless, the resistivity method is considered to have been effective in 1) detecting a low resistivity anomaly over the pillars around the main shaft, 2) tracing the dolomite-shale boundary, and 3) ascertaining the coincidence between the center of high gravity anomaly zone and the high resistivity zone.

In the 1960's when the gravity surveys in earlier days were reviewed, a number of comments were made. In one of these comments, it is stated that the gravity data was influenced more by the mass effect than by ore bodies, and that rocks differing in lithofacies also differed in the degree of weathering and this was manifested as gravity anomaly.

The area has a very flat topography, covered with a thick layer of overburden extending down to a depth of several to several tens of meters from the ground surface. It is therefore likely that the bedrock configuration is reflected in the gravity distribution. In fact, the study team noted that the massive dolomite showed extreme complexity of configuration at the site of open-pit mining.

In 1955, an experimental radiometric prospecting using a scintillometer was made in the neighbohood of the Kabwe Mine, but no anomalies were found that deserved special attention and all measured values were stabilized at low levels.

In 1958, electromagnetic prospecting aimed at finding massive sulphide was conducted using a newly developed equipment, with survey lines spaced at 30 m and station intervals set at 15 m. Since the estimated depth of orebody was larger than 60 m, observation was made at a coil interval of 105 m. In this survey, a vertical coil had to be used instead of a horizontal one in many places owing to the noise from railways and high-tension transmission lines, and this caused a decline in the equipment sensitivity and exploration depth. Furthermore, the frequent occurrence of mechanical trouble at the early stage of prospecting resulted in the entry of erroneous data.

The results of this survey proved to be unsatisfactory because of many anomalies which obviously lacked any definite meaning (anomalies that could not be clearly interpreted). In a report of this investigation, it is stated that an anomaly indicating the presence of a big conductor was obtained, but it could not be interpreted owing to the complexity of relevant data.

These data were not available, but it appears that the said anomaly was a reversed inphase component anomaly attributed to the presence of a magnetic substance such as magnetite. Although no satisfactory results were obtained from this prospecting operation, it was concluded that the presence of big conductor immediately below the ground surface was not possible. It may be said that the electromagnetic method was preferred by the prospecting specialists of those days because they did not give up to find massive sulphide which they considered to be a good conductor. Today, there are few who would use the electrical or electromagnetic method for immediate exploration of ore deposits, but none can nevertheless deny an existence of conductive ore bodies.

In 1966 and 1967, prospecting by the combined use of three methods was carried out. These were the gravimetric, ground magnetic and IP methods.

Prior to this investigation, the validity of the gravitational method was questioned because it was considered that the presence of many cavities and fissues around orebody would make it impossible to obtain a sufficient density contrast. On the other hand, the IP method was considered to be capable of detecting low-grade galena with high accuracy and prospecting down to larger depths than the electromagnetic method. However, neither the IP method nor the electromagnetic method could obtain any clear anomaly from ore bodies consisting of sphalerite or silicate ore because sphalerite with little iron content is a nonconductive and non-polarized substance. The magnetic method was used in combination with the IP method for prospecting of magnetic minerals.

Each of the above prospecting methods was conducted with survey lines spaced at 30 m and station intervals set at 15 m. In the IP method, the pole-dipole method was used to raise efficiency and eliminate electromagnetic coupling. In the gravity survey, a Worden gravimeter was used, with corrections using a graph. In this survey, gravity anomalies of 0.1 mgal were detected and drilling was conducted to investigate these anomalies, but nothing was discovered and none could think of any reason to explain it. The results of IP showed no coincidence with those of gravitational prospecting, and this was explained by the absence of density contrast due to coexistence of mineralization and fissures. Thus, the combined use of the three prospecting methods did not produce any notable results.

Toward the end of 1967, prospecting by the gravimetric and radiometric methods was conducted in another area. In this survey, 467 stations were established and a gravity map on a scale of 1/25,000 was prepared.

Using a Worden gravimeter, precision levelling at each station and close base control were maintained to make drift corrections, with a surface density of 2.1 g/cm^3 as a reduction factor. In data processing, the regional trends were removed by the multiple regression analysis using a computer (IBM1130). As a consequence, low order anomalies not exceeding 0.2 mgal were found in many places.

The radiometric method was used because of a discovery of a value in the neighborhood of one ore body which was higher than the normal background level. This anomaly was attributed to slag as well as to the solid angle effect and the mass effect of discarded rocks.

From 1967 through 1968, a residual analysis of gravity data collected in 1948 was made at the ACC Data Processing Center at Kitwe for extraction of local anomalies from the gravity map. A report of this analysis indicates that the regional gravity gradient involved an extremely large number of variations.

Of the local anomalies thus extracted, positive anomalies of 0.3 - 0.6 mgal were traced by drilling. However, the significance of anomalies of 0.1 - 0.2 mgal was doubted for the following reasons.

1) Low precision of the gravimeter used in the early stages of prospecting operation.

2) Inaccuracy of data due to the geological condition and multiple regression analysis.

There were also some who argued that minus anomalies should be given significance if fissures and cavities found in the neighborhood of an ore body are sufficiently large. Thus, the gravitational method aroused much discussion regarding the problems encountered in its application, but was generally accepted as being worth trying owing to the absence of any other effective prospecting method.

As described above, the Kabwe Mine area and vicinities were covered by geophysical prospecting of various kinds from the 1920s through the 1960s. These included the electromagnetic, gravitational, radiometric, IP, SP and magnetic method, and efforts were made to discover massive ore deposits using all these available methods except seismic survey.

Drilling was conducted in many anomaly zones detected by these prospecting operations, but failed to penetrate any ore body that could be exploited for commercial mining operation.

3.2.2 Geophysical Prospecting in Areas West and Northwest of Kabwe

Areas situated to the west and northwest of Kabwe have long been known for many prospects such as Chiwanda, Sebembere, Mplembe and Lukali. In the 1950s and 1960s, extensive geochemical surveys were carried out in these areas, and the anomalies extracted were traced by geophysical prospecting using various methods such as the gravitational, magnetic, resistivity, IP, SP, EM and radiometric methods. Although the geophysical prospecting was conducted by combining some of these methods in each area, it did not produce any noteworthy anomalies.

The gravity method was applied to trace the Katanga System - Basement contact, but the results of this survey have not been confirmed yet. In the Copper Belt lying about 100 km to the north of this survey area, the Basement Complex is considered to be higher in density than Katanga System. The magnetic prospecting in this area disclosed a linear magnetic distribution striking parallel to the Katanga System as well as a high magnetic anomaly that reflected a diabase occurrence. Hence, the survey was focused on one locality where a disseminated zone of magnetic was found in the Katanga System - Basement contact. In the electromagnetic prospecting, only low anomaly zones were detected, which were ascribed to lithological variations and to disseminated zones of pyrite. The radiometric prospecting produced no anomalies that deserved attention.

3.2.3 Geophysical Prospecting in Kabwe West Area

In the 1950s, a zinc mineralization was penetrated by drilling conducted in the west of Sebembere. In 1976, a systematic geochemical prospecting was started in the Kabwe West area (Fig. 3-2-1). This was accompanied by a concurrent detailed magnetic prospecting, during which a grid survey (200 x 50 m) and a partial detailed survey (100 x 25 m) were conducted on soil sampling stations over a survey area of 12.8 km^2, with a Geometrics, proton magnetometer. The magnetic data collected in this survey, plotted on a map on a scale of 1/10,000 at contour intervals of 100 γ, was used to amplify the geological information obtained so far. A high magnetic anomaly is generally attributed to a trend of argillaceous phyllite, but the one found in the southern part of the area is considered due to an occurrence of diabase. The

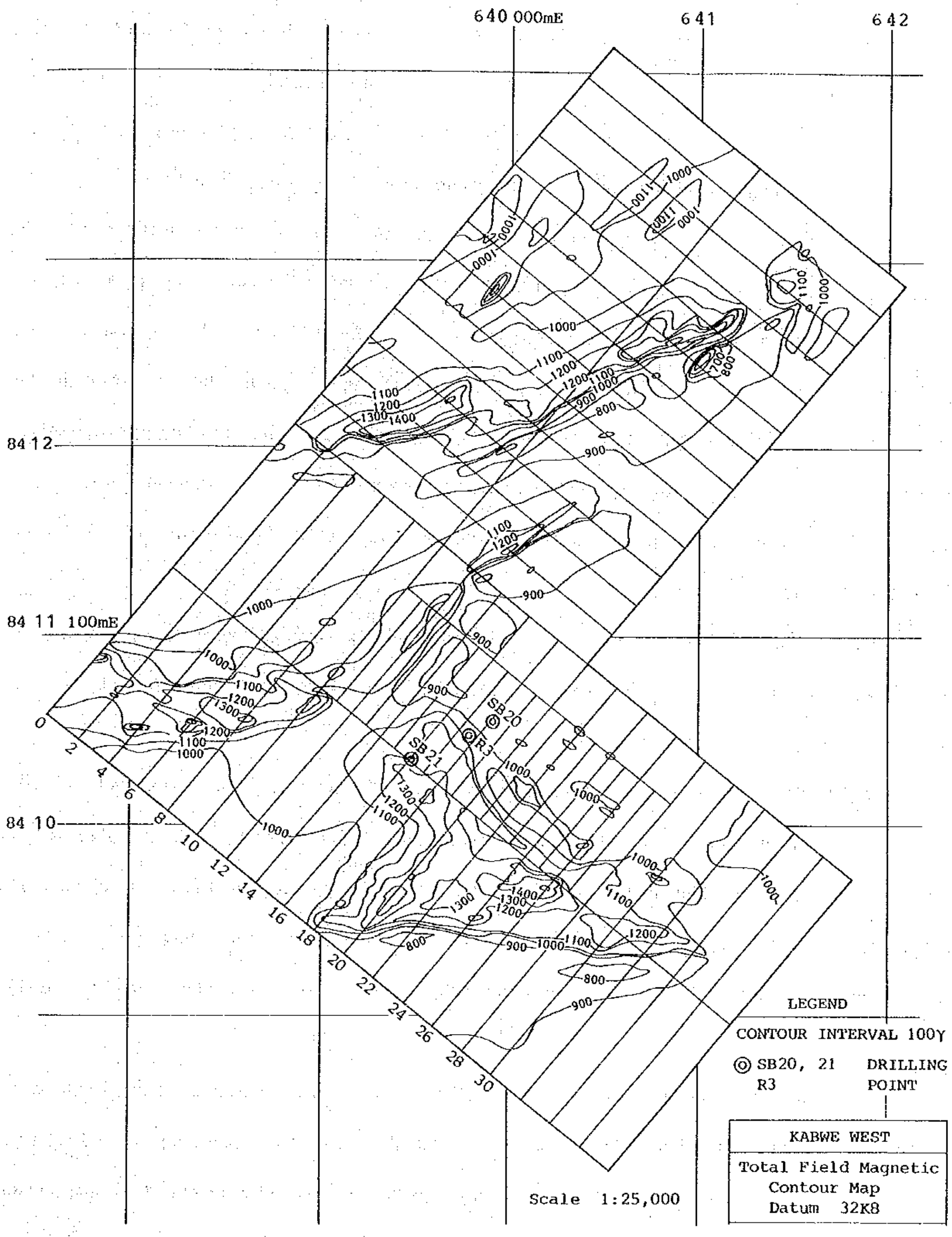


Fig. 3-2-1 Total Field Magnetic Contour Map

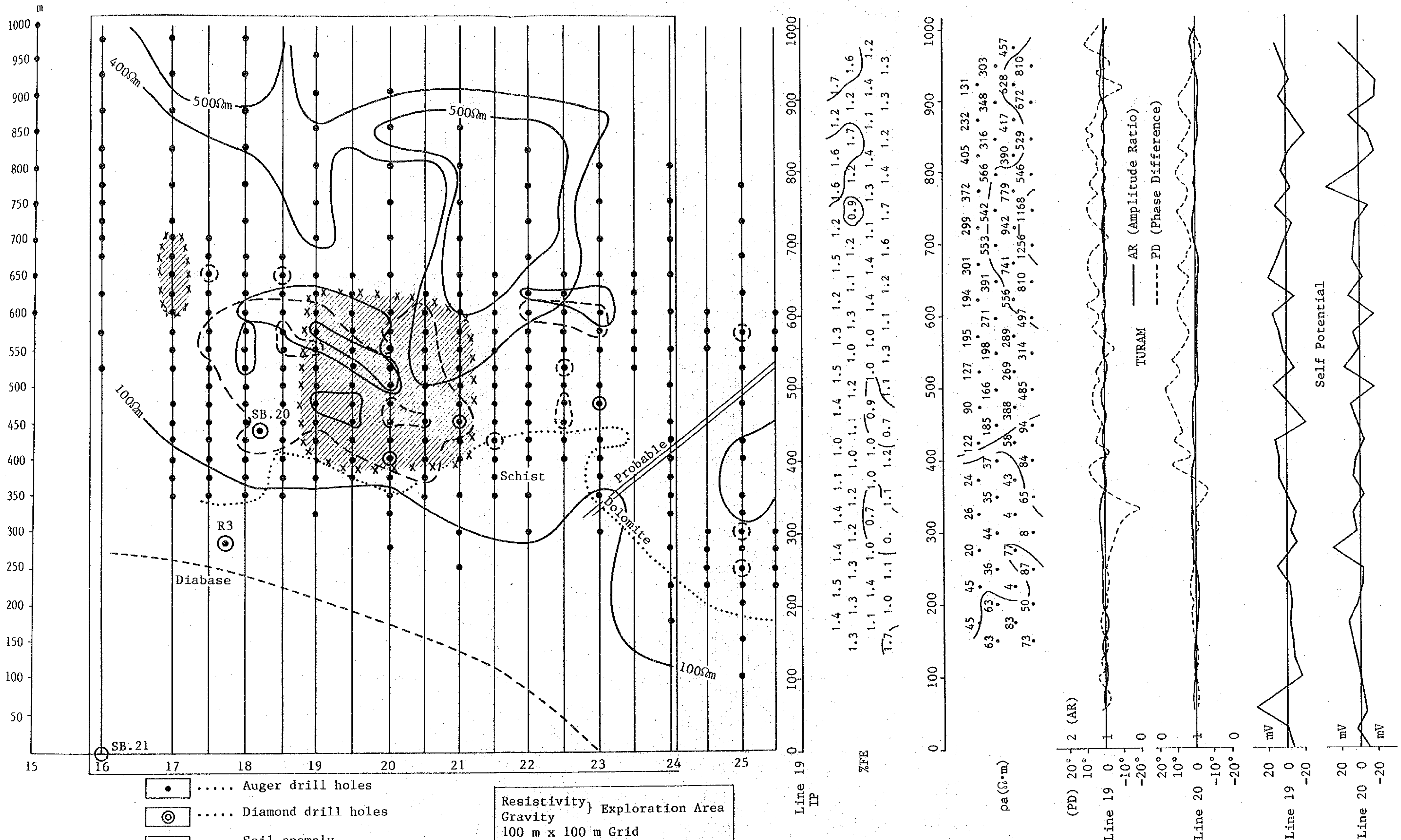
magnetic trend was in a NE - SW direction in the northern part of the area, and in an E - W and NW - SW directions in the southern part. Localities lacking in magnetic anomaly can be considered to be in the dolomite-distributed area. Data of the ground magnetic prospecting showed general conformity to those of the airborne magnetic map (1/50,000).

An experimental geophysical investigation was carried out over the strong anomaly zones detected in the said geochemical prospecting using the gravity, resistivity, IP, electromagnetic (TURAM) and SP methods. The purpose of this survey was to examine applicability of these methods for prospecting of the Kabwe Mine-type ore deposits in the strong geochemical anomaly zones. Accordingly, all available geophysical techniques were used for a difficult task of exploring massive or pipe-like lead-zinc ore deposits in dolomite (Fig. 3-2-2).

However, no anomaly zones were delineated by any of such methods as the IP, TURAM and SP which were generally considered capable of direct exploration of mineralized zones.

The IP data were obtained along line No. 19 at a dipole interval of 50 m (n = 1 - 4), using a Geoscience's equipment (Frequency; 3,0.3 Hz) which seemed to indicate the background level at a frequency effect of about 1%, and hardly discriminated anomalies. Thus it is considered that an existence of pyrite disseminated zone accompanied with an anomaly is virtually eliminated.

The TURAM method was conducted with a 2 - km transmission line at a frequency of 660 Hz along lines No. 19 and 20, and two receiving coils were spaced at 15 m. Data of this survey was expressed in the corrected amplitude ratio and phase difference. In the neighborhood of line No. 19 - 340, an anomaly with an amplitude ratio of 1.2 and a phase difference of 20° was detected. However, this was interpreted as an anomaly existing on the



KEY:

•	..... Auger drill holes
◎	..... Diamond drill holes
(line)	..... Soil anomaly
(dashed circle)	..... > 1% Zinc auger anomaly
○	..... > 5% Zinc auger anomaly
(dotted line)	..... Dolomite-schist boundary
(hatched)	..... Gravity anomaly (-1.5)

Resistivity, Gravity } Exploration Area
100 m x 100 m Grid
N-S E-W
11 x 9 = 99 Stations

Line 19: IP (Frequency 3, 0.3 Hz)
a = 50 m, n = 1 ∿ 4)
Line 19, 20: {Turam, SP

KABWE WEST
Auger Drill, Gravity and Soil Anomaly Map
Geophysical Exploration Results

Scale: 1:5000

Fig. 3-2-2 Auger Drill, Gravity and Soil Anomaly Map

contact between the low resistivity zone in schist and dolomite because the IP data showed no frequency effect anomaly in the same place. The apparent resistivity data obtained by the IP method indicated that the apparent resistivity ranging from 4 to 40 Ω - m in schist increased to 4 - 5 times higher than this level on the contact with dolomite. The SP method was implemented along lines No. 19 and 20, as was the case with the TURAM method, with electrodes spaced at 25 m, but no discernible anomalies were discovered.

The gravitational and resistivity methods were more effective than other methods. The gravity survey was conducted using a Worden gravimeter to cover an area of 800 x 1,000 m with a 100-m grid, with the correction density of 2.0 g/cm^3. A high gravity anomaly of 0.2 mgal found in the central part of the survey area coincided with the geochemical anomaly. Since this anomaly lacked in magnetic anomaly, it is considered to be an anomaly in the dolomite-distributed area.

The resistivity prospecting was conducted by the Schlumberger method at the same points as adopted in the gravity survey, using a combination of AB = 150 m and NN = 20 m. It is believed that the apparent resistivity data covered depths of 50 - 70 m from the ground surface. The apparent resistivity was lower in the southern part of the area than in the northern part, which can be ascribed, among other reasons, to a large overburden thickness. The bedrock became larger in depth in places where it changed from dolomite to schist, indicating that the apparent resistivity contour of 100 -m generally coincided with the schist-dolomite contact. Variations in apparent resistivity were also observed within areas where the dolomite distribution was considered likely. It is probable that the high apparente resistivity reflected the distribution of massive dolomite with few fissures.

3.2.4 Geophysical Prospecting in the Future

It is necessary to pay attention to the following points in implementation of geophysical prospecting in the future to explore for the Kabwe Mine-type ore deposits.

(1) Ore deposits of the Kabwe Mine are massive, pipe-like deposits with a steep dip. Each ore body measures 20 - 40 m in width, 100 - 200 m in plane length, and 400 - 800 m in plunge length.

(2) These ore deposits are overlain by overburden having a thickness of several to several tens of meters. The ore zones are resistant to weathering, and the bedrock presents a protrudent topography. The bedrock configuration varies largely in depth owing to the varying degrees of weathering caused by differences in lithofacies.

(3) Host rock is pure dolomite, and its contact with ore deposits is distinct.

(4) Cavities and fissures are developed near ore deposits.

(5) Sphalerite having a low iron content and oxidized ore have very high electric resistivities just as pure dolomite.

(6) Ore deposits accompanied with galnea and pyrite are found in some parts.

(7) Ore deposits are situated in the central part of syncline.

The applicability of geophysical methods is reviewed below on the basis of the above characteristics of ore deposits of the Kabwe Mine.

(a) The electric and electromagnetic methods present some adaptability problems because the Kabwe type ore deposit comprises mainly sphalerite and oxidized ore which have high electric resistivities, whereas the resistivity method can be used in prospecting for dolomite-distributed areas.

(b) It is theoretically possible to apply the detailed gravimetric method to explore for the bedrock configuration and massive ore deposits. When this method is used, it should be noted that the lithological variations, cavity and fissure zones also give gravity anomalies.

(c) The seismic reflection method can be used to explore for synclines, Basement granite - Katanaga System contact, and structures in the Katanga System. The presence of a reflection plane in dolomite offers the possibility of finding an ore deposit, a cavity, or a fissure zone. This method can also be used to measure a depth of bedrock.

The seismic reflection method which is a main geophysical exploration technique for oil has not been tested in this field. But recently the reflection method using non-dynamite energy source was developed and it became possible to explore a shallow geological structure with high resolution. Since the seismic reflection method is considered capable of producing the largest amount of useful data, it is recommended that this method be used in the initial year of prospecting operation. For the second year, it is advisable to make a choice from among the resistivity (CSAMT), detailed gravitational and seismic reflection methods on the basis of the prospecting data collected in the initial year.

IV OVERALL EVALUATION

IV OVERALL EVALUATION

4.1 Kabwe Mine

4.1.1 Ore Reserves

At the end of March, 1987, ore reserves of the Kabwe Mine standed at 1.5 million tonnes, being of 6.8% Pb and 17.5% Zn. About 10% of ore reserves comes from sulphide ore and remaining 90% comprises silicate ore. Total ore reserves increased by 688 thousand tonnes during the period of April 1986 to March 1987, mainly due to transfer of ore reserves from 'resources' in rib pillar and unclassified ore reserves which were referred as 'resources'.

Such a large amount of increase in ore reserves would not be expected under the present condition. If a present level of production is maintained, sulphide ore will be terminated within a few years. Underground mining of silicate ore does not seem feasible. Consequently, a production in the future involves a modified treatment in which the leaching plant and Waelz kilns will be in operation together with a lead furnace. The feed for the reduced operation will be either ore from the ground or from previous residues on dumps.

4.1.2 Prospects

Escavation of several prospects in the Foundry Area at the east of the mine is in progress and a shipment of ore has been commenced. The deposits are said to be small without having been intersected by drill holes. A drilling programme at Airfield also has been worked out where a subordinate amount of silicate ore at a low grade has been delineated. Mining of the Star Zinc deposits, which are in the suburbs of Lusaka, is being investigated.

4.1.3 Geophysical Prospecting

Since the commencement of the mining at Kabwe, latest techniques in geophysical prospecting have been tested and applied for at each stage. These involve self-potential, resistivity, electromagnetic, induced polarization, magnetic, gravitational, and radioactivity methods. Only seismic methods remain untested. Due to an existence of treatment plants, structures, railways and power lines, and due to a small contrast in physical properties, most of these methods have failed to discriminate between ores and wall rocks. A detailed study of performances in the past indicates that the detailed gravity method and the resistivity method are still applicable to obtain some geological information.

4.1.4 Potential

The immediate vicinities of mining area have been subjected to the extensive drilling programmes in the past, both on the surface and in the underground. Although a possibility of new find cannot be wiped out, a potential seems fairly small in the adjacent areas of known orebodies.

4.2 Western Areas of Kabwe

4.2.1 Geochemistry

Due to a flat topography and ill-defined drainage, sampling of stream sediments were not effective from an early stage of exploration in the past. Therefore, most of the study area was covered by regional soil sampling grids. Anomalies were followed up by detailed mapping and sampling, geophysical prospecting, pitting and trenching, auger drilling and diamond drilling. Dicovery of copper mineralization in basal Katanga quartzites at Sebembere made by Mineral Search of Africa Ltd. was claimed as the first successful application of geochemical prospecting methods in Southern Africa.

4.2.2 Drilling

At the Chiwanda area, five diamond drill holes were put down by Mineral Search of Africa, with a total length of about 500 metres. Zamanglo sunk fourteen drill holes totalling 1,069 m to reveal sporadic patches, veinlets and blebs of galena with a lesser amount of sphalerite.

At Sebembere, a number of 28 boreholes were drilled totalling some 10,700 metres by the Rio Tinto Co. between 1955 to 1959, but little information is available on the results of this programme. The Sebembere Claims had been taken up by Geomin and nine holes were drilled totalling 2,629 m with a shaft to a depth of 37 metres between 1970 and 1972. Further five holes were sunk by the Mokambo Development Co. in 1975. It would seem that the Sebembere area has proven reserves of 3 million tonnes grading 1.6%Cu.

In the Lukali area, Mineral Search drilled five holes at Lukali No.1 of Cu anomalies totalling 1,589 m and other five holes at No.2 of silicate zinc anomalies totalling 1,469 m. A considerable amount of regional pitting was undertaken by Chartered Exploration Ltd. to define the lithologies of the rocks and ten holes were drilled with a total length of 1,667 m. At the CPL blocks in the west, six holes of 30 m each were sunk, and at Mplenbe in the southwest, three inclined holes totalling 613 m intersected copper mineralization up to 1.41% Cu over a drilling length of 1.37 m.

Between 1925 and 1927, approximately 2,000 tonnes of vanadium ore grading 18 to 19% V_2O_5 were mined at Carmarnor and these prospects were re-investigated by Chartered Exploration in 1964. Fourteen diamond drill holes were put down but failed to intersect significant economic mineralization.

4.2.3 Potential

It is observed that great efforts have been made over the areas and each anomaly has been adequately defined and tested. As the result, the copper deposits at Sebembere were delineated and probably because of this, much attention had not been paid for zinc mineralization in the immediate vicinity.

4.3 Kabwe West

The Kabwe West area was first prospected in detail during 1950's by Rio Tinto for copper. One of diamond drill holes sunk for the Sebembere copper prospect intersected zinc mineralization with 6.16% Zn at a section between 96.08 and 105.23 m of drilling length. The finding was not followed up any further although one drill hole was put down in the west by Geomin without intersecting any zinc mineralization.

For research of zinc deposits, a prospecting licence was applied for and granted to MINDEX in 1976, and the Licence was named Kabwe West PL.142. The Licence expired in 1980 and a new Licence PL.187 has been also relinquished.

4.3.1 Geochemical Prospecting

In 1976, a number of 5,961 soil samples were collected and their assay results were processed using log-probability plots. Details of this processing has not been described but, judging from the present manual for data processing inherited in MINEX, the writers are of the opinion that data have been adequately processed to define anomalous areas which were taken up as targets for a programme of auger drilling.

4.3.2 Auger Drilling

The auger drilling programme was designed in order to investigate the behaviour of zinc content in the overburden over the areas which covered anomalous areas delineated by geochemical prospecting.

The zinc content increases generally with the depth and highest assay results are reported from the bottom of each hole. No information is available to a further depth. Consequently, it is not necessarily adequate to discuss a lateral distribution of zinc, because of lack of uniformity in sampling standards. Despite some uncertainities in the subsurface distribution, noticeable zinc values up to 30% Zn have been recorded within the overburden immediately overlaying the bedrocks.

4.3.3 Potential

The most important fact is that the existence of sulphide mineralization in the overburden has been confirmed and its occurrence in the bedrocks must be located.

When assay values from the bottom of auger drill holes are statistically processed, anomalous area of more than 3.5% Zn is delineated between Line 17 and Line 21 being at 400N to 575N of geochemical sampling grid(Area A). This anomalous area roughly overlaps with the area where various geophysical methods have been tested. Writers are of the opinion that this area is worth drilling.

A broad anomalous area in Zn has been detected in the east, during the course of geochemical prospecting, between Line 25 and Line 30. Although the assay results from auger drilling did not yield more than 2% Zn in bottom samples the area is accompanied with anomalies in Pb, Cu and Co(Area B). Two or three of diamond drill holes may be necessitated to elucidate a specific character of anomaly or mineralization in the area.

The third anomalous and possibly anomalous area of zinc in soil has been delineated 2 to 3 km north of these areas, extending in an east-northeast direction(Area C). The anomalies have not been tested by auger drilling but these geochemical anomalies would require a support from geophysical investigation prior to be drilled.

V CONCLUSION AND RECOMMENDATION

V CONCLUSION AND RECOMMENDATION

5.1 Conclusion

5.1.1 Kabwe Mine

Planned production figures are 195,000 tonnes total hoisted per annum comprising 156,000 tonnes of ore and 39,000 tonnes of waste. Grade are currently running at 10% total lead and 23.6% total zinc. Total depleted ores since 1915 stand at 10.5 million tonnes being of 25.4%Zn and 14.7%Pb. Metal production accumulated at 1.8 million tonnes of Zn and 0.8 million tonnes of Pb.

Even if those are not of latest, dressing and treatment plants and smelters are properly organized to handle unique ores and are well maintained minimizing additional investments. Some 1.8 thousand persons are engaged in the present production. If the present level of production is maintained, sulphide ore will be terminated within a few years. A production in the future involves a modified treatment of ore from the ground or from previous residues on dumps. But the operation of the mine has a great effect on local economy, especially from a view point of employment, and also keeps inflow of foreign currencies. Being a sole supplier of lead and zinc in Southern Africa, operation of the mine should be maintained as long as possible.

5.1.2 Mineral Prospects

Most of the study area has been covered with regional soil sampling grids from an early stage of exploration. Anomalies were followed by detailed mapping and geophysical prospecting, pitting and trenching, auger drilling and diamond drilling. Most of anomalies have been adequately defined and tested. Among them, due to an existence of copper mineralization in the Sebembere prospect, an intersected mineralization of zinc was not followed up until 1976, when MINEX carried out the detailed geochemical prospecting at Kabwe West which was followed by a series of auger drilling programme. Zinc assays reached as much as 10 to 30%Zn in several localities near the bedrocks. The field work was suspended when the priority was given to exploration for fertilizer raw materials. The area offers the most promising opportunities to be developed as indicated by an existence of sulphide ore in the overburden.

5.2 Recommendation

5.2.1 Selection of Target

The targets for exploration of mineral resources in the Kabwe area would be concentrated within the areas at Kabwe West. The Kabwe West areas are divided into three blocks depending on their potentials indicated by the investigation in the past.

The Area A refers to a block between Lines 17 and 21 of geochemical sampling grid where high values of zinc up to 30% have been recorded by the auger drilling programme from the overburden immediately above the bedrocks.

The Area B is located between Lines 25 and 30 of the grid where a broad anomaly in geochemical prospecting has been delineated. Assay values from the subsurface sampling are rather low and a variety of geophysical investigation has not been tested. The area comprises anomalies of zinc, lead, copper and cobalt.

The Area C is situated 2 to 3 km north of the above two and represented by an elongated geochemical anomalies in zinc which has not been tested yet.

5.2.2 Methods

The Kabwe area has been covered by geochemical surveys and a further investigation would not be warranted except a case in which a specific purpose is envisaged.

Various methods of geophysical prospecting have been applied to the area including magnetic, electric, electromagnetic, gravitational, radio-active, etc. Although a reflection seismic survey has not been applied for, this method seems to be applicable to delineate minor structures in the underground which may be related to the mineralization. A resistivity method and a detailed gravitational prospecting will be able to provide a geological information.

Mineralization is to be confirmed by the diamond-drilling and drillers should be well equipped and capable to recover cores as much as possible.

5.2.3 Survey Programme

A prospecting right over an area at Kabwe West does not exist, but it can be obtained easily when it becomes necessary. Surface rights are covered by a local forest, Tabaco Board of Zambia, ranching companies and private individuals, but no difficulties are expected for implementation of prospecting activities.

Prior to the commencement of mineral research, a topographic survey should be carried out to mark the areas. A base line direction has not been retained and most of old drill holes have not been marked. Traverse lines are to be connected with a datum point such as a prospecting shaft for copper.

(1) First Year

It is recommended to commence the survey with a diamond drilling programme over the Area A, where sufficient information has been collected and diamond drilling should proceed directly. Tentatively, six vertical holes of 250 m each are proposed on a grid of 100 m interval over the area at the northeast of Rio Tinto's intersection(SB20).

Fifteen traverses of 1,000 m long each of the reflection seismic survey will be laid down over the Areas A, B and C, of which three lines will run on the grid defined by drill holes to correlate signals with subsurface structures (Fig. 5-1-1).

(2) Second Year

When one or two of drill holes in the first year intersect the mineralization, an interval of grid is reduced to be of 50 metres.

If none of these holes intersects mineralization, and no indication is obtained by the geophysical method, drill holes of the second year programme will be collared at the centres of original grid and neighbouring squares. A number of holes and required lengths depend on resulting information. At least, two holes will be allocated to the Area B.

Selection of the geophysical method to be adopted in the second year shall be made after the completion of the first year programme. One of resistivity, detailed gravitational with a small spacing or, if effective, the reflection method will be selected to delineate targets for the drilling programme at the third year.

(3) Third Year

When ores of minable grade have been found, drill holes will be alloted for a calculation and evaluation purpose of ore reserves. If remarkable mineralization has not been intersected, targets are selected from geophysical anomalies which are considered to be related with mineralization. Two holes are drilled to intersect the downward projection of anomalies in the Area C. In case of a new find during the course of the third year programme, a follow-up investigation will be conducted in the next year.

5.2.4 Schedule

It is desirable that features of mineralization at Kabwe West become obvious during the period in which the treatment plant of sulphide ore is still in operation at Kabwe. The writers are of the opinion that necessary measures should be taken at an earliest convenience.

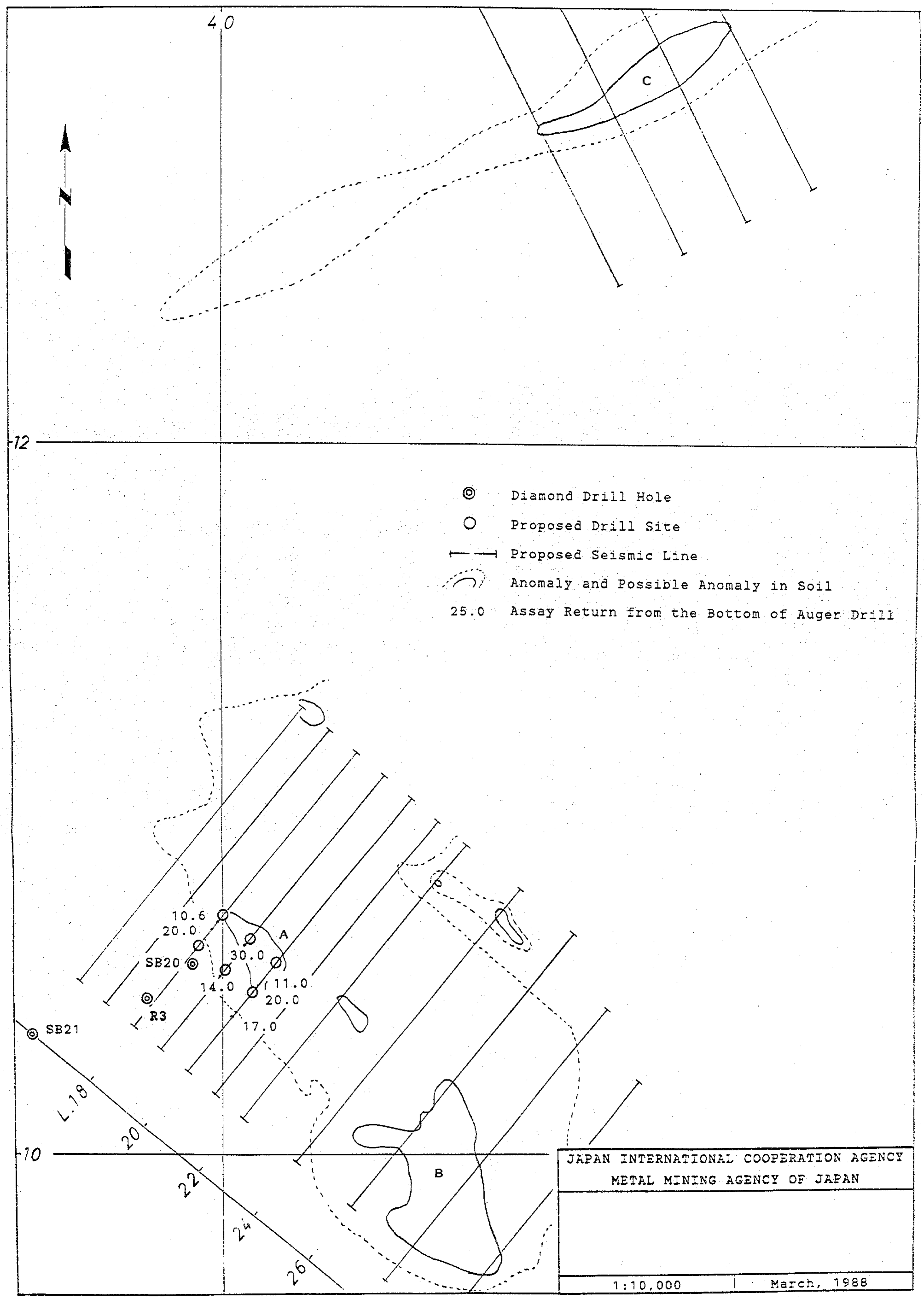


Fig. 5-1-1 Proposed Survey Plan for the First Year

APPENDICES

Chronological Table of Exploration

	GENERAL	KABWE MINE	CHIWANDA	SEBEMBERE	LUKALI
1902		Discovery of Outcrops		Discovery of Cu-Showing	
1915		Continuous Production Commenced			
1925-27					Vanadium Mining in Carmarnor
1929-30				Loangwa Concessions' survey	Loangwa Concessions' survey
1953			Acquired by Rio Tinto	Acquired by Rio Tinto	Acquired by Rio Tinto
1955-59			DDH 4 Holes	DDH 28 Holes, 10,700 m	DDH 10 Holes 3,058 m
1962		Introduction of ISF			
1963			Abandoned		Abandoned
1964	Zambia's Independence	INDECO acquired an interest in AAC.	Acquired by Chartered Ex. DDH 16 Holes, 1,292 m		Acquired by Chartered Ex. DDH 26 Holes, 4,970 m
1969			Re-named Zamangle Ex.		Re-named Zamangle Ex.
1970	Mines & Minerals Act	NCCM established	DDH 14 Holes, 1,069 m	Exploration by GEOMIN DDH 9 Holes, 2,629 m Shaft 37 m	DDH 14 Holes, 700 m (Carmarnor)
1971	MINDEX established.				
1972			Abandoned		Abandoned
1975				Terminated	
1976				MINDEX's Exploration as Kabwe West Auger drills 403 Holes, 6,418 m etc.	
1978	MINDEX becomes MINEX				
1981		ZCCM established.			
1983				Relinquished.	

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