EXPLORATION OF A MATURE COPPER MINING LICENSE - A COPPERBELT CASE HISTORY

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INTRODUCTION

Konkola Copper Mines (KCM) plc is an integrated copper producer operating on the Copperbelt in Zambia. KCM has numerous mining operations located in the towns of Chililabombwe (Konkola Mine), Chingola (Nchanga Open Pit and Underground operations), Lusaka (Nampundwe Mine), with a smelter located in Kitwe (Nkana Smelter) and an SX-EW plant in Chingola (Nchanga Tailings Leach Plant).

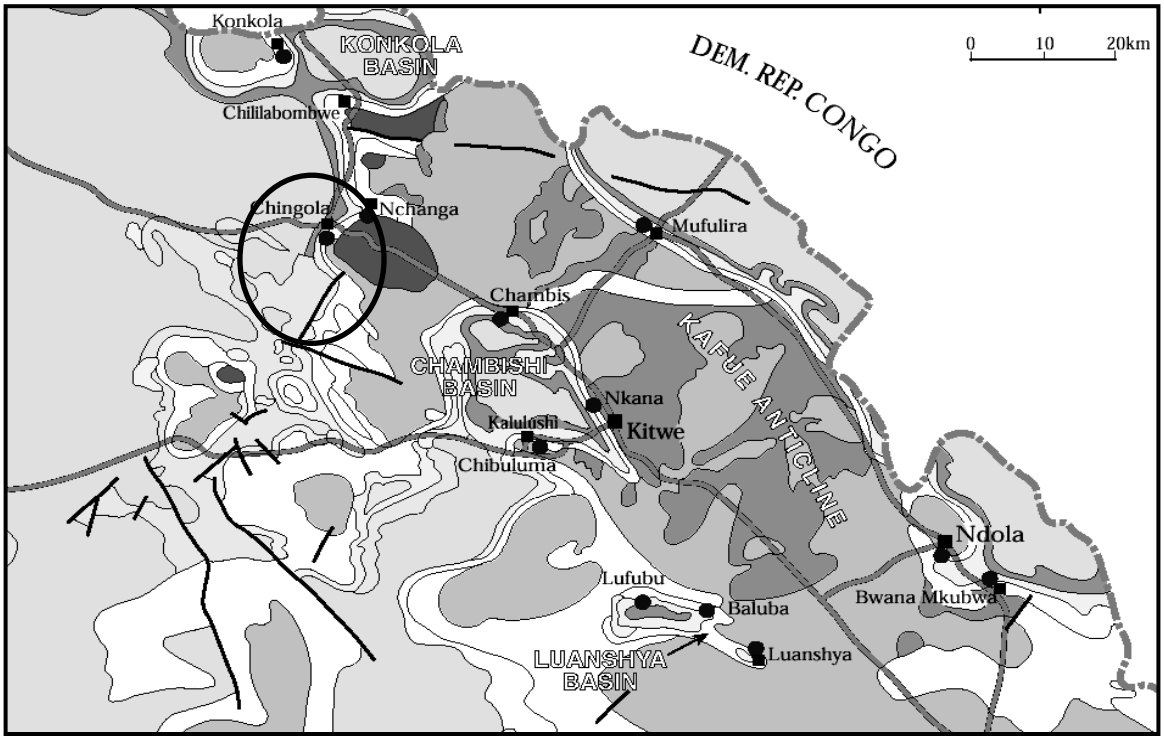


Figure 1. Geological map of the Zambian Copperbelt, showing the area of the study.

The golden period of exploration activity beyond the operating mines on the Nchanga Mining License occurred in the period between 1958 and 1974. In the period 1975 to 1999, exploration was largely limited to step out drilling on known resources.

In the two years that KCM was managed by Anglo American post privatization in 2000, all attention was focused on the Konkola Deeps Mining Project, which had a planned Life of Mine in excess of 30 years. As a result, scant attention was paid to the long-term need to undertake brownfields exploration for new resources at Nchanga where Open Pit operations will cease in 2009 and Underground operations by 2013.

In mid 2003, KCM management recognized the need to add to the Nchanga mineral resources inventory through brownfields exploration in order to sustain production into the 21st century. It was further recognized that if this exploration activity were to be successful, new exploration methodologies and techniques not previously carried out on the Nchanga Mining License would need to be applied. Budget provisions were made during 2003 to fund the exploration activities during 2004.

PRELIMINARY PROGRAMMES

Two preliminary investigations were initiated during 2003 as a precursor to the 2004 programme in order to optimize data collection and target selection, prior to commencement of more expensive drilling activities.

Data Retrieval and Computerization

The first investigation was the completion of a thorough review of all surface exploration work carried out on the property since mining commenced in the 1930's. This was carried out prior to ground investigations to ensure optimal utilization of exploration funds. A period of 5 months was spent collecting, collating and reviewing reports and maps at the Chamber of Mines (CoM) archives in Kalulushi as well as long forgotten CSD (NCCM Central Services Division) reports held in the Nchanga Mineral Resources Department.

Table 1 provides a breakdown of the data collected including soil, pit and auger geochemistry, as well as diamond drilling geological and assay data.

TABLE 1.	**Copper**		**Cobalt**		
	Sample locations	Assays	Sample locations	Assays	Comments
Soil sampling points	20,686	20,686	14,417	14,417	2 campaigns:1958 and 1963
Pits	4,759	24,852	2,130	10,607	1963-1971
Auger Holes	324	2,288	0	0	1964-1966
Short DD holes	138	2,197	136	2,112	1969-1971
	25,907	**50,023**	**16,683**	**27,136**	

From November 2003 to date, the Nchanga soil and litho geochemical database has been expanded by a total of 42,590 new sampling locations. In the process, a total of 77,159 Cu and Co assays were recovered. All pit, auger, short diamond drill hole and soil data locations were geo-referenced and imported into the *ArcView 3.2 Geographical Information System* for manipulation and coding of data. Drillhole and pit data were imported into the *Earthworks Downhole Explorer* geological software for viewing and interpretation of drillhole sections. At the same time, extensive digitizing of old geological plans was carried out in *Microstation* and data made available as DXF's for import into *ArcView* and *Geosoft Oasis*.

Soil geochemical data was hand contoured in the 1960's on individual 1:5000 map sheets using a variety of contour intervals and colour schemes, with a 50 ppm copper range being the most common. It is highly likely that this non-statistical treatment of the data led to misidentification of anomalies and wasted resources in follow-up efforts on the Nchanga License area in the past, as well as the possibility of having missed subtler, yet significant mineralisation possibly indicating blind orebodies.

Statistical analysis of this data during 2004 has allowed topological coding of the data in *ArcView* to better represent background vs anomaly levels. The different data sets were split by campaign and analyzed separately with class ranges being determined on the basis of population mean and standard deviation. In addition, dambo and non-dambo soil geochemistry data points were separated into different populations and analyzed in order to reduce the possibility of false anomalies due to hydromorphic effects, where mobile cations adsorb to clay species in marshy areas. The high background value for dambo areas is clearly evident when comparing dambo vs non-dambo statistics in Tables 2, 3 and 4.

Table 2. Statistical analysis of 1958 ***copper-in-soil*** *geochemistry*

TABLE 2.		**MIMBULA-CHABWANYAMA AREA**		**MUSENGA AREA**	
CLASS		NON-DAMBO	DAMBO	NON-DAMBO	DAMBO
0-m	B-ground	0-35	0-137	0-58	0-559
m+σ	B-ground	36-59	138-236	59-104	560-1065
m+2σ	2σanomaly	60-83	237-334	105-149	1066-1571
m+3σ	3σanomaly	84-108	335-433	150-195	1572-2077
m+5σ	anomaly	109-156	434-630	196-285	2078-3089
m+7σ	anomaly	157-205	631-827	286-376	3090-4101
m+9σ	anomaly	206-254	828-1025	377-476	
>m+9σ	anomaly	>254		>476	

Table 3. Statistical analysis of 1963 ***copper-in-soil*** *geochemistry*

TABLE 3.		**MIMBULA-CHABWANYAMA AREA**		**CHINGOLA AREA**	
CLASS		NON-DAMBO	DAMBO	NON-DAMBO	DAMBO
0-m	B-ground	0-56	0-262	0-96	0-262
m+σ	B-ground	57-117	263-702	97-198	263-702
m+2σ	2σanomaly	118-178	703-1141	199-300	703-1141
m+3σ	3σanomaly	179-239	1142-1580	301-403	1142-1580
m+5σ	anomaly	240-360	1581-2459	404-607	1581-2459
m+7σ	anomaly	361-482	2460-3338	608-811	2460-3338
m+9σ	anomaly	483-604	3339-4216	812-1015	3339-4216
>m+9σ	anomaly	>604	>4216	>1015	>4216

Table 4. Statistical analysis of 1963 ***cobalt-in-soil*** *geochemistry*

TABLE 4		**MIMBULA-CHABWANYAMA AREA**		**CHINGOLA AREA**	
CLASS		NON-DAMBO	DAMBO	NON-DAMBO	DAMBO
0-m	B-ground	0-0.6	0-19	0-15	0-23
m+σ	B-ground	0.7-6.5	20-53	16-30	24-50
m+2σ	2σanomaly	7-12.5	54-87	31-45	51-77
m+3σ	3σanomaly	13-18.5	88-121	46-60	78-104
m+5σ	anomaly	19-30.5	122-188	61-90	105-159
m+7σ	anomaly	31-42.5	189-265	91-120	160-213
m+9σ	anomaly	43-54.5	266-324	121-150	214-267
>m+9σ	anomaly	>54	>324	>150	>267

Further statistical work was carried out on the pits, auger and short diamond drillholes (SDDH) and the approximately 42,000 samples associated with these data sources. An arbitrary selection of the maximum copper and cobalt analytical value was made from each pit, auger or SDDH irrespective of depth or host substrate. While it would have been advisable to make this selection based on soil / weathering profile (A, B or C horizon), this classification did not exist in some pits. This data was used to define anomalous copper and cobalt litho-geochemistry in the 1-20m depth rock record, and further narrow the search area for mineralisation.

The analysis of the Nchanga Copper- and Cobalt-in-soil geochemistry, together with the litho-geochemical data indicated ***seven*** Copper and ***one*** Cobalt anomalies. While many of the copper anomalies are known areas of mineralisation, the cobalt anomaly has not been described in any known documents. These anomalies have been ranked according to intensity of soil and litho geochemistry and are as follows:

Priority 1 areas

- ***Fitula – Mimbula anomaly*** – very strong, continuous and wide Cu anomaly in soil and pits extending to the NW of Fitula orebody.
- ***Chabwanyama Dambo Cu anomaly*** – strong Cu anomaly in soil to the south of the dambo, clearly continuing through the dambo in a NNW direction. Pitting and short diamond drillholes confirmed anomalous Cu values at depth.
- ***Chabwanyama-Mimbula East limb anomaly*** – a linear Cu anomaly (in pits only) extending 3.5km along the east side of the Mimbula-Chabwanyama Syncline. Cu/Co mineralisation at depth found in drillholes in north part of this anomaly.
- ***Mimbula Pits*** –very strong soil and pit Cu anomaly to the south and north of Mimbula 2 Open Pit. Coincides in the south with a copper clearing. Drilling confirms good Cu mineralisation at depth.
- ***Fitula E Basement anomaly*** – strong Cu anomaly in soil and pits, extending to the east of Fitula Pit, into Basement Complex. Possibly generated by mineralized schists or situated along a fault line.

Priority 2

- ***Chabanyama Co anomaly*** – very high cobalt anomaly associated with the Chabwanyama Anticline (?). Copper values in this area remain at background levels, which is highly unusual. Source and character of this mineralisation remains enigmatic.
- ***Chiwempala Cu anomaly*** – strong soil anomaly discovered in 1958. This campaign concentrated on the west part of the area under discussion where the Cu soil values are lower hence a much lower background compared to other areas (see Table2). Follow-up drilling in 1959 indicated low-grade mineralisation.

Priority 3

- ***South of COP-D*** – pitting data shows that the Cu anomaly present in COP D extends a further 500m south of the orebody. Area inadequately drilled to prove or disprove the continuation of the orebody.

Priority 4

- Fipuya and Mimbula W area
- Far West area

  Very scant geochemical information suggests possibility of low order cobalt anomalies in these areas.

In summary, the desktop geochemical data study has been a technical success. Putting a time and cost value to the recovered data is difficult, but it has been estimated that an exploration programme to re-acquire the soil geochemical, pitting and drilling data by physically re-sampling in the field using modern techniques would take approximately 2-3 years at a cost of upwards of $2,000,000.

Figure 2. Combined Copper-in-soil geochemistry indicating anomalies.

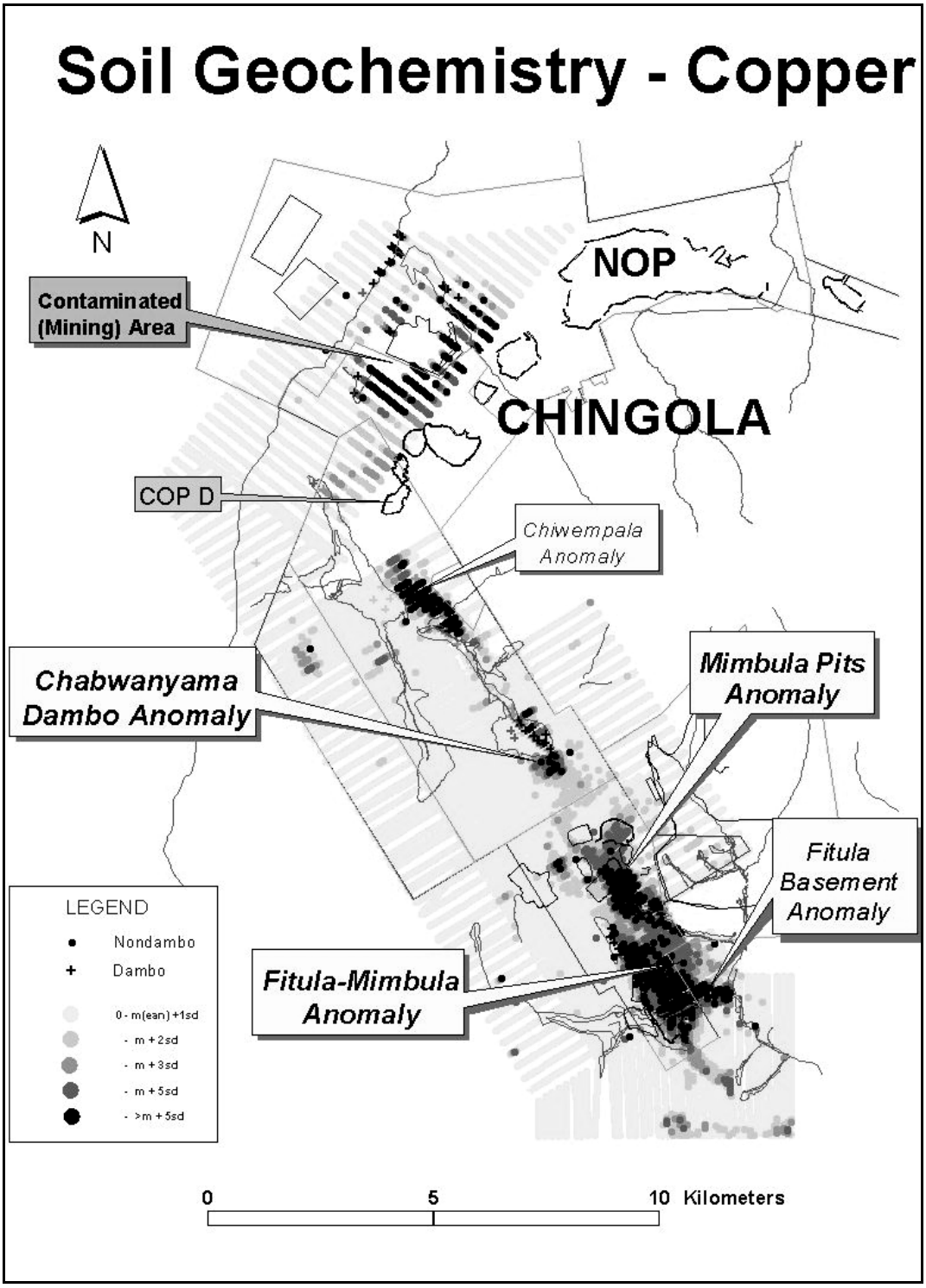
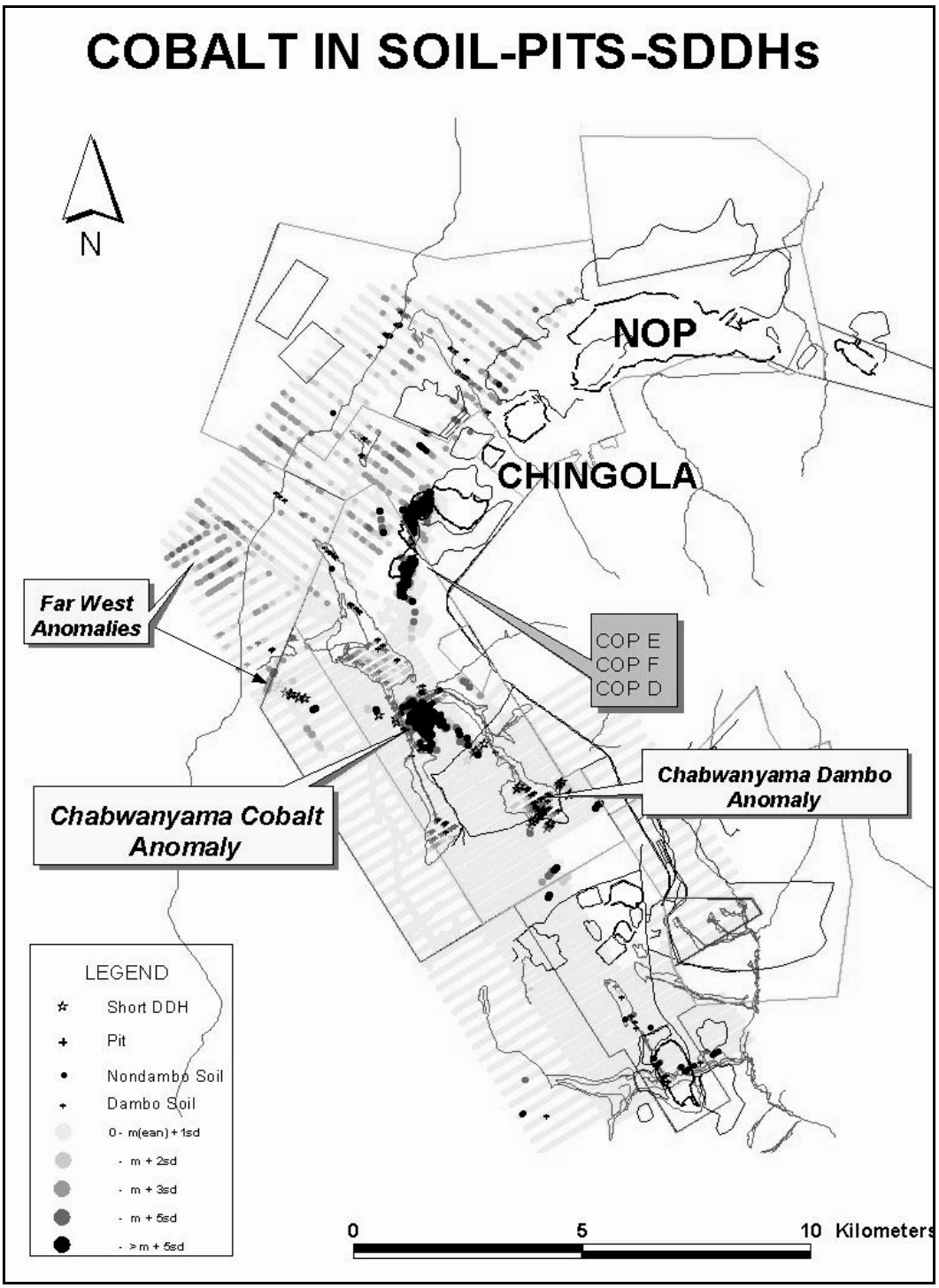


Figure 3. Maximum Cobalt-in-Pits irrespective of depth or substrate.



Orientation Geophysics

Before commencing investigation of individual targets through drilling, it was decided that the best strategy would be to undertake a range of geophysical surveys over the Chabwanyama, Mimbula and Fitula synclines.

Limited success in the application of geophysical techniques in the discovery of orebodies on the Copperbelt during the 1960's when much of the original work was completed had resulted in a generally held, negative attitude towards the use of geophysics as a primary exploration tool. As a result, extremely limited geophysical work was ever carried out over the Nchanga License area. This was recognized in 2003 as a positive factor for discovery of new orebodies at Nchanga due to the significant improvements in the technology over the last 40 years.

As a precursor to a much larger programme, a 48 line.kms orientation geophysical study was undertaken over the Chingola Open Pit D and F deposits (COP D&F) towards the end of 2003. GeoQuest, a Lusaka based geological consultancy, together with geophysical subcontractors completed this work over a period of 6 weeks. The prime objective of this survey was to test the ability of a suite of methods to detect sulphide mineralisation, to map the Roan Formation stratigraphy, and to elucidate the morphology of the basement paleo-topographic surface, which is considered to be a significant control on the location of stratabound Cu-Co mineralisation.

Four initial geophysical techniques were selected:

- Ground magnetics
- Gravity
- CSAMT (Controlled Source Audio-Magnetotellurics)
- Induced Polarisation – Resistivity and Chargeability

A 9 x 6.5 km area was covered with gravity and magnetometry and 9 line.km's of Induced Polarization (IP) surveys were completed over the low to moderate grade COP DF deposit (insitu resource of 43 Mt @ 1.6% TCu) considered to be typical of the potential targets in the remainder of the license area.

This work indicated that the combination of Gradient Array IP (resistivity and chargeability) and gravity had the greatest potential to reveal new shallow depth targets and geological information respectively. Ground magnetics could, however, be used as a follow-up technique to assist in the interpretation of selected anomalies, especially as magnetite in Basement Lufubu formations appeared to result in chargeability anomalies. Trial IP lines were also surveyed using pole-dipole arrays to assess whether deeper sulphide mineralisation could be detected.

CSAMT produced spurious results along the 2 lines in the test survey due to apparent noise in the phase data, and did not allow for successful smooth model inversion. NSAMT (Natural Source AMT) data however showed better depth of penetration and resolution at depth than the pole-dipole resistivity or CSAMT, and was recommended for further testing in the follow-up survey.

Benefits of the Preliminary Programmes

The benefits of the geochemical data review and the orientation geophysical survey have been the cost effective identification of exploration targets from work carried out in the 1960's and 70's, and the development of an exploration methodology based on an Nchanga-specific, empirically tested geophysical response of near surface sulphide mineralisation.

2004 GEOPHYSICAL PROGRAMME

On the back of the success of the 2003 programmes, a decision was taken to extend geophysical coverage over all the prospective Roan Formation rocks to the south of the COP-DF orebody on the remainder of the Nchanga License area. A budget of approximately US$500,000 was approved for the 2004 programme.

Table 5 indicates the geophysical production survey parameters used for the 2004 Programme

Technique	Line Spacing	Station Spacing	Equipment
Gravity	100m	20m	Scintrex CG3 Autograv Gravimeter
Gradient Array IP and Resistivity	100m	40m receiver dipoles, 6 - 8 receivers	Zonge GDP16
Pole-dipole IP and Resistivity	200m	40m	Zonge GDP16
NSAMT	Selected Lines	4x50m Ex electric dipoles and single centrally situated Hy magnetic measurement coil	Zonge GDP16

A geophysical survey grid was thus laid out, covering the areas shown in Figure 4. While the orientation survey results had indicated an optimal line spacing of 50m, 100 m line spacing was eventually decided on as a compromise, due to cost and time constraints, in order to cover all the known geochemical anomalies and areas of previously identified mineralisation.

In total, 266 line.km's were completed during 2004 over an area of 2,693 hectare on the Nchanga License area using **ground gravity** and **gradient array IP**. Six smaller blocks were later identified for detailed **pole-dipole (PD) IP** coverage based on a preliminary assessment of coincident geochemical and gradient array IP anomalies. As the Gradient Array IP is a shallow mapping technique in the order of 50m, the PD

arrays were selected as a follow-up to provide depth continuity information on anomalous resistivity and chargeability zones to depths in excess of 100 m. The PD data was also useful for determining the dip of mineralized zones for drillhole planning.

Ground geophysics crews investigated priorities 1, 2 and 3 during the course of 2004, and were again coordinated by GeoQuest. Survey work commenced in August and was completed in December 2004. The survey grid was established using a Chingola based contract surveyor. Problems with manual leveling and delays later in the survey however led to the decision to bring in a second contractor and to complete the survey using a Digital GPS crew.

Figure 4 shows the extent of the 100m line Gradient Array IP and gravity grid in grey, with the wider spaced pole-dipole follow-up grids in black. The survey grid length is 14.5 km extending from the COP-DF open pit in the northwest to the Fitula pit in the southeast, with a maximum width of 3.5 km in the Mimbula pit area.

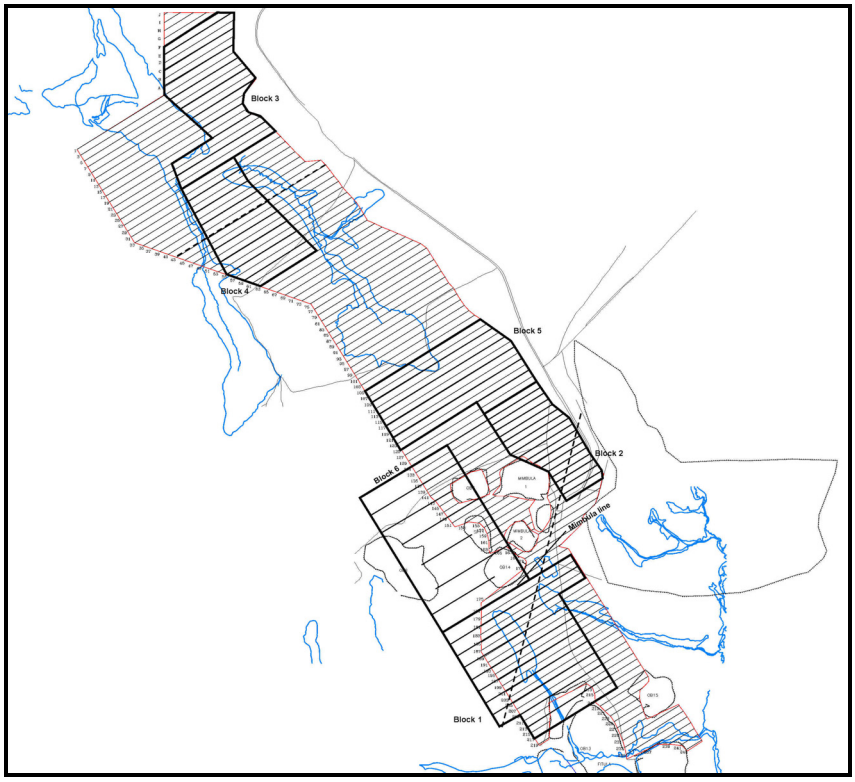


Figure 4. 2004 Nchanga Mining License geophysical survey grid.

Geophysical Survey Interpretation

Corner Geophysics Namibia (CGN) carried out a detailed interpretation of the Nchanga License Area gravity and IP surveys with a final report available in April 2005. In addition, a 20km x 45km strip of airborne magnetic and radiometric data covering the Nchanga and Konkola License areas from the 1997 Zamanglo Kitwe airborne survey as

well as data from the 1972 RCM (Roan Copper Mines) Chipopo Bouguer gravity data set to the west of Chingola, was interpreted with a view to upgrading the existing regional geological mapping.

Detailed and regional interpretation maps were provided by CGN at scales of 1:10,000 and 1:50,000.

Gravity and Resistivity Anomaly Mapping

As a first pass, all geophysical anomalies were mapped and overlain onto the existing geological map of the area. This allowed geophysical property characteristics to be attributed to various stratigraphic layers. The above exercise complemented and upgraded the physical property characteristics derived in the COP-DF pilot study (Corner 2004).

With regards to the gravity data, a conclusion reached on studying the bulk density analyses in the COP-DF open pit area showed that the presence of ore did not affect the bulk rock densities as much (if at all) as variations in weathering and/or degree of cementation. It was noted that the greater the degree of cementation, and consequent higher resistance to weathering, the higher were the apparent resistivities and relative density contrasts. Gravity is thus considered, first and foremost, as a lithological mapping tool.

The following anomaly types were mapped in individual layers using the *Geosoft Oasis* software:

- Gravity highs,
- Resistivity highs with corresponding gravity lows, or neutral gravity,
- Resistivity highs with corresponding gravity highs,
- Conductivity highs with corresponding gravity highs, or neutral gravity.

Where one or more of the above anomaly types was fragmented along strike of a particular stratigraphic unit, a combination of all of the above improved or revealed strike continuity. This facilitated stratigraphic mapping and allowed a more cohesive geological map to be prepared. The disposition of all mapped anomalies in the above four categories was then combined in a Geophysical Elements map, which was a precursor to the final interpretation map.

Chargeability and Resistivity Anomaly Mapping

Two resistivity and chargeability data sets were acquired and mapping products produced:

- Gradient array data was combined into gridded chargeability and resistivity products. These are presented in Figures 5 a and b.
- Pole-dipole (PD) data was inverted as pseudo sections and apparent depth slices. All sections were combined into separate resistivity and chargeability stacked section maps (Figure 6). These maps greatly facilitated line-to-line correlation of features.

The gradient array data, when compared to the PD data, appeared to be responding to maximum depths in the range 50-80 m. The 120m PD depth slice was found to be the most diagnostic when considering anomalies potentially related to mineralisation. These PD depth slices were compared to the gradient chargeability data to determine both depth migration, i.e. dip, and amplitude continuity with depth.

The well resolved gradient array chargeability data proved to be extremely useful, not only for direct target identification, but for structural and lithological fabric mapping. The PD stacked chargeability sections, although of much coarser resolution, proved to be invaluable in structural mapping, particularly when overlain on the Geophysical Elements Map.

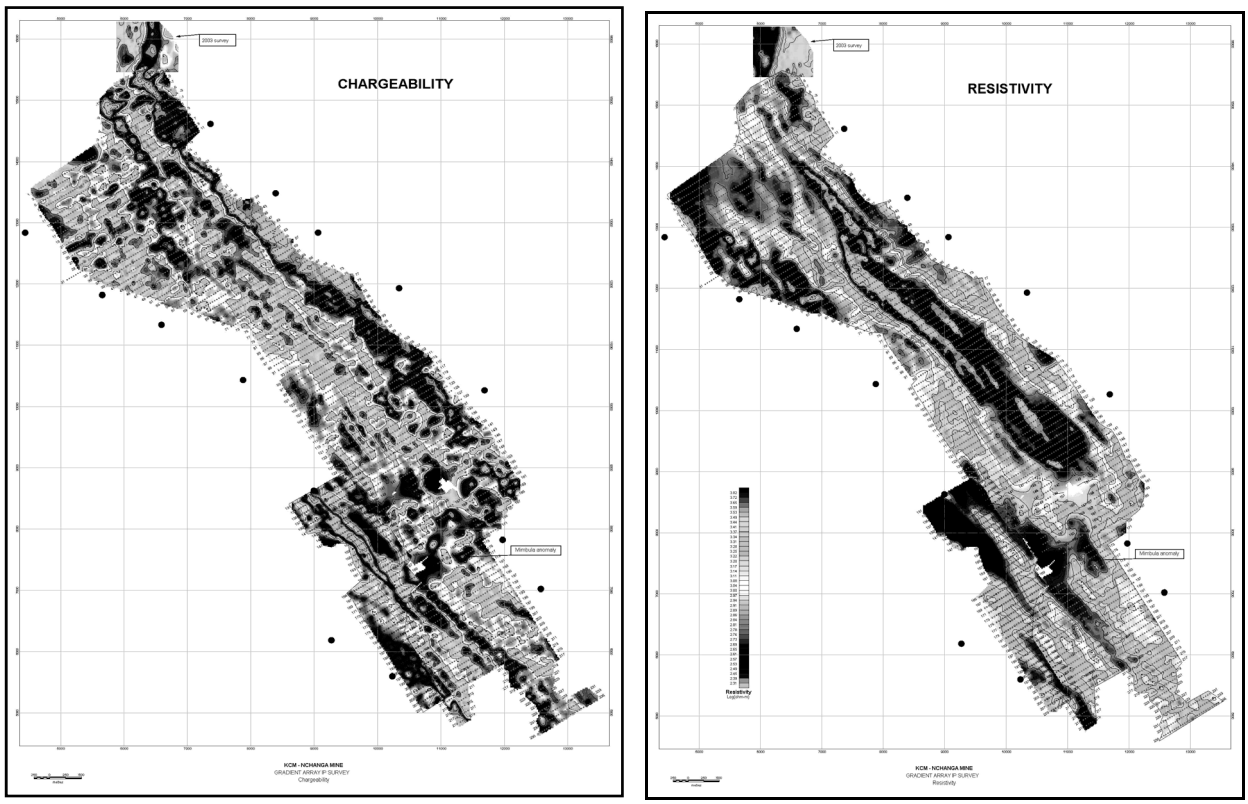


Figure 5a and b. Gridded Gradient Array IP – Chargeability (left) and Resistivity (right) plot of the Nchanga Survey Area.

Figure 6. Stacked Pole-Dipole sections for Block 1 in the Mimbula Fitula area

This process was however not without its problems and a number of potential pitfalls were identified during this exercise. These were briefly as follows:

- The inversion process did not always link anomalies correctly as a function of depth, e.g. in some cases two units, one higher than the other stratigraphically, dipping into the basin would be linked, erroneously suggesting a syncline.
- Ambiguity of structural style was evident for less well-defined PD features, even if of a high amplitude, when comparing with other data sets.
- The resolution of the PD sections was significantly reduced when compared to the gravity and gradient array data, so the identification and effects of faults mapped from the latter could not always be discerned.
- Ambiguity was evident between the PD chargeability inversion sections and the depth slices derived from these sections, in that an apparent offset of the same anomaly was noted on occasion. The lateral continuity of the PD anomalies as gridded in the PD depth slices was often questionable given the distance between lines (200m).
- The PD data was generally insufficiently resolved to ascertain a clear fault dip, or even any significant displacement or sense thereof.
- Gradient array anomaly amplitudes may change significantly for equivalent mineralisation, when crossing from one gradient array setup to another.

- The data for both gradient array and PD data sets became noisier and anomalies more fragmented in the vicinity of the Fitula and Mimbula dumps and pits, due to cultural noise and electrode problems, in the first instance.

Nevertheless, the important objective of identifying continuity of chargeability with depth, as well as of mapping smaller scale synclines structure was possible using a combination of the data sets.

NSAMT Profiles (Natural source audio magneto-tellurics)

Two NSAMT profiles were laid out over large structures identified from the gradient array IP/resitivity and gravity surveys. Even considering the relatively coarse resolution of this deeply penetrating technique, interpreted thrust faults were fully supported on the one profile. On the other profile, a deep basement fault was confirmed by a large sharp resistivity contrast at depth. The technique is thus considered to be of value in identifying and mapping the nature of deep basement faults.

Derived Interpretation Map

An all-important task in interpretation is the accurate mapping of lithologies and structure, such that the final product satisfies all data sets, both geological and geophysical. This not only enhances geological understanding of the area but allows for a better assessment of chargeability anomalies, and their ranking as targets.

The following procedure was adopted in linking a geophysical signature with a particular lithology:

- Previously drilled boreholes were used as “absolute” ground truth.
- Areas of improved accuracy of geological mapping, or where consistent correlations were seen with expected geophysical responses, were used to type geophysical signatures.

The above analysis revealed many areas of disagreement between the previous mapping, and the present geophysical data (Figure 7a and b). The previous mapping was based on pitting, photo geological interpretation and limited outcrop mapping carried out since the early 1930’s. Compilation of the upgraded geological map thus involved the redrafting of all stratigraphic units through iterative comparisons of the geophysical anomaly elements with existing geological mapping, borehole and pit information.

Deriving an upgraded geological map, which was the best fit to all of these data sets, as well as to the mapped faults, proved to be an extremely complex exercise, particularly since there are many areas on the Nchanga Mining Licence where there is both poor geological control and changes in stratigraphic nomenclature.

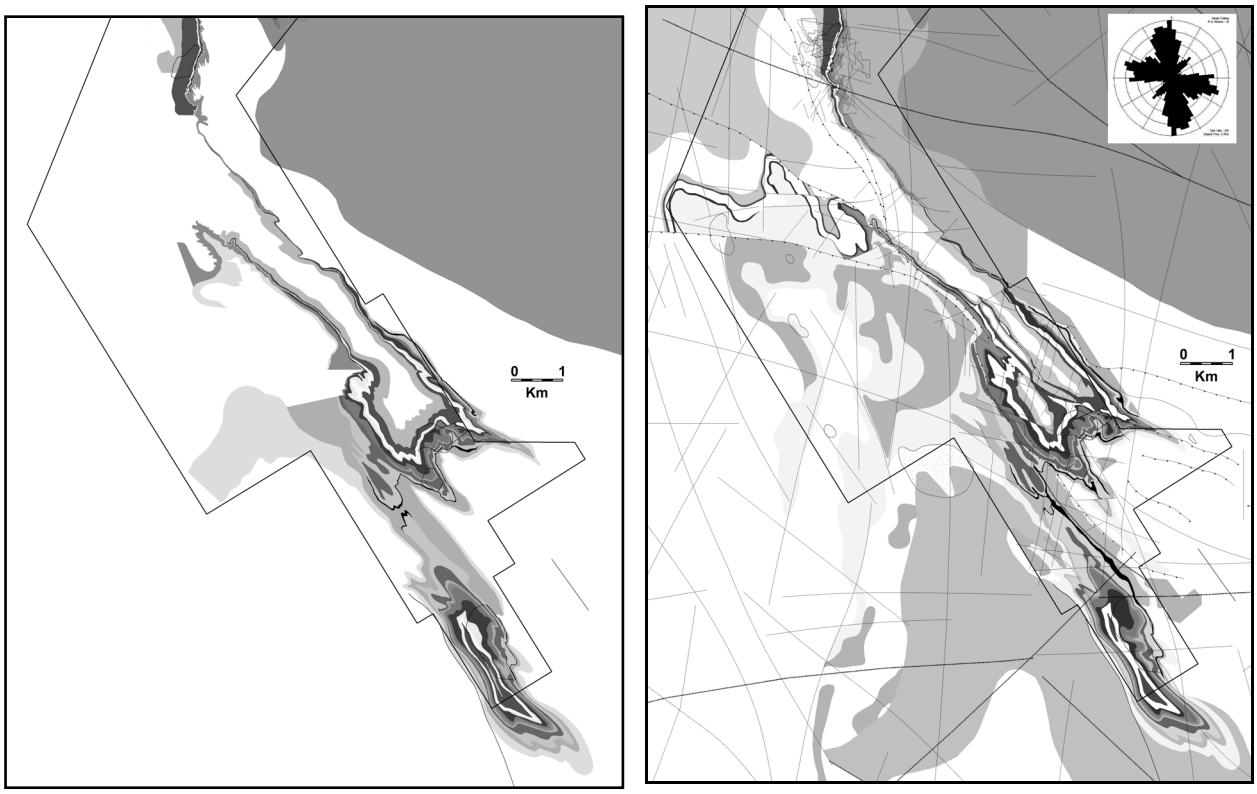


Figure 7 a and b. 1975 Nchanga Licence geological map (left) based on pitting, mapping and photo-geological interpretation compared with 2005 geological interpretation (right) based on geophysical element mapping and previous interpretations.

A number of units proved to be extremely useful geophysical markers, facilitating the mapping process.

- The F2(4)0 arkose unit in the Mimbula-Fitula area, occurs below the Copperbelt Orebody Member in the Nchanga Footwall Succession (Mindola Clastics Formation) and is also the ore horizon for the exhausted Fitula Open Pit. This unit yields a prominent resistivity high in both gradient and PD array data. In hand specimen this feldspathic arkose is hard and well cemented, and thus expected to be resistive and relatively dense (apart from the contributing factor of possible sulphide mineralisation adding to the density).

- The BSS-TFQ (Banded Sandstone – Feldspathic Quartzite) package occurs stratigraphically directly above the Copperbelt Orebody Member, represented by the LBS (Lower Banded Shale) unit in the Nchanga area. This package shows a compelling correlation in the Chabwanyama Syncline with a prominent, continuous resistivity high. The LBS in these areas also correlates closely with the "base" of this anomaly. This resistivity high is also present in the PD inversion sections and

correlates with a low to neutral gravity response flanking the major basement high in the east.

Mineralisation Mapping

In general, no compelling correlation was observed between conductivity and gravity highs as a potential indicator of massive sulphides.

What was of significant interest though was that, particularly in the southern area between the Mimbula and Fitula open pits, chargeability highs tended to correlate with higher resistivity units. It is strongly suspected that this is indicative of the rich but disseminated Fitula ore, which in hand specimen, is highly cemented and expected to be resistive. This area is also characterised by anomalous soil and pit geochemistry.

In the study area, identification and mapping of potentially mineralized zones was based on an understanding of the geophysical responses of the host rocks, and the nature of the sulphides in this host.

Target Identification

The results of the survey are very encouraging although are yet to be drill tested. In total 13 potentially mineralised targets were identified in the geophysical study, and are in essence a combination of geochemical, gravity, gradient array and pole-dipole IP anomalies.

The most significant of these targets, and associated structures, are:

Fitula North

- Linear coincident high chargeability-resistivity IP anomalies extend NW from Fitula and are associated with surface geochemical anomalies in the F2(4)0 arkose despite the one good intersection (surrounded by low grade ones) being in the F1 horizon.
- This target horizon is considered to hold high potential for Fitula type ore. The entire strike extent of approximately 3km is considered to be prospective
- Similar IP anomalies, but associated with weak geochemical anomalies, occur on the opposite (SW) limb of the syncline over the F2 arkose.
- Numerous thrust related structures are evident from the gravity data, indicating significant changes in the old interpretation of the area.

Mimbula

- A chargeability high corresponds to the Mimbula south orebody, and was confirmed by drilling following a single IP line conducted at the time of the Phase I 2003 survey.

- Extending south southeastward from, and in faulted contact with, the Mimbula south syncline are a series of linear resistivity-gravity anomalies. They have the geophysical appearance of arkose units but occur in what is mapped as basement.
- These are interpreted to be the continuation southward of the Mimbula syncline. This syncline correlates with a geochemical anomaly, but only of low order.

Mimbula Far East Syncline

- Gravity results are extremely interesting and suggest that a major fault exists on the southern edge of this structure with a deep clastic wedge on the north side. This is an extremely interesting exploration target allowing entrapment of mineralization and resembles a similar structure detected by gravity surveys in the trial area close to COP D.
- No chargeability anomalies exist and only weak geochemical anomalies are present around the supposed nose of the syncline. However, blind mineralization could be present at depth.
- En-echelon, slightly transgressive and discontinuous chargeability anomalies occur in a long linear belt on the north-eastern limb and may be the product of cross-fault displacement of mineralization. These faults would then be roughly parallel to the main southern limb fault.
- Previous drilling in this area is inadequate to assist in the interpretation of the geophysics as these holes were targeted at the Lower Banded Shale (LBS) and not the underlying arkoses.

Chabwanyama East Copper Anomaly

- Geochemical anomalies coincide with chargeability anomalies.

Chabwanyama East Cobalt Anomaly

- Chargeability anomalies here are possibility related to the reappearance of carbonaceous LBS but are also found along the Basement Complex (BC) / Lower Roan (LR) contact where previous drilling has indicated copper and cobalt mineralization.

Chabwanyama Copper Anomaly

- Very weak chargeability anomalies exist here associated with the dambo related copper anomaly and thus deeper penetrating pole-pole IP is needed to check the potential of this area.
- There are again possible problems with the local geological interpretation.

Chiwempala Copper Anomaly

- A series of high chargeability anomalies exist along the BC / LR contact coincident with surface geochemical anomalies.

- To the SW, in Upper Roan dolomite, another chargeability anomaly exists whose source is uncertain.

Chiwempala– Anticline Cobalt Anomaly

- No significant anomalies exist in the area and the mode of occurrence of the high cobalt values remains an enigma.
- The geophysical data nevertheless facilitated mapping of both structure and lithological continuity in this area.

Drilling Results

A limited drilling programme was undertaken in 2004 in the Mimbula area to gain more reliable geological and assay information by twinning old holes drilled in the 1960's and 1970's.

An old hole (M226, EOH depth 79m) to the south of Mimbula II was twinned to investigate the source of a chargeability anomaly identified by the single line of pole-dipole IP carried out over this area in the 2003 orientation survey. This hole had clearly not penetrated deep enough, and re-drilling of M348 intersected a significant malachite and chalcocite mineralisation intersection of 2.03% TCu over 35m from 83 to 118m, with a high grade core zone of 3.28% TCu over 11m from 91meters depth.

A detailed follow-up drilling programme will commence in earnest during June 2005 to test prioritised exploration targets.

CONCLUSIONS

Many new conclusions and insights were derived during this study, of which the most important are enumerated below as an overview.

i) Digitising of previously 'missing' or 'unknown' geochemistry data, from both the CoM's Kalulushi archive and within the Nchanga Mineral Resources Department has been a major source of data in this exercise. The CoM's archive is a significant source of Zambian exploration data and significant efforts need to be made to catalogue and reference this remarkable, but disorganised source of data.

ii) The separation of the geochemical data into discrete populations based on spatial-temporal filters has refined and improved the statistical identification of geochemical threshold and anomaly levels.

iii) A significant cobalt-in-soil anomaly, and numerous copper-in-soil anomalies have been identified and delineated at little cost to KCM. The use of GIS software has been an extremely useful tool for interpretation and presentation of this data.

iv) The guidelines for the most appropriate geophysical survey methodologies, as recommended by the 2003 COP-DF orientation study, were fully confirmed in the 2004 study.

v) The combination of gravity, gradient array IP, pole-dipole IP and NSAMT proved to be an excellent combination of tools for mapping, target identification, and borehole siting.

vi) Extremely few geologically mapped faults were indicated on the old geological maps compared to the geophysically derived set. Of note structurally, a number of thrust faults have been interpreted, subdividing the area into a number of structural domains.

vii) The integrated remapping, of the project area, has led to some major map modifications. In particular;

- Parts of the eastern margin of the main syncline south of COP-DF have been mapped farther eastward.
- An anticline and sub-syncline, in the western portion of the previously mapped main Upper Roan syncline and coincident with the Chabwanyama Co anomaly is suggested by the data.
- The structural domain northwest of Mimbula is also significantly modified with the identification of a sub-syncline and anticline.
- The area north of Fitula, and the Chabanyama-north cobalt anomaly area, both important target areas for mineralisation, are more definitively mapped.

viii) A total of 13 potentially mineralised target zones have been identified, of which a number are considered to hold high potential for copper or cobalt ore. Depth profiling using IP resistivity and chargeability data has provided extremely useful data for siting of drillholes in a first phase follow-up drilling programme to be completed in 2005.

The long period over which the Nchanga License area has been mapped and interpreted means that multiple schools of thought have influenced the interpretation itself. The map in use prior to the geophysical interpretation was produced during the 1960's and 1970's in a period when much of the Zambian Copperbelt was seen as autochthonous, with only nominal faulting and displacement of the Lower Roan stratigraphy.

This new interpretation represents a revised geological paradigm, with considerably more compressive tectonics structural features being recognized and mapped for the first time on the Nchanga License area.

The southern portion of the Nchanga License area now appears to represent the juxtaposition of a complex array of fault-bounded blocks, and provides the framework to interpret the geochemical and geophysical anomalies recently identified. The nature of, and controls on mineralisation within these blocks is still poorly understood, and now requires considerable ground truthing through drilling and iterative re-interpretation.

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