A PRELIMINARY APPRAISAL OF THE MINERAL POTENTIAL OF VENDA BASED ON A RECONNAISSANCE GEOCHEMICAL SOIL SAMPLING SURVEY AND LITERATURE REVIEW

BY

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ABSTRACT

A reconnaissance soil sampling survey was carried out over Venda by Cycad (Pty) Ltd and the samples were analysed for 36 elements using XRF techniques, by Anglo American Research Laboratories in Johannesburg. The data resulting from this survey forms the basis for the present interpretive study. Initially the sample positions were co-ordinated, then the geological, soil and sample types were allocated to each point. Twelve lithological groupings were chosen which incorporated most of the available data, retained significant geological characteristics and consisted of statistically significant sample populations. Statistical manipulation was undertaken for each of the lithological groups. Using a final population of 5768 samples, means were determined and anomalous values were identified using a threshold of mean plus two standard deviations. Due to time and budgetary constraints, 24 of the 36 elements were chosen for statisical manipulation and fourteen of these, with particular economic significance, were chosen for plotting, wherever significant numbers of anomalies were present. The element overlays were plotted so as to co-incide with 18 of the 25, 1:50 000 topographic sheets covering Venda, the remaining 7 having inadequate sample coverage to yield meaningful contours. In this way a total of 175 element overlay sheets were plotted, each showing contoured element levels, with selected anomalous values.

The treatment of the vast body of information made available by the Cycad sampling programme has thus been selective and has continually been aimed at highlighting and concentrating attention on the areas of greatest indicated mineralization potential, rather than on specific anomalies. In this regard it is felt that the present study has been successful, in spite of limited sample coverage in some areas. Combining the results of this study with a modern tectonically-based appraisal of mineralization potential and a knowledge of the local geology and previously known mineralization gleaned from an extensive literature review, the following types of mineralization are considered to have the highest potential in Venda:

i) Nickel-copper-platinum mineralization as well as magnesite, in the olivine dolerite sills which intrude the base of the Karoo Sequence in Northern Venda.

ii) Coal in the basal Karoo Sequence sediments in a broad zone from Jazz 715 MS in the west, and along the Klein Tshipise fault from Amonda 159 MT to the Mutale Copper Fields then east of these to the Kruger National Park. Where intrusives invade these lower Karoo sediments the potential exists for amorphous graphite.

iii) Hydrothermal copper and possibly gold and silver concentrations, in Nzhelele and Sibasa Formation rocks, particiularly those associated with faults known to have been active in post-Soutpansberg times.

iv) Sediment-hosted massive sulphide deposits (Cu-Pb-Zn) close to basin margin faults, near intersections with cross cutting faults that have resulted in localized basin formation. These are most likely in the Soutpansberg sediments.

v) Marble, flake-graphite and late stage skarn mineralization (including lead, zinc, gold and tungsten), in calcareous rocks of the Gumbu Formation.

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1. INTRODUCTION

1.1 Background to the Project

During the period October 1985 to November 1988, Cycad (Pty.) Ltd., the exploration arm of De Beers in the Republic of Venda, undertook extensive stream and loam sampling throughout all parts of Venda that were easily accessible. Their principal objective was to sample soils and stream sediments for heavy minerals and indicators of kimberlite development. For their purposes it was thus adequate to sample streams at the foot of the rugged Soutpansberg and no sampling was undertaken in mountainous terrain. As the result of an agreement between Cycad and the Minister of Economic Affairs in Venda, Cycad were requested to collect a suite of geochemical soil samples at sites close to their own sampling. In this way, in excess of seven thousand samples were collected and most were subjected to XRF analysis for a suite of 36 elements, shown as Table 6. Sampling was conducted throughout the year and all samples were taken at a depth of 10 cm below surface.

During late 1987 the South African Development Trust Corporation Ltd. (STK.), was requested to further process and interpret the data that had accumulated as a result of the Cycad sampling programme.

1.2 The Aim and Achievements of This Interpretation

The principal aim of this study is to stimulate further exploration for mineral deposits in the Republic of Venda, in the hope that economically viable ore bodies may be located and mines developed. In attempting to achieve this objective, the following has been accomplished:

i) Co-ordinates, lithological, soil and sample types have been attributed to a data set of over seven thousand samples.

ii) A statistical analysis of data for 5 768 loam samples, each of which has been processed for 24 elements in relation to twelve principal lithological groups (See Table 7). The results of this study can be compared with results from the literature, which are presented as Table 1 in Appendix 1.

iii) Contour plots have been prepared of 175 sheets at 1:50 000 scale, with single element levels contoured and anomalous values (determined as above a threshold of mean plus two standard deviations) plotted on each.

iv) Composite overlays have been produced showing all plotted anomalous data for each of the eighteen, 1:50 000 topographic sheets which had sufficient sample density to warrant plotting.

1.3 The Physiography of Venda

The Republic of Venda covers an area of approximately 7000 km^2 and consists of three portions, the two largest of which occur to the east of the N1 road to Zimbabwe, whilst the smaller third portion lies west of the N1 and southwest of Louis Trichardt. The country falls between latitudes 22°22' and 23°31', longitudes 29°34' and 31°05'. (Fig.1)

Venda is contained totally within the historical limits of the Transvaal Province of the Republic of South Africa though it now shares a north-eastern border with the Kruger National Park, and a south-eastern border with both GaZankulu and Lebowa.

Venda can be divided into four broad physiographic regions (Wellington 1975), which are shown on Fig. 2.

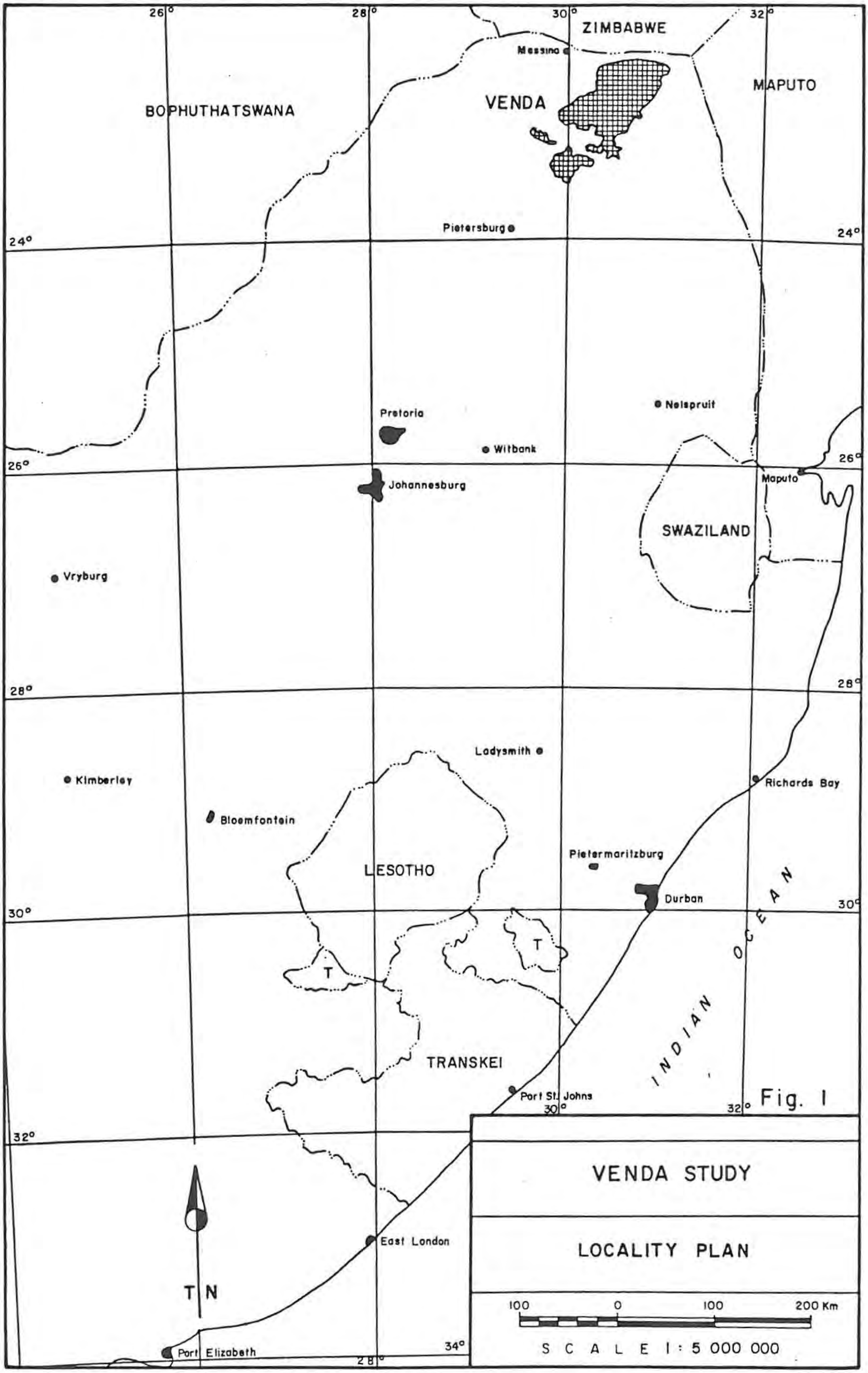

Fig. 1

VENDA STUDY

LOCALITY PLAN

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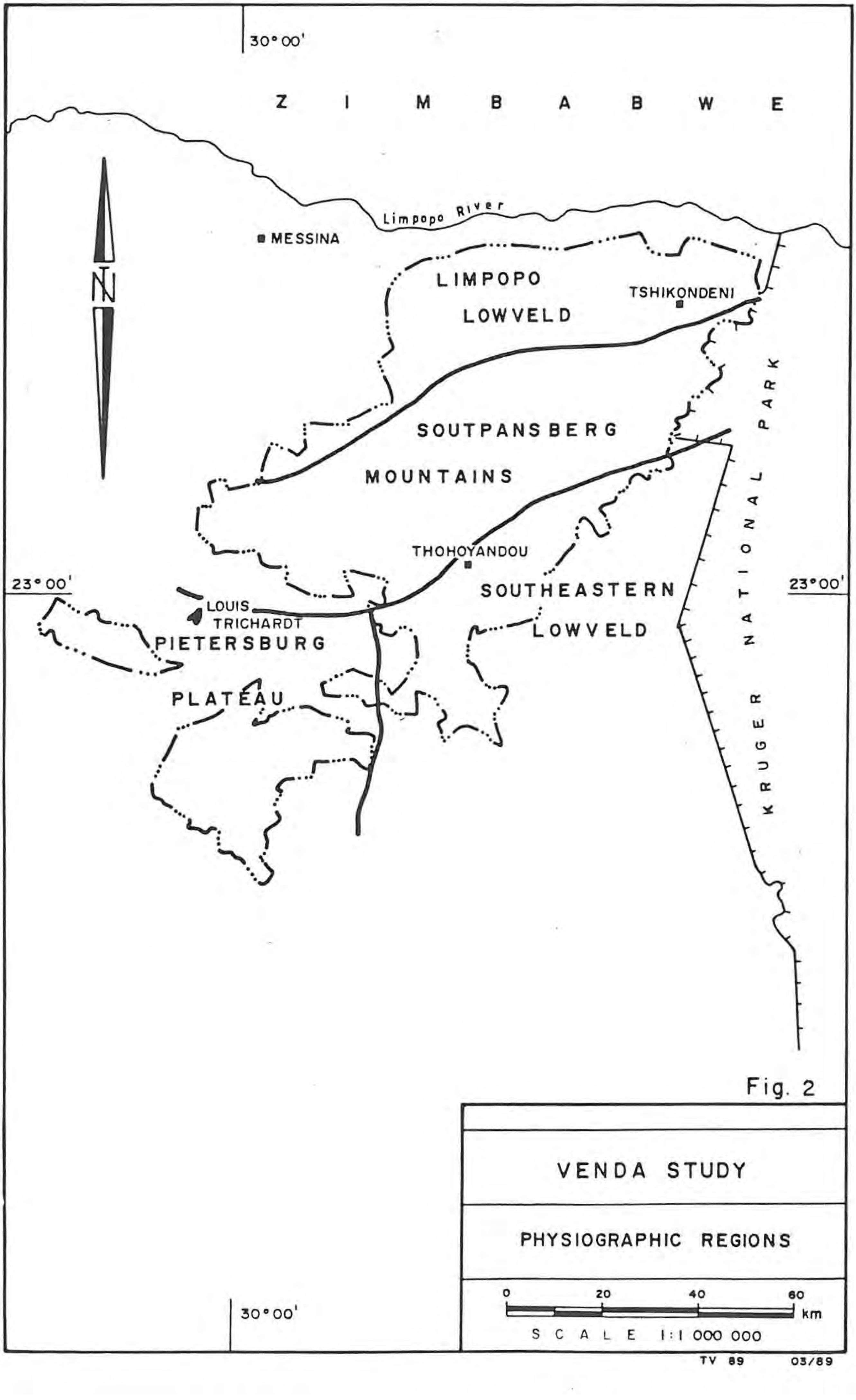

Fig. 2

VENDA STUDY

PHYSIOGRAPHIC REGIONS

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Limpopo Lowveld

The Limpopo Lowveld is gently undulating to hilly and has an elevation of between 240 and 560 m above sea level. The summers are extremely hot with maximum temperatures generally in the upper thirties to lower forties (°C) and a very low rainfall of 50 to 75 mm per month, between December and February (during which time evaporation averages around 200 mm per month). Between May and September the rainfall is generally less than 10 mm per month and the average annual rainfall is less than 400 mm. The winters are moderate with temperatures in the lower twenties (°C). Because annual evaporation exceeds precipitation much of this area is underlain by calcrete. In addition parts of the area are covered in tertiary to recent transported red sands. Soils commonly vary from red sandy loams to grey calcareous types and are generally thin except in flood plains and river valleys.

Soutpansberg Mountains

The central portion of the country is covered by the rugged Soutpansberg Mountains (see plate 1) and elevations range from 560 m to almost 1 600 m. The annual rainfall varies greatly between 300 mm in the Nzhelele valley west of Siloam Mission and the foothills regions, to 2 000 mm in the mountains north and west of Thohoyandou. This region is generally cooler than those to the north and south, with maximum temperatures generally between 11°C and 22°C in the mountains and warmer temperatures along the northern, eastern and southern foothills. Soil development varies from deep, well structured red sandy loams (in some valleys) through shallow stony apedal clays or loams, to stony sandy lithosols on slopes, and Tertiary to Recent transported sands.

Pietersburg Plateau

The Pietersburg Plateau area in the southwest averages 1200 m in elevation and has an average annual rainfall of 400 mm. Shallow lithosolic soils are developed in most of the area. The maximum temperatures vary between 12 and 30°C and winters are cool.

Plate 1

A view over the sacred Lake Fundudzi in the heart of the rugged Soutpansberg Mountains. This lake was formed when a landslide dammed the Mutale river. The hill rising out of the left background of the photograph attains an elevation of over 500 m above the level of the lake.

Southeastern Lowveld

The southeastern lowveld portion averages 500 to 600 m in elevation and has similar temperature and rainfall characteristics to the Limpopo lowveld. The narrow plateau slopes which separate the southern lowveld from the Pietersburg Plateau receive rainfall of up to 1 000 mm per annum and medium textured red apedal soils are developed here.

The estimated mean annual runoff for Venda is almost 650 million m^3 (Dept. of Water Affairs, 1978). Most of this enters the Limpopo River through three main river systems namely the Mutale-Luvuvhu, the Nzhelele and the Nwanedi in order of decreasing importance. A small proportion of runoff enters the Letaba River system to the southeast. Drainage in the mountains is good but to the north and south in the more gently sloping areas it is fair to poor, with many channels in the northern flats being choked with sand (van Eeden, et al., 1955). Within the Soutpansberg Mountains, which are formed by a homoclinal, northerly dipping, volcano-sedimentary sequence, cut mainly by major ENE faults, a series of ENE trending longitudinal valleys interspersed with sandstone and quartzite dip and scarp slopes have developed, resulting in an assymetrical drainage pattern. Major discordant valleys such as the Luvuvhu and Mutale river courses, indicate superimposition of drainage from a pre-existing Karoo cover (Barker, 1979).

1.4 Previous Investigations of the Mineral Potential of Venda

Whilst reading this section it will be helpful to refer to figure 3 which is in a folder at the back of the document.

1900 to 1945

Whereas the copper deposits of Messina (some 60 km N and W of Venda) have been known since ancient times (Sohnge, 1945) and magnetite from the Schiel Complex has been smelted and used for iron production for several centuries, it appears as though the earliest modern mining activities in the area that today constitutes the Republic of Venda, were the extraction of copper (between 1904 and 1914) and coal, both in the Mutale area (Grewar 1907, Maree 1947, Loxton, et al., 1972, Coetzee, et al., 1969), as well as the extraction of coal from Mpefu's Location (Hawkins, 1978). One of the more reliable and significant early reports of mineralization (Rogers, 1925) is from the southern bank of the Mutale river 3 to 5 km west of the Mutale Mine, and mentions a series of brecciated zones with northwesterly and westerly trends, which cut both volcanic rocks and sediments. These breccia zones are reported as being filled with quartz, specularite and small amounts of copper minerals. Reference is also made to Roet's coal pit in the Mtamba valley. This report also mentions the occurrence of brittle chrysotile asbestos on the farm Bosbokpoort just a few kilometres west of the present boundary of Venda (in the north).

Also in 1925, Hall wrote a report on phosphate occurrences associated with pegmatite on the farms Schaapkraal 387 LS, Spelonkwater 383 LS and Mahilashoek 388 LS, in the south eastern portion of Venda (fig.3)

A later report (Kent, 1939) described an occurrence of copper mineralization in amygdaloidal Soutpansberg lavas and associated with faults and fractures in quartzites, on the farm Bosch 234 MT, a few kilometres west of Venda and close to the tarred road from Louis Trichardt to Thohoyandou. Other copper deposits, associated with the Tshipise fault system are reported on the farms Stayt 183 MT, Hughes 151 MT and Xmas 140 MT, just to the west of Venda (Söhnge, 1945) and this may have some relevance to potential mineralization within Venda, associated with the Tshipise fault. These occurrences, referred to as the Mtamba workings are very similar to the copper mineralization in the area of the Nwanedzi and Luphephe dams, in northern Venda.

1945 to 1970

According to Visser (van Eeden, et al., 1955) the Soutpansberg rocks have been becciated in close proximity to major faults and alteration has occurred with epidote, calcite and specularite being the most common products. The copper is associated with the altered material, principally in Soutpansberg lavas and diabases. Van Eeden's report also mentions the occurrence of coal in boreholes on the farms Gaandrik 162 MT and David 160 MT, just northwest of the Nwanedi dam. It is noted that some of the coal has been altered to anthracite and graphite as a result of intrusive activity. This has also occurred where lower Karoo sequence sediments have been intruded by late to post Karoo olivine dolerite sills further east, in both the Mutale and Pafuri river valleys. The presence of several thermal springs within and adjacent to what today constitutes the Republic of Venda, was also reported, some enriched in sulphur and fluorine. Such occurrences are of obvious significance in the search for epithermal mineralization. Also of economic importance are the magnetite-quartzites (in Malala Drift Formation rocks in northern Venda) that contain an average of 50% total iron oxide and which Van Eeden suggests may constitute a possible source of iron ore.

Further reference was made to graphite occurrences at the Mutali graphite mine and on the farm Bali 84 MT both within Venda, as well as to several occurrences along the Limpopo River and on other properties close to Venda (de Villiers, 1963). A more comprehensive review of the graphite mineralization north of the Soutpansberg (Wilke, 1969) reveals that three types of mineralization are present in the area. One type (e.g. Bali 84 MT and Dawn 71 MT) is associated with metamorphism in the rocks of the Beit Bridge Complex and in these cases the graphite occurs in granitic, gneissic, marble and calc-silicate rocks. This graphite is referred to as crystalline or flake graphite and is generally present in very small flakes, which may constitute up to 30% or more of the rock. The second type of graphite is termed amorphous and is typified by the Mutali Graphite Mine where sporadic production has occurred since 1943. In this occurrence coal and carbonaceous shales of the Karoo Sequence have been metamorphosed, most probably by the intrusion of proximal olivine dolerite sills. The third type of occurrence is unlikely to be economically viable but may well serve as a useful indicator for graphite deposits of the abovementioned types. Graphite flakes apparently occur within near surface calcrete, which is fairly extensively developed in the Limpopo Valley. Where such flakes occur in calcrete and secondary haematite is also present, there is a chance of buried graphite deposits existing (Wilke, 1969).

Another significant industrial mineral which has been produced in Venda is magnesite. The known magnesite occurrences north of the Soutpansberg were fairly well documented (Wilke, 1965). In northern Venda several larger deposits of amorphous magnesite occur in altered olivine dolerite sills and Karoo limburgites. The magnesite is present as veins and irregular masses which formed by alteration of the olivine-rich igneous rocks. The largest deposit was the Nyala magnesite mine (6,5 km west of Klein Tshipise, which is now called Sagole Spa) where some 300 000 tonnes of magnesite were proven to a depth of 22 m. The smaller deposits on Adieu 118 MT, Ettie 33 MT, David 160 MT, Gaandrik 162 MT, Amonda 159 MT and Fallershall 74 MT were some that were large enough to attract interest and exploitation, despite being an order of magnitude smaller in their reserves. Exploitation of the magnesite deposits revealed that near surface calcrete was frequently developed to a depth of 2,5 m. Most of the known deposits were exploited during the 1960's, though those on David and Fallershall were still producing in the 1970's when an estimated 200 000 tonnes of reserves were believed to exist (Hawkins, 1978).

Plate 2

Evidence of the fairly large scale extraction of magnesite during the 1960's and 1970's is provided by these impressive dumps within the present limits of the Nwanedi National Park in the northern Lowveld of Venda.

A considerable amount of work was carried out by FOSKOR over the Schiel Complex between 1965 and 1968 and reserves of phosphate in weathered ore were calculated at 57 million tonnes containing 5,0% P_2O_5 and vermiculite (Viljoen, 1966).

1970 to the present

In 1972 Loxton, Hunting and Associates produced a short report on the geology and mineral potential of Venda. They considered that the highest potential for further exploration lay in searching for copper. Also in 1972 Phalaborwa Mining Company conducted photogeological mapping and soil sampling over a portion of Southern Venda between Sibasa and the Kruger Park. Follow-up soil sampling, radiometric survey and some diamond drilling were undertaken over various anomalies. They assessed the overall mineral potential as poor, though they found frequent disseminated chalcopyrite in epidotised lavas of the Sibasa Formation and these were often indicated by elongated copper and nickel soil geochemical anomalies. In addition a mineralized cupriferous shear zone trending ENE with limited grade copper in a gossan was located on Mhinga's Location just east of Venda (Mostert, 1972).

During 1977 a comprehensive report was produced on Venda by the Institute of Development Studies at the Rand Afrikaans University. In the Section on geology and mineral potential du Toit (1977) drew attention to the potential for copper in the Sibasa Formation, radioactive minerals in the conglomerates and tuffaceous members of the Nzhelele Formation and coal in the lower Karoo sediments. He also mentioned the potential for molybdenum in addition to the already known apatite, magnetite and vermiculite mineralization associated with the Schiel Complex in southern Venda.

During 1978 a significant review of the mineral potential of Venda was produced by the Minerals Bureau (Hawkins, 1978). This report recognised 14 known economic mineral commodities from 81 sites. The mineral commodities with the highest potential were considered to be coal, magnesite and flake graphite. The next most important exploration target was phosphate at Schiel and minerals assessed as having low potential included corundum, copper, barytes, gold, nickel and tin.

In 1979 a regional stream sediment sampling programme was undertaken over the largest of the three portions of Venda by the Bantu Mining Corporation (Ras, 1979). In this survey, silt in drainage channels was sampled at an average density of 1 sample per km^2 and each sample was analysed for 8 elements namely:

Copper
Lead
Arsenic
Yttrium
Rubidium
Strontium
Thorium
Uranium

The analyses were carried out by the geological survey and computerised statistics were applied to the data with distinctions being made between lithological units. Anomalous values were taken as those above mean plus two standard deviations and anomalies were graded according to the number of elements showing anomalous values at each sample site. Thus second order anomalies would show two of the elements elevated. A total of 15 anomalies were found to be second order or above and follow-up work was limited to these. Seven of these 15 anomalies had elevated lead contents. Maximum copper values obtained in follow-up work were 267 ppm. over rocks of the Wyllies Poort Formation. No copper anomalies were found to be of economic significance and no copper anomalies showed in the Mutale Copper Fields. No zinc anomalies of any economic significance were found in follow-up work and the highest zinc value obtained was 129 ppm. Lead values of up to 233 ppm were obtained. Cu, Pb and Zn were all elevated in dolerites where anomalies were near to these. In his conclusions of this silt sampling survey, Ras (1979) states that the rugged terrain and high rainfall (500 mm to 2 000 mm per annum) both contributed towards the ineffectiveness of the sampling technique. He further stated that the survey had been of limited use because of the small number of elements examined (in particular he felt that nickel should have been included) and because it only covered one of the three portions of Venda. During initial sampling a -80 mesh fraction was assayed and during follow-up work a -200 mesh fraction was used and no appreciable difference was found in the results from the different fractions. Finally he mentioned that copper mineralization was known to be associated with a series of post-Karoo faults in Venda and that Iscor had found a significant uranium anomaly in Ecca Formation equivalents (Madzaringwe, Mikambeni or Fripp Formations) in the Masisi area.

Since 1981 geologists of the Bantu Mining Corporation and STK have made several suggestions and observations concerning potential mineralization in Venda and some of the more significant of these are mentioned below:

i) Copper occurs in two broad ENE-WSW bands along and close to the northern and southern contacts of the Soutpansberg Group rocks in Venda. In the less significant southern zone, copper is concentrated in joints, faults and shear zones within Sibasa Formation basalts, or is disseminated in epidotized lava. During an examination of 50 km's of strike (out of a total of 90 km) no economic deposits were located.

In the northern zone, copper is associated with flow top amygdales in the basal Musekwa Basalt Member of the Nzhelele Formation. Copper is also associated with a tuffaceous horizon within the Nzhelele Formation (Gain, 1981 a) but most occurs in fissures and quartz veins within these rocks.

ii) The potential for uranium mineralization in the Bosbokpoort Formation in northern Venda has been recognised (Gain, 1981 b) as this is a correlate of the Elliot Formation and experience in QwaQwa has revealed the presence of uranium mineralization within this horizon.

iii) A comprehensive investigation was made of the coal potential on the farm Jazz 715 MS and the western portion of Mpefu 202 MT in western Venda (Schutte, 1982). Almost 4 km of diamond drilling and 556 m of percussion drilling indicated 94 million tonnes of low rank blend coal to a depth of 300 m. The coal was intersected at depths of between 15 and 364 m in an horizon that dipped to the north at 21°. The coal seams range from 1 cm to 3,65 m in thickness and occur in the basal units of the Karoo Sequence.

iv) The potential for tungsten mineralization in the calc-silicates and magnetic quartzites of the Gumbu Formation (Beit Bridge Complex) in northern Venda has been suggested by Winfield (1982).

v) A suggestion was made by Germiquet (1985) that the copper occurrences north of Siloam Mission could have formed in a similar way to the Olympic Dam deposits because of several similarities including the following:

a) Both developed in an intracratonic basin.

b) Both contain abundant basal volcanism and permeable zones of tuff, agglomerate and sandstone occur in both.

c) Hydrothermal activity has taken place and both systems are capped by a thick sedimentary succession (Fundudzi and Wylliespoort Formations).

d) The trace element signatures are similar.

Even though ideas have changed concerning the genesis of the Olympic Dam and some workers now interpret the mineralization as being associated with sub-volcanic haematite-rich breccias (pers. comm. Western Mining Geologists, 1987), that formed as part of an alkaline intrusive system (Mortimer et. al., 1988), the origin remains contentious. If the original volcano-sedimentary model (Roberts and Hudson 1983) is considered, the potential for economic grade Cu-U-Au mineralization having formed is high in the Soutpansberg succession.

However even using the alkaline intrusive model for Olympic Dam mineralization and bearing in mind recent conclusions arrived at to explain geophysical anomalies associated with the area around the Schiel Complex (which suggest a much more extensive low density intrusive granitoid rock underlying a large area around the outcropping Schiel (alkaline) intrusive and spreading at least as far as the Entabeni and Palmietfontein granites and possibly beyond (De Beer, pers. comm., 1989)), the potential for a similar deposit exists in the southernmost Soutpansberg area around the Entabeni pluton.

In either event this type of copper, uranium and gold mineralization is considered worth prospecting for.

Finally, for further information on previously known mineral occurrences see the attached Table 1 and figure 3.

TABLE 1

SUMMARY OF DATA CONCERNING MORE INTERESTING MINERAL/METAL OCCURRENCES WITH POSSIBLE ECONOMIC POTENTIAL (MODIFIED AFTER HAWKINS 1978)

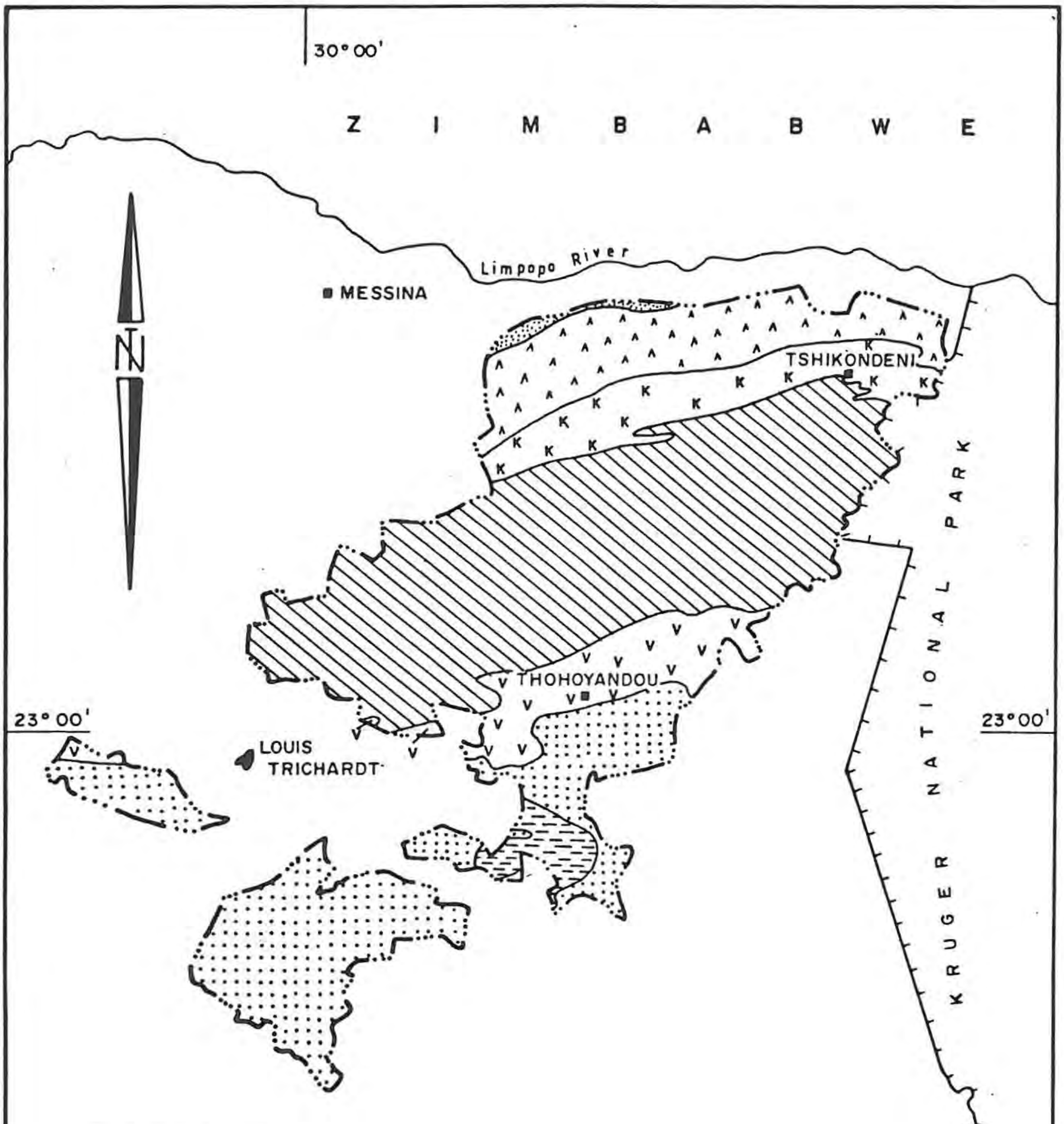
METAL/MINERAL COMMODITY	LOCATION OF KNOWN OCCURRENCES	GEOLOGICAL ASSOCIATION IF KNOWN
Barytes	Spelonkwater 383 LS/Schaapkraal 387 LS/Mahilashoek 388 LS	A monazite bearing barite-apatite vein in Archaean granite.
Barytes	Wendy 86 MT.	No geological information.
Coal	Mpefu Location 202 MT.	Indicated reserves of 94 Mt of low rank blend coal located in a 30 m thick succession to a depth of 300 m.
Coal	Mutale	Metallurgical grade coal in a seam. Ave, 2,6 m thick over 36 km2. Highly faulted.
Copper	Nwanedi-Luphephe Dam Area.	Cu occurs in qtz. veins and breccia zones in lavas dolerite sills and sediments.
Copper	Sagole Spa (Klein Tshipise) Area.	Cu occurs in qtz veins and fractures in Soutpansberg lavas and sediments. Disseminated Cu also occurs in banded tuffs.
Copper	Serolle 205 MT/Afton 171 MT/Mpefu's Location 202 MT.	All occur in Soutpansberg lavas with the Serolle occurrence having an associated Gabbroic body.
Corundum	Schiel 54 LT/Baviaanskloof 384 LS/Boschluiskloof 412 LS/ Roodegrond 393 LS/Stukfontein 478 LS.	Usually develops at the contact between ultramafic rocks and intrusive granitic material (A contact metamorphic and anatectic occurrence).
Gold	a) Schiel 54 LT. b) South West Venda. c) Nwanedi Area. d) Doornhoek 480 LS.	a) Attempts to verify this unsuccessful. b) Generally in intrusive amphibolite. c) Qtz vein association. d) No details.
Nickel	Schaapkraal 387 LS.	Serpentinite on this farm contained 0,45% Ni and talc schist 0,32% Ni.
Manganese	Boundary of Keerweder 1609 MT and Strathaird 173 MT. Bloemfontein 223 MT.	Mn occurs in Waterberg sediments but best occurrences in a brecciated quartzite.
Monazite	Same occurrence as under Barytes above.	As above under Barytes.
Tin	Mangundi 279 MT.	No information available.
Iron	a) Schiel 54 LT and Tabaan Location 55 LT. b) Knopneuzen Location 230 MT. c) Woodhall 35 MT.	a) Occurs as magnetite (titaniferous) of low grade. b) No information available. c) Magnetite quartzite >50% combined iron oxide.

2. GEOLOGY AND MINERALIZATION OF VENDA

2.1 Introduction to the Tectonic Setting and Principal Lithologies of Venda

The rocks occuring in Venda formed over a period of almost 3,0 Ga. ranging from early Swazian to Jurassic times. The oldest lithologies present are the gneisses and there are two main categories of these, namely the Goudplaats gneisses with greenstone remnants (Bandelierkop Complex and Giyani Group) in the south of the country and those of the Beit Bridge Complex in the north. (See fig. 4 and Table 2.) The presence in northern Venda of highly metamorphosed and deformed Beit Bridge Complex rocks, which constitute part of the Limpopo Province, indicates that present day Venda straddles the northern margin of the Kaapvaal Craton and the Limpopo Province (fig. 5). In fact Swazian rocks in all of Venda have been influenced by the high grade metamorphism and deformation that accompanied the Limpopo event which ended 2,6 Ga. There is no consensus regarding the tectonic processes that were involved in forming the Limpopo belt, but it is fairly certain that a degree of rifting, deep burial, uplift and erosion have occurred, to allow such intensely metamorphosed rocks to be exposed on surface. Following the Limpopo event, at about 2,5 Ga syenites and hornblende granites of the Schiel Complex were intruded into Goudplaats gneiss in the south of Venda and these were closely followed by the slightly younger Palmietfontein and Entabeni granites. This event was followed (Table 2) by the formation of the Soutpansberg trough, at about 1,8 Ga, (probably by re-activation of Limpopo age faults and uplift of the Central Zone of the Limpopo Belt (fig. 6)), into which basaltic lavas were extruded and sediments deposited, forming the Soutpansberg Group.

During Permian times deposition of Karoo sediments commenced with carbonaceous basal sediments, suggestive of swamp-like conditions. As Karoo sedimentation progressed, there is evidence of the palaeo-environment becoming progressively more arid until by the time the Clarens Formation was deposited, desert like conditions are thought to have prevailed, as indicated by the presence of aeolian sands. The



LEGEND

^ ^ ^	LETABA FORMATION (KAROO SEQUENCE)
K K	KAROO SEQUENCE SEDIMENTS
▧	SOUTPANSBERG GROUP (PREDOMINANTLY SEDIMENTS)
V V	SIBASA FORMATION LAVAS (SOUTPANSBERG GROUP)
☰	SCHIEL COMPLEX
░	BEIT BRIDGE COMPLEX
⠿	SWAZIAN GNEISS

Fig. 4

VENDA STUDY

SIMPLIFIED GEOLOGY

0 20 40 60 km

SCALE 1:1 000 000

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TABLE 2.

Informal Lithostratigraphic Column for Venda

ERATHEM	GROUP COMPLEX	FORMATION UNIT	PRINCIPAL LITHOLOGY
QUARTERNARY			Alluvium
JURASSIC			Syenite
			Picrite / Olivine dolerite sills
	Karoo Sequence	Letaba Fm.	Basalt / Nephelenite/ Limburgite
		Clarens Fm.	Sandstone
TRIASSIC		Bosbokpoort Fm.	Siltstone / Sandstone
		Klopperfontein Fm.	Sandstone
		Solitude Fm.	Shale / Siltstone
PERMIAN		Fripp Fm.	Sandstone
		Mikambeni Fm.	Shale /Carbonaceous
		Madzaringwe Fm.	Shale/Carbonaceous
		Tshidzi Fm.	Diamictite
MOKOLIAN	Soutpansberg Group	Nzhelele Fm.	Basalt / Sediment
		Wyllies Poort Fm.	Sandstone
		Fundudzi Fm.	Sandstone
		Sibasa Fm.	Basalt
		Tshifhefhe Fm.	Sandstone / Conglomerate
VAALIAN		Palmietfontein & Entabeni	Granite
	Schiel Complex		Syenite / Hornblende - granite
SWAZIAN	Beit Bridge Complex	Gumbu Fm.	Calc - silicate
		Malala Drift Fm.	Gneiss / Quartzite / Pelite
	Banderlierkop Complex		Ultramafic / Mafic / Pelitic
	Giyani Group		Ultramafic / Mafic / Pelitic
		Goudplaats Gneiss	Gneiss

sedimentation was followed by outpourings of a lava (Letaba Formation) which is predominantly basaltic in composition but which contains nephelenites and limburgites. The Karoo Sequence, which outcrops in northern Venda, was intruded by late to post Karoo picritic sills of similar composition to the limburgites of the Letaba Formation. Also at this time, some small Jurassic syenites were intruded close to the northern border of Venda (fig. 4a).

Following this is a brief review of the more significant contributions to the geology of the area and then a more detailed account, in chronological order, of the principal lithologies. Frequent reference to Figures 4 and 4a (the latter in a folder at the back of the report) as well as Table 2, will greatly assist in understanding the regional geology.

2.1.1. Significant Contributions to the Geology of the Area

Most of the previous investigations of the geology of the area have been carried out by members of the Geological Survey of South Africa. One of the earliest references to the geology and rock types in the area was made by Mellor and Trevor (1908) who examined parts of the western Soutpansberg and were the first workers to associate the Soutpansberg rocks with the Waterberg System. Rogers (1925) also correlated the Soutpansberg sediments with those of the Waterberg and recognised the Karoo Successions to the north. He also identified the limburgites (Letaba Formation) and intrusive olivine dolerite bodies in the area. He noted the presence in the extreme east, of nepheline in some of the Karoo basalts and referred to various types of mineralization (see Section 1.4 of this report).

The correlation of the Soutpansberg with Waterberg rocks was agreed to by du Toit (1926) and Hall (1929). Some notes were published by Jannisch (1931) on the formation of Lake Fundudzi and the chemical composition of its water. In 1939, Kent subdivided the basal lava sequence from the Waterberg System. Willemse and others (1944) recognized the essentially conformable nature of the Soutpansberg stratigraphy, as did van Zyl (1950) who mapped in detail, a traverse through the Soutpansberg, along the national road, north of Louis Trichardt. Van Zyl interpreted the faulting

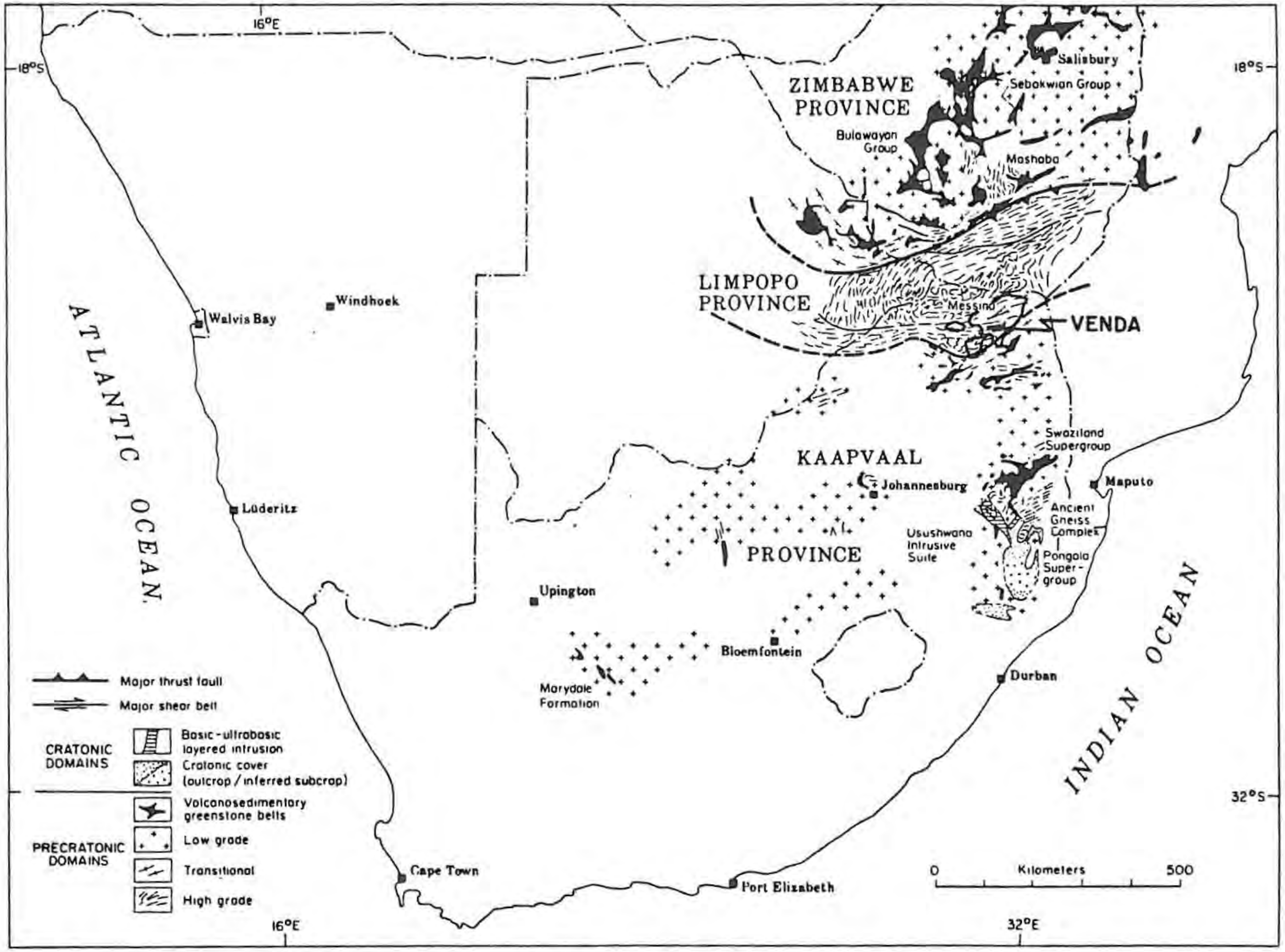
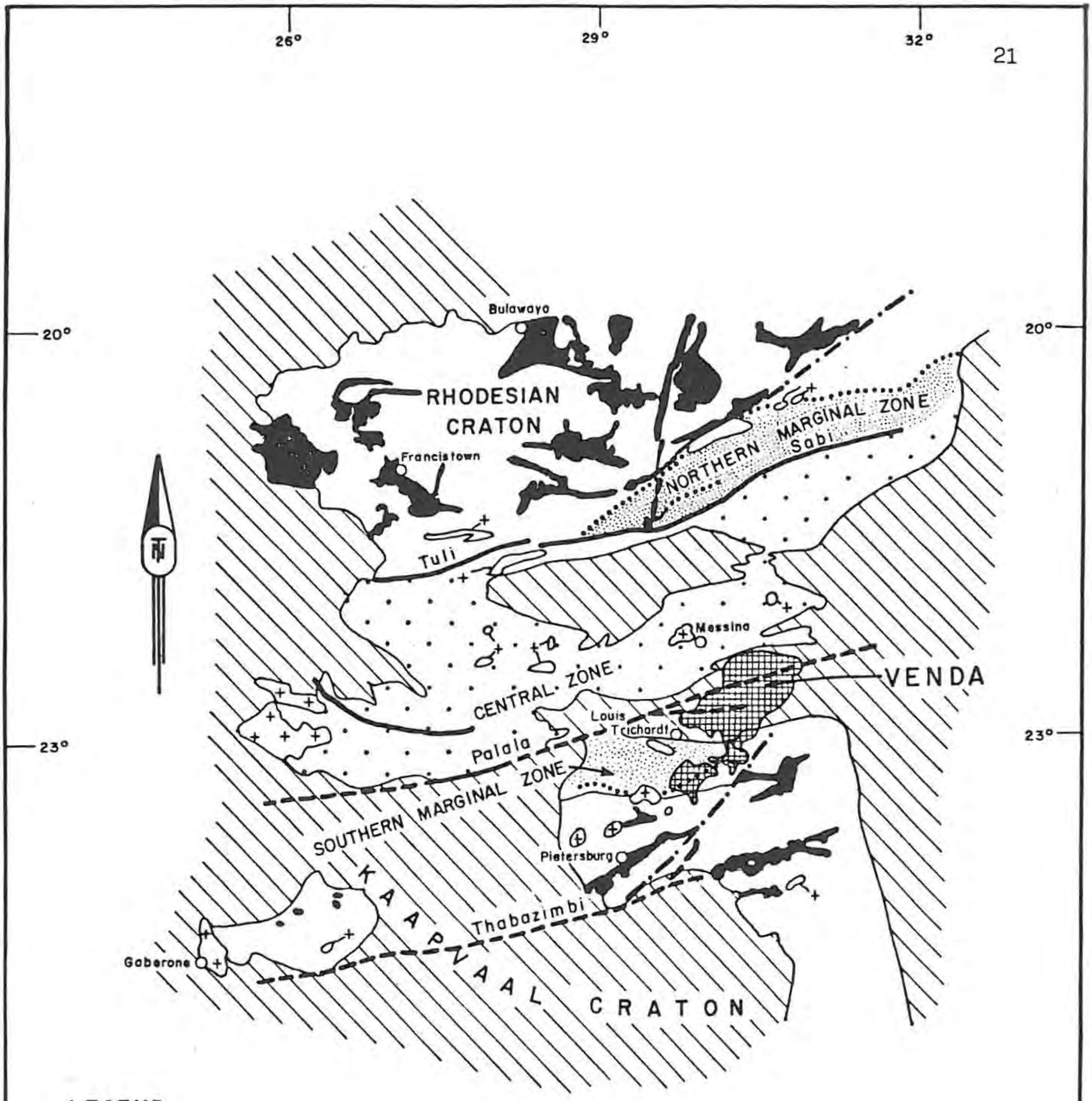


Figure 5. Venda in Relation to the Archean Crustal Provinces of Southern Africa Modified after Tankard et al (1982).



LEGEND

━	SHEAR ZONES REACTIVATED SINCE 2 000 Ma
━·━	POST -2 600 Ma SHEAR ZONES
·····	ORTHOPYROXENE ISOGRADS··· AND ORTHOAMPHIBOLE ISOGRAD —
☐	ARCHAEAN TO PHANEROZOIC COVER SEQUENCES
+ +	-2 600 Ma GRANITIC PLUTONISM
· ·	CENTRAL ZONE
▨	GRANULITE GRADE MARGINAL ZONES
■	GRANITE - GREENSTONE TERRANES

Fig 6

SKETCH MAP OF THE
LIMPOPO METAMORPHIC COMPLEX
IN RELATION TO VENDA

100 0 100 200 Km

SCALE 1 : 5 000 000

(After du Toit et al, 1983)

as normal faulting of a conformable succession and felt that the sediments had been transported from the north west. Geological survey memoir No. 40 (Söhnge, 1945) covered the geology of the area around the Messina Copper Mines and gave special attention to the copper occurrences. Geological survey map sheets for Messina (Sohnge et al., 1948) and Soutpansberg (van Eeden et al., 1955) followed and provided the first real geological base maps of the area. The mapping and descriptions of the Archaean rocks (Basement Complex) was accurate and reliable and has changed little over subsequent years.

However, influenced perhaps by Truter (1949), who subdivided the previously known Waterberg System into an upper (Waterberg) and lower (Loskop) system, on the basis of an unconformity he recognised in the Loskop Dam area, the subdivision of the Soutpansberg Group as made by van Eeden et al., (1955) was extremely complex and required normal and reverse strike faults for explanation. Lavas in what is today known as the Nzhelele Formation were explained as reverse faulted equivalents of the Sibasa Formation basalts. In addition the basal Sibasa Formation lavas were correlated with the Dominion Reef System. As a result of this interpretation, the conformable nature and simple normal faulting of the Soutpansberg succession that had been favoured previously, was no longer considered correct. This more complex subdivision was supported by de Villiers (1967) but doubted by Haughton (1969).

It was only in the 1970's that Tickell (1973), Meinster (1974) and Jansen (1975), who had been remapping the Waterberg rocks, officially rejected van Eeden et al.'s interpretation of the Soutpansberg Stratigraphy. This resulted in dropping the Waterberg/Loskop subdivision of strata, as well as the correlation of the basal Soutpansberg lavas with the Dominion Reef. This new interpretation of the Soutpansberg as a single group was supported by geological survey mapping in 1975/76 as well as by the thorough photo-geological interpretation of the Soutpansberg made by Barker (1979) and forms the basis on which the present SACS stratigraphic subdivision has been made. (S.A.C.S. 1980)

A significant insight into the Southern Gneisses as well as the Bandelierkop and Schiel Complexes, was provided by du Toit (1979), who mapped the area south of the Soutpansberg from west of Bandelierkop to Schiel. This was the first time that the Southern Gneiss terrain and Bandelierkop Complex had been mapped in such detail. Recent geophysical work over this area indicates an extensive development of less dense granitic material below the gneiss, which separates the Schiel Complex outcrop from the Palmietfontein and Entabeni granites (J. de Beer, pers. comm., 1989). Further recent work in the area has been reported by Brandl (1981, 1986 and 1987) in explanations of the new 1:250 000 geological map sheets of Messina, Pietersburg and Tzaneen respectively. In addition a valuable contribution to the understanding of the Limpopo Belt was made in 1983 (van Biljon and Legg, eds.). In this volume a proposed tectonic model for the evolution of the Soutpansberg Group was presented by Barker. In 1984 a volume on the Petrogenesis of the Karoo Volcanic rocks (Erlank ed. 1984) included useful geochemical data on the Letaba and Jozini Formation volcanics (Bristow, 1984 a and b; Cox and Bristow, 1984), as well as ideas on the tectonic significance of the lavas (Eales et al., 1984) and results of age dating (Fitch and Miller, 1984).

Finally in 1986 a volume was published on various aspects of the geology of the Kruger Park, which included a summary of the geology of the Kruger Park (Schutte, 1986) and an overview of the development of the Soutpansberg Group (Bristow, 1986) amongst other papers of relevance to the geology of Venda.

2.2 Regional Geology of Venda

2.2.1 Swazian Gneisses and the Limpopo Event

The Sand River Gneisses outcropping in the Limpopo Belt northwest of Venda are believed to be amongst the oldest rocks on earth, having been dated at 3780 Ma (Barton and Ryan, 1977). These rocks have been intensely deformed and metamorphosed and are believed to have formed the basement for subsequent volcano-sedimentary sequences which have in turn been deformed and metamorphosed to form the Mount Dowe, Malala Drift and Gumbu Formations of the Beit Bridge Complex. The latter two formations occur in the extreme north and west of Venda and will be discussed further. Though the origin and tectonic history of the Limpopo Province are contentious, the very high grades of metamorphism and deformation which have occurred suggest deep burial and subsequent uplift for much of the area, particularly the central zone (Fig. 6). A northern and southern marginal zone of metamorphosed and deformed rocks has also been identified and Venda falls largely within the southern marginal zone. The metamorphic event associated with the Limpopo Province is believed to have terminated by 2,65 Ga (Watkeys, et al., 1988). Thus all rocks which formed before this time and which occur within the Limpopo Province have been affected to varying degrees by high grade metamorphism, deformation and uplift. This includes the Beit Bridge Complex rocks in the north of Venda, the Goudplaats Gneiss and included "greenstone" remnants, which outcrop in Southern Venda, as well as the mafic and ultramafic rocks of the Bandelierkop Complex which also outcrop in the south. These will now be discussed in more detail. The following descriptions are summarized and modified largely from work published by Brandl (1981, 1983, 1986, 1987).

Plate 3

Partially assimilated mafic material displaying intense deformation, within the Goudplaats gneiss in Southern Venda.

The Malala Drift Formation

This formation is made up of a predominant leucocratic quartzo-feldspathic gneiss with garnet, a subordinate pink granitoid hornblende gneiss, some intercalated layers of scapolite bearing granulites, a few calcareous horizons and minor magnetite quartzites, amphibolites and metapelites. Considering trace element concentrations of the pink granitoid hornblende gneiss, it seems likely that is is of sedimentary origin. The scapolites are thought to have originated as evaporitic shales.

The Gumbu Formation

The formation consists mainly of calc-silicate rocks and marble. The calc-silicates are grey or greenish grey in colour and produce a rough, fluted brown weathering surface. Coarse grained white and fine grained pink marble with differing amounts of olivine, form lenticular layers within the calc-silicates. Light green and black scapolitic rocks are closely associated with the calc-silicates and marbles in places. This formation is principally of sedimentary origin and is frequently overlain by thick calcrete.

The Goudplaats Gneiss

This includes gneiss, banded gneiss and migmatite, associated with leucocratic granite in varying proportions. Later stage leucocratic bands occasionally cut across earlier concordant melanocratic and leucocratic banding and thus several periods of anatexis and mobilization were probably involved in their formation. The slightly darker grey migmatitic gneisses are of tonalitic and quartz-dioritic composition, whilst the leucocratic material is adamellitic to tonalitic. The Goudplaats gneiss is thought to have formed the basement for Pietersburg Group volcano-sedimentary rocks and has been intruded by Bandelierkop Complex rocks. The age dates obtained from the Goudplaats Gneiss range between 2652 and 3054 Ma, but these are believed to be the ages of younger metamorphic overprints.

Bandelierkop Complex

This complex is believed to represent an attenuated and deformed greenstone belt succession (du Toit, 1979). Ultramafic, mafic and pelitic units predominate whilst meta-quartzite and marble are also present. The ultramafics include komatiitic peridotite, dunite, metapyroxenite and hornblendite. Most of the ultramafics are believed to have extruded as lavas and there is evidence of pillow lavas. The mafic rocks include mafic granulite and amphibolite.

2.2.2 The Proterozoic Schiel Complex

Age dating of the Schiel Complex (the largest portion of which falls within Venda) has revealed that it is 2 150 to 2 572 Ma and thus older than the Phalaborwa Complex which has been dated at 2 012 to 2 047 Ma. In outcrop the intrusive complex has a mushroom shape and is predominantly syenitic in composition, with hornblende granite occurring at the outer contact between the syenite and Goudplaats Gneiss. In places the syenites are associated with minor bodies and veins of pyroxenite, foskorite and carbonatite, which host phosphate mineralization (Viljoen, 1966). The Schiel Complex has intruded close to the junction of the Kudu River Lineament and the inferred extension of the significant Siloam Fault and Kransberg Lineament (See fig. 7). The attitude of the three main lobes which make up the body parallels these three directions as well. A small body of Gabbro has also been located on the southern lobe and the younger Entabeni granite is along the inferred extension of the northern lobe and may be associated with the Schiel Complex (M.C. du Toit, pers. comm., 1988). The Palmietfontein Granites are also believed to be of similar age though very slightly younger, because they are less deformed. Recent geophysical work suggests that the complex may be associated with a substantially larger body of intrusive felsic rocks than is indicated by outcrop (De Beer J.H. pers. comm., 1989).

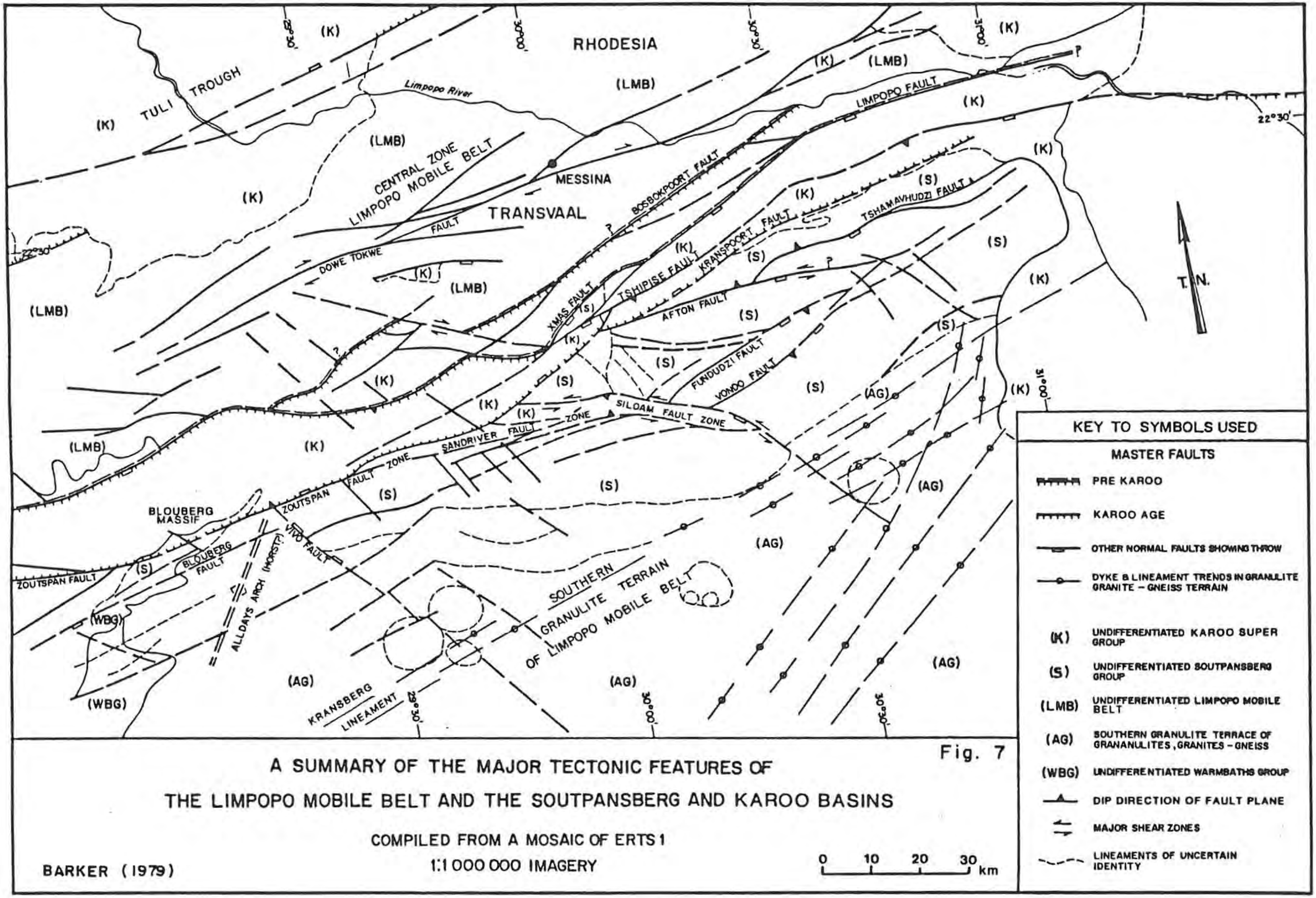


Fig. 7

A SUMMARY OF THE MAJOR TECTONIC FEATURES OF THE LIMPOPO MOBILE BELT AND THE SOUTPANSBERG AND KAROO BASINS

COMPILED FROM A MOSAIC OF ERTS 1
1:1 000 000 IMAGERY

BARKER (1979)

2.2.3 The Proterozoic Soutpansberg Group

Reactivation of the ENE-WSW faults which had initially developed during the Limpopo event, combined with rising of the Central zone of the Limpopo Province, is believed to have resulted in the formation of the Soutpansberg trough. The trough which is 450 km long and up to 45 km wide, trends ENE and started developing in the east, gradually spreading westward (Jansen, 1976; Barker, 1979). Mapping in the western portion (Jansen, 1975) revealed that faulting was taking place during eruption of the basal lavas which are primarily tholeiitic.

The Tshifhefhe Formation

This occurs at the base of the Soutpansberg succession in some places and is a thin, sporadically developed layer of epidotised arenaceous sediments (see the stratigraphic column Table 2).

The Sibasa Formation

This overlies the Tshifhefhe Formation and consists of a cyclically erupted sequence of porphyritic to massive tholeiitic basalts with thin interbedded clastic sedimentary horizons and tuffs in places. Alumina contents of the basalts are below 16% and labradorite is the predominant plagioclase. Low potash contents confirm an Archaean or Proterozoic origin. The maximum development is 3 300 m in the Sibasa area where a major volcanic centre is believed to have existed. A second less significant volcanic centre is postulated for the area east of Sagole Spa, formerly Klein Tshipise (Brandl, 1981). Amygdaloidal and pyroclastic horizons occur frequently and are associated with lava flow tops often displaying abundant iron oxides. The Sibasa Basalt Formation outcrops continuously, forming the southern Soutpansberg Mountains from Vivo in the west to the Kruger National Park in the east. There is another extensive exposure of Sibasa basalts in the Nzhelele Valley (northern Soutpansberg).

The Fundudzi Formation

This conformably overlies the Sibasa volcanics and attains its maximum thickness of 2 800 m near Lake Fundudzi. The formation is composed largely of white, pink or purple, cross bedded sandstones with some coarse material and minor conglomerates. Up to four bands of basaltic lava, each about 50 m thick are intercalated with the upper sediments and some thin tuffaceous horizons are also present. Palaeocurrent measurements indicate a provenance area to the northwest and the sediments are believed to have been deposited in a fluvial flood plain environment (Barker, 1979).

The Wyllies Poort Formation

This conformably overlies the Fundudzi Formation and underlies most of the mountainous part of the Soutpansberg. It is an arenaceous succession and reaches its maximum thickness of 4 000 m in the Thengwe and Ha-Makunya areas. A purple to reddish sandstone and a white quartzite are the predominant rock types. Both types are massive and well sorted with rounded quartz grains. Thin lenses of grit or conglomerate are developed locally and a few lenticular bands of argillaceous sediments occur. South of the Tshamavudzi Fault and east of Sagole Spa (Klein Tshipise) minor lava and tuff horizons occur near the top of the succession, in some places resembling the overlying Nzhelele Formation. The Wyllies Poort Formation is believed to have been deposited in a fluvial to shallow water, braided stream type of environment (Jansen, 1979).

The Nzhelele Formation

This formation has a basal volcanic unit consisting of lava and subordinate pyroclastics which concordantly overlay the Wyllies Poort Formation. The basal lava is basaltic in composition, persistent and up to 400 m thick, thus forming a useful marker horizon. Syngenetic copper mineralization is associated with the basal volcanic unit (Bristow, 1986). Overlying this basal volcanic unit is a succession up to 600 m thick, of predominantly argillaceous material which is generally red in colour.

The upper portion of the formation is cleaner, clastic, light coloured cross-bedded sandstone and quartzite, with only minor shaly intercalations. Narrow tuff and ignimbrite zones occur at erratic intervals throughout the succession. The pyroclastics in this succession suggest explosive volcanicity and represent the last significant volcanic activity in the Soutpansberg Succession (Barker, 1979). The Nzhelele Formation outcrops mainly along the northern edge of the Soutpansberg in the Nzhelele dam area, the Nwanedi National Park and eastwards to the Mutale copper fields and beyond. In the Mutale copper fields (figs. 3 and 4a), the Nzhelele Formation outcrops further north as it has been preserved in a down thrown block which has been intensely fractured and in which copper is widely distributed (Loxton et al., 1972).

The Stayt and Mabiligwe Formations

The associated Stayt and Mabiligwe Formations, which appear to represent localized restricted development of the Soutpansberg Succession, are both developed outside the boundaries of Venda.

General Comments on the Soutpansberg Group

Overall the Soutpansberg Group is a consistently northward dipping, volcanic and sedimentary succession which was laid down in an elongated ENE trending fault bounded trough. Because this trough developed from the eastern edge of the Kaapvaal Craton, towards the interior, Jansen (1975) termed it an aulacogen. Other workers however, (Barker, 1979; Mason, 1973) point out that the patterns of sedimentation are more typical of a yoked basin. The unimodal cross-bedding, lack of marine sediments and paucity of overbank deposits further support a yoked basin model and also suggest a steadily uprising hinterland during sedimentation. The Soutpansberg Group is unusual amongst the later Proterozoic basins of the Kaapvaal Craton (such as the Transvaal and other Waterberg basins), in that it contains almost equal proportions of lava and sediments, whereas the others are predominantly sedimentary. This could reflect the high degree of structural control on the Soutpansberg and the significance of the major faults associated with it (see Fig.7) as well as the proximity to the rising Central Zone of the Limpopo Belt which continued to rise through most of the Soutpansberg development and provided sediment for the trough (Barker, 1979). There is a suggestion that some of the faults tapped basaltic magma from the mantle and that the basalts rather than originating from two or more discrete volcanic centres, actually poured out of the fault fissures in the manner of flood basalts (Bristow, 1986). Many of the faults are believed to have been reactivated several times since the Limpopo event and several, such as the Bosbokpoort and Limpopo (which form the northern margin of the trough) have been active during Karoo times (Barker, 1979).

Three ages of diabase intrusion have been recognized in the area from Soutpansberg times and the chemistry of all the intrusives is similar to that of the Sibasa Formation basalts. The main periods of intrusion were:

i) 2 216 ± 150 ma;
ii) 1 876 ± 68 ma; and
iii) 1 776 ± 70 ma.

2.2.4 The Karoo Sequence

The next tectonically significant activity to affect the northern Kaapvaal Craton and indeed most of Southern Africa, was the formation during Permian and Triassic times of thick sedimentary accumulatiuons which are now known as the Karoo Supergroup. This was followed by fairly extensive volcanism between 200 Ma and 120 Ma, which was associated with the break up of Gondwanaland (Eales et al., 1984). The Karoo Sequence in Venda occurs exclusively north of the Soutpansberg and represents an incomplete and abbreviated sequence when compared with the main Karoo Basin, the sediments being up to 1 000 m thick and the overlying volcanic formations up to 2 000 m. The descriptions of the formations below are taken principally from Brandl (1981).

The Tshidzi Formation

At the base of the Karoo Sequence is a diamictite comprising angular to rounded clasts in a blue-grey silty to muddy matrix. This, the Tshidzi Formation, is up to 20 m thick and is thought to be of fluvioglacial origin and probably a correlate of the Dwyka Formation. It outcrops along and mainly to the north of the Klein-Tshipise fault from the north-eastern Venda border to the downthrown block of the Mutale Copper fields.

The Madzaringwe Formation

This has a maximum thickness of 200 m and is best developed in the northern Kruger National Park and north-eastern Venda, where up to 40 m of carbonaceous shale, shaly coal and coal, are present at the base of the formation (Schutte, 1986). A prominent coal layer which occurs in the succession is up to 3,9 m thick, north-east of Punda Maria and is one of two being exploited at Tshikondeni. The formation outcrops in an area from east of the Mutale Copper fields, southwards into the Kruger National Park. Undifferentiated basal Karoo Sequence sediments including Madzaringwe Formation rocks, outcrop in places from Jazz 715 MS in western Venda to the Mutale area in the east.

The Mikambeni Formation

This is made up of dark to pale mudstone and black shale, with occasional laminae and thin seams of coal throughout the succession. A few thin sandy layers occur near the base of the succession and siderite nodules near the top. The maximum thickness of the succession is 150 m and as is the case with the underlying Madzaringwe Formation, it is believed to have formed in a swamp environment. This formation has an arcuate outcrop similar to and overlying that of the Madzaringwe Formation.

The Fripp Formation

This white to grey, feldspathic and cross-bedded sandstone rests with a sharp contact on the Mikambeni Formation. The grain size is medium to coarse, though some minor conglomerates are developed. Palaeocurrent measurements indicate transport from the northeast and the maximum thickness of 110 m is developed in the northeastern portion. The formation was believed to have been deposited by braided streams. The main outcrop is arcuate in eastern Venda and into the Kruger National Park (as with the underlying Mikambeni and Madzaringwe Formations), but it also occurs in small lenses north of or surrounded by the olivine dolerites which have intruded along and north of the Tshipise and Klein Tshipise Faults, from the north-eastern boundary of Venda to the downthrown block of the Mutale Copper fields. The Mikambeni, Madzaringwe and Fripp Formations are believed to be correlates of the Ecca Group in the main Karoo Basin.

The Solitude Formation

This is composed of alternating multicoloured shale and mudstone with occasional cream coloured siltstone and green or red sandstones intercalated in places. Carbonaceous shale occasionally occurs near the base of the formation, which attains a maximum thickness of 170 m and is a tentative correlate of the Beaufort Group in the main Karoo Basin. This formation has a fairly extensive outcrop of up to 5 km wide from the NE border of Venda to the Kruger National Park.

The Klopperfontein Formation

This is a narrow unit, generally between 10 and 20 m thick, of white to grey feldspathic and cross-bedded sandstones, similar to those of the Fripp Formation. They are believed to have been deposited by braided streams. These sandstones have limited outcrop, mainly in a discontinuous arc from 20 km south-west of Masisi into the Kruger National Park.

The Bosbokpoort Formation

This formation consists of dominantly red, fine grained lithologies. Mudstone forms the base of the formation and is overlain by siltstones, which occasionally grade upward to fine sandstones. The unit is up to 100 m thick in the Tshipise area west of Venda and thins eastward. It has a discontinuous outcrop across northern Venda and into the Kruger National Park. It is believed to have been deposited in a flood basin under arid conditions.

The Clarens Formation

This formation can be subdivided into two mapable units viz. the basal Red Rocks Sandstone Member and the upper Tshipise Sandstone Member, both of which are thickest (each approx. 150 m thick) in the Tshipise area and thin eastwards. The Red Rocks Member consists of a very fine-grained pink to red argillaceous sandstone with paler mottling and an irregularly developed 1 m thick siliceous limestone unit interbedded near the base. The overlying Tshipise Member displays a gradational contact with the Red Rocks unit and is a massive white to cream, fine-grained equigranular rock. Both members of the Clarens Formation contain calcareous concretions and were probably formed in an aeolian environment. This formation outcrops continuously from some 15 km south-west of Tshipise, into the Kruger National Park with a second downfaulted occurrence forming the Tshirundu Hills just north of the Tshipise fault, due north of the Nwanedi National Park.

The Letaba Formation

This formation is made up of extrusive mafic volcanics which rest conformably on the Clarens Formation. The basalts are differentiated and considered to represent flood basalts that extruded along reactivated faults and fissures during the early stages of fragmentation of Godwanaland. In the northern Kruger National Park, nepheline bearing (nephelinite) horizons form the base of the succession and above these are olivine and picrite basalts (Bristow, 1984). Tholeiitic basalts with occasional rhyolitic intercalations cap the succession (Schutte, 1986). In Venda nephelinites only occur east of a point 10 km east of Masisi (G Brandl, pers. comm. 1989). The Jozini Rhyolites are only rarely present in Venda, as intercalations in the picritic and tholeiitic basalts of the Letaba Formation.

The definition of picrite basalts as applied to Letaba Formation rocks by Bristow (1984), is based on an MgO content of greater than 9% whilst values of up to 23% MgO have been obtained (Cox and Bristow, 1984). Intrusive rocks with similar magnesium contents (such as the olivine dolerite intrusives that outcrop along and north of the Tshipise and Klein Tshipise fault at the base of the Karoo Sequence and which host many magnesite workings (Wilke, 1965) would be called picrites. In composition they closely resemble the olivine basalts (once called limburgites) of the Letaba Formation and are probably related to them. The Letaba Formation lavas reach their maximum thickness of 2 000 m along the Kruger National Park/Venda boundary. Near the base of the formation, tuff, ignimbrite, tuffaceous sandstone and even pumice have occasionally been observed in a five metre wide zone. A 2 m wide tuffaceous horizon has also been noted along the contact between the Tshipise Sandstone Member and the Letaba Formation. Thin flows of andesitic rock are also developed sporadically.

The Letaba Formation outcrops in a strip averaging 10 km wide immediately south of the Bosbokpoort fault, all the way from Tshipise into the Kruger National Park. Outcrop is poor with overlying clays developed in most areas (pers. obs., 1988).

Some post Karoo Instrusives are also present and include dolerite, syenite, ijolite and granitic rocks. Only the dolerite sills and some small plug-like bodies of syenite west of Masisi are of potential economic significance to Venda.

2.3 Structural Geology

Sohnge et.al.,(1948) recognised the Dowe-Tokwe and Messina strike slip faults (fig. 7) to the north of Venda and identified the east-north-east tectonics and right lateral movement along the major strike slip faults in the region. Cox et. al., (1965) in compiling a tectonic map of the Limpopo region recognised the extensive continuity of the strike-slip faults and the fact that they had been active as recently as Karoo times. The granulite grade metamorphism of the Limpopo Belt rocks suggested to Mason (1973), that they had undergone deep burial and subsequent uplift and this component of uplift is supported by the fact that workers in both the Transvaal (Button, 1973) and Soutpansberg (Barker, 1979), have evidence of the sediments being derived largely from the Limpopo Belt.

In addition to the predominant east-north-east trending faults of the area a secondary northwesterly fault trend has also been noted in the Soutpansberg rocks (fig. 7). The most significant of these is the Siloam fault zone which is believed to have resulted in relative uplift of up to 4 000 m (Barker, 1979). The other N-W faults such as the Witkop, Mufungudi, Luphephe and Verdun faults are not as significant, with estimated throws of up to 1 800 m. The main east-north-east-trending strike slip faults display a rotational component which results in varying degrees of associated dip-slip movement and all but four of these major faults dip steeply to the south. These faults generally manifest themselves as wide fault zones of between 200 and 500 m, with a central brecciated portion (often cemented by hydrothermal silica and/or iron oxide), around which is a zone of intensely silicified rocks and then highly jointed country rocks. There is evidence that these strike slip faults (which include the Siloam fault) have been reactivated repeatedly since 2 700 Ma.

East of the Siloam fault there is a marked increase in the number of dolerite dykes intruded into Soutpansberg rocks. In its southern extremity the Siloam fault displays a left lateral strike slip motion of 5 km and it is suggested that the Mandale and Fundudzi faults are related to this movement as conjugate Riedel faults.

Finally in his interpretation of ERTS.1 images of the area, Barker (1979) noted a linear feature south of the Soutpansberg called the Kransberg Lineament. Along and just south of this he located several circular structures, one of which occurs at the intersection of the lineament with the extension of the Siloam fault and coincides with the Schiel Complex (Fig. 7).

2.4 Tectonically and Geologically Indicated Mineralization of Venda

The development of the earths crust and thus of the continents has been a unidirectional evolutionary process resulting from changing thermal and chemical conditions, which reflect a gradual cooling of the earth (Bickle and Nisbet, 1986). As tectonic processes are essentially heat loss mechanisms, they have changed in response to variations in physico-chemical conditions and an increasing accummulation of continental crust. The different tectonic processes are reflected in distinctive rock assemblages and associated mineralization which have been generated in different environment over time (Söhnge, 1986). Thus whilst Phanerozoic type tectonic models have in some instances been reported here to explain Archaean and Proterozoic events, this is only because they have been invoked and used by certain workers as models to explain tectonic evolution. Likewise with regard to the Limpopo Belt and Soutpansberg, potential suites of mineralization are presented based on Phanerozoic analogues and these may in fact vary substantially from the actual minerlization formed. Nevertheless they are included to stimulate a wider and perhaps new approach to the mineralization potential of Venda.

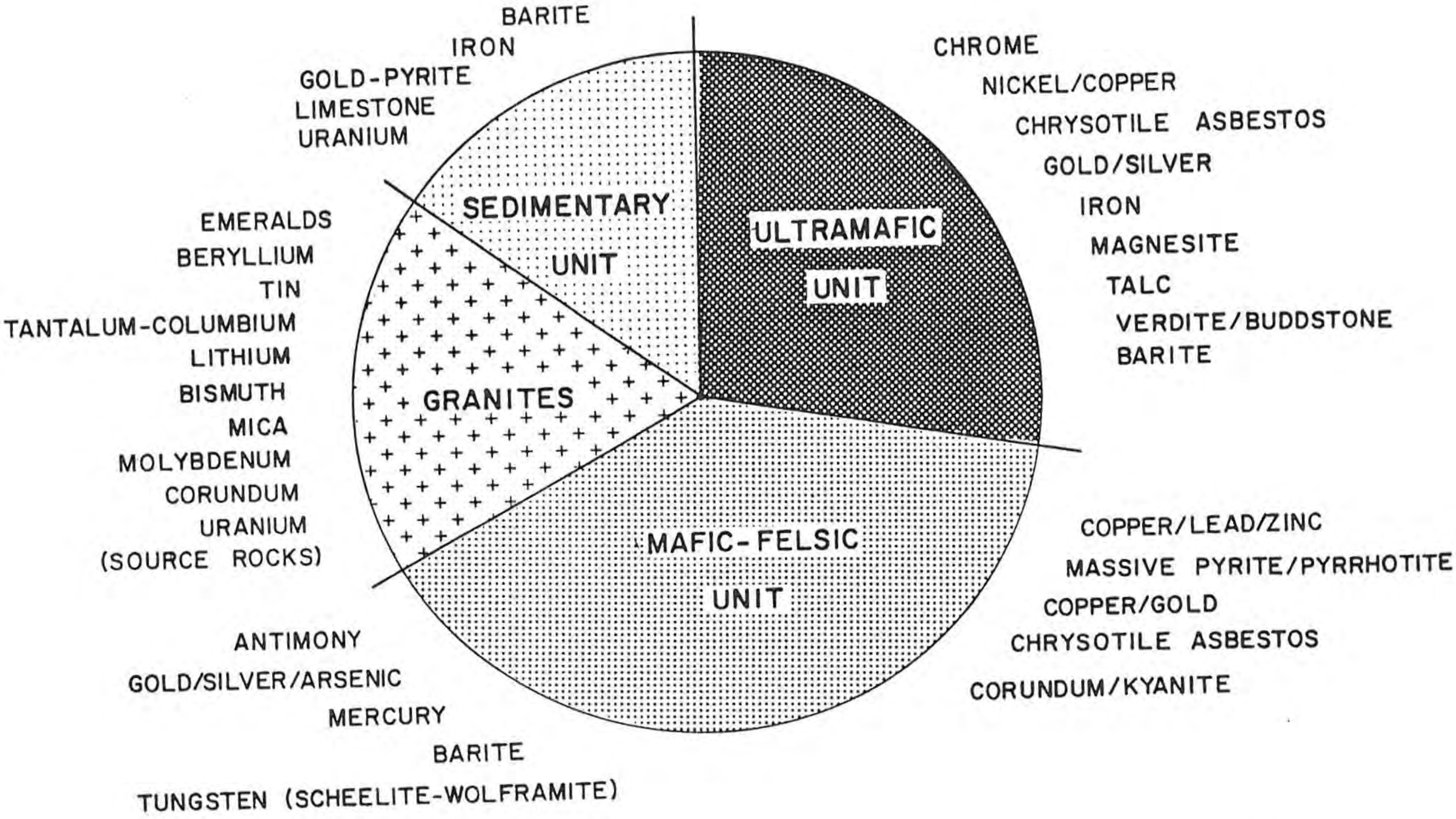
2.4.1 Mineralization Potential of the Archaean Granite-Greenstone Areas

What remains of Archaean rocks in the Kaapvaal Craton and other parts of the world can be divided into a lower, green-schist to amphibolite grade component, consisting of ultramafic to mafic and felsic volcanic with sedimentary rocks - all of which generally constitute the greenstone assemblages and a higher grade granite-gneiss component. The granite-gneiss of Archaean assemblages is generally very poorly mineralized. (Pretorius, 1976)

The Greenstone components on the other hand are generally highly mineralized and normally represent high priority target areas for mineral exploration. A fairly comprehensive summary of potential mineralization is presented as Figure 8. The subsequent high grade metamorphism and shearing to which the greenstone remnants in Southern Venda (which fall within the southern marginal zone of the Limpopo Province) have been subjected, will obviously have affected any mineral deposits present and this will make the search for most types of mineralization more difficult. However, the potential in particular for gold, nickel-copper and antimony deposits in the greenstone remnants should still be good, whilst that for shear-related (asbestos and talc) and metamorphic mineralization (such as graphite, garnet, kyanite-sillimanite and corundum), could in fact be enhanced. Later stage epithermal type mineralization could be present as a result of post Limpopo re-activation of major shear zones, whilst volatile elements such as mercury may well have been dispersed by the Limpopo event and later tectonic activity. Finally a potential for nickel laterites is suggested over the greenstone remnants in south central Venda, along the sloping, high rainfall area between the Pietersburg Plateau and the southeastern Lowveld.

2.4.2. Mineralization Potential of the Limpopo Province

Whilst the Limpopo Belt is generally accepted as being an intracratonic mobile belt (Barton, 1981) there is little consensus on the tectonic processes which contributed to its formation. Whatever the mechanisms involved in its initial formation, the Limpopo event was associated with strong compressive forces and high grade metamorphism towards the end of its evolution. Most models which attempt to explain it's origin resort to imbricate thrusting or rotation of crustal wedges to explain the presence at surface of extremely high grade metamorphic rocks and such a complex pattern of juxtaposed structural domains. This final compressional phase



MINERALISATION RELATED TO ARCHAEAN LITHOLOGIES

Fig. 8
(Anhaeusser 1981)
6/89 TV 103

and associated metamorphism would have overprinted much of the earlier geology and mineral deposits and as a result, though potential mineralization associated with intracratonic rift zones is shown as Table 3, it is more likely that the types related to continent-continent collision (shown as Table 4) would prevail. However, several influencing factors should be borne in mind when discussing mineralization in the Limpopo Belt, including the following:

i) A great deal of detailed geological, structural, geophysical and geochemical work still needs to be done before a better understanding of the area can be obtained.

ii) As a result of high grade metamorphism and intense shearing, the character of ore deposits which may have been present will have been changed.

iii) As a result of a prolonged period of uplift and erosion of the Limpopo Belt that must have occurred (to explain the high metamorphic grade and the observations that upper Transvaal group and Soutpansberg group sediments were derived largely from a Limpopo provenance), it is likely that most upper crustal material and mineralization has been removed by erosion. Small portions of upper level crust may be preserved in rotated crustal slices or thrust slices and thus a very detailed examination of metamorphic differences across faults and domain boundaries may guide one to upper level crustal remnants which could host mineralization.

iv) The continued re-activation of some strike slip faults until post Karoo times and the existence to this day of several thermal springs in the area and hot ground waters within the Messina Copper Mine, point to an excellent potential for post Limpopo event epithermal and hydrothermal mineral deposits of gold, copper and silver.

TABLE 3

(Mitchell & Garson 1981

Mineral deposits characteristic of hot spot and collision-related intracontinental rifts and aulacogens.

Tectonic setting	Association	Genesis	Type of deposit/ metals	Examples
	Carbonatites	Magmatic–metasomatic	Apatite + vermiculite, Cu–U–baddeleyite, pyrochlore; rare earth ± strontianite	Palabora, S Africa (Proterozoic) Oka, Canada L Cretaceou Chilwa, Kangankunde, Malawi L Cretaceous
	Undersaturated alkaline complexes	Magmatic	Apatite	Baikal rift (U Palaeozoic); Oslo Graben (Permian)
Intracontinental rifts and aulacogens	Kimberlites associated with carbonatites	Magmatic	Diamonds	Tanzania (Mesozoic?) and S Africa (Proterozoic and Cretaceous)
	Basic–ultrabasic intrusions	Magmatic	Cr–Ni–Pt–Cu	Great Dyke, Zimbabwe (L Proterozoic); Bushveld, S Africa (L Proterozoic); Duluth Complex, Minnesota (U Proterozoic)
	Biotite granite	Magmatic–meteoric hydrothermal	Porphyry Mo	Glitrevann, Oslo rift (Permian)
	Shales, commonly calcareous and bituminous, above unconformity and beneath evaporites	Diagenetic or early epigenetic meteoric hydrothermal	Stratabound Cu	Atlantic margin Africa (Aptian); Kupferschiefer Europe (Permian); Zambia, Zaire (U Proterozoic)
	Shales, commonly bituminous, within terrigeneous sequence	Diagenetic or early epigenetic meteoric hydrothermal	Strarabound Ag-Pb–Zn 'Sullivan type'	Sullivan Mine, Br. Columbia (U Proterozoic); Mt Isa, Queensland (U Proterozoic); McArthur River (mid-Proterozoic); Gamsberg S Africa (U Proterozoic)
	Terrigeneous clastics	Diagenetic or epigenetic	Stratabound sandstone type U	Athapuscow aulacogen Canada (M Proterozoic)
Intracontinental rifts and aulacogens	Magnesian carbonates	Chemical sedimentary	Evaporites	Zechstein (Permian)
	Lacustrine brines and evaporites	Sedimentary	Na and K salts, magnesite and phosphate	E. Africa Rift lakes (Quaternary)
	Veins in black shale (Benue Trough)	Magmatic–connate hydrothermal	Pn–Zn veins	Benue Trough and Amazon fracture zone (Cretaceous)
	Veins in faults and lineaments	Meteoric, magmatic and connate hydrothermal	F veins	W North America (Cenozoic); Illinois (U Cretaceous)
	Veins in granite and basement	Epigenetic hydrothermal	Mo–quartz veins Ag Co–Ni arsenides	Oslo Graben (Permian); Keweenawan Rift (U Proterozoic)

TABLE 4 (Modified after Mitchell & Garson 1981)

Mineral deposits characteristic of continental collision belts

Tectonic setting	Association	Genesis	Type of deposit/ metals	Examples
Remnant basins	Black shale	Biochemical-chemical sedimentary	Phosphorite	Nevada (L Carboniferous)
Suture zones	Obducted ophiolite	Submarine exhalative sedimentary sulphide	Stratiform Cyprus-type Cu, Fe	Betts Cove, Newfoundland (Ordovician)
	Obducted ophiolite	Magmatic	Podiform Cr	Semail, Oman (Cretaceous)
	Metamorphic	Meta-magmatic	Jadeite, nephrite	Burma (pre-Albian)
Hinterland margins	Regional metamorphism, pegmatites or nepheline syenites	Metasomatic	Gemstones	Mogok, Burma, (Tertiary); Hunza, Kashmir?
Foreland thrust belts	Tectonically emplaced shelf rocks		Deposits of continental shelf	
	"S-type" peraluminous granites	Magmatic–meteoric hydrothermal	Sn, W	Higher Himalayas (Tertiary); SW England (L Permian); Main Range Malaysia (L Triassic)
Foreland thrust belts	"S-type" leucogranite	Magmatic–meteoric hydrothermal	U	Massif Central, France (Devonian); Rossing, Namibia (U Proterozoic)
Foreland basins	"Molasse"	Diagenetic or epigenetic	Stratabound sandstone-type U (Cu, V)	Siwaliks, India and Pakistan (U Tertiary)
	"Molasse"	Chemical sedimentary	Evaporites	Ebro Basin, Spain (Tertiary)

v) Within the calcareous horizons which abound in the Gumbu Formation, several types of hydrothermal mineralization may have been precipitated. Included in these would be Mississippi type lead-zinc deposits (possibly from de-watering of the Soutpansberg trough) and skarn type gold and tungsten mineralization. Gold in association with graphite may also occur in this formation as may nickel and barytes.

2.4.3 Mineralization Potential of the Proterozoic Schiel Complex

The alkaline intrusive rocks of the Schiel Complex are difficult to relate directly to any major tectonic events, though dating carried out on the complex so far suggests intrusion between 2 600 and 2 150 Ma, which is post Limpopo in age and pre-Soutpansberg. It would seem likely that the alkaline intrusive formed as a result of late Limpopo Event tectonics and metamorphism. The position of the Schiel Complex at the intersection of the Kranskloof Lineament and the extension of the Siloam fault, near the Kudus River lineament, strongly suggests that its intrusion was associated with re-activation of these fractures. Alternatively an intracontinental hot spot could have caused its development. In either event, apatite, magnetite, vermiculite, pyrochlore and REE, associated with alkaline rocks and carbonatites would be expected to occur (and indeed the first three of these are known to occur in the complex). In addition, hot spot activity would be expected to give rise to the development of titanium, tungsten, fluorite, molybdenum, silver and uranium mineralization associated with anorogenic granites (the Palmietfontein and Entabeni granites which are of similar age to the Schiel complex may be ideal targets for investigation). Younger intrusives are also frequently responsible for remobilization and concentration of hydrothermal type deposits including gold.

2.4.4 Mineralization Potential Associated with the Proterozoic Soutpansberg Group

The Soutpansberg Group formed at a time when significant ore deposits were forming worldwide (2,0 Ga to 1,7 Ga) including the unconformity related uranium deposits (e.g. Jabiluka and Key Lake) and Red Bed copper deposits (e.g. White Pine) in America and the large volcano-sedimentary Pb/Zn deposits of MacArthur River and Mt Isa in Australia. In addition both the Keeweenawan and Soutpansberg rifts are associated with elevated gravity readings and both contain widespread copper mineralization. This suggests that further exploration work is warranted in the Soutpansberg.

The Soutpansberg group rocks are thought to have been deposited in a trough which may have been formed as an aulacogen (Jansen, 1975) or a yoked basin resulting from intra-continental rifting. The absence of recognizable marine successions is a disadvantage in terms of mineralization potential. Nevertheless this succession (which is thought to have formed between 2 000 and 1 700 Ma) formed at one of the most productive periods of mineral development on earth and must have potential for several types of mineral deposits. A list of the more significant potential mineral deposits is given in Table 5. However, some are so relevant and applicable to the Soutpansberg, that they deserve further comment.

Perhaps the most important type of deposits associated with both this period in the earth's history and this type of tectonic setting, are the massive sulphide deposits. These deposits are generally large, with reserves frequently in excess of 100 million tonnes. Both volcanogenic hosted and sediment hosted varieties may well have developed within the Soutpansberg Succession, although the chances of sediment hosted deposits occurring are greater. Most of the worlds largest Pb-Zn-Ag and Cu-Pb-Zn sediment hosted massive sulphide deposits are associated with the marginal taphrogenic faults of epicratonic re-entrants, which may display many of the characteristics of aulacogens. These mantle tapping marginal faults (such as those in the Soutpansberg which are thought to have been conduits

TABLE 5 MINERALIZATION RELATED TO INTRACONTINENTAL RIFTS AND AULACOGENS

(Modified after Michell & Garson 1981)

Intracontinental rifts and aulacogens	Shales, commonly calcareous and bituminous, above unconformity and beneath evaporites	Diagenetic or early epigenetic meteoric hydrothermal	Stratabound Cu	Atlantic margin Africa (Aptian); Kupferschiefer Europe (Permian); Zambia, Zaire (U Proterozoic
	Shales, commonly bituminous, within terrigeneous sequence	Diagenetic or early epigenetic meteoric hydrothermal	Strarabound Ag-Pb-Zn 'Sullivan type'	Sullivan Mine, Br. Columbia (U Proterozoic Mt Isa, Queensland (U Proterozoic); McArthur River (mid-Proterozoic); Gamsberg S Africa (U Proterozoic)
	Terrigeneous clastics	Diagenetic or epigenetic	Stratabound sandstone type U	Athapuscow aulacogen Canada (M Proterozoic)
	Magnesian carbonates	Chemical sedimentary	Evaporites	Zechstein (Permian)
	Lacustrine brines and evaporites	Sedimentary	Na and K salts, magnesite and phosphate	E. Africa Rift lakes (Quaternary)
	Veins in black shale (Benue Trough)	Magmatic-connate hydrothermal	Pn-Zn veins	Benue Trough and Amazon fracture zone (Cretaceous)
	Veins in faults and lineaments	Meteoric, magmatic and connate hydrothermal	F veins	W North America (Cenozoic); Illinois (U Cretaceous)
	Veins in granite and basement	Epigenetic hydrothermal	Mo-quartz veins Ag Co-Ni arsenides	Oslo Graben (Permian); Keweenawan Rift (U Proterozoic)

for the upwelling Sibasa Formation basalts (Bristow, 1986)), are believed to be highly significant as channelways for mineralized hydrothermal fluids and solutions.

Within these large troughs, smaller basins are needed as it is proposed that restricted flow conditions such as prevail in a small basin (Large, 1983) may result in the formation of concentrated brines and enhance reducing conditions which would assist in metal precipitation. Frequently the base of successions in the local basins would be conglomeratic and in deposits such as Sullivan in Canada, abundant boron (in the form of tourmaline) is present in the footwall. The fact that there was a later stage of volcanic activity in the Soutpansberg succession when the Nzhelele Formation lavas and pyroclastics were deposited above hundreds of metres of Wyllies Poort and Fundudzi Formation sediments, means that sufficient thermal energy would have been available from the active magma chamber, to enhance exhalative activity.

To locate deposits such as these, attention needs to be focussed on major marginal faults and more detailed attention focussed on areas adjacent to other major cross-cutting faults such as the Siloam fault where the potential for smaller, local basin development is best. Aeromagnetic and seismological investigations as well as detailed gravity surveys would be useful in locating suitable basins and possibly even economic mineral deposits. The argillaceous horizons of the Nzhelele Formation would be excellent targets for these deposits.

Unconformity-related uranium deposits occur in both Canada and Australia and are believed to have formed between 1,9 Ga and 1,6 Ga. They have most frequently developed close to unconformities between early and mid Proterozoic sedimentary successions, or between Archaean and Proterozoic successions. The mineralization in these deposits usually occurs in veins hosted by carbonaceous or pyritic shales, cherts or BIF horizons.

Red Bed type copper deposits and Olympic Dam type uranium-copper mineralization are also worth looking for in the Soutpansberg succession.

2.4.5 Mineralization Potential Associated with Karoo Sequence Rocks

From the Permian until the Jurassic, large epicontinental basins existed into which Karoo sediments were being deposited. In these basins fairly extensive coalfields and carbonaceous shales developed. At present the coal resources of Venda are being exploited at Tshikondeni in the north-east of the country but there are still large areas of basal Karoo Sequence sediments which are not being exploited.

In addition heavy mineral sands would also be expected to have accummulated in places and are likely to contain ilmenite, magnetite, garnet, zircon, rutile and monazite. Channel fill uranium deposits may also have accummulated and epigenetic uranium deposits of both the hypogene and supergene types could also be expected to occur (Hutchison, 1983). Potential also exists for the development of uraniferous black shales and Mississippi type deposits, the latter whilst commonly hosted in carbonate rocks, can be hosted in other sediments. Associated with Mississippi type Pb-Zn deposits one could hope to find fluorite and barite developments as well.

The potential also exists for diamonds associated with kimberlites and for alkaline intrusives with their associated rare earth elements (REE), tin and tungsten potential. The Jurassic syenites which have intruded south of Malala Drift and close to the northern Venda border are of this type and should be thoroughly checked. The late to post Karoo intrusive olivine dolerite and picrite sills which intrude the base of the Karoo Sequence in northern Venda, have a good potential for Norils'k type nickel-copper-platinum mineralization. The sills are of a similar age, thickness and composition to those at Norils'k.

3. THE METHODS AND RESULTS OF THIS STUDY

3.1 The Approach and Techniques Used

3.1.1. Sample Collection, Treatment and Analysis

This part of the project was handled totally by Cycad, De Beers and Anglo American Research Laboratories Staff. STK had no input or control on sample distribution decisions and this is to be regretted, as much more powerful computerized statistical techniques could have been applied if sample distribution had been more systematic and complete.

The geochemical soil samples were collected between October 1985 and November 1988 at sites close to those sampled by Cycad (Pty) Ltd for heavy element concentrates. The vast majority of the geochemical samples for this study were loam samples and the following procedure was adopted in taking them:

i) They were taken at a depth of 10 cm below surface using wooden instruments to avoid metal contamination.

ii) Approximately 4 kg of material was collected at each sample site.

iii) The material was dried then powdered using a ceramic pestle and mortar.

iv) The material was sieved to -80 mesh in a nylon mesh sieve.

v) Approximately 150 g was sent to the Anglo American Research Laboratories, for chemical analysis.

Once the material was received by the Anglo American Research Laboratories at Crown Mines, it was milled with a polystyrene/wax binder and pressed into brickettes. It was then analysed using an ARL 72000S multi channel spectrometer, which was fitted with individual element monochromators for the 22 trace elements. The rated accuracy for trace elements ranges from 1 ppm detection limit to 20 ppm detection limit at one standard deviation from the mean. Detection limits would obviously increase significantly for samples at 2 or even 3 standard deviations from the mean. Elements with poorer detection limits include Sb, Ba, Sn, W, Ta and Te and for this reason all of these with the exception of barium, (where concentrations are very high, being several hundred ppm compared with a detection limit at one standard deviation of 20 ppm) have been excluded from plotting in this study. The full list of 36 elements for which each sample was analysed is attached as Table 6. The determination of major elements was carried out on the same machine using an energy dispersive system and these results should be considered as semi-quantitative (E. Baumgartner pers. comm., 1989).

3.1.2 Processing of the Data

The first useable analytical results were received by STK, on floppy disks during January 1988 and subsequently at intervals until the end of August 1988 when it was decided to process all existing information and leave the remainder outstanding. Co-ordinates for sample sites were not made available to STK and thus the first step was to co-ordinate sample points. The zero datum for the co-ordinate system used in this study was taken as the intersection between latitude 22°15'S and longitude 31°15:E (see fig 9). The digitization was initially carried out by Advanced Technical Computing of Pretoria, as STK had no digitizing facilities at that stage. Once the co-ordinated sample points were plotted on sepia film, they were superimposed on 1:50 000 geology sheets. Some of these sheets were available on open file from the Geological Survey in Pretoria, whilst others were available only in original form for use at the Pietersburg Offices of the Geological Survey. Finally sheets covering the Bandelierskop and Levubu areas which had been mapped as part of a PhD thesis by Dr M.C. du Toit (1979) were available at the Rand

TABLE 6: The elements for which XRF data is available.

Asterisks denote data that has been plotted.

1. Uranium*
2. Thorium
3. Bismith
4. Lead*
5. Tungsten
6. Tantalum
7. Barium*
8. Tellurium
9. Antimony
10. Tin
11. Molybdenum*
12. Niobium*
13. Zirconium*
14. Yttrium*
15. Strontium
16. Rubidium
17. Selenium
18. Arsenic*
19. Zinc*
20. Copper*
21. Nickel*
22. Cobalt*
23. Iron
24. Manganese
25. Chromium
26. Vanadium
27. Titanium
28. Calcium
29. Potassium
30. Sulphur
31. Phosphorus
32. Silicon
33. Aluminium
34. Magnesium*
35. Sodium
36. Fluorine*

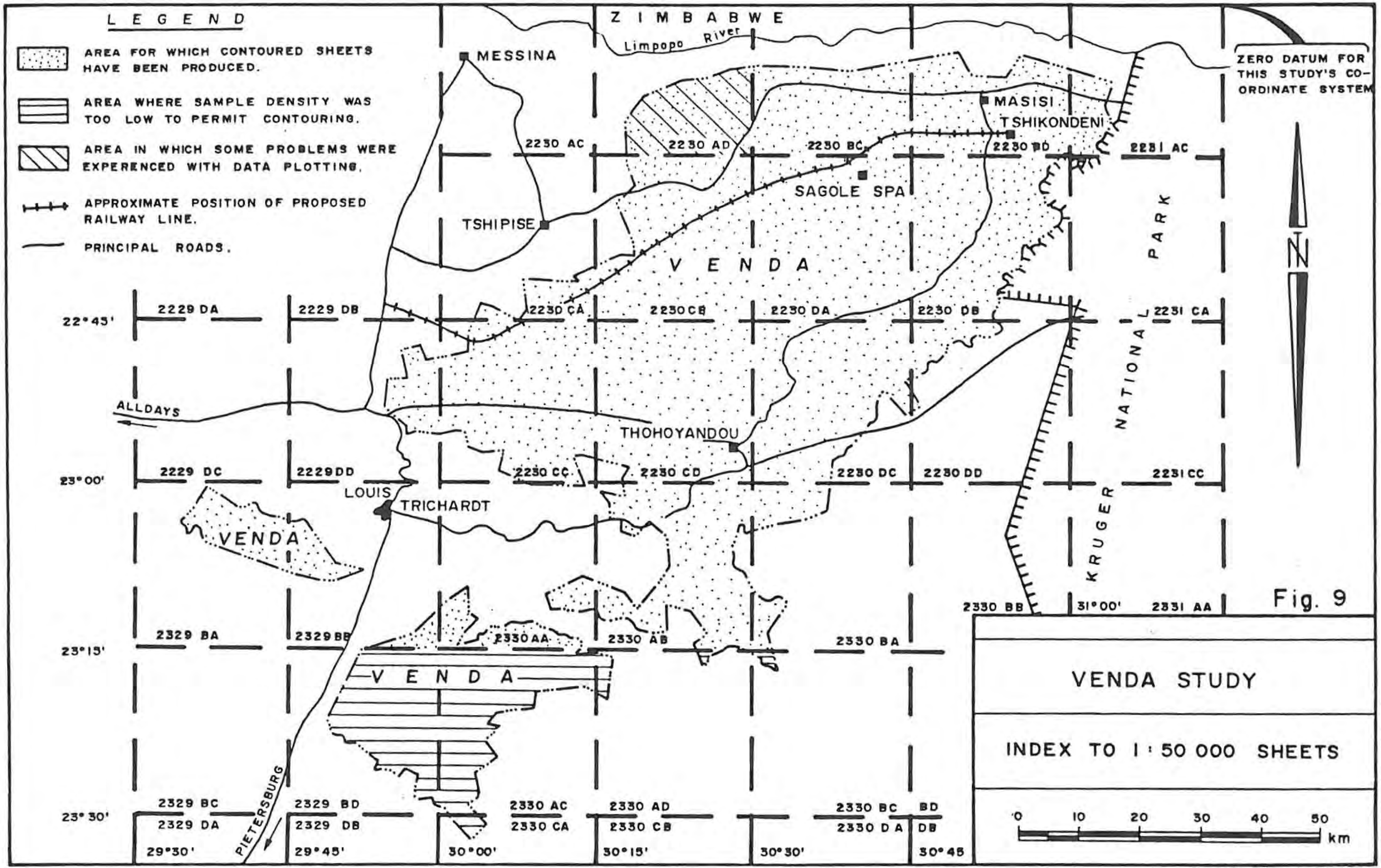


Fig. 9

VENDA STUDY

INDEX TO 1:50 000 SHEETS

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Afrikaans University. Despite the difficulties in locating and using all the 1:50 000 geological sheets, it was considered that the information so obtained would be much more meaningful than that available on the published 1:250 000 sheets, produced by the Geological Survey. A unique three letter code, modified from that used by the Geological Survey was devised and used to allocate geological data.

The Computer System and Software Used

This body of information was entered into the primary data file of a custom made computer programme. The computer used was an IBM Personal System 2 Computer, model 60. This has a 40 megabyte hard disk on board and accepts a 1,4 megabyte 3 1/2" diskette in the disk drive. Unfortunately the operating system used was the IBM/Microsoft Disc Operating System 3.3 which limits the readily accessible Random Access Memory to 640 kilobytes. This meant that statistical manipulations could not be carried out with more than approximately 2000 values. This precluded the performance of global statisitics on the whole population but was not a limiting factor when performing statistics on specific lithological groupings.

The software programme which was custom made for this project by Johan Strassheim and Associates of Pretoria, consisted of a base module written in PDS Adept with a data input section, main menu and file manipulation and reporting capabilities. Attached to this is a Statistical Graphics package called Statgraphics (version 2.6), which is powerful but not particularly designed for geological applications. Numerous problems were encountered with various aspects of the statistical graphics package, only some of which were able to be corrected. Also attached to the base module is a versatile and useful modelling programme called Model Maker. This is locally produced by Advanced Technical Computing of Pretoria and was adequate for the contour plotting that was undertaken. The contouring procedure requires a triangulation system to be designed over the data points and the operator can manipulate individual triangles to allow simulation of regional strike and grain if required. Once the array of triangles has been constructed over a sheet area, then data is entered for each of the elements, one at a time, and a contour plot can be made, element by element in this way. A Roland DPX 3300 flat bed A1 plotter was coupled to the IBM computer and used for later digitization and plotting.

Selection and Treatment of the Data Set

An example of the input data menu is shown as Fig. 10. From this it can be seen that an identification number and label as well as the co-ordinates and map reference number can be inserted along with the rock and soil types. In addition to this and because the overall data base incorporated both loam and stream sediment samples, a sample type can be entered to distinguish between these types. A major element flag facility exists to mark analyses where major element totals are unsatisfactory so that these can be excluded if required. The geological soil and sample type information, once entered manually, was integrated with co-ordinate and analytical data and any ratio's or combinations of elements required could be calculated and attributed to the results functions. The soil types allocated were taken from a series of maps prepared by Loxton, Hunting and Associates in 1970 but this was unfortunately incomplete, as the boundaries of Venda have changed since the survey was conducted.

Once it was decided to close the data set in August 1988, all incomplete entries were excluded and a final set of samples with analytical, co-ordinate, sample and rock type data was established. This meant the exclusion of 641 samples (11,2%) because of missing analytical results, and the further exclusion of 580 samples (10%) which were stream sediment samples as opposed to loam samples. By grouping some of the data using geological criteria it was possible to create 12 groupings with statistically significant populations, yet which still retained sufficient unifying geological characteristics in terms of their suitability as targets for various types of mineralization. Thus merging the calcareous rocks of the Gumbu Formation with the predominantly orthoquartzitic gneisses of the Malala Drift Formation was avoided, because the types of mineralization one could expect in each would not be the same. The twelve lithological groupings finally selected are shown as Table 7 and their

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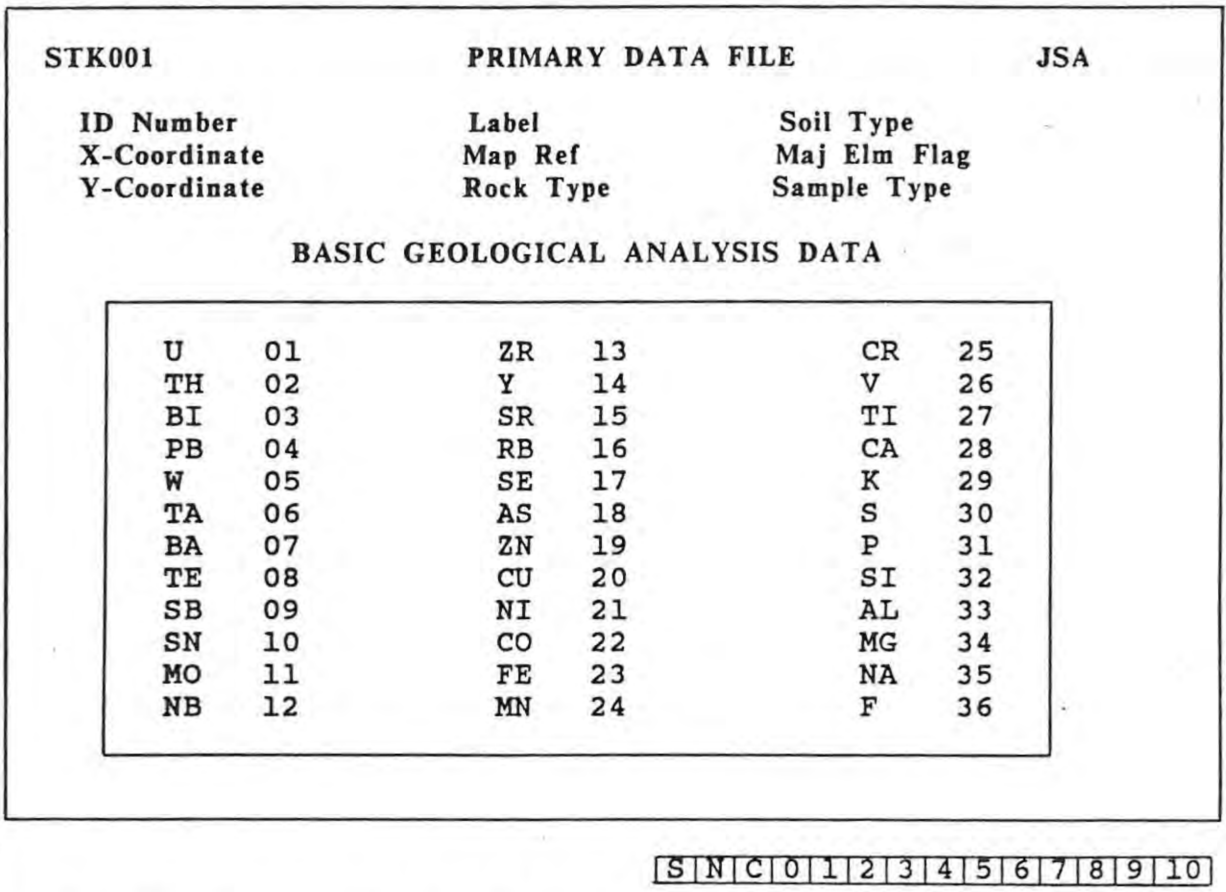

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STK001                      PRIMARY DATA FILE                     JSA

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  X-Coordinate               Map Ref              Maj Elm Flag
  Y-Coordinate               Rock Type            Sample Type

                   BASIC GEOLOGICAL ANALYSIS DATA

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      TH    02            Y     14            V     26
      BI    03            SR    15            TI    27
      PB    04            RB    16            CA    28
      W     05            SE    17            K     29
      TA    06            AS    18            S     30
      BA    07            ZN    19            P     31
      TE    08            CU    20            SI    32
      SB    09            NI    21            AL    33
      SN    10            CO    22            MG    34
      MO    11            FE    23            NA    35
      NB    12            MN    24            F     36

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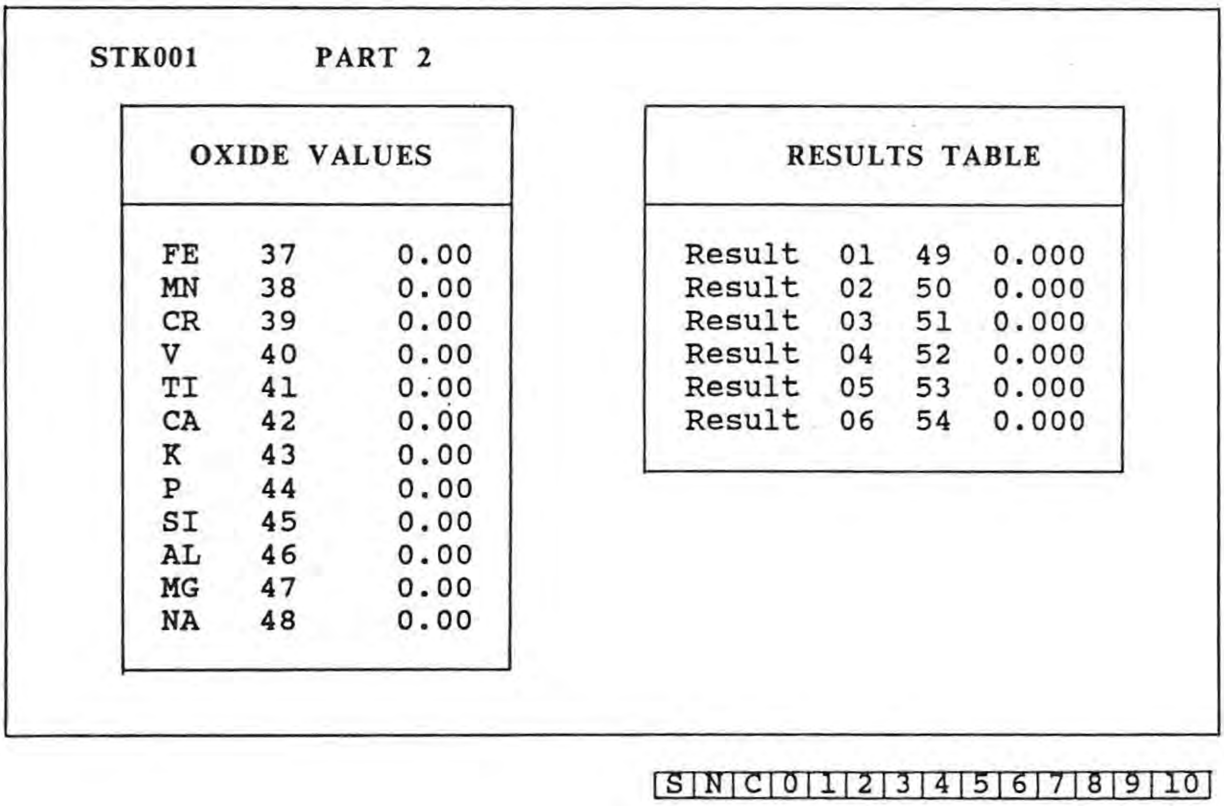

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STK001        PART 2

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  MN    38      0.00       Result  02   50   0.000
  CR    39      0.00       Result  03   51   0.000
  V     40      0.00       Result  04   52   0.000
  TI    41      0.00       Result  05   53   0.000
  CA    42      0.00       Result  06   54   0.000
  K     43      0.00
  P     44      0.00
  SI    45      0.00
  AL    46      0.00
  MG    47      0.00
  NA    48      0.00

                          [S|N|C|0|1|2|3|4|5|6|7|8|9|10]
```

DATA INPUT MENU FROM S.T.K. CUSTOM MADE SOFTWARE PROGRAMME

FIG 10

VENDA STUDY

TABLE 7: A list of the twelve lithological groups selected for study; individual elemental thresholds, means and other statistical data have been determined for soils overlying these rock types.

1. Swazian - Goudplaats Gneiss. (746)

2. Swazian - Beit Bridge Complex - Malala Drift Formation rocks. (26)

3. Swazian - Beit Bridge Complex - Gumbu Fm calc silicates. (53)

5. Vaalian - Schiel Complex syenites and granites. (106)

5. Mokolian - Soutpansberg Group - Sibasa Fm Basalts. (349)

6. Mokolian - Soutpansberg Group - Wylliespoort Fm sediments (sst and qtzite). (489)

7. Mokolian - Soutpansberg Group - Nzhelele Fm rocks. (220)

8. Mokolian - Soutpansberg Group - Fundudzi/Sibasa/ Tshifhefe and Mabiligwe Fm Sediments. (232)

9. Permian/Triassic - Karoo Sequence Sediments. (960)

10. Jurassic - Karoo Sequence Letaba Fm basalt. (1450)

11. Quarternary - All alluvial, sand, scree and float deposits. (835)

12. All dolerite and diabase dykes and sills. (302)

NOTE: The numbers in brackets at the end of each lithology represent the population of loam samples taken over the respective rock type.

sample populations are given in brackets next to each. The outstanding 580 samples that were not included in the final data for study, were spread over 100 lithologies and the individual sample populations were statistically insignificant being below 25 in all cases. These samples were thus excluded leaving a final useable data set over the twelve selected lithologies of 5768 samples.

This entire sample set was available for contouring purposes though a small proportion had to be left out where sample distribution was too sparse to result in meaningful contouring. With the bulk of the data being presented in contour form the next stage was to select some of the data as anomalous.

The Statistical Approach Used

Because of the irregular sample distribution of this survey it was decided not to apply averaging and smoothing techniques such as trend surface or moving average analyses, as these require even distribution of data to avoid artifically distorted surfaces (Doveton and Parsley, 1970). Thus simple contouring of the data was undertaken as a first step in presenting the information in a useful way. In addition, as the major objective of this study is to accentuate anomalous element concentrations rather than to smooth them out, a more classical approach has been used, with anomalous data considered as that greater than two standard deviations above the mean. This approach is felt to be justified for three reasons, firstly because the data had already been allocated to lithological groups as recommended by Hawkes and Webb (1962) and one does not need to recognize or identify the different populations corresponding to various lithologies (an exercise which is best achieved by graphical interpretation). Secondly because the survey is a regional one as opposed to a detailed follow-up survey over an area of known mineralization, the problem is not in generating sufficient anomalies but more in reducing the total number of anomalies to be investigated in such a way that most real anomalies are included and most false anomalies excluded and previous studies have revealed that a threshold of mean plus two standard deviations should include most of the significant anomalies (Rose, et.

al., 1979). Thirdly the suitability of the threshold value used, i.e. two standard deviations above the mean, is amply demonstrated by the graphs on Figures 11 to 14 which are of data from this study. Such results could only be expected however, where populations are reasonably homogeneous and have already been divided into lithological units as has happened in this study. At this stage statistics were calculated for each of 24 elements over each of the twelve lithological groupings.

The Selection of Elements and Sheets for Plotting

The 24 elements chosen for statistical analysis were those considered economically significant as well as having reliable analytical results. The statistical data obtained in this way are summarized as Table 8.

The next step involved the selection of fourteen elements, considered to be of particular economic significance for further treatment and plotting purposes. The sheets chosen for plotting were those where sufficient sampling data existed for meaningful contouring, though some sheets such as 2230 DD (with only 35 samples) and 2230 DB (with only 111 samples) were plotted despite being marginal and not particularly satisfactory. This was done in an effort to make the study as wide ranging and useful as possible. In this way 18 out of a potential 23, 1:50 000 sheets were selected for plotting. Which of the selected 14 elements should be plotted for each sheet, was determined by the number of anomalous points occurring on each sheet. The cost in time and materials involved in plotting each sheet as well as the overall aim of stressing the areas of greatest indicated potential were the reasons for limiting the number of elements plotted for each of the eighteen chosen sheets. The philosophy that regional scale soil surveys of the type discussed here, should not be expected to locate actual orebodies, but should rather be used as a guide to areas of greater or lesser mineral potential (Govett, 1983) is adhered to in this study. In this way 81% of all anomalies indicated were plotted and these reveal the areas of greater potential. The final list of sheets plotted and the number of element overlays per sheet is summarized as Table 9. The distribution of 1:50 000 sheets over Venda is shown as Fig. 9, so the extensive coverage and scope of this study can be appreciated.

Figure 11. Niobium Content of Soils
over Sibasa Formation Basalts in Venda.

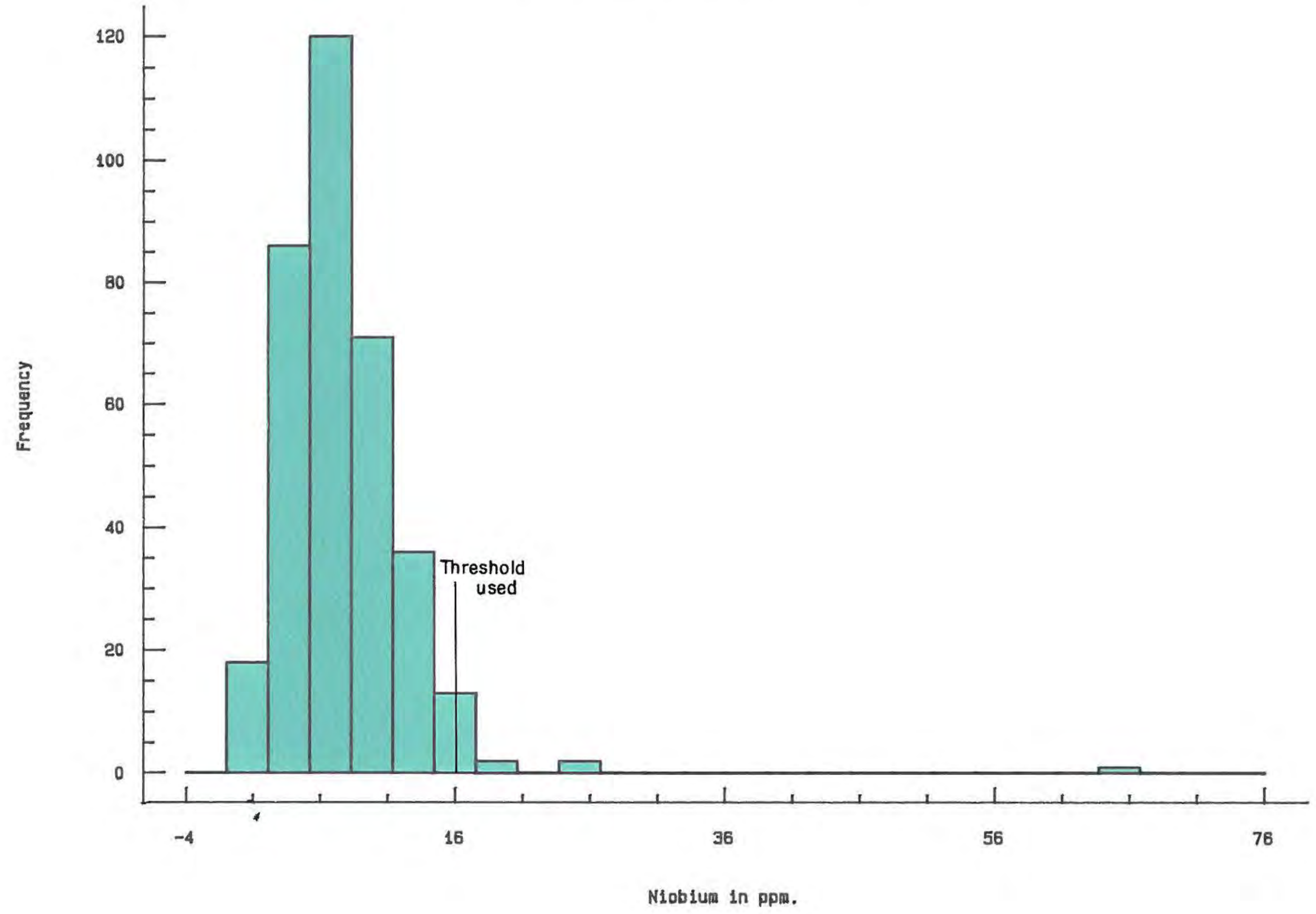


Figure 12. Niobium Content of Soils

over Letaba Formation Basalts in Venda.

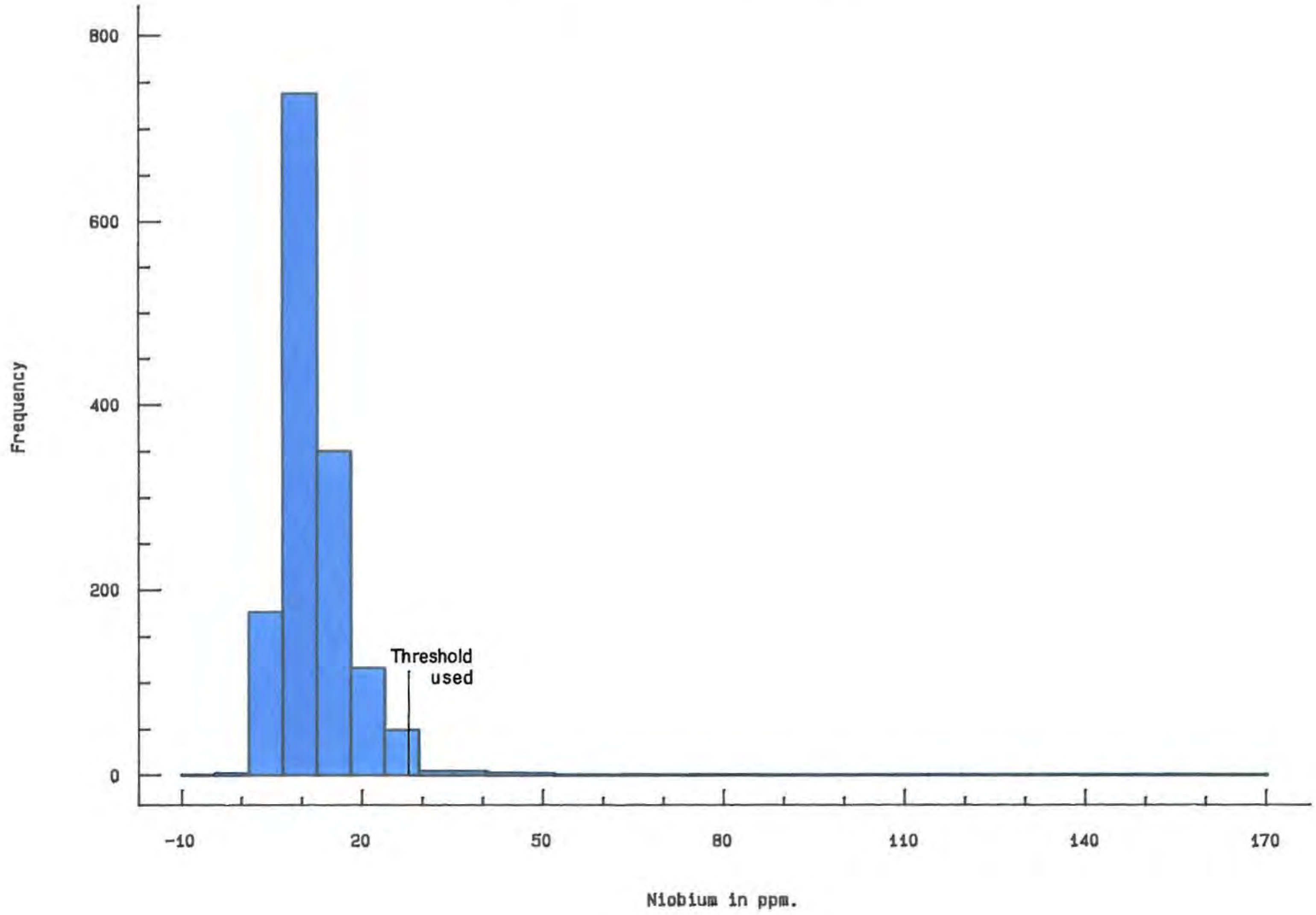


Figure 13. Copper Content of Soils

over Letaba Formation Basalts in Venda.

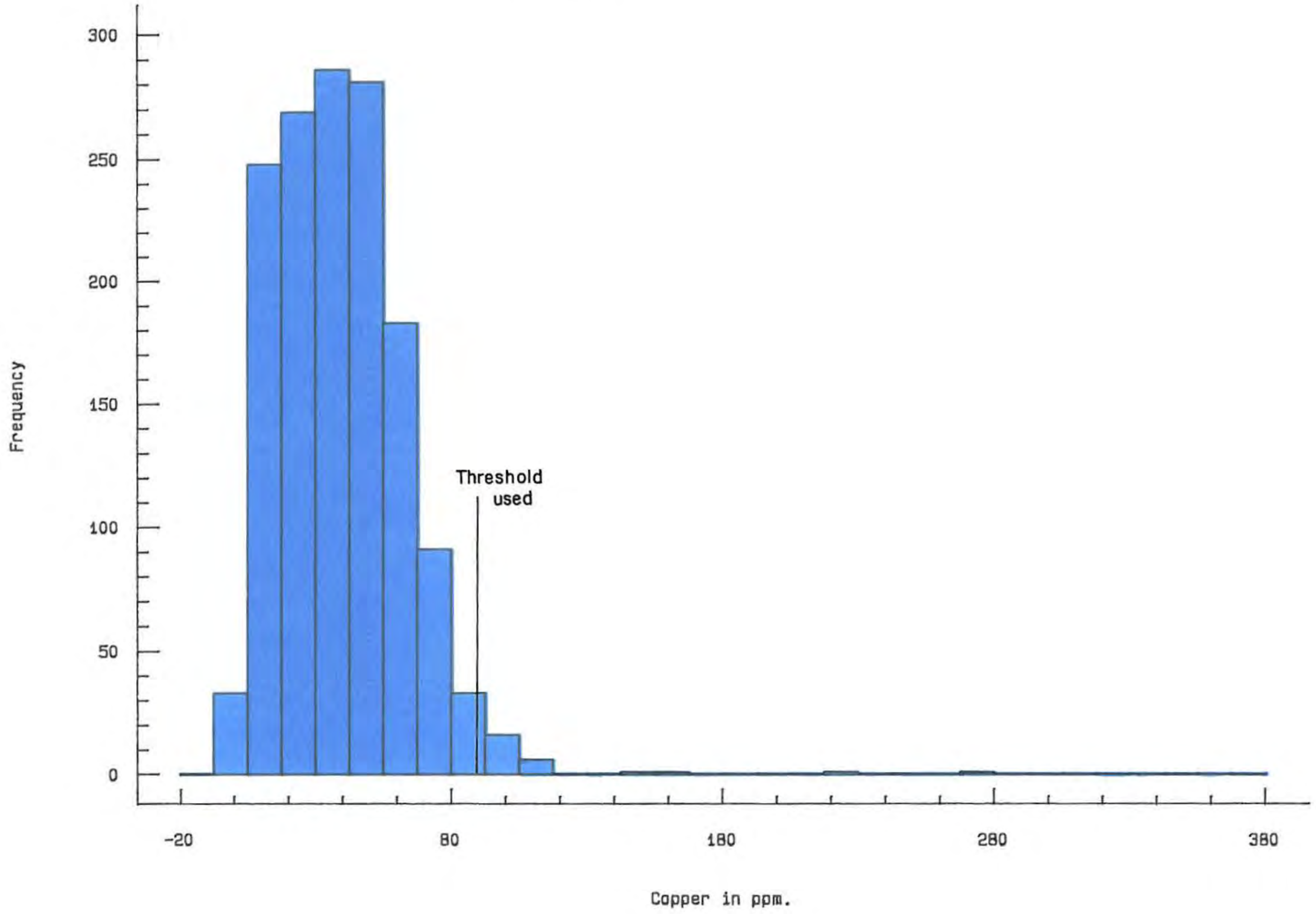


Figure 14. Zinc Content of Soils over

Dolerite and Diabase Intrusives in Venda

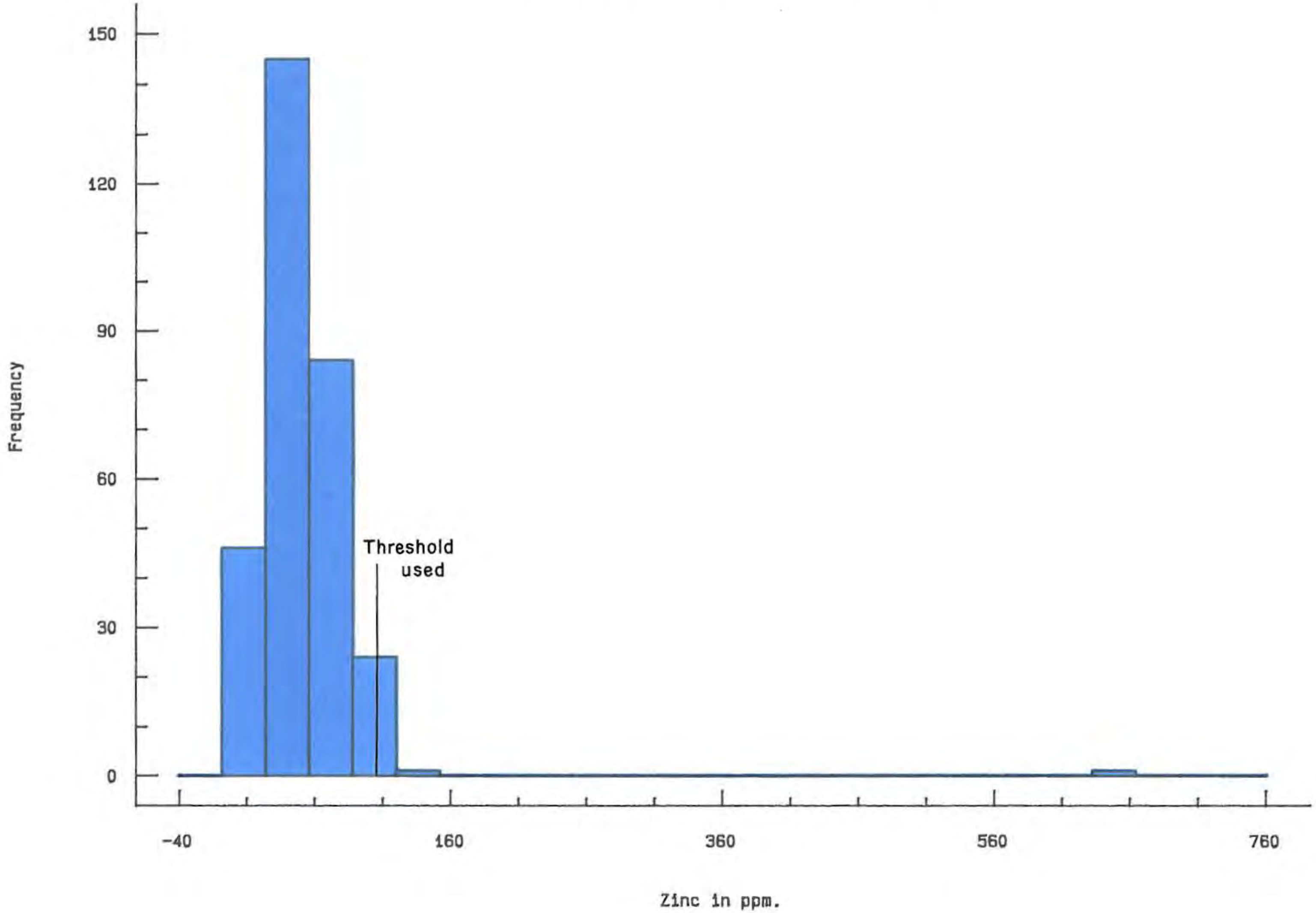


TABLE 8 SUMMARY OF RESULTS OF THIS STUDY

ARCHAEAN			BEIT BRIDGE COMPLEX						VAALIAN			SOUTPANSBERG GROUP												KAROO SEQUENCE						QUARTERNARY			DOLERITE			
GOUDPLAATS			MALALA DRIFT			GUMBU FORMATION			SCHIEL COMPLEX			SIBASA FORMATION			WYLLIESPOORT			N ZHELELE			OTHER SEDIMENTS			KAROO SEDIMENTS			LETABA FORMATION			ALLUVIUM			INTRUSIVES			ELEMENT
X	T	M	X	T	M	X	T	M	X	T	M	X	T	M	X	T	M	X	T	M	X	T	M	X	T	M	X	T	M	X	T	M	X	T	M	
10,8	21	38	5,4	10	10	4,2	10	10	23,1	38	55	4,5	13	21	4,4	9	15	4,7	10	11	5,8	13	31	3,7	11	24	3,1	10	17	5,1	14	17	5,9	20	26	U
5,3	14	23	2,7	12	12	3,7	12	14	9,0	19	26	4,1	15	21	5,5	11	14	5,0	11	12	7,2	17	19	4,6	12	17	4,0	12	16	5,5	12	14	4,3	11	20	Bi
21,3	44	74	15,9	27	27	13,8	24	31	29,2	48	51	8,4	23	59	6,7	16	20	7,0	17	24	9,7	23	46	10,9	31	71	6,7	17	28	9,8	21	468	10,2	32	59	Pb
5,3	26	43	3,9	14	14	3,9	10	12	5,4	12	19	3,9	21	38	5,6	23	44	6,4	28	41	5,1	26	36	5,0	14	21	4,4	13	26	5,9	28	46	4,6	26	53	W
6,5	14	26	4,6	16	16	3,9	6	12	11,2	21	31	2,2	8	12	3,5	11	14	3,0	10	11	3,0	8	10	4,1	12	17	3,1	7	13	4,1	10	16	3,2	11	19	Ta
935,3	3093	6162	445,4	661	661	388,3	725	835	2595,8	5161	6318	392,4	932	5189	322,2	604	2490	292,7	551	630	358,4	870	5017	385,2	752	2139	411,8	812	1358	361,9	707	2355	464,8	1553	3848	Ba
14,4	32	41	4,8	11	11	10,9	44	44	23,2	40	47	13,7	22	34	18,4	37	46	26,0	62	67	12,7	27	29	14,6	52	68	11,8	47	62	16,9	40	54	14,6	41	54	Sb
14,5	40	48	4,5	16	16	6,5	22	25	20,6	38	41	11,6	37	45	14,6	33	45	18,5	43	53	10,7	23	29	9,7	34	40	7,3	24	36	14,4	36	46	11,9	36	47	Sn
14,7	29	45	1,2	3	3	1,1	2	4	21,5	36	39	8,4	26	35	10,9	22	32	11,1	24	20	11,9	30	34	4,0	15	21	1,4	5	12	9,7	23	35	8,4	24	31	Mo
9,7	23	33	13,4	25	25	9,5	17	19	16,4	40	52	7,8	16	66	6,4	19	23	5,7	13	20	8,0	18	29	11,5	37	66	12,4	27	157	9,4	20	33	11,3	35	56	Nb
428,6	1031	2322	522,5	1033	1033	422,9	906	920	801,3	1629	4718	286,4	629	1745	508,1	1005	1914	435,7	955	1428	415,5	791	2108	519,0	1186	8334	365,0	621	1312	436,1	797	1973	400,5	827	1906	Zr
19,6	49	96	40,1	99	99	19,6	37	40	32,0	62	75	34,2	59	73	21,4	41	72	22,6	37	42	28,7	47	76	20,4	42	73	20,2	36	53	20,0	42	57	22,1	40	66	Y
9,6	20	124	4,7	19	19	4,3	14	14	13,3	28	39	7,3	18	112	4,9	14	76	6,7	16	22	6,7	16	19	5,4	19	28	4,1	13	23	6,0	15	25	7,2	21	58	As
49,3	96	274	82,1	116	116	52,2	112	125	47,7	107	153	66,6	133	239	28,8	81	147	34,9	79	86	42,5	107	427	32,8	96	230	53,6	109	137	37,4	94	474	51,4	108	660	Zn
48,0	168	307	49,8	165	165	41,1	77	737	45,6	111	162	127,3	244	290	35,0	127	165	48,7	138	165	74,9	190	322	23,1	79	147	39,5	89	276	42,0	144	248	47,0	166	200	Cu
109,0	422	983	76,7	133	133	62,8	146	153	73,8	171	210	85,1	185	271	27,4	109	357	40,4	127	238	51,9	138	180	51,2	288	688	191,9	568	1136	69,4	291	788	126,5	821	1173	Ni
21,3	85	153	23,0	39	39	13,7	25	27	13,9	37	42	46,6	123	189	9,0	41	69	12,9	40	57	23,5	85	148	9,7	34	60	22,9	49	110	17,2	61	156	22,1	79	106	Co
5,3	11,8	15,3	6,0	12,1	12,1	3,7	6,5	6,7	4,2	7,1	8,3	9,5	14,8	17,1	3,4	9,1	12,3	4,4	8,9	9,1	5,9	12,6	14,2	2,8	6,7	8,9	4,8	8,4	10,0	4,0	9,9	14,7	5,1	11,9	12,8	Fe
0,11	0,2	0,4	0,16	0,2	0,2	0,15	0,2	0,3	0,1	0,2	0,2	0,08	0,2	0,2	0,12	0,2	0,2	0,12	0,2	0,2	0,11	0,2	0,2	0,15	0,3	0,5	0,19	0,3	0,5	0,13	0,2	0,4	0,16	0,5	0,8	Cr
67,0	0,1	0,1	923,0	0,1	0,1	811,0	0,1	0,1	170,0	0,1	0,1	103,0	0,1	0,1	58,0	0,1	0,1	59,0	0,1	0,1	108,0	0,1	0,1	363,0	0,1	0,1	610,0	0,1	1,9	112,0	0,1	0,1	266,0	0,1	0,1	S
0,0087	0,1	0,4	0,1192	0,2	0,2	0,1038	0,2	0,2	0,1764	1,2	1,3	0,0089	0,1	0,4	0,0409	0,2	1,2	0,0386	0,2	0,8	0,0466	0,4	1,7	0,0891	0,3	0,4	0,1130	0,3	0,5	0,0461	0,3	0,7	0,0673	0,3	1,1	P
7,7	10,5	12,5	4,6	8,0	8,0	3,5	6,9	6,9	7,7	8,9	9,0	7,4	10,4	12,3	4,7	7,8	9,9	5,3	7,8	8,3	5,7	8,8	10,3	3,8	7,8	12,0	3,5	6,4	7,5	5,2	8,9	10,0	5,0	8,5	9,9	Al
0,86	2,8	5,1	1,87	3,1	3,1	1,22	3,0	4,3	0,46	1,6	2,3	0,65	2,6	5,1	0,44	2,2	3,5	0,77	3,0	4,3	0,44	1,9	2,2	0,7	3,3	9,1	2,34	6,7	12,4	0,51	2,4	5,0	1,68	11,3	13,8	Mg
0,04	0,2	9,2	0,10	0,3	0,3	0,29	0,7	2,1	0,08	1,0	3,3	0,08	0,3	0,4	0,03	0,4	1,4	0,13	1,1	1,7	0,06	0,3	0,4	0,17	1,1	1,6	0,1	0,5	1,2	0,05	0,5	1,2	0,09	0,8	2,3	F

NOTES: X denotes mean values for each group.
T denotes threshold values of mean plus two standard deviations for each group.
M denotes maximum values obtained in each group.
The values for all elements except the last seven listed are in ppm.
The last seven are given in percent except for sulphur where the means are in ppm.

TABLE 9 - SHOWING THE ELEMENT OVERLAY SHEETS THAT HAVE BEEN PLOTTED FOR THIS STUDY

TOPOGRAPHIC SHEET NUMBER	NO. OF OVERLAY SHEETS	U	Pb	Ba	Mo	Nb	Zr	Y	As	Zn	Cu	Ni	Co	Mg	F
2230 CA	5			1			3		1	3				3	
2330 BA	4	1	2	7	1										
2230 CC	12	3	10	6	4	2	10		9	3	5	6	10	9	
2230 DA	14	13	3	3	13	5	5	12	5	5	8	3	3	4	2
2229 DD	5		1	1		6	5		2						
2230 CD	9		3		4	5		6	1	10	16	1	14		
2330 AB	14	20	18	21	13	20	16	19	17	8	8	15	10	9	23
2230 DC	13	19	21	8	26	10	6	18	12	6	16	2	13		19
2329 BA	10	16		3	10	4	1		19	6	2		2	11	
2230 DB	6			2		2		2	1			1			10
2230 DD	5			2		1	1					1	1		
2330 AA	4						4	3				1		2	
2231 AC	14	9	8	23	7	16	7	7	10	10	18	24	19	7	4
2329 BB	12	24	14	6	14	4	2	1	5	11	0		1	5	
2230 BC	13	11	2	2	16	15	6		11	24	13	8	16	24	5
2230 CB	14	40	17	6	9	27	11	5	27	20	10	16	22	30	23
2230 BD	14	7	20	28	18	16	36	20	15	9	10	11	4	4	19
2230 AD	7	3	20	2				5	8				3	5	
NUMBER OF ANOMALIES PLOTTED	**175**	**166**	**139**	**121**	**135**	**133**	**113**	**98**	**143**	**115**	**106**	**89**	**118**	**103**	**105**

Check Sampling

Finally, once the various element overlays had been contoured on trial paper copies, several anomalies were chosen for check sampling. In all, nine anomalies were check sampled and though this is a small proportion of the total number of anomalies indicated, it was limited by time and cost considerations. Further processing of data and checking of a wider variety of anomalies is recommended if funds become available to continue the study. The anomalies checked occur on sheets 2230 CB, 2230 BC, 2230 BD and 2329 BB and on each of the composite overlays which have been produced to allow easier interpretation of anomalous data, the positions of the check sampling traverses are shown. (See Appendix 2). The results obtained during check sampling are compared with contoured values from the De Beers data set (collected by Cycad, analysed by Anglo American Research Laboratories and plotted by STK) on Figures 15 to 21 inclusive. The check samples were taken along a single traverse line (except in the case of anomaly No. 3 on sheet 2230 CB where two parallel lines, 500 m apart, were sampled) and samples were taken at 100 m intervals and 10 cm depths. The samples were sieved to -80 mesh but were not milled using pestle and mortar. The geology observed in all cases was in accordance with that represented on the geological survey map sheets, though in the Limpopo Lowveld in the north of Venda, calcrete was ubiquitously developed and this could be expected to shield some real anomalies. A fairly broad spectrum of elements was checked namely:

Copper
Cobalt
Niobium
Lead
Nickel
Molybdenum
Zinc
Barium
Arsenic

During the first phase of check sampling (Wilson, 1989) which was restricted to three anomalies on sheet 2230 CB, the samples were all analysed by the McLachlan and Lazar Laboratory in Johannesburg. The arsenic was determined using XRF techniques and was not able to support the anomaly indicated by De Beers data. However, the other elements tested were all determined by atomic absorption techniques after being extracted by nitric/percholoric, hydrochloric and hydrofluoric acids. In the case of these elements (see Figs. 15, and 16), the elevated values indicated by the De Beers study were all confirmed by the check sampling, though in some cases anomaly peaks were displaced by several hundred metres. This was considered an excellent correlation on the whole, as the Cycad samples were usually more than a kilometre apart as compared with 100 m spacings on the check samples.

During a second phase of check sampling, it was decided to check anomalies in other parts of Venda and those on sheets 2230 BC, BD and 2329 BB were checked. Several other anomalies were visited in the south of the country but in all cases it was found that human contamination could have been considerable and the checking was not undertaken. In the north of the country where most checking was carried out, human settlement is limited and the chances of contamination in most cases was remote. During the second phase of check sampling all samples collected (once again at 100 m intervals, 10 cm depth and sieved to minus 80 mesh) were analysed using XRF techniques by the Bergstrom and Bakker Laboratory in Johannesburg. These results are indicated on the graphs on Figures 17 to 21 inclusive and are marked B + B to distinguish them. Two traverses namely BD1 (from sheet 2230 BD and shown as Fig. 20) and BC3 (from sheet 2230 BC and shown as Fig. 19) were also checked by the McLachlan and Lazar Laboratory and these results are marked M + L. The correlation between the two laboratories was exceptionally good and that between the check sampling and De Beers results (as collected by Cycad, analysed by Anglo American Research Laboratories and plotted by STK) was satisfactory, except for arsenic values and one molybdenum traverse (Fig. 17) Notwithstanding the limited extent of check sampling undertaken, a very pleasing confirmation of elevated values was obtained and this considerably enhances confidence in the data. It is recommended that if more time and funds become available, further check sampling of anomalies should take place. During phase one of the check sampling, one pit was dug on each of the anomalies tested and horizons were sampled at surface, 10 cm and 50 cm depths. The correlation between the three sets of data was good and it was concluded that no overall benefit would have resulted from sampling the surface or deeper (50 cm) horizons than had been achieved at 10 cm depth.

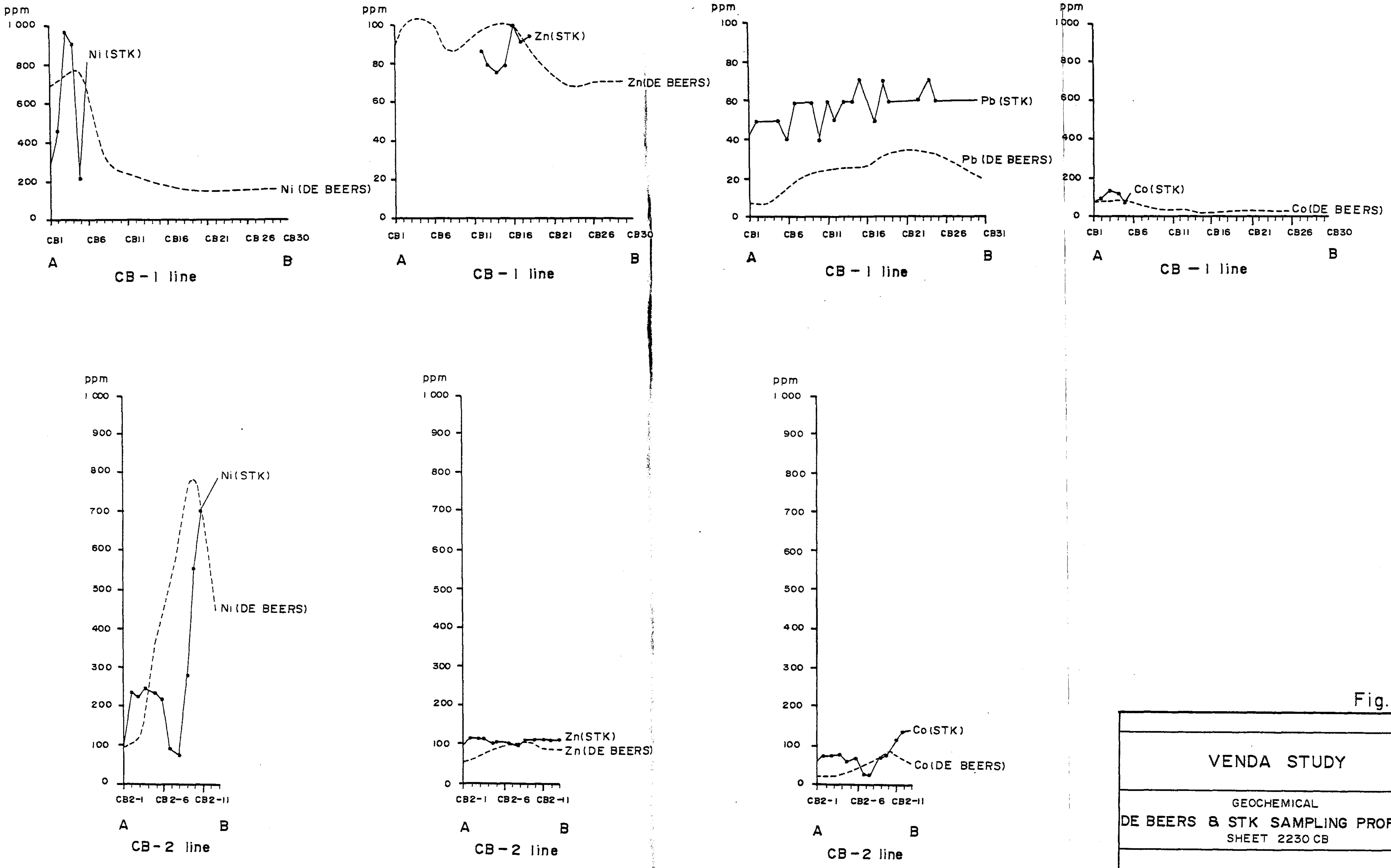
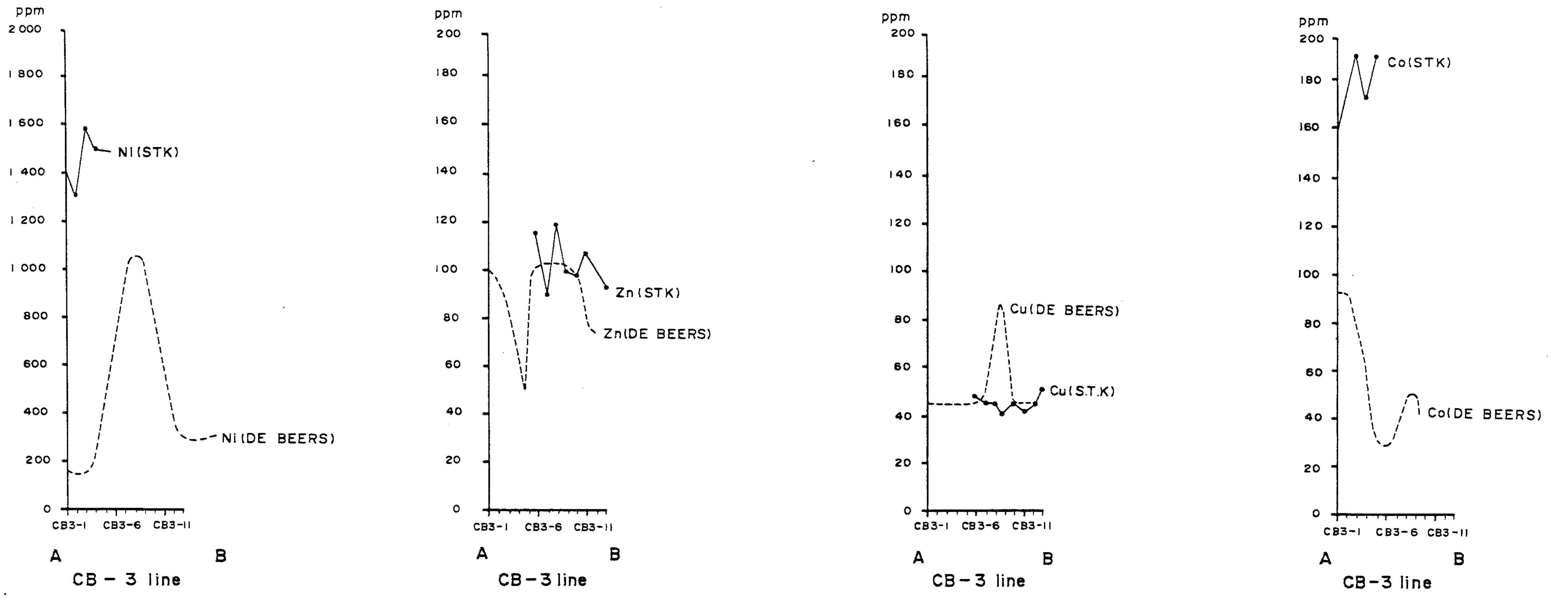


Fig. 15

VENDA STUDY

GEOCHEMICAL
DE BEERS & STK SAMPLING PROFILES
SHEET 2230 CB

HORIZONTAL SCALE 1:50 000



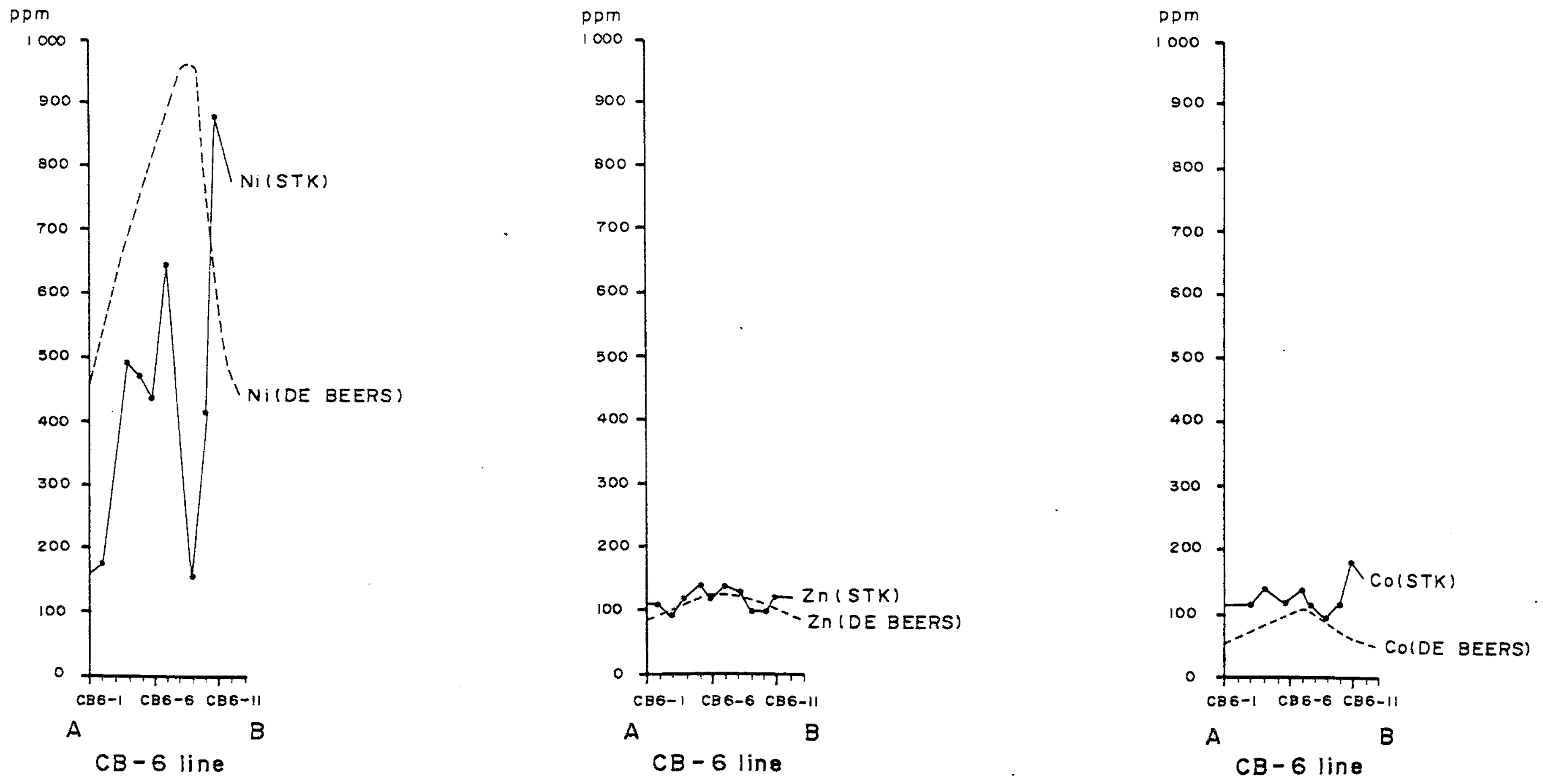


Fig. 16

VENDA STUDY

GEOCHEMICAL
DE BEERS & STK SAMPLING PROFILES
SHEET 2230 CB

HORIZONTAL SCALE 1:50 000

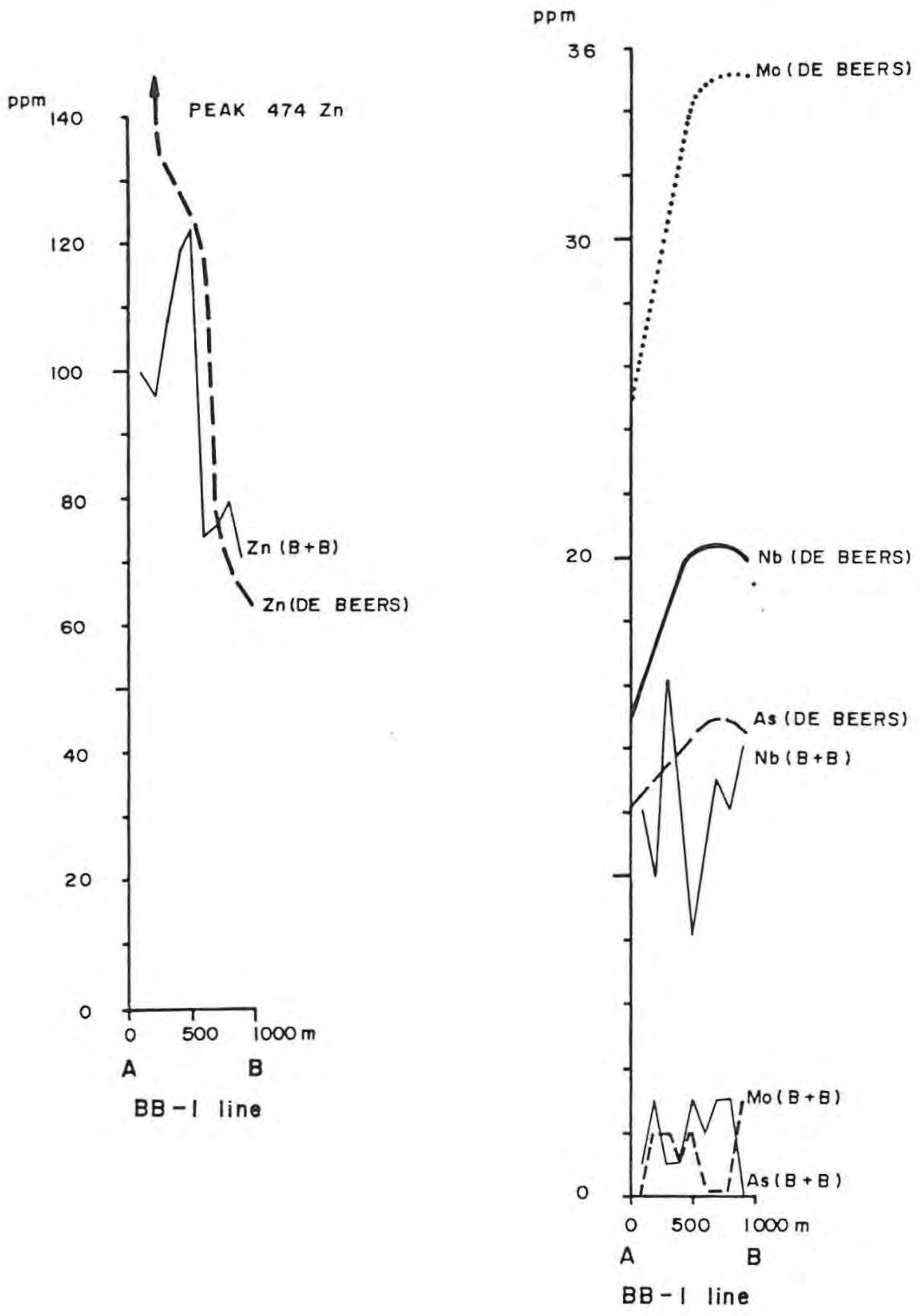


Fig. 17

VENDA STUDY

GEOCHEMICAL
CHECK SAMPLING PROFILES
SHEET 2230 BB

HORIZONTAL SCALE 1: 50 000

TV 78 03/89

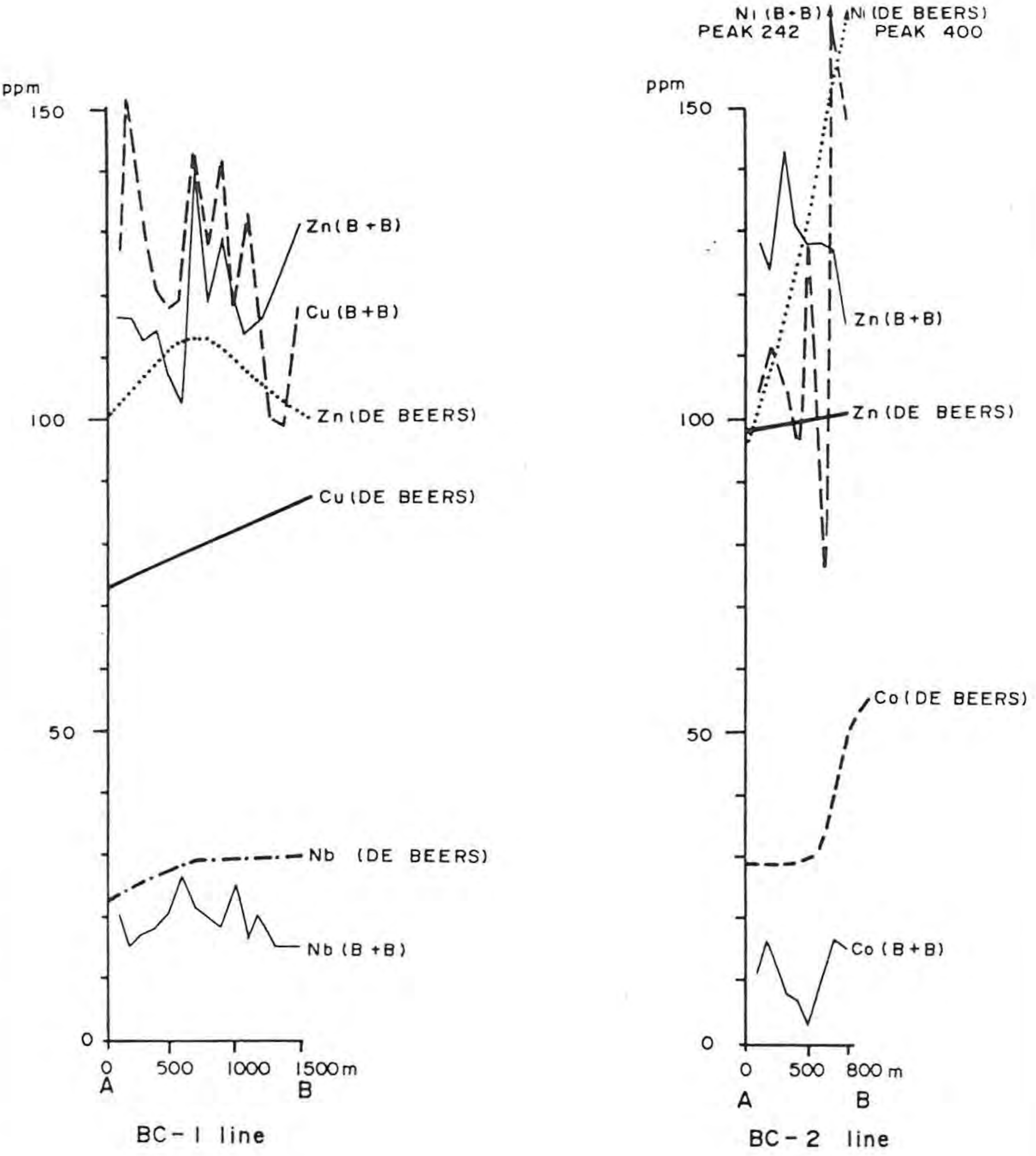


Fig. 18

VENDA STUDY

GEOCHEMICAL
CHECK SAMPLING PROFILES
SHEET 2230 BC

HORIZONTAL SCALE 1:50 000

TV 79 03/89

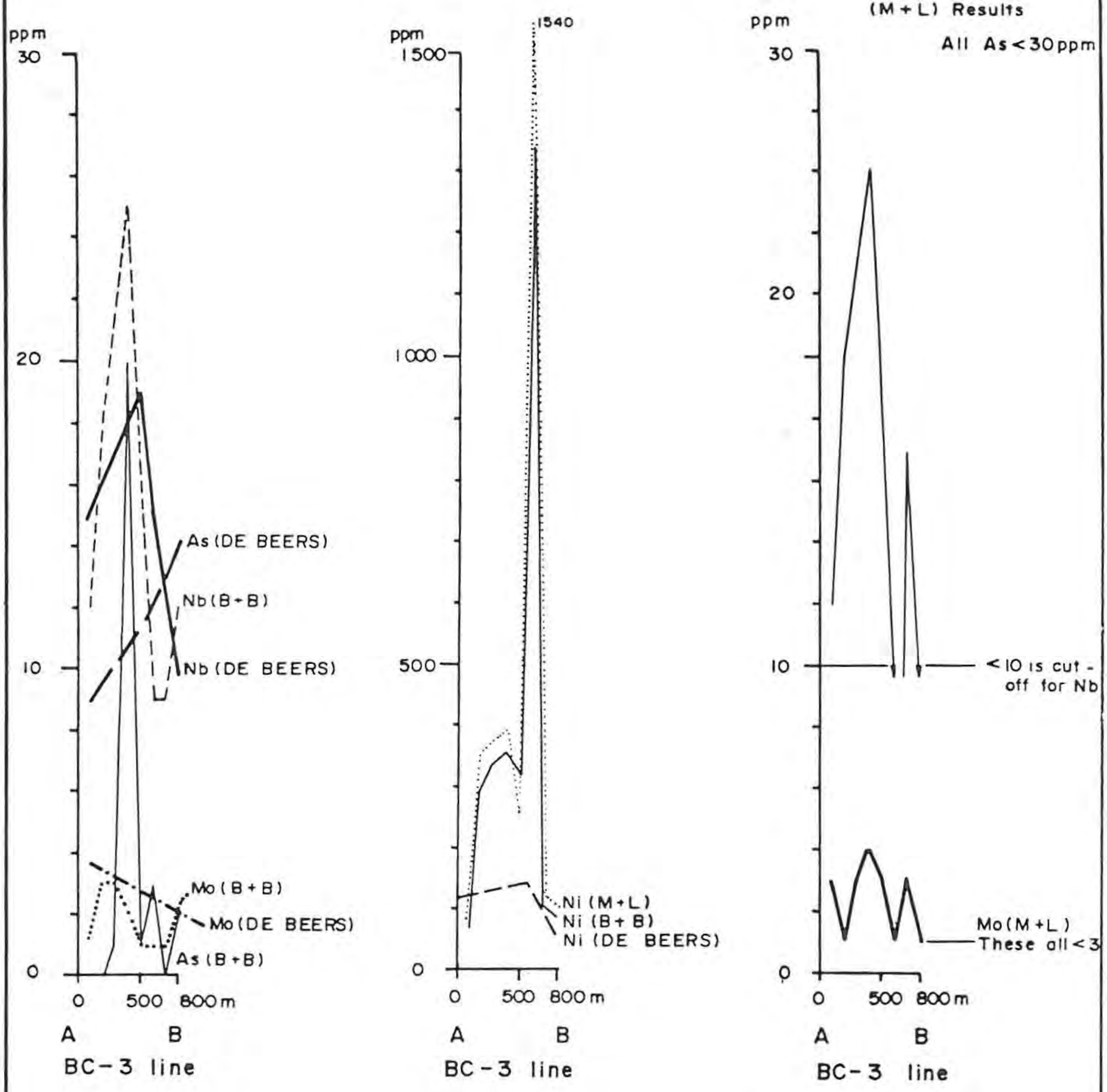


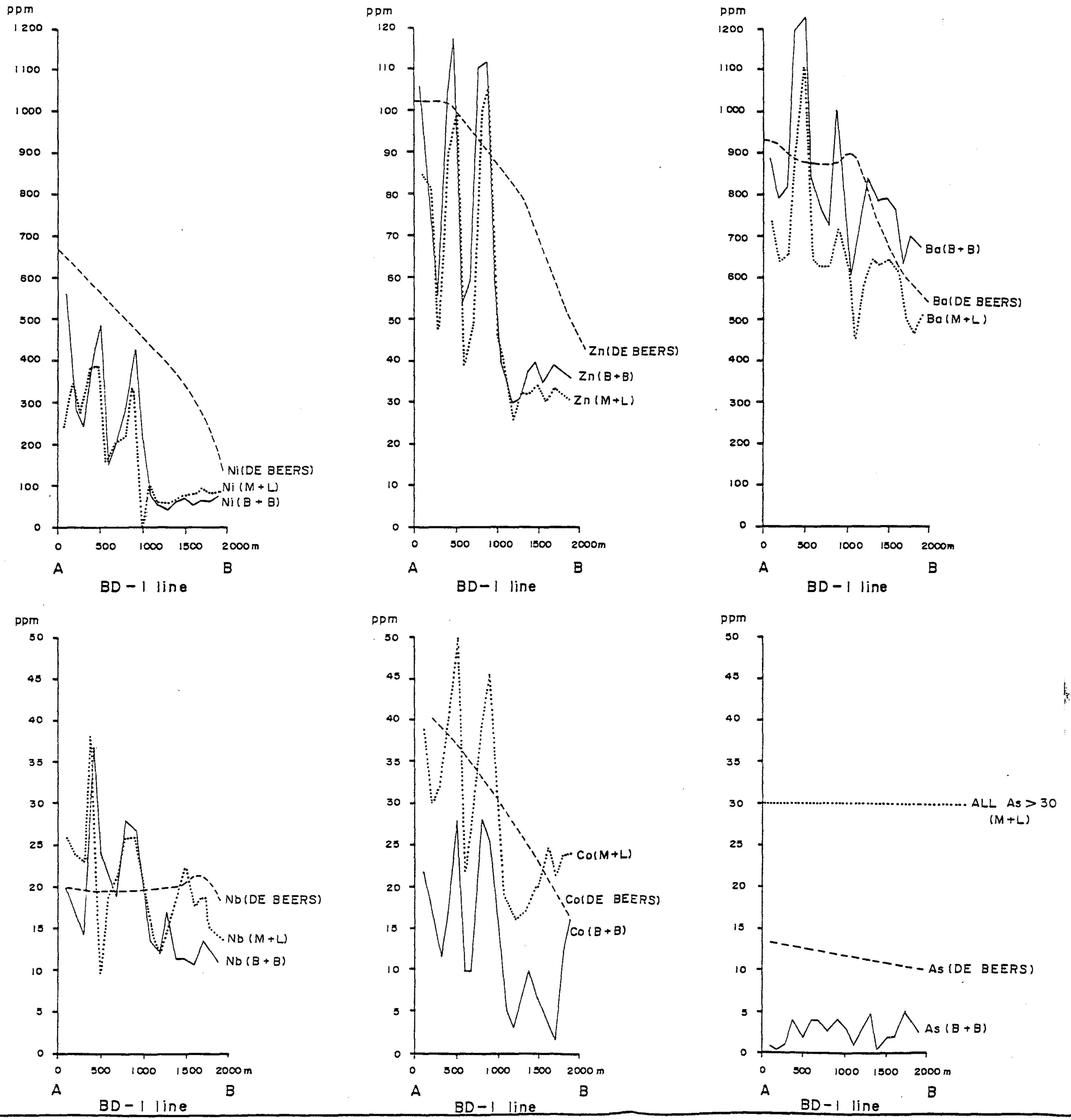
Fig. 19

VENDA STUDY

GEOCHEMICAL
CHECK SAMPLING PROFILES
SHEET 2230 BC

HORIZONTAL SCALE 1: 50 000

TV 80 03/89



LEGEND

(B + B) SAMPLING BY STK AND ANALYSIS BY BERGSTROM AND BAKKER.

(M + L) SAMPLING BY STK AND ANALYSIS BY M LACHLAN AND LAZAR.

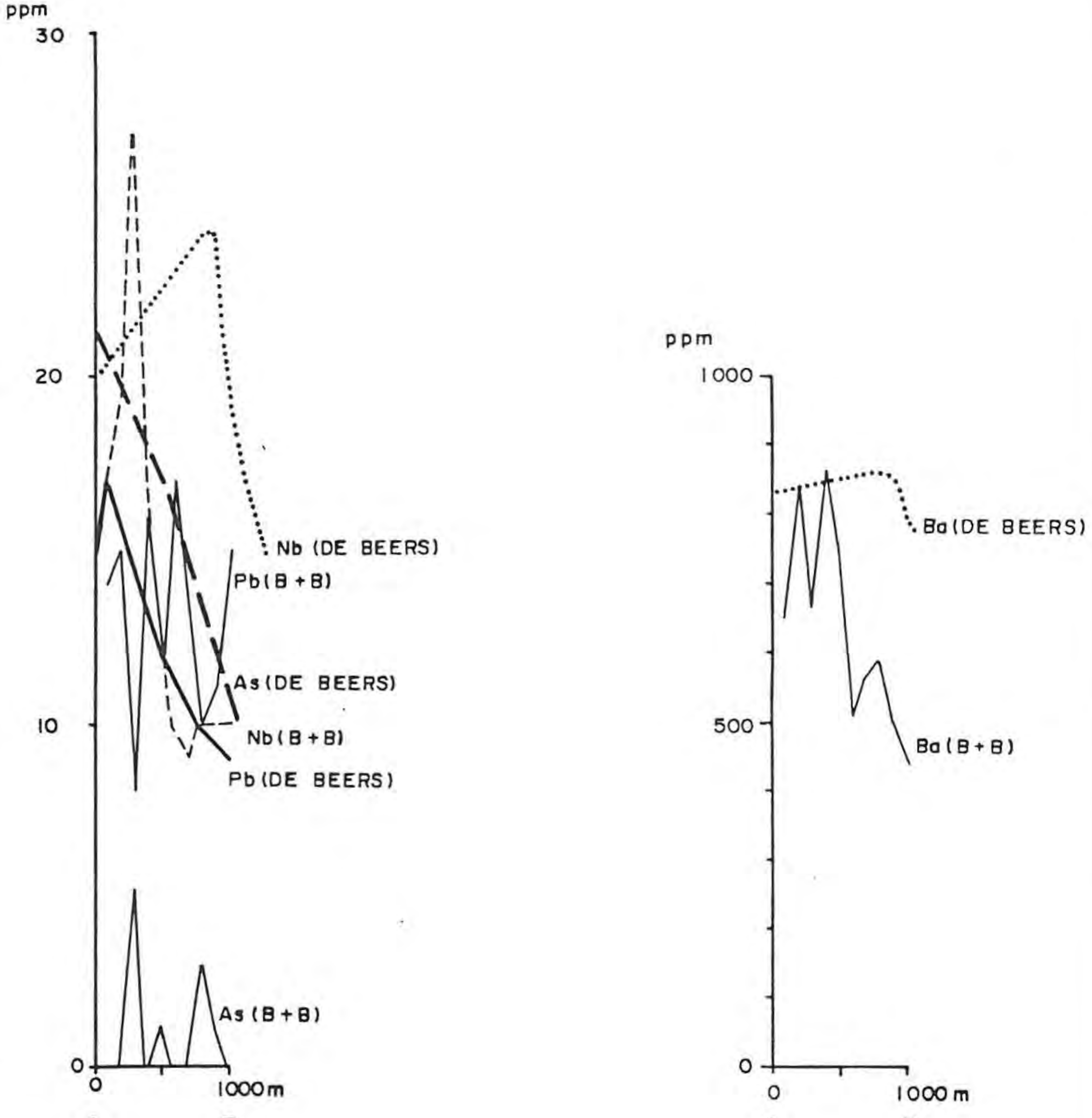
Fig. 20

VENDA STUDY

GEOCHEMICAL
DE BEERS & STK SAMPLING PROFILES
SHEET 2230 BD

HORIZONTAL SCALE 1 : 50 000

TV 102 06/89



BD-2 line

BD-2 line

Fig. 21

VENDA STUDY

GEOCHEMICAL
CHECK SAMPLING PROFILES
SHEET 2230 BD

HORIZONTAL SCALE 1: 50 000

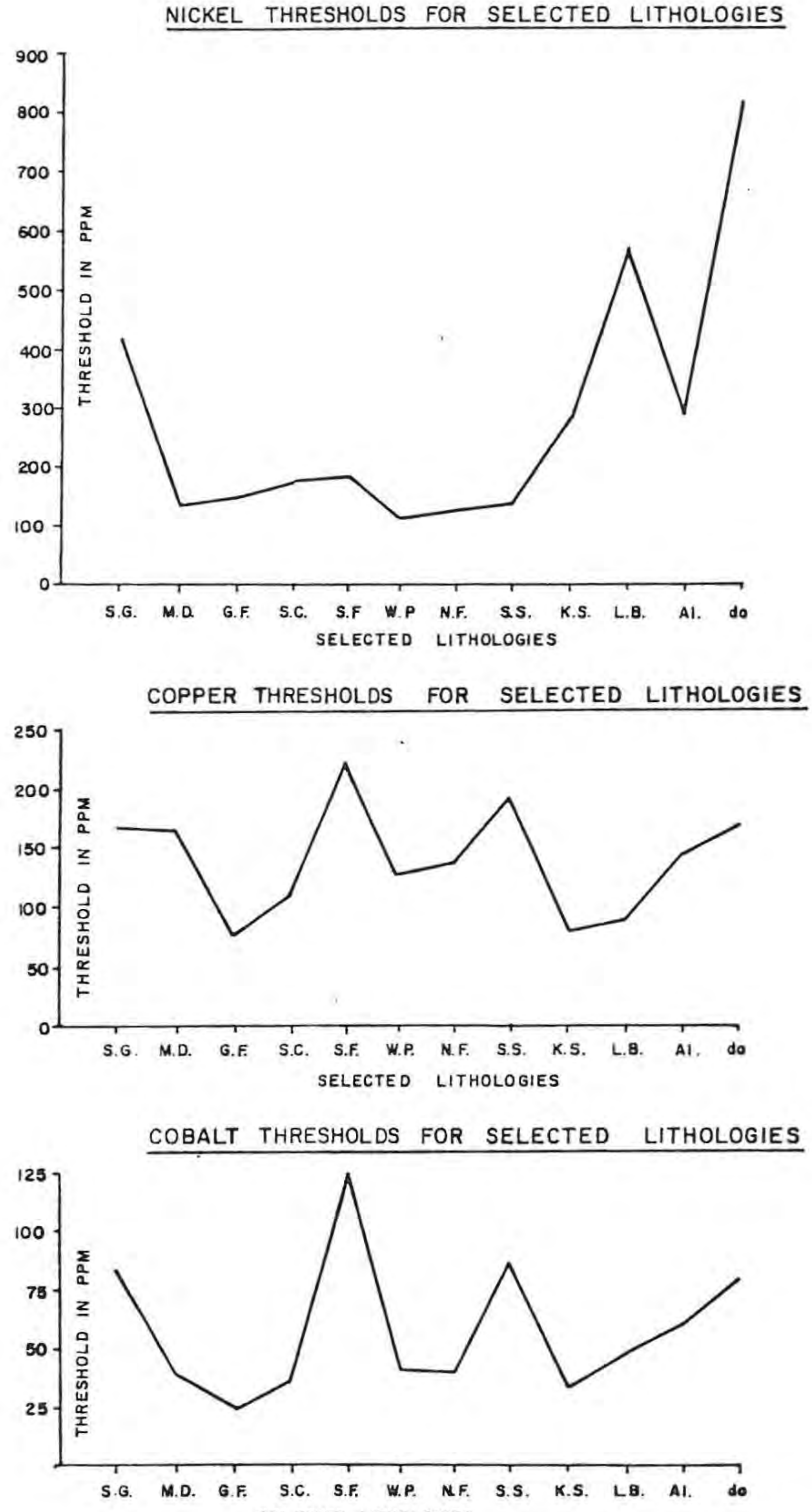
TV 83 03/89

3.2 Interpretation of Data

A very large body of information is available from this study and several different approaches have been used in its interpretation. Because the principal aim of the study is to promote exploration activity in Venda with the objective of enhancing the potential for discovering viable orebodies, which may lead to the development of mines, the interpretation will begin with an examination of trends displayed by three main groups of associated elements. This will be followed by an element-by-element assessment of trends and finally a sheet-by-sheet account of indicated and proposed mineral potential will be given.

3.2.1 Element Associations with Respect to Lithology

Reference to Fig. 22 shows the threshold levels of nickel, copper and cobalt with respect to the twelve selected lithological groups. These three elements are commonly associated, particularly in known nickel sulphide deposits, associated with ultramafic and even mafic rocks. Reference to the graphs reveals that dolerite and diabase intrusives as well as Letaba formation basalts and Swazian gneisses, are all fairly enriched in nickel. The enrichments in the intrusives and Swazian gneisses are also displayed by both copper and cobalt. This would tend to indicate that the most favourable lithologies in which to search for nickel-copper sulphide deposits would be the intrusives and Swazian gneisses. Taking cognisance of geological factors, this assessment is considered accurate, particularly with respect to the intrusive dolerites which include the large olivine dolerite and picritic sills at the base of the Karoo Sequence. Considering figure 14 which shows the frequency histogram for zinc in intrusive rocks in Venda one sees a fairly tight normal distribution with little skewness. However, when examining the frequency histograms for cobalt and nickel over the intrusive rocks (fig.'s 23 and 24) it is clear that a positive skewness exists and is probably the result of a second, smaller but higher grade nickel and cobalt enriched population, within the overall population of dolerite and diabase intrusives. Checking back reveals that all of the anomalous nickel data and all but two of the anomalous cobalt data come from soils



NICKEL THRESHOLDS FOR SELECTED LITHOLOGIES

COPPER THRESHOLDS FOR SELECTED LITHOLOGIES

COBALT THRESHOLDS FOR SELECTED LITHOLOGIES

Fig. 22

LEGEND

S.G.	SWAZIAN GNEISS	S.F.	SIBASA FORMATION
M.D.	MALALA DRIFT FORM.	W.P.	WYLLIES POORT FORM.
K.S.	KAROO SEDIMENTS	Al.	ALLUVIUM
G.F.	GUMBU FORMATION	N.F.	NZHELELE FORMATION
S.C.	SCHIEL COMPLEX	S.S.	SOUTPANSBERG SEDIM.
L.B.	LETABA FORMATION	do	DOLERITE & DIABASE INTRUSIVES

VENDA STUDY

ULTRAMAFIC ASSOCIATED
SULPHIDE ELEMENTS

Figure 23. Cobalt Content of Soils over

Dolerite and Diabase Intrusives in Venda

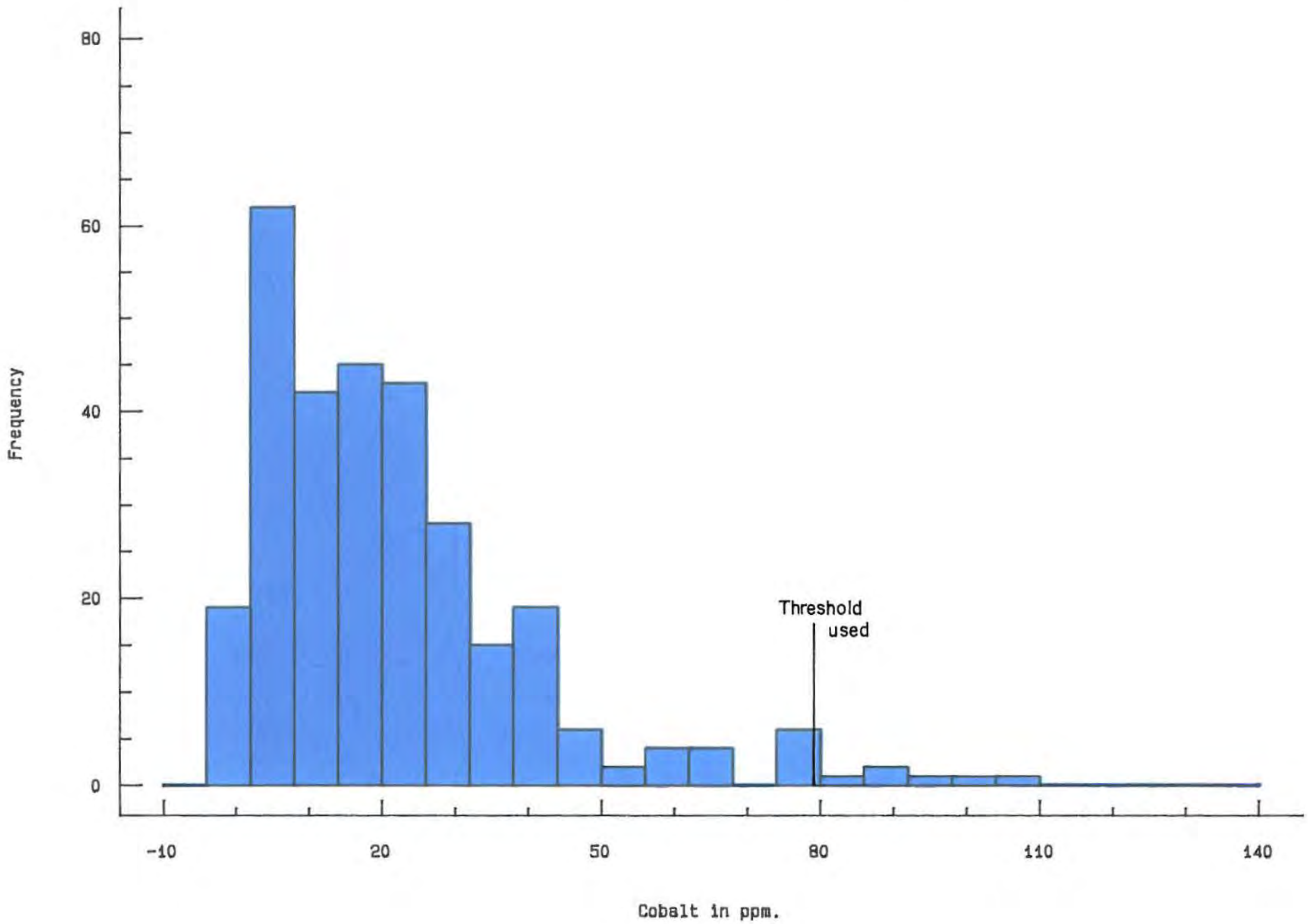
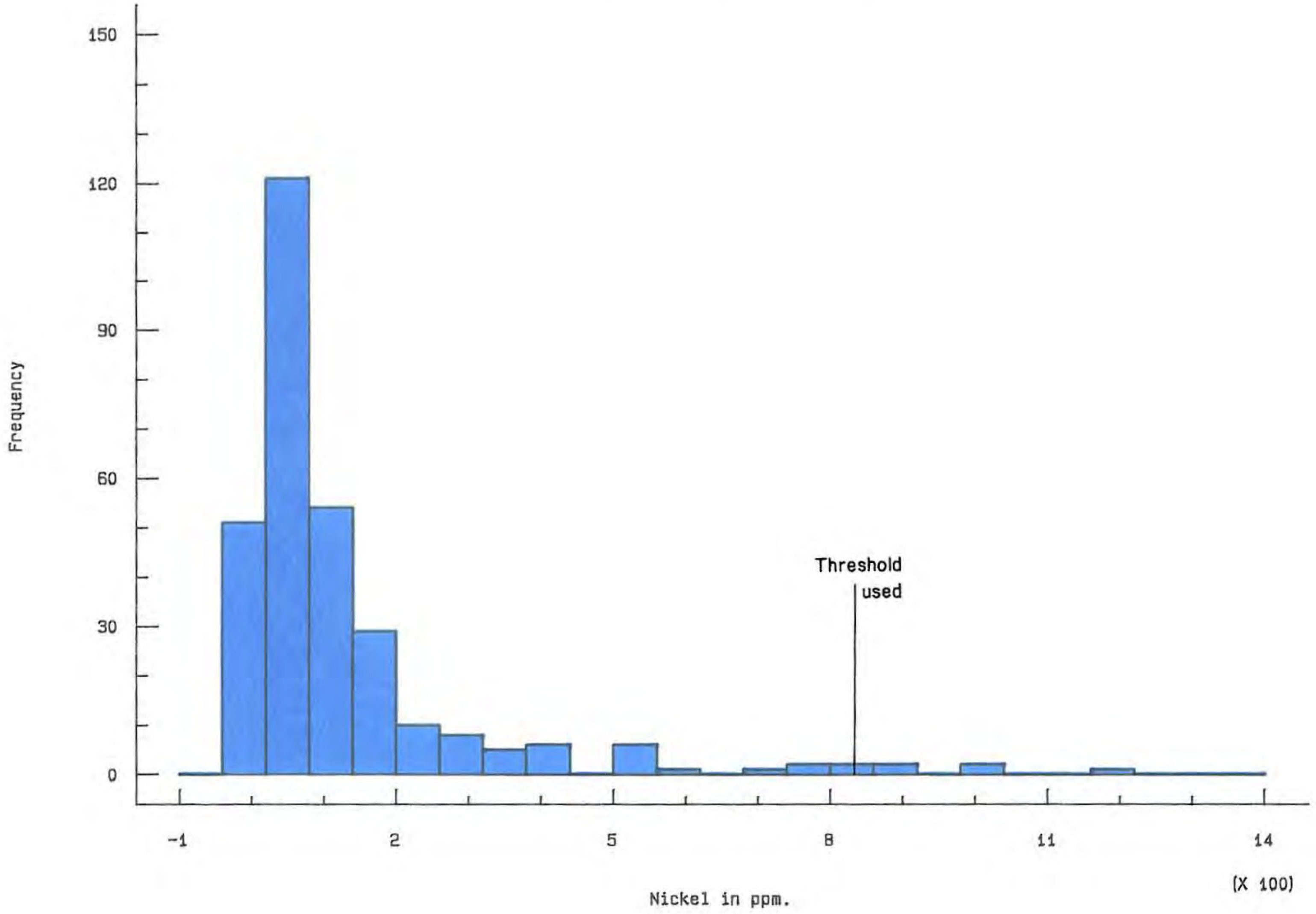


Figure 24. Nickel Content of Soils over

Dolerite and Diabase Intrusives in Venda



over the picritic sills which intrude the basal Karoo rocks in northern Venda. This is interpreted as indicating the presence of a nickel and cobalt enriched population within soils over the picritic (olivine dolerite) sills and is considered as good evidence for the potential presence of nickel and cobalt mineralization within this unit. The anomalous copper data does not reflect this enrichment to the same extent. Although all but two of the nickel and cobalt enriched samples from the picritic sills, do fall within an upper population group above 70 ppm copper and are thus slightly enriched in copper as well. As a result, these picritic (olivine dolerite) sills are considered to have a very high potential for nickel, copper and platinum mineralization similar to that occurring at Norils'k in Russia.

Both the late to post Karoo sills in Venda and those at Norils'k are of similar age and scale and both are associated with flood basalt events (the Letaba basalts in Southern Africa and the Siberian Trapps in Russia) related to continental rifting. In both cases the sills have intruded arenaceous to argillaceous sediments containing carbonaceous shales and coal seams (the Karoo sequence in Southern Africa and the Tunguska series in U.S.S.R.) (Hulbert et. al., 1988). Experimental work (Buchanan, 1988) reveals that intrusion of basaltic magmas into graphitic sediments improves the sulphur carrying capacity of the magma significantly. This criterion has been met in both localities. The only major difference between the Russian and Venda intrusives is the lack of an underlying marine dominated sedimentary pile in the case of Venda. It is argued that the presence of evaporites (particularly anhydrite lower in the succession at Norils'k) may have resulted in sulphur enrichment, enhancing the chances of mineralization. However the fact that two significant sulphur anomalies are known in close association with olivine dolerite sills where they intrude carbonaceous lower Karoo sediments on sheet 2230 CB in Venda, suggests the presence of sufficient sulphur to have allowed economic grade mineralization to form. There are so many geological parallels between Norils'k (Sawkins 1984) and the picrite sills in northern Venda, that further detailed investigation is considered essential. (See sheet description for 2230 CB for the positions of sulphur anomalies).

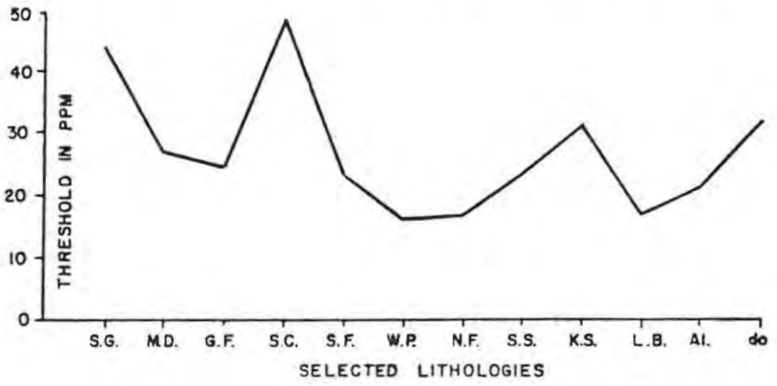
The lithological grouping of the Swazian gneisses is intimately associated with some minor greenstone remnants and Bandelierkop Complex ultramafics and mafics and samples taken over or adjacent to these may have mistakenly been attributed to the gneisses during sampling. The ultramafic remnants are however, considered the second best targets for nickel mineralization after the picrite sills in the north of Venda.

Considering the graph for copper on Fig. 2, the Sibasa Formation has the highest overall copper content. This confirms the observations made by several workers (including Ramagwede and Fletcher, 1984) that copper occurs in disseminated form in epidotized lavas of the Sibasa Formation as well as in amygdaloidal cavities within the lava flow tops. The elevated copper in Sibasa Formation rocks is supported by elevated cobalt (with the highest cobalt contents being in this formation). Zinc is also elevated in Sibasa formation rocks.

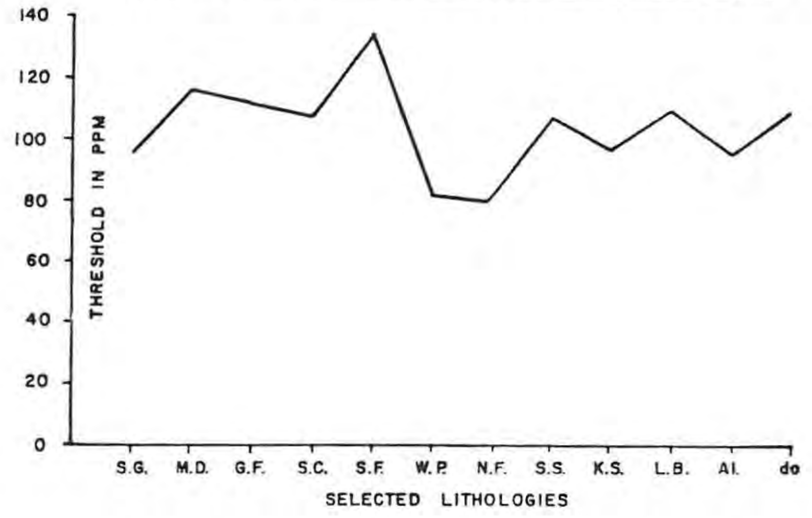
The generally elevated copper levels in Soutpansberg sediments is taken as an encouraging indication of the potential for sediment hosted copper mineralization within the succession and is supported by elevated cobalt as well. Stratiform copper mineralization is frequently associated with early stage continental rifting and both Kilembe in Uganda and Udokan in U.S.S.R. are examples that formed during early Proterozoic times (Sawkins 1984).

Fig. 25 shows the distribution of lead, zinc and barium, which are frequently associated with copper in massive sulphide deposits. Schiel complex rocks display the highest threshold levels of both lead and barium and high contents of zinc. This is fairly typical of an alkaline mineral association and there are also elevated levels of niobium, zirconium and uranium (see Fig. 6). The general Soutpansberg sediment group (which includes the Fundudzi Formation) displays elevated zinc, copper, cobalt, reasonable lead and barium contents as well as fair uranium contents. This would appear to have a high potential for sediment hosted mineralization, particularly adjacent to the Siloam fault. Karoo sediments on the other hand are particularly enriched in lead, niobium and zirconium, though the known barite occurrence on Wendy 86 MT in Karoo

LEAD THRESHOLDS FOR SELECTED LITHOLOGIES



ZINC THRESHOLDS FOR SELECTED LITHOLOGIES



BARIUM THRESHOLDS FOR SELECTED LITHOLOGIES

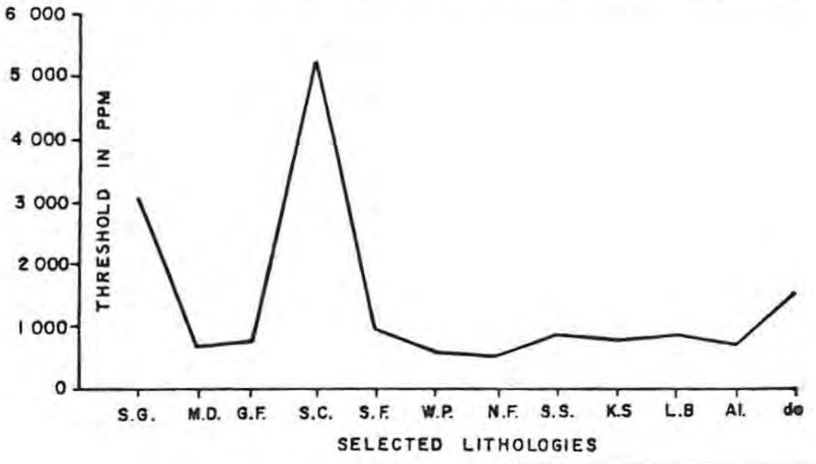


Fig. 25

LEGEND

S.G.	SWAZIAN GNEISS	S.F.	SIBASA FORMATION
M.D.	MALALA DRIFT FORM.	W.P.	WYLLIES POORT FORM.
K.S.	KAROO SEDIMENTS	Al.	ALLUVIUM
G.F.	GUMBU FORMATION	N.F.	NZHELELE FORMATION
S.C.	SCHIEL COMPLEX	S.S.	SOUTPANSBERG SEDIM.
L.B.	LETABA FORMATION	do	DOLERITE & DIABASE INTRUSIVES

VENDA STUDY

MASSIVE SULPHIDE
ASSOCIATED ELEMENTS

sediments near the major Bosbokpoort fault system, could well be associated with sulphide mineralization and should be investigated.

The potential may also exist in lower Karoo sediments (which are carbonaceous) for stratiform copper mineralization similar to the Kupferschiefer, which is associated with black shales and is also of Permian age.

With reference to Fig. 26, as would be expected, the Schiel Complex rocks have elevated contents of most alkaline associated elements. This is obviously the best target area for REE, igneous uranium mineralization, as well as for phosphate, fluorspar, tin and tungsten. The high yttrium content of the Malala Drift Formation rocks is unexpected.

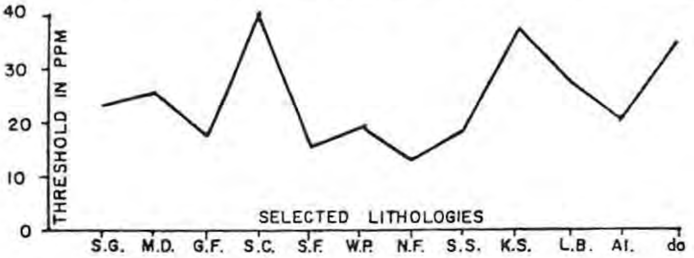
3.2.2. Trends Displayed by 24 of the Elements Analysed

In the elemental assessments that follow, general observations are made concerning the maximum and minimum mean element levels as well as the lithology in which the highest values occurred, for this survey. Other trends concerning the data are noted. In almost all cases the final paragraph mentions significant sources of the element as well as common associations and trends. This latter information is drawn largely from Boyle (1974) and Rose, et al.,(1979), though other sources and personal experience have also been drawn on. Note that the numbering applied to the elements is according to that received from the Laboratory and shown on Table 6. Comparison of the mean element levels obtained in this survey, with those from the literature (shown in appendix 1), may prove useful and interesting.

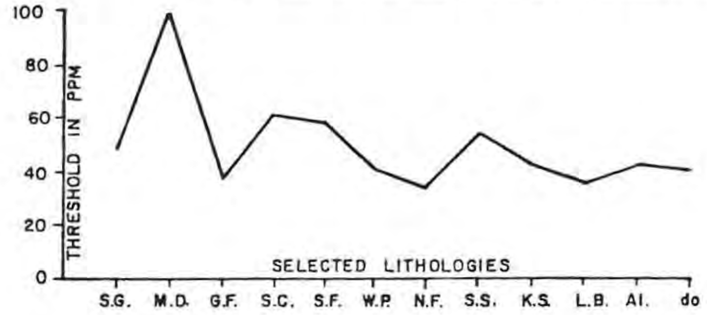
1. URANIUM

1.1 Generally the levels obtained are much higher than expected with the lowest mean value being obtained from soils over the Letaba Basalt Formation (3,1 ppm).

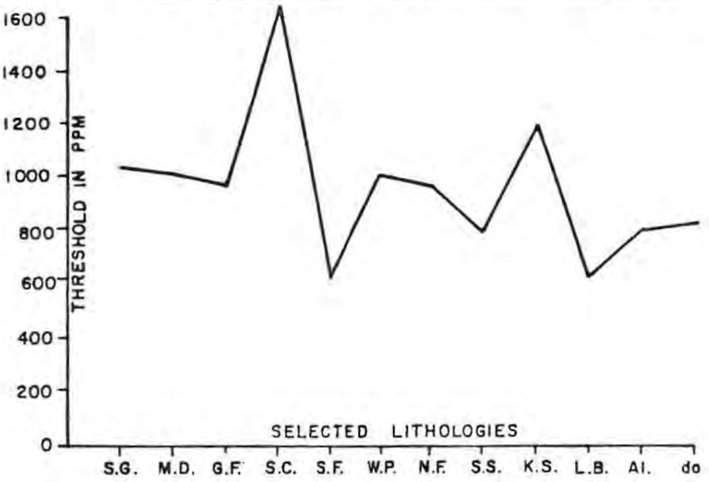
NIOBIUM THRESHOLDS FOR SELECTED LITHOLOGIES



YTTRIUM THRESHOLDS FOR SELECTED LITHOLOGIES



ZIRCONIUM THRESHOLDS FOR SELECTED LITHOLOGIES



URANIUM THRESHOLDS FOR SELECTED LITHOLOGIES

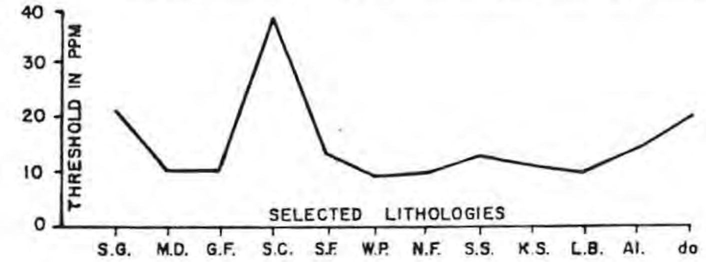


Fig. 26

LEGEND

S.G.	SWAZIAN GNEISS	S.F.	SIBASA FORMATION
M.D.	MALALA DRIFT FORM.	W.P.	WYLLIES POORT FORM.
K.S.	KAROO SEDIMENTS	Al.	ALLUVIUM
G.F.	GUMBU FORMATION	N.F.	NZHELELE FORMATION
S.C.	SCHIEL COMPLEX	S.S.	SOUTPANSBERG SEDIM.
L.B.	LETABA FORMATION	do	DOLERITE & DIABASE INTRUSIVES

VENDA STUDY

RARE EARTH AND ALKALINE
ASSOCIATED ELEMENTS

1.2 Both the highest uranium contents (55 ppm) and highest mean (23,1 ppm) were obtained in soils over Schiel Complex rocks. Soils derived from Swazian Gneisses have mean contents of 10,8 ppm.

1.3 Soutpansberg Group rocks all average between 4,4 ppm and 5,8 ppm uranium and Karoo Sequence rocks have lower contents. There is little difference in uranium contents between sediments and lavas in these groups, though Nzhelele Formation and Fundudzi Formation sediments are slightly enriched when compared with the others.

1.4 Uncharacteristically the uranium contents of dolerite and diabase intrusives are higher than expected which may suggest incorrect sample attribution or analytical errors.

1.5 Because of the perceived potential for economic grade uranium mineralization in parts of Venda, it was chosen as one of the elements to be plotted on overlays.

1.6 Uranium is generally elevated in granites and certain sediments. It is highly mobile under oxidising conditions and concentrates in bogs, carbonaceous shales.

3. BISMUTH

3.1 The average content of bismuth in soils over the lithologies tested ranges from lows of 2,7 and 3,7 ppm in the Malala Drift and Gumbu Formations of the Beit Bridge Complex, to a high of 9 ppm over Schiel Complex rocks. The maximum value of 26 ppm was obtained in soils over Schiel Complex rocks. Other high values were obtained over Swazian Gneisses and Sibasa Formation basalts.

3.2 Bismuth is often associated with lead and frequently with antimony and arsenic in sulphide deposits. It may be an indicator of certain gold deposits. Concentrations of bismuth are highest in shales and granites (1 ppm and 0,3 ppm respectively) and thus bismuth contents are generally very low. For this reason and the fact that many results were below the analytical detection limit, bismuth was not plotted on overlay sheets.

4. LEAD

4.1 Mean lead contents of soils vary between 6,7 and 29,2 ppm with the former occurring over Wylliespoort formation sediments and the latter occurring in soils over the Schiel Complex.

4.2 Soils derived from the Swazian Gneisses have the next highest mean at 21,3 ppm.

4.3 The trends in lead mirror those found in uranium, except that there are significant differences between Karoo sediments and lavas, with the sediments having mean values of 10,9 ppm and the lavas only 6,7 ppm.

4.4 The highest value (468 ppm) was obtained in alluvium. This comes from sheet 2230 CC and deserves follow-up as it may well reveal a heavy metal concentration or primary lead deposit. See sheet 2230 CC assessment)

4.5 Lead is generally elevated in shales and granites. It has a low mobility but concentrates in iron-manganese accumulations. It is often associated with silver in precious metal deposits and for this reason it was one of the elements chosen for plotting on the contour overlays.

5. TUNGSTEN

5.1 Mean tungsten contents of soils ranged between 3,9 ppm (in the Malala Drift, Gumbu and Sibasa Formations) and 6,4 ppm (in Nzhelele Formation rocks). The highest value of 53 ppm was obtained in soil over intrusive rocks.

5.2 It is worth noting that both Beit Bridge Complex Formations (i.e. Gumbu and Malala Drift) are fairly depleted in tungsten, particularly in the light of the suggestion (Winfield 1982), that the calcareous and other horizons within these formations could host tungsten mineralization.

5.3 Because the mean tungsten contents in soils were below the detection limit of 4 ppm at one standard deviation, much of the data was considered unreliable and it was not plotted on contour overlays.

5.4 Tungsten is generally most highly concentrated in acid rocks such as granites, pegmatites and porphyries. It is regionally (though seldom locally) associated with gold, in several parts of the world.

6. TANTALUM

6.1 Average tantalum contents of sampled soils over the selected lithologies varied between a low of 2,2 ppm over Soutpansberg basalts and a high of 11,2 ppm over Schiel Complex rocks. The highest single value of 31 ppm tantalum was obtained over Schiel rocks.

6.2 The Swazian Gneisses are also fairly enriched in tantalum as would be expected because tantalum is generally elevated in granitic rocks and pegmatites. It is usually closely associated with niobium except in alkaline igneous rocks. Because of the common association of tantalum with niobium and because the detection limit for niobium is much lower than that of tungsten, niobium data was plotted on contour overlays instead of that for tantalum.

7. BARIUM

7.1 The average barium content of sampled soils over the selected lithologies, vary widely between 293 and 2596 ppm with the former occurring in Nzhelele Formation rocks and the latter being associated with the Schiel Complex, where contents of up to 6318 ppm were obtained.

7.2 Neither the Soutpansberg nor Karoo sediments are enriched in barium when compared with their contemporary lavas.

7.3 Barium is generally elevated in syenitic and granitic rocks as well as certain sediments such as shales, calcareous sediments and "red bed" deposits. It is frequently enriched in coals and iron manganese precipitates as well as being associated with many massive sulphide deposits, polymetallic deposits and carbonatites. For this reason barium was one of the elements selected for plotting on the contour overlays.

9. ANTIMONY

9.1 The average antimony content of sampled soils over the selected lithologies varies from lows of 4,8 and 10,9 ppm over the Malala Drift and Gumbu Formations of the Beit Bridge Complex to a high of 26 ppm over Nzhelele Formation rocks. The highest value of 68 ppm was obtained in soil over Karoo sediments.

9.2 Since antimony is frequently associated with gold deposits and is frequently enriched in the major lead-zinc-silver deposits of the world, it is worth noting. It is generally elevated in shales and sandstones. Antimony is frequently enriched near epithermal precious metal deposits (such as hot spring gold deposits) where it is associated with arsenic, titanium, mercury and often a manganese halo. Had it not been for time and budgetary constraints antimony data would have been plotted on contour overlays despite its relatively high detection limit of 4 ppm. at one standard deviation.

10. TIN

10.1 The average tin content of samples over the selected lithologies varies from lows of 4,5 and 6,5 ppm over the Malala Drift and Gumbu formations of the Beit Bridge Complex, to a high of 20,6 ppm over

Schiel Complex rocks. The highest single value of 53 ppm was in soil over Nzhelele Formation rocks, which also had the second highest average contents.

10.2 Tin is generally elevated in granitic rocks and some sediments and in the former it concentrates with other incompatibles in late stage fluids such as those which form pegmatites. In the weathering environment tin has low mobility and frequently accumulates with heavy elements in alluvial deposits. Because of its low mobility and high detection limit, as well as the fact that late stage granitic intrusives are not common in Venda, tin was not chosen for plotting on contour overlays.

11 MOLYBDENUM

11.1 The average molybdenum content of sampled soils over the selected lithologies varies from lows of 1,2 and 1,1 ppm over the Malala Drift and Gumbu Formations of the Beit Bridge complex to a high of 21,5 ppm over Schiel Complex rocks. The maximum value of 45 ppm was obtained in soil over Swazian Gneisses.

11.2 Molybdenum is generally enriched in acid igneous rocks and black shales. Molybdenum is relatively mobile except under acidic conditions and in the presence of lead. It is commonly associated with copper in porphyry deposits and W, Sn and Bi in skarn and vein deposits. Because of these characterisitics molybdenum was chosen for plotting on contour overlays.

12. NIOBIUM

12.1 The average niobium content of sampled soils over the lithologies selected ranges from a low of 5,7 ppm over Nzhelele Formation rocks to a high of 16,4 ppm over Schiel Complex rocks. The next highest average values were obtained in soils over Malala Drift Formation rocks. The highest content of 157 ppm was obtained from soils over Letaba Formation rocks and was probably associated with a nephelinite horizon in the basalt.

12.2 The Karoo Sequence Sediments are comparatively enriched in niobium when compared with Soutpansberg sedments in the area.

12.3 Niobium is rare and is generally concentrated in certain pegmatites, albite granites, carbonatites and sediments derived from these. Its most frequent associate is tantalum, though in alkaline rocks it is usually associated with Ti, REE, U, Th and P. Niobium is frequently associated with Cu, Zn, Pb, Mo, V, Sn, Ba, Sr, REE and P in soils. Niobium has been used as an aid to locating carbonatites and even kimberlites (though garnet and ilmenites are more frequently used for the latter). Because of these characteristics and its relatively low detection limit using XRF. analysis, niobium was chosen for plotting on contour overlays.

13. ZIRCONIUM

13.1 The average content of zirconium in sampled soils over the selected lithologies ranges from a low of 286,4 ppm over Sibasa Formation rocks to a high of 801,3 ppm over Schiel Complex rocks. The maximum content of 4718 ppm was also obtained in soils over Schiel Complex rocks.

13.2 As was the case with niobium, the Karoo Sequence sediments are enriched in zirconium when compared with Soutpansberg sediments.

13.3 Zirconium is most commonly concentrated in sedimentary strata, beach and river sands derived from weathering of granites, pegmatites, alkaline rocks and nepheline syenites. It may contain thorium or uranium which could result in a weak radiometric anomaly. Because of recent increased demands for zirconium it was considered worth plotting on the contour overlays.

14. YTTRIUM

14.1 The average yttrium content of sampled soils over the lithologies selected ranges from lows of 19,6 ppm over Swazian Gneisses and Gumbu Formation rocks to a high of 40,1 ppm over Malala Drift Formation rocks. The maximum value of 99 ppm was also from soils over the Malala Drift Formation. A high of 96 ppm was obtained over the relatively depleted Swazian Gneisses.

14.2 Rare earth elements (REE) are being used increasingly in the manufacture of super conductors, ceramics, in polishing optical glass and colouring cubic zirconia as well as in the production of permanent magnets and colour television screens, to mention a few of the applications. Because of the increasing demand for REE (O'Driscoll 1988), yttrium which is classified with them and behaves similarly to them, was chosen for plotting on the contour overlay sheets. These are elevated in granitic and alkaline rocks and more specifically in carbonatites and pegmatites, though placer accumulations are also important. Yttrium has been used in locating carbonatites and indicating high grade fluorite deposits.

18. ARSENIC

18.1 The average arsenic content of sampled soils over the selected lithologies varies from a low of 4,1 ppm over Letaba Formation rocks to a high of 13,3 ppm over Schiel Complex rocks. The highest value of 124 ppm was obtained in soils over Swazian Gneisses and should be considered a potential guide to gold mineralization. (see assessment for sheets 2330 AB and 2230 CD in section 3.2.3).

18.2 The Beit Bridge Complex rocks are depleted in arsenic as are all the Karoo Sequence rocks and the Wylliespoort sediments.

18.3 Arsenic is usually elevated in granites, sediments and sulphidic veins. It is commonly associated with gold, silver, copper, lead, zinc, nickel and cobalt deposits as well as those of tungsten and tin. Because of its broad association with mineralization and its usefulness as a pathfinder, arsenic was one of the elements chosen for plotting on the contour overlays. Arsenic is often concentrated in limonites, coal, bogs and marshes. In coal measures arsenic may often be associated with concentrations of Ba, Sr, Cu, Pb, Ag, Sb, Mo, Ni and Co.

19. ZINC

19.1 The average zinc content of sampled soils over the selected lithologies ranges from a minimum of 32,8 ppm over Karoo Sequence sediments to a maximum of 82,1 ppm over Malala Drift Formation rocks. The single highest value obtained (660 ppm) was from soil over an olivine dolerite sill (see assessment of sheet 2230 CB). Both Soutpansberg and Karoo sediments are depleted in zinc in comparison to their associated volcanics.

19.2 Zinc is a very useful indicator mineral for base and precious metal deposits and in addition it shows a positive correlation with REE and Nb. Because of this zinc was one of the elements selected for plotting on contour overlays. Zinc is fairly mobile but accumulates in bogs and coals. It is elevated in mafic volcanic rocks and shaly sediments.

20. COPPER

20.1 The average copper content in sampled soils over the selected lithologies ranges from a low of 23,1 ppm over Karoo Sequence sediments to a high of 127,3 ppm over the Sibasa Formation (basalts). The highest value of 737 ppm comes from soils over Gumbu Formation rocks. (See the assessment of sheet 2230 AD).

20.2 The long recognised presence of disseminated copper mineralization in epidotized lavas of the Sibasa Formation is borne out by this study.

However the well known and long recognized association of copper with Nzhelele Formation rocks is not obvious from the results of this sampling exercise. This is simply a reflection of the following factors;

i) copper mineralization associated with the Nzhelele Formation is generally in fissures and quartz veins which are secondary features (Grewar, 1907) and little if any significant disseminated copper has been located,

ii) in addition copper is known to be concentrated in amygdaloidal flow tops and associated tuffaceous horizons and such concentrations may have left the bulk of the lava depleted in copper,

iii) sample distribution over much of the Nzhelele Formation, particularly in the Mutale copper fields was very poor with most of the areas having apparently been avoided.

20.3 As with zinc, copper contents of Wylliespoort and Karoo sediments are low, but in the case of copper, the Letaba Formation is also depleted.

20.4 Copper behaves in a similar way to zinc in that it is elevated in mafic volcanics, shales and coal measures and has pathfinder applications in geochemistry. Because of this and the fact that numerous copper occurences have been identified in Venda it was chosen as one of the elements for plotting on contour overlays.

Copper is known to occur in a wide variety of deposits, some of which (such as "red bed", amygdaloidal basalts, hydrothermal, massive sediment hosted and shale deposits in particular) have great relevance when considering the mineralization potential of the Soutpansberg in Venda.

21. NICKEL

21.1 The average nickel content of sampled soils over the selected lithologies ranges from a low of 27,4 ppm over Wylliespoort sediments to a high of 191,9 ppm over Letaba Formation rocks. The maximum values obtained were 1173 ppm and 1136 ppm over intrusive rocks and Letaba basalts respectively. The high nickel contents of the Letaba Formation and intrusive rocks is not surprising in view of the olivine rich nature of many of these. The picritic sills in particular are thought to be excellent targets for nickel, copper and platinum mineralization. (See section 3.2.1 for more detail).

21.2 High nickel contents were also displayed by the Swazian Gneisses (which are intimately associated with greenstone remnants), as would be expected. Considering that at least two nickel occurrences are known over Gumbu Formation rocks, the average nickel content of overlying soils seems low.

21.3 Nickel is elevated in ultramafic rocks where levels of 2 000 ppm are common. Nickel is a relatively immobile element and is useful in geochemical soil sampling for ultramafic bodies and kimberlites. Nickel is frequently associated with Cu, Co and Pt in sulphide deposits. Because of this and the perceived potential for nickel mineralization in Venda, it was chosen for plotting on the element overlay sheets. It accumulates in bogs and manganese rich clays and oxides.

22. <u>COBALT</u>

22.1 The average cobalt content of sampled soils over the selected lithologies ranges from a low of 9,0 ppm over Wylliespoort sediments, to a high of 46,6 ppm over Sibasa Formation basalts. The highest cobalt value of 189 ppm was also from a soil over Sibasa Formation rocks.

22.2 Wylliespoort and Karoo Sediments are fairly depleted in cobalt as are Gumbu Formation rocks when compared with those of the Malala Drift Formation.

22.3 Cobalt is closely associated with nickel in many environments and also with magnesium in mafic and ultramafic rocks. Cobalt is more mobile than nickel and has been used as a pathfinder for copper, nickel, uranium, native silver-nickel-cobalt arsenide deposits, as well as for some lead-zinc veins and cobaltiferous gold deposits. Because of this it was selected as one of the elements to be plotted on contour overlay sheets.

23. IRON

23.1 The average iron content of sampled soils over the selected lithologies ranged from a low of 2,8 % in Karoo Sequence sediments to a high of 9,5% over Sibasa Formation basalts. The highest single value of 17,1% iron was also in soils over Sibasa Formation basalts.

23.2 Iron is generally highest in ultramafic and mafic igneous rocks and it has moderate to low mobility. Some ore metals (including gold) are prone to precipitation by iron. The iron content of organic matter in peat bogs is sometimes useful as a guide to massive sulphide mineralization. Generally though, iron is not a useful geochemical indicator or pathfinder, and for this reason it was not plotted on the contour overlays.

25. CHROMIUM

25.1 The average chromium content of sampled soils over the selected lithologies ranged from a low of 0,08% over Sibasa Formation basalts to a high of 0,19% over Letaba Formation basalts. The highest chromium value of 0,8% was obtained in soils over intrusive dolerites and may well reflect the olivine rich sills included in this group. The values obtained were frequently below the detection limits of 0,1% at one standard deviation and are thus not considered reliable. For this reason chromium was not one of the elements chosen for plotting.

25.2 Chromium is concentrated in ultramafic igneous rocks and has a low mobility. It has limited geochemical applications and is mainly used for locating ultramafic bodies.

30. SULPHUR

30.1 The average sulphur content of sampled soils over the selected lithologies ranged from a low of 0,0068% over Wylliespoort Formation rocks to highs of 0,0811% over Gumbu Formation rocks and 0,0923% over Malala Drift Formation rocks. Only three anomalously high sulphur contents were located and all of these were in soils overlying Letaba Formation rocks. Two of these, a 1,9% and a 0,6% are located at X = 30021, Y = 95680 and X = 28404, Y = 89396 respectively, on sheet 2230 CB. The other anomalous value of 1,0% sulphur occurs at X = 19757, Y = 71222 on sheet 2230 BC. The higher average contents of sulphur in soils over Beit Bridge Complex rocks is of interest. With the exception of the three anomalous values mentioned above, all the values obtained were below the detection limit of 0,1% at one standard deviation and are thus not considered reliable. For this reason the sulphur contents were not plotted as contour overlays.

30.2 Sulphur is generally concentrated in sedimentary limestones or shales, or around sulphur springs. It is not commonly used as a pathfinder in soil geochemical surveys though it has been shown to be enriched in mineralized (Cu-Ni) ultramafic plutons in the Canadian Shield (Cameron et. al., 1971).

31. PHOSPHOROUS

31.1 The average phosphorous content of sampled soils over the selected lithologies ranges from a low of 0,0087% over Swazian Gneisses to a high of 0,1764 % over Schiel Complex rocks. The highest values of 1,7% and 1,3% occurred in soils over Soutpansberg sediments (other than the Wylliespoort and Nzhelele Formations) and over Schiel Complex rocks respectively. The values obtained were frequently well below the detection limit of 0,1% at one standard deviation and are not considered reliable. For this reason the phosphorous data was not plotted as contour overlays.

31.2 Phosphorous is generally concentrated in mafic igneous rocks and has a low mobility. It is not generally used in geochemistry except as a guide to apatite and phosphate deposits.

33. ALUMINIUM

33.1 The average aluminium content of sampled soils over the selected lithologies ranged from a low of 3,5% over Gumbu and Letaba Formation rocks, to highs of 7,7% over Schiel Complex and Swazian Gneiss rocks.

33.2 Aluminium is not generally used as a pathfinder in soil geochemical surveys and for this reason, it was not one of the fourteen elements selected for plotting on the contour overlays.

34. MAGNESIUM

34.1 The average magnesium contents of sampled soils over the selected lithologies ranged from lows of 0,44% over Wylliespoort and other Soutpansberg sediments to a high of 2,34% over Letaba formation rocks. The highest values of 13,8% and 13,5% magnesium were obtained in soils over dolerite intrusives and obviously represent soils over the magnesite yielding olivine dolerite sills.

34.2 Magnesium is not generally used as a pathfinder in soil geochemical surveys but it was specifically plotted on geochemical overlay sheets during this study because historically, magnesite has been one of the more significant mineral exports from the area.

36. FLUORINE

36.1 The fluorine content of sampled soils over the selected lithologies ranged from a minimum of 0,03% over Wylliespoort Formation rocks to a maximum of 0,29% over Gumbu Formation rocks. The highest value of 9,2% is exceptional and occurs over Swazian Gneisses not far from the Schiel Complex. Many of the values obtained are below the detection limit of 0,1% at one standard deviation and are not considered reliable.

36.2 Fluorine is generally concentrated in granitic igneous rocks in the form of fluorite and biotite and has been used as a pathfinder for carbonatites and fluorite deposits. Because of the known presence of syenite and carbonatite forming part of the Schiel Complex in southern Venda and the potential for other similar occurrences, fluorine has been plotted on contour overlays during this study. In some cases it may also be useful in indicating hydrothermal activity and significant faulting.

RUBIDIUM AND STONTIUM

These are particularly useful in granitic terranes to help determine highly differentiated granites from others Because of the paucity of the younger granites in Venda and the fact that most of the granitic terrain has been gneissified and metamorphosed, it was not considered worth processing the data for rubidium and strontium.

3.2.3. Sheet by Sheet Assessment of Data and Mineral Potential

In this section the eighteen sheets plotted for this study are listed in order of decreasing mineralization potential based on the following:

i) The potential as determined by rock types, structure and other geological factors.

ii) The potential as indicated by anomalous values generated during this study.

iii) The potential based on previously recognized mineralization and exploration.

However, whilst examination of the plotted sheets and overlays will indicate areas of higher indicated mineralization potential, it must be remembered that the data used in this study have certain limitations namely:

i) Most mountainous and rugged parts of Venda have not been sampled at all.

ii) Several areas of known mineralization including the Mutale Copper Fields and the known copper provenance area around the Nwanedi and Luphephe Dams, have very limited sample coverage.

iii) The study cannot really indicate mineralization such as coal, corundum and graphite, all of which are highly significant minerals in Venda.

iv) Only fourteen elements out of a potential 36 have been plotted and some 81% of anomalies obtained have been plotted.

The written assessments of each sheet which follow try to redress some of the above shortcomings by mentioning the potential for mineralization not indicated by this study either because of poor sample coverage or because the elements checked would not indicate it. In addition each sheet description gives an indication of sample distribution and density for the sheet. Frequent reference to figures 3 and 9 should assist in understanding spatial aspects and reference to the appended composite anomaly sheets will be useful in each case (Appendix 2).

SHEET 2230 CB (GAANDRIK)

This sheet has perhaps the best indicated mineralization potential, particularly for nickel-copper mineralization and heavy metal accumulations. The northern portion of the sheet between the Tshipise Fault and the central hills has been well sampled but the north-western and southern portions have very poor sample coverage. A total of 794 sets of sample results are available, for the area covered by this sheet.

The area of known copper mineralization around the Nwanedi and Luphephe dams which is associated with intrusive diabases, is not reflected on this sheet because the area is in rugged terrain and was not sampled. The intrusive picritic olivine basalts which outcrop near the base of the Karoo Sequence, close to the Klein Tshipise and Tshipise fault systems, are considered potential targets for Norils'k type nickel-copper-platinum sulphide mineralizatin and this supposition is supported in places by anomolously high nickel values, frequently associated with high cobalt, magnesium and occasionally copper. See section 3.2.1 of this report for more detail. Nickel anomalies, particularly those that are supported by cobalt and copper and that occur near the base of picritic sills, deserve particular attention in terms of follow-up work. In addition, the fact that 2 of only 3 sulphur anomalies found during this geochemical survey occur in association with such Ni-Cu-Co anomalies (2 and 3) near the base of sills on this sheet, is further compelling evidence that follow up work is required. The sulphur anomalies are as follows; 1,9% at X = 30021, Y = 95680 and 0,6% at X = 28404, Y = 89396. The only other sulphur anomaly occurs on sheet 2230 BC. Anomaly number 2, also has the highest Zn and a good Pb anomaly associated with it. Many uranium anomalies are associated with the lower sediments of the Karoo Sequence and some of these could represent interesting targets for channel-type carbon-bound or even epigenetic, uranium mineralization. Several small lead anomalies appear to be associated with the Tshipise fault and this should also be investigated for copper mineralization as copper has been found close to the Tshipise fault on the farms Stayt 183 MT, Hughes 151 MT and Xmas 140 MT, west of Venda. (see fig. 3)

Limited follow-up work was undertaken across anomalies 1, 2 and 3. In each case exposure was poor but basically the lithologies agreed with those present on the 1:50 000 geological survey sheet. A single traverse of samples was taken across anomalies 1 and 2 and two traverses were taken (500 m apart) over anomaly 3. (See composite sheet for 2230 CB and figures 15 and 16). Samples were taken at 10 cm. depths every 100 m along the traverses. The elevated levels of nickel, cobalt, zinc, copper and lead were proven beyond any doubt but elevated arsenic values could not be duplicated. The other elements such as niobium and magnesium were not checked.

Abundant copper and magnesite occurrences are known from the area covered by this sheet as are two small graphite occurrences and one of gold. Large deposits of magnesite are known in the area with silica contents of 2,5% (Winfield O., pers comm., 1989), as only the higher grade material was extracted (with approx. 1% SiO_2), during past mining operations.

Plate 4

An example of some of the abundant 'in situ' magnesite which still exists in altered olivine rich sills and lavas in Northern Venda.

In addition a real potential still exists for coal which is known to occur in a belt between David 160 MT and a point north of Sagole Spa and further work is recommended in this regard. Where the late to post Karoo picritic sills intrude carbonaceous shales and coal seams of the lower Karoo, there is a good chance of amorphous graphite having formed.

A tarred road runs through the north of the sheet from south-west to north-east giving good access to the area except in the rugged terrain to the south. It should be noted that calcrete is developed over much of the area and may well shield or diminish the surface expression of any mineralization that may exist. Examination of the calcrete for graphite flakes may be a good guide to buried graphite deposits. (Wilke 1969). Transported sands are present over the southern parts of this area and may also obscure geochemical signatures.

SHEET 2230 DA (THENGWE)

This sheet appears to have a good potential for mineralization. There is an old magnesite mine (The Nyala) in the north-central portion of the sheet and this is reflected by a slightly displaced soil magnesium content of up to 2%. Two known copper occurrences in the north-eastern quadrant of the sheet are reflected by copper contours of 100+ ppm and 50+ ppm. The former is associated with a tuffaceous horizon in the Nzhelele Formation and the latter with Wylliespoort Formation sediments. The tuffaceous units of the Nzhelele Formation are known to be anomalously mineralized with respect to copper. A total of 689 samples have been taken over the area covered by the sheet and most of these were taken in the northern half and southern third with the intervening, rugged Soutpansberg mountains not having been sampled.

The dog-legged Mo anomaly with Y associated in the north-eastern portion of the sheet is supported by elevated Cu, as is the U-Mo anomaly to its west and the Mo anomaly due east. The olivine dolerite sills in the north of the sheet should be considered as targets for Norils'k type Ni-Cu-Pt deposits, as well as for magnesite. The undifferentiated basal Karoo Formations (also in the north) may well host coking coal of a smilar type to that currently extracted at Tshikondeni. As the intrusive dolerite sills are fairly intimately associated with the potential coal bearing sediments, the chances for amorphous graphite development at places is considered good.

The Nzhelele Formation rocks which outcrop in a strip up to 3 km in width in the northern third of the sheet are of interest, particularly as they are known to host copper mineralization in the Mutale Copper Fields and elsewhere. It is also significant that most of the anomalies generated on this sheet occur over Nzhelele Formation rocks. In addition the potential for sediment hosted copper mineralization within the Wylliespoort sediments (which underlie some 66% of the sheet) should not be overlooked.

The thermal spring at Sagole Spa in the north-eastern quadrant of this sheet is evidence of current hydrothermal activity and along with the numerous faults in the area suggests a fairly good potential for hydrothermal mineralization, particularly copper and possibly even silver and gold. The arsenic anomalies associated with faulting in several places should be checked for gold. Much of the northern and central portions of this sheet, close to the escarpment edge, are covered by recent transported sands which may obscure geochemical signatures. Access to Sagole Spa is by means of a good gravel road but much of the rest of the sheet area has moderate to poor access.

SHEET 2230 BC (MULALADRIFT)

This sheet has been well sampled with the exception of the southern portion of Doppie 95 MT and Bali 84 MT (the latter being excluded from Venda at the time of the survey). A total of 820 samples were taken over the sheet. Access to the area is good, by way of a tarred road from Tshipise to Pafuri which runs roughly through the middle of the sheet. Generally the area is considered to have fair to good mineral potential, particularly in the Gumbu Formation rocks where several known graphite occurrences have been reported on the farms Bali 84 MT and Wendy 86 MT. Not only is there a current shortage, worldwide, of flake graphite (Russel, 1988) but the potential for gold mineralization associated with graphite has not been investigated in most cases. The Gumbu Formation calcareous meta- sediments should be assessed as hosts for Mississippi Valley type base metal mineralization, associated with fracturing, related to the Soutpansberg graben, and may also host epithermal and skarn type gold and tungsten mineralization. In addition a barite occurrence is known on the farm Wendy 86 MT in association with Karoo sediments. The fact that this falls near the edge of a downfaulted basin between the Bosbokpoort and Tshipise faults suggests the potential for sediment hosted massive sulphide mineralization. It is recommended that this area be thoroughly checked and evaluated.

The area around the Jurassic syenite intrusives and the anomalies associated with them are also considered to be worthy of further investigation, because if the syenites are agpaitic they could be associated with REE, uranium, zirconium, tin, tantalum, niobium and zinc. In addition the intrusive bodies themselves could have acted as heat engines and volatile sources for hydrothermal mineralization, which may have resulted in the concentration of base metals, gold, REE's and uranium. A field checking exercise was undertaken over portions of anomalies 1, 2 and 3 on this sheet (see composite overlay and figures 18 and 19) and elevated values of zinc, copper, niobium, nickel and arsenic were confirmed. In addition the relatively low molybdenum values occurring in anomaly three were confirmed. The cobalt values of up to 51 ppm encountered on anomaly 2 were not reproduced and values of up to 17 ppm were obtained. Substantially higher nickel values than those indicated by De Beers sampling over anomaly 3, were obtained, with a maximum of 1 540 ppm being obtained over calcareous rocks of the Gumbu Formation. Within the Limpopo belt, nickel is currently mined at the Selebi-Pikwe deposits in Botswana. There is also a known millerite deposit in Gumbu Formation marbles close to a serpentinised ultramafic intrusive near Mabiligwe, north of Venda. Several magnesium, nickel and cobalt anomalies are present over the Letaba Formation olivine basalts as would be expected. Also of significance on this sheet is the presence of one of only 3 sulphur anomalies (1%) at X = 19757 and Y = 71222.

Major faults such as the Bosbokpoort and significant shear zones on Feskaal 85 MT and to the east of it, could also be significant locations for hydrothermal type mineralization and should not be overlooked, particularly as the thermal spring at Sagole Spa occurs on the adjacent sheet to the south of this one. It should be noted that much of this area is underlain by various thicknesses of calcrete and this may screen geochemical signatures from underlying rock types. Graphite flakes in calcrete may be a guide to underlying graphite deposits.

SHEET 2230 BD (MADIMBO)

This is one of the parts of Venda where intermittent mining activities have taken place over the last 85 years. It is reported (Loxton, et al., 1982) that copper was extracted from quartz filled dilation veins in Nzhelele Formation rocks between 1904 and 1914 in the Mutale area and that subsequent bursts of mining activity have taken place. The potential for copper and coal were described by Grewar (1907) and he also makes mention of a possible diamond pipe in the area. In addition to this, graphite has been extracted in several places on this sheet. The Gumbu Mine, Khonoga Kop and Madimbo occurrences, all occur in the north of the sheet, outside Venda but the Mutale graphite mine falls within Venda in the south-centre of the sheet. The Mutale Mine was operated between 1943 and 1962 (Wilke, 1969) and has subsequently operated occasionally. In this deposit the graphite is of the "amorphous"variety (actually being cryptocrystalline) and has formed by metamorphism of a coal horizon. There is believed to be a strong possibility of further deposits occurring along the same coal horizon east and west of the mine (Wilke, 1969).

In addition it is suggested that there is a potential for gold mineralization associated with the graphite. However, at present the most significant known mineralization in the area is the high grade coking coal which occurs at Tshikondeni in the south-east of the sheet. Base metal prospecting rights of the Tshikondeni area are held presently by ISCOR who are operating the coal mine. In a recent analysis of coal from the Tshikondeni deposit Boshoff (1988) reports a calorific value of 29,7 MJ/kg which is higher than most coals mined in the Transvaal and Orange Free State. In addition he reports low water contents of 0,9% and moderate ash contents of 16,9%. Thus the quality of coal produced in Venda appears to be fairly good. At Tshikondeni there are two economically important coal horizons, an upper seam of 2,5 to 3,0 m thick and 95 cm below this a 2,0 to 2,5 m thick lower seam. The yield of coal from the upper seam is expected to average 67% at 16% ash content (ISCOR News, 1988). Some of the many anomalies occurring in the ISCOR ground at Tshikondeni may have been highlighted by pitting activities for coal. However, it is recommended that some of these be followed up as it is felt that the potential, in particular for uranium, is fairly good. It should also be noted that zirconium contents of up to 3 334 ppm have been recorded from soils in the extreme southeast of the sheet. In addition copper anomalies obtained by this survey confirm the elevated copper levels in the Nzhelele Formation rocks of the area.

Excluding the Tshikondeni area from further discussion, there are still some anomalies of interest, including numbers 1 and 2. Follow-up work undertaken on anomalies 1 and 2 has confirmed elevated barium and niobium are elevated over both (See appended composite overlay and figs. 20 and 21). In addition nickel, zinc and cobalt are confirmed as elevated over anomaly 1 whilst lead is confirmed as elevated over anomaly 2. The follow-up work once again, could not confirm elevated levels of arsenic over the anomalies tested.

Unlike those in the south-east of the sheet, the zirconium anomalies in the west of the sheet are relatively low grade. The presence of several single point fluorine anomalies may well reflect the highly faulted nature of the southern portion and some barite may be associated with faulting, though most is considered to be of sedimentary origin. The numerous single point molybdenum anomalies over Letaba Formation rocks are enigmatic.

This sheet has been well sampled except over the Nzhelele Formation rocks in the south-central area and some 670 samples have been taken. The area is assessed as having a good potential for mineralization with the most significant types including the following:

i) Copper in Nzhelele Formation rocks.

ii) Nickel, copper and PGE's in the picritic sills, although the thicker sills developed further west have the best potential.

iii) Graphite in Madzaringwe Formation rocks adjacent to intrusive sills.

iv) Coal in Madzaringwe Formation rocks.

v) Heavy element concentrates and channel type uranium mineralization within Karoo Sequence sediments.

Finally the possible shielding effect of calcrete, which is developed in the area, should be borne in mind. Access to the southern portion of the area covered by this sheet is by tarred road from Tshipise to Pafuri.

SHEET 2330 AB (LEVUBU)

Of all the sheets covering Venda this is one of the few to contain tracts of gneiss and one of only three where syenitic and alkaline rocks occur. The Schiel Complex rocks contain anomalous levels of the twenty elements U, Pb, W, Ba, Sb, Sn, Mo, Nb, Zr, Y, As, Zn, Cu,Ni, Co, Fe, P, Al, Mg, F. In addition to this the Schiel Complex lithologies have the highest average enrichments of several elements including U, Pb, As, Ba, Ta, Bi and Sn. They present a good provenance area for mineralization associated with the elements listed. This sheet appears to be amongst the most highly mineralized, based on the results of this study. It is evident that barium is fairly abundant in soils over the syenites, granites and gneisses, as is fluorine and this suggests the presence of hydrothermal systems in the area and a high potential for mineralization. The Shirindi Granite (tonalitic) intrudes along the eastern edge of the sheet and the bulk of the intrusion lies on sheet 2330 BA to the east. Whilst the intrusion itself lies out of Venda, it may well have acted as a heat and volatile source for mineralization in adjacent areas. The alkaline assemblage of the Schiel Complex which includes carbonatite material, would explain the relative enrichment of REE and F over these rocks and one would also expect enrichments of Nb-Ta, Zr, P and Ti. The very high arsenic values on this sheet combined with other encouraging indications of hydrothermal mineralization and a recorded gold occurrence (Hawkins, 1978) suggest that the potential for gold mineralization is real and should not be overlooked. The single highest arsenic anomaly of 124 ppm was obtained at X = 92977 and Y = 84663 over Swazian Gneisses. This anomaly lies on the southward extension of the Siloam fault and should be checked. The very high fluorine contents in the south eastern portion of the sheet go up to 9,2% which is significant and may indicate hitherto unknown hydrothermal systems. Quartz veining and breccia are associated with the extension of the important Siloam fault and attention should also be paid to the possible extension of the Barotta fault zone, for epithermal Au, Ag and Sb mineralization.

Sample distribution is good except in the central portion of the sheet and a total of 497 samples having been taken. Access is good to the northern portions by means of a tarred road and fair to poor in the south.

SHEET 2230 AD (ESMEFOUR)

Venda occupies approximately thirty-five percent of this sheet, in the south-eastern portion. Sampling within this portion of Venda is patchy with no sampling having been carried out over the Ha-Tshirundu hills and very little over the farms Zisaan 31 MT, Minnie Skirving 34 MT, Woodhall 35 MT, Humie 36 MT and N'jeleles Drift 38 MT. In addition to this, two sets of sample positions were given for several of the farms on this sheet. Consequently, difficulty has been experienced in clarifying the data on this sheet and it is considered less reliable than the others. Because sample positions had to be redigitized for parts of the sheet, problems were encountered with plotting and certain elements including nickel, copper, zinc, cobalt and fluorine were not able to be plotted correctly. Despite the various reservations about this sheet and its sample distribution, it is reckoned to have good potential for the following types of mineralization:

i) Coal in the Madzaringwe Formation just north of the Tshipise fault. Amorphous graphite may also be locally developed where fault movement has occurred or where intrusive dolerites are present.

ii) Flake graphite is known to occur at places on the farm Dawn 71 MT and Wilke (1969) considers at least one deposit of significance. The Gumbu Formation calc-silicates stretching from Dawn into Venda, represent a good target area for flake graphite.

iii) There is potential for dimension stone (in the form of marble) along the sliver of Gumbu Formation calcareous rocks north of the Bosbokpoort fault.

iv) In several places ultramafic dykes have intruded the Letaba Formation and these have been pitted for magnesite (O Winfield, pers. comm., 1989).

v) On the farm Woodhall 35 MT, within Malala Drift Formation rocks there are magnetite quartzite horizons which contain more than 50% total iron (Van Eeden et al. 1955) and these should be investigated as sources of both iron and gold mineralization.

vi) The highest copper anomaly obtained during this survey (737 ppm) was from soil over Gumbu Formation rocks at X = 22991, Y = 96968 and this warrants further attention. Due to difficulties experienced with plotting this sheet, a contoured overlay of copper values could not be produced.

On this sheet, the Karoo sequence is deposited in a localised trough or basin which has been downfaulted between the Bosbokpoort and Tshipise faults. Both of these are major faults and have obviously been active over a long period of time. As basin edge faults they would form favourable loci for sediment hosted massive sulphide deposits and on the farm Wendy 86 MT immediately to the east of this sheet, a barite occurrence is known and should be further investigated.

Access to this area is good and the terrain despite being hot, is relatively easy to work in. The effectiveness of soil sampling over much of this area is diminished by the presence of calcrete, and this is particularly true over Gumbu Formation calcareous rocks. This could help explain the relative paucity of anomalies in such a potentially mineralized environment. On the other hand careful examination of calcrete for flake graphite may prove useful in locating a graphite deposit and the present worldwide shortage of flake graphite (Russel, A., 1988) should not be forgotten.

SHEET 2231 AC (MABILIGWE)

Venda occupies the south-western portion of the map sheet, between the Kruger National Park and the western edge of the sheet in the lower half. With the exception of a narrow corridor from 2,5 to 4,5 km from the bottom of the sheet in which the terrain is very rugged, the area has been well covered by samples with a sample density of approximately 1,5 samples per km^2 having been achieved, which is well above the average density for the study.

As a general observation the area seems to contain a high density of anomalous values, most of which occur over Letaba Formation basalts. Uranium, niobium, yttrium, zinc, zirconium and barium are commonly present at anomalous levels and this is probably best explained by the fact that nephelinites are interspersed between layers of more olivine rich basalt, suggesting an alternating alkaline-ultramafic assemblage, with the former generally high in incompatibles such as the uranium, niobium, yttrium, zinc, zirconium and barium observed in this area. These nephelinites only extend a few kilometers west of this sheet, being uncommon west of a point 10 km east of Masisi (Brandl,G., pers. comm.,1989). This means that the majority of Letaba Basalts within Venda do not contain significant nepheline and this eastern portion will thus appear anomalous in elements associated with alkaline nephelinites when compared with the whole Letaba

Basalt Formation. The fairly widespread nickel, cobalt and magnesium values are probably the result of the olivine and magnesium rich basalt horizons. Finally copper appears anomalous in places but this is to be expected in basalts, though the high correlation between copper, nickel and cobalt is suggestive of sulphide deposits (Boyle 1974) and should be investigated.

Despite the large number of anomalies indicated in the area the possible shielding effect of calcrete should be remembered. Immediately to the south and west of this area, coal is currently extracted at the Tshikondeni Mine and drilling in the south of the sheet has shown an extension of the coal deposit into the Kruger National Park. (fig. 3).

In general the area is highly faulted and the potential for mineralization is assessed as fair to good. It is felt that an as yet undiscovered carbonatite or alkaline syenite intrusive may be present in this area. Access is good except in the rugged southern portion near the Luvhuvhu river.

SHEET 2230 DB (HA-MAKUYA)

The results of soil sampling on this sheet suggest that it is poorly mineralized but this is largely a result of poor sample coverage with only the north-western corner having been reasonably well covered. Observations by the Geological Survey resulted in numerous copper occurrences being recorded on parts of this sheet that were not sampled during this study. These copper occurrences are mainly within rocks of the Nzhelele Formation though some are associated with Wylliespoort sediments and faults. The northern portion of the sheet forms part of the Mutale Copper Fields and within this area at least 32 cupriferous quartz vein occurrences have been reported and investigated. In addition further west of the sheet in the Sagole Spa (Klein Tshipise) area, copper mineralization has been reported in a 1 to 2 m thick, dark mauve coloured vitric tuff which can be traced from the Nwanedi National Park to the

Mutale area. Despite the fact that the southern portion of this sheet is covered by fairly incised and rugged terrain, the reasons for the sparse sample cover over most of the rest of the sheet (only 111 sets of analytical results available, many of which are stream sediment samples) are not obvious. It is stressed here that the Nzhelele Formation volcanics, particularly the tuffaceous horizons, are known to be good potential sites for copper mineralization (See discussion of Sheet 2230 DA).

The presence of anomalously high values of fluorine at several locations on this sheet is suggestive of hydrothermal activity and this is supported by the presence of a thermal spring (Sagole Spa) a few kilometers west of the sheet. In addition an arsenic anomaly in reasonably close association with copper mineralization, implies that there may be a potential for gold mineralization in the area. This is borne out by records of fine grained gold having been found, associated with copper mineralization in a fault system at the old Musunda copper mine (O Winfield pers. comm 1989). Access to the area covered by this sheet is fair near the Thohoyandou - Masisi road, but poor away from this and in the more rugged areas.

SHEET 2230 CC (NZHELELE)

Generally this sheet displays a moderate development of mineralization. Two previously known copper deposits and one manganese deposit fall out of the areas sampled and are thus not indicated by the present study. The present regional geochemical survey of Venda shows the highest mean copper and cobalt concentrations occuring in Sibasa Formation basalts and this is supported by many references to copper mineralization in this formation (Ramagwede and Fletcher 1984).

It is possible that 3 of the four molybdenum anomalies (which are fairly significant being up to 30 ppm) that occur in the south-east of the sheet, may be associated with a north-east to south-west trending fault and breccia zone. There are several zirconium anomalies, mainly in the northern section of the sheet and these appear to be associated mainly with alluvium or Wylliespoort sediments and they are not supported by other elements. These zirconium anomalies are thus felt to be localized palaeo-accumulations in the Wylliespoort rocks, or more recent ones in the alluvium and in either case are not thought to be of great economic significance.

Sampling carried out over this sheet was restricted to the northern and central valleys and almost no sampling was carried out in the rugged mountainous areas which rise to over 1 600 m. The south-western portion, north-east corner and central Nzhelele Valley are served by tarred roads, whilst the mountainous areas have poor accessibility. A total of 499 samples were taken over the sheet area. The Siloam fault which cuts the central portion of the sheet, is a major dextral fault and is the only major post Soutpansberg fault that trends west-north-west and along which duplication of strata has occurred (Barker, 1979).

A prospecting programme was carried out over Tonondwe 198 MT, Siloam 199 MT, the eastern half of Sendedzane 200 MT and the intervening state land, in the early nineteen eighties and copper mineralization was the main target, though analyses were also conducted for nickel, zinc and lead. It is reported (Ramagwede and Fletcher, 1984) that two main types of copper mineralization were recognized in the area:

i) Irregular though generally low grade hydrothermal copper mineralization associated with the epidotized upper portion of the lavas, an irregularly developed tuff horizon and the lower 20 cm of an overlying red shale. The copper mineralization occurs as veinlets, cavity and amygdale fillings as well as disseminated in the epidotized lava.

ii) Hydrothermal copper mineralization associated with calcite, chlorite and specularite in fracture zones and quartz veins. Epidotization, feldspathization and chloritization of the country rocks is frequently associated with mineralization.

Similar types of copper mineralization were noticed and investigated on Mpefu 202 MT (Schutte, 1978). It is suggested that conglomerates and "agglomerate" horizons above the red shale should be examined for evidence of boron (tourmaline), barium and alteration, with a view to the association with sediment hosted massive sulphide deposits. In addition the presence of several major faults in the area (Siloam, Fundudzi, Mufangudi) and the presence of two thermal springs, strongly suggest the potential for hydrothermal mineralization (including copper, silver and gold).

The presence of coal has long been known on Mpefu 202 MT and should not be forgotten. A thorough investigation of the coal potential on the western portion of Mpefu 202 MT and Jazz 715 MS (both on the adjoining sheet 2229 DA), was carried out by Mining Corporation between 1979 and 1982 (Schutte, 1982). This revealed the presence of up to 94 million tonnes (to a depth of 300 m) of low rank blend coking coal.

Nzhelele Formation rocks in the Mufungudi river valley represent a further target for copper mineralization and the Afton fault which passes into the extreme north centre of the sheet is reported to have gold and copper mineralization associated with it, east of the Nzhelele Dam (O Winfield, pers. comm., 1989).

SHEET 2230 CD (THOHOYANDOU)

The area represented by this sheet has been very poorly sampled and no real assessment of the mineral potential can be made based on the present study, except in the north-eastern and south-eastern corners where sampling was good. A broad spectrum of lithologies are present on the sheet, the oldest being Archaean Goudplaats Gneiss with minor metamorphosed Giyani Group "greenstone" remnants, which occur in the extreme south-east of the sheet. The latter would present fair targets for nickel, copper and gold mineralization, though none is reported from previous work. North of this and trending east-north-eastward across the map is a belt of Sibasa Formation rocks, some ten kilometres wide. Interspersed within the predominantly basaltic lavas are subordinate sandstone and shale horizons, as well as a tuff. Whilst investigating a portion of the south-west of this sheet and the Siloam Valley on the adjoining sheet (2230 CC), Ramagwede and Fletcher (1984) noted the presence of two main styles of copper mineralization in the area.

i) Irregular though generally low grade hydrothermal copper mineralization (copper lower than 0,4%) associated with the epidotized upper portion of the lavas and an irregularly developed tuff horizon, above which are red shales. The copper minerals occur as veinlets, void and amygdale fillings, or disseminated in the epidotized lava.

ii) Hydrothermal copper mineralization associated with calcite, chlorite and specularite in fracture zones and quartz veins. Alteration of the country rocks is reported to be associated with the mineralization and epidotization, feldspathization and chloritization are assessed as the most common and significant types.

In both these styles of mineralization nickel, zinc and lead, which were also checked, appeared to be insignificant and sub-economic. Some "spectacular" copper occurrences are alluded to. Mention is also made of conglomerate horizons which have been recognized above the red shale in the area and these would be worthy of further attention both in terms of uranium/gold and other heavy element deposition sites, as well as basal successions of localized third order basins that may be associated with sediment hosted massive sulphide deposits. "Agglomerates" overlying some of these conglomerates should be thoroughly checked for mineralization and alteration, as well as boron indications (tourmaline).

The important Siloam fault cuts through the south-western portion of the area and trends west-north-west to east-south-east. A cobalt anomaly is developed where the Siloam fault intersects Archaean Gneiss at the edge of the Sibasa Basalts and this should be checked. Though follow-up work performed to date on this study has failed to confirm elevated arsenic values it is felt that the arsenic anomaly of 112 ppm which is closely associated with a fault intersection zone, should not be overlooked and should be checked for gold and copper mineralization. In addition the recently active Fundudzi fault cuts through the northern portion of the sheet and trends east-north-east to west-south-west. Numerous smaller faults are also present and the presence of a thermal spring just west of the map area coupled with recently active faults and recognized hydrothermal mineralization, suggest a high potential for hydrothermal mineralization in the area.

In addition it is worth noting that a small outcrop of Nzhelele Formation rocks are present in the Mufungudi river valley in the north-west portion of the map sheet and these represent a further target for copper and possibly gold mineralization. Thohoyandou, the capital of Venda is situated in the southeast of the sheet area and covers the northern half of a large anomaly. Whilst the southern portion of the sheet area is well served by tar roads, much of the rest is fairly mountainous terrain with moderate to poor accessibility.

SHEET 2329 BA AND BB (MARA AND LOUIS TRICHARDT)

Only the central third of these sheets is incorporated in Venda and of this area over a half is covered in recent deposits and alluvium. There is a high density of village development, particularly on Sheet 2329 BB and it is believed that zinc and lead anomalies are largely the result of human activities. Village development is much more extensive than indicated on the 1:50 000 topographic sheet. Because of poor outcrop and dense human habitation, the area is one of the most difficult parts of Venda to assess meaningfully. The present study has highlighted some potential targets though the potential is considered best for nickel, copper, corundum and gold mineralization. Access to the area is good and several tarred roads exist.

A check soil sampling traverse (A-B) was positioned across a niobium, zinc, arsenic and molybdenum anomaly and samples were taken every one hundred metres along the traverse. (See attached composite overlay (Appendix 2) and fig. 17). Elevated values of both niobium and zinc were proved beyond doubt, though the peaks obtained by check sampling were not as high as those obtained by De Beers. However, in the cases of both molybdenum and arsenic, the values obtained by check sampling were very low and did not reflect the elevated values obtained by De Beers. The magnesium-cobalt-molybdenum anomalies just south of Tshikwani village are considered real and significant, as they occur near a contact between acidic gneisses and partially assimilated ultramafic rocks. Both nickel mineralization and vermiculite (du Toit 1979) are known from a serpentinised ultramafic just south of this area and outside Venda. The zinc anomaly around Tshikwani village is believed to be the result of extensive corrugated iron (galvanized) sheeting and the small lead anomaly is around the store and petrol pump area and thus probably the result of contamination.

SHEET 2230 DC (MAKONDE)

The sampling over this sheet was patchy, being good in the north-western and south-western corners, and fair in the central strip trending east-north-east to west-south-west. Large portions of Mpapuli 278 MT and Mangundi 279 MT were sampled, but analytical results are not available. A known tin occurrence is reported from Mangundi 279 MT. The rugged terrain in the north-eastern portion and a strip adjacent to and north of the Thohoyandou-Punda Maria tar road have not been sampled at all. Much of the area sampled is fairly densely inhabited and there are many villages, particularly in the western half. The southern quarter of the sheet is underlain by Swazian Gneisses with minor metamorphosed "greenstone" remnants. These hold potential for nickel, copper and gold mineralization, amongst others. A strip of Sibasa Formation rocks, predominantly basalts, occurs to the north of this and varies between 6 and 13 km in width. The Sibasa Basalts are known to host copper mineralization in places and single point copper anomalies are common over these rocks. In addition six single point barium anomalies are present over Sibasa Formation rocks, though most of these appear in close association with faults. Fairly numerous tuffaceous horizons have been noted in a strip from Mungindini trending east-north-east. North of the Sibasa Formation rocks are Fundudzi Formation rocks in the west and Wylliespoort Formation rocks in the east. The northern and southern quadrants of the sheet area host abundant intrusives with an east-north-east to west-south-west and north-east to south-west trend predominating. Access to most of the area covered by the sheet with the exception of the mountainous terrain in the extreme north-east, is good.

SHEET 2229 DD (WYLLIE'S POORT)

Venda occupies approximately 15% of this sheet forming a strip between 5 and 15 km wide straddling the centre of the sheet, east of the main Louis Trichardt-Messina road. Much of this area is rugged and mountainous and sampling was restricted principally to the valley floors. Access is also poor except in the valleys.

Wylliespoort sediments are the predominant lithology present, with smaller areas underlain by Nzhelele and Sibasa Formation rocks and Karoo sediments. Perhaps the most significant known mineralization in the area is the coal which occurs on Jazz 715 MS and the western portion of Mpefu 202 MT. This was thoroughly investigated and drilled by Mining Corporation between 1979 and 1982 (Schutte, 1982). Some 94 million tons of low rank blend coking coal were indicated by a programme of almost 4 km of diamond drilling and 556 m of percussion drilling. The coal seams located, varied in thickness from 1 cm to 3,65 m and were intersected at between 15 and 364 m below surface. The coal measures dip at 21^{0} to the north.

In addition to this a copper occurrence is reported from the west of Mpefu 202 MT and is associated with Sibasa Formation lavas (Hawkins, 1978). Potential for copper mineralization also exists in Nzhelele Formation rocks in the area. The presence of several thermal springs on this sheet, one of which occurs in Venda with the others just a few kilometres west, combined with intense faulting and fault breccia development, indicate that there may be a potential for hydrothermal mineralization in the area and in fact fault associated hydrothermal copper mineralization has been identified on Mpefu's 202 MT (Schutte, 1978).

SHEET 2230 CA (TSHIPISE)

Venda only covers approximately 12% of this sheet in the south and east. The sampling within this portion of Venda is poor and there has been no sampling in the Lavhalisa and Tshikombani hills. The main lithologies present within this portion of Venda are the Sibasa, Wylliespoort and Nzhelele Formations. In addition there are some diabase sills. The Nzhelele Formation rocks are concentrated around the Nzhelele Dam. Known mineralization includes a manganese occurrence associated with Wylliespoort Formation rocks on the farm Keerweder 169 MT, a copper occurrence associated with Sibasa Formation rocks near the Afton fault and a gold occurrence associated with the Afton fault, east of the Nzhelele Dam (O Winfield pers. comm. 1989). The presence of the Tshipise thermal spring, north of Venda, on this sheet and the complex system of faults suggests a reasonable potential for hydrothermal type mineralization. Access to the area is fair.

SHEET 2330 AA (RATOMBO)

At the time of the sampling exercise Venda constituted a horn or crescent shaped portion in the southern half of this sheet. The sample coverage is poor except in the eastern half of the area, south of the Klein Letaba river, where some 69 samples were taken. As a result of this and the recent inclusion of other farms in the area into Venda, the sampling is considered inadequate and does not represent the true mineral potential of the area, which is considered fair.

Within the limited portion that has been sampled, four types of mineral occurrences have been noted as anomalous. There is a nickel and magnesium anomaly over an ultramafic body of the Bandelierkop Complex near the village of Ha Mashamba and this has been previously reported as a nickel occurrence. (Fig. 3). The zirconium anomaly near the Klein Letaba river is associated with a small plug of Palmietfontein Granite (which is of similar age to the Schiel Complex).

In the remaining portion of Venda that falls on this sheet, two nickel occurrences have been previously noted, in association with ultramafic rocks of the Bandelierkop Complex, west of Elim Hospital. In addition, four phosphate occurrences have been previously reported as can be seen from figure 3. Fairly widespread nickel and corundum have been reported from other parts of the sheet. Access to the portions of Venda that occur on this sheet is fair to good.

SHEET 2330 BA (TLANGELANE)

The portion of this sheet which is occupied by Venda is approximately 16% and is limited to the north-eastern and south-eastern corners. Sampling within this portion of Venda is good, both in distribution and density. Swazian Gneisses cover most of this portion of Venda and some major diabase dykes are present striking east-north-east. In addition three small bosses of Shirindi Granite (tonalitic) intrude the area. The main body of Shirindi Granite lies between the two portions of Venda and extends slightly into the Schiel sheet to the west. The Schiel Complex also lies on the adjoining sheet to the west and may be responsible for the high barium concentrations in the area. Finally the Kudu's River Lineament trends in a north-easterly direction and cuts through the north-western corner of the southern portion of Venda, just touching the south-eastern extremity of the northern portion of Venda. A barium anomaly is closely associated with the Kudu's River Lineament. Access to the area is good, and the terrain is undulating. Only one small metamorphosed "greenstone remnant" is recorded within the Swazian Gneiss covering this portion of Venda. The major barium-lead anomaly cannot be explained by its co-incidence with the tonalitic Shirindi Granite and should be checked. It is possible that small syenitic plugs may be located in the area, related to the Schiel Complex. The potential for mineralization on this sheet is assessed as fair to poor.

SHEET 2230 DD (KA-XIKUNDU)

Venda constitutes less that 15% of this sheet and is restricted to the north-western corner of the sheet. Sample coverage is very poor with sampling having been conducted between the secondary road from Thohoyandou to Ka-Mhinga (which runs along the foot of the mountains) and the Luvhuvhu river.

The predominant lithology underlying the sampled area is the Nzhelele Formation of the Soutpansberg Group. The area is generally heavily faulted with a predominant north-west to south-east direction and secondary east-north-east fault direction. Access to the area is good except in the north where it is poor. The mineralization potential of the area is assessed as poor.

4. CONCLUSIONS AND RECOMMENDATIONS

1. By its very nature, a regional soil sampling study such as this one, should not be expected to locate specific orebodies or mineral deposits (though against all odds it may in fact do this!), rather it should be considered as a first pass appraisal to indicate areas and lithologies with higher mineralization potential than others (Govett, 1983). It is felt that this particular study has been successful in indicating some areas and lithologies of higher mineral potential.

2. Because the sampling and analytical phase of this survey was carried out by one organisation and the interpretation by another and because the regional loam sampling was secondary to the principal objective of heavy mineral sampling (designed principally to locate kimberlites), the sample distribution was not ideal for a study of this type. The irregular sample distribution was exacerbated by the very rugged terrain in parts of Venda and restrictions on sampling over certain claim ground. With large areas left unsampled it was impossible to meaningfully use the more powerful statistical techniques such as geostatistics, trend surface or moving average analyses.

3. Whereas the use of a computer in handling a geochemical data base of this size was invaluable and saved a great deal of time, problems were encountered because of the 640 Kb random access memory (RAM), that resulted from using a conventional disc operating system. In addition the lack of total interactivity between spatial and other variables and the inability of the statistical package available, to handle lognormal populations directly, were distinct drawbacks and anyone wishing to undertake a similar exercise is firmly recommended to ensure that their computer software does not suffer from similar deficiencies.

4. The availability of 1:50 000 scale geological information from the Geological Survey was a great help and meant that a meaningful subdivision of data could be made into lithological groupings. In

addition, use of the 1:50 000 scale has allowed the contoured overlay sheets produced during this study to be directly used in conjunction with existing geological and topographic maps that have been produced by the Geological Survey and Surveyor-General respectively.

5. The check sampling that has been carried out over nine of the indicated anomalies confirmed the existence of elevated values of all elements tested with the exception of arsenic and in one instance molybdenum (see figs. 15 - 21). However should funding become available to extend this study it is recommended that infill sampling be undertaken in areas of interest and in addition more extensive check sampling of anomalies be undertaken. It would also be advantageous to extend the elements plotted from the 14 presently chosen and to plot all anomalous data for each of the elements studied, rather than selected ones.

6. It is worth noting that most of the minerals that have been mined and exploited in Venda in the past, including coal, magnesite, corundum and graphite, would not have been located by a geochemical soil sampling programme such as the one under review. For this reason an extensive literature survey has been undertaken and a large body of information concerning these minerals is included in an effort to give a balanced appraisal.

7. As a result of both the interpretation of the regional geochemical survey and an extensive literature review of known mineralization, the following types of mineralization are considered to have the greatest potential for economic grade occurrence in Venda:

    i) Nickel-copper-platinum mineralization in the picritic sills which intrude coal bearing lower Karoo sediments of the Madzaringwe and Mikambeni Formations. All the samples anomalously enriched in nickel occur on sheet 2230 CB and the area around anomalies two and three on this sheet is felt to be of particular potential because of the presence of anomalous sulphur. The potential for amorphous graphite is also very high where the sills intrude the coal bearing lower Karoo sediments. Conversley where there are fewer sills there is less chance of the coal measures having been devolatilized to any great extent.

ii) The coal potential of the Madzaringwe Formation at the base of the Karoo sequence is considered very good. Coal is currently being produced at Tshikondeni in the east of Venda but substantial reserves have been proven on Mpefu 202 MT and Jazz 715 MS (on sheet 2229 DD). In addition coal has been intersected in boreholes on the farms David 160 MT and Gaandrik 162 MT on the sheet 2230 CB. The potential is considered best on sheets 2229 DD, 2230 DA, 2230 CB and 2230 CC.

iii) The presence of copper mineralization has long been known in the Sibasa and Nzhelele Formation rocks in Venda and hydrothermal copper mineralization has been identified. Because several fault systems in Venda are known to have been re-activated periodically from Limpopo event times until post Karoo times and because of the presence in Venda of currently active thermal springs and known hydrothermal mineralization, the potential for hot spring type and other epithermal gold and silver mineralization is considered to be high. The possible association of gold with hydrothermal copper should also be investigated, particularly along the Siloam, Afton, Fundudzi and Tshamavhudzi faults. Greenstone remnants in the Goudplaats Gneiss should also be investigated for gold, particularly in the vicinity of the Schiel, Palmietfontein and Entabeni intrusives and major fault and breccia zones. Finally the potential for epithermal and skarn type gold mineralization in Gumbu Formation rocks, should not be overlooked.

iv) With the Soutpansberg succession having developed in a trough or graben which had mantle tapping marginal faults (as evidenced by outpourings of the basal Sibasa Formation basalts along these faults (Bristow 1986)) and the fact that the extruded basal lavas were rich in copper, it is felt that the chances of subsequent sediments being enriched in stratiform copper must be good. In addition to this, lava outpourings both at the commencement and near the end of basin formation and sedimentation, suggest that an active magma chamber and system was in existence during the intervening sedimentation. Thus the chances of exhalative activity are fairly good and the chances for volcanic and particularly sediment hosted massive sulphide deposits having formed are considered better than average. Sedimentary successions near major basin faults and cross-cutting faults such as the Siloam fault are considered good targets for this mineralization. Fundudzi Formation rocks and the shaly horizons of the Nzhelele Formation warrant particular attention in this area as does the known barite occurrence on Wendy 86 MT, even though it is in Karoo Sequence rocks.

v) The Gumbu Formation calc-silicates, though highly metamorphosed should be investigated for skarn mineralization as well as Mississippi Valley type base metal mineralization along major faults, possibly resulting from the dewatering of the Soutpansberg or Karoo troughs. In addition, the high grade metamorphism to which the calc-silicates have been subjected should have resulted in a fine equigranular texture which is ideal for dimension and building stone. The metamorphism has also resulted in the formation of flake graphite in places and as there is a world-wide shortage of this product at present, it warrants further investigation.

vi) The potential exists for unconformity, channel and coal associated uranium mineralization, as well as for copper-uranium gold mineralization of the Olympic Dam type.

vii) The iron ore potential of the magnetite quartzites which form part of the Malala Drift Formation in northern Venda, deserves more detailed investigation. In addition the chance of economic gold mineralization being associated with the magnetite quartzites, should not be overlooked.

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APPENDIX 1

TABLE OF ELEMENT CONTENTS FROM THE LITERATURE FOR COMPARATIVE PURPOSES.

APPENDIX I

TABLE I

TABLE OF TRACE ELEMENT CONTENTS OF VARIOUS ROCK TYPES

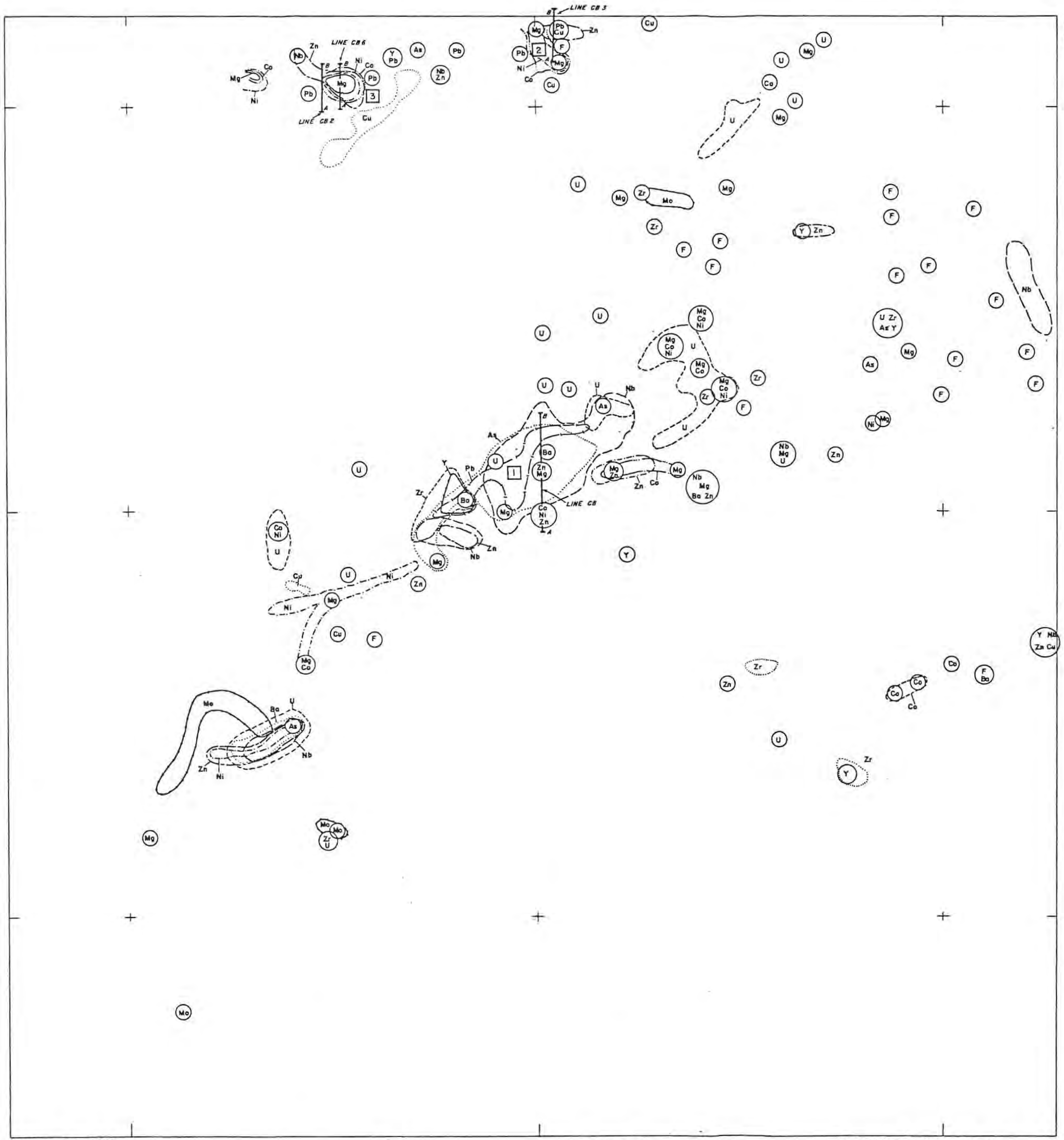
REFERENCES: *LEVINSON A.A. (1974)
+HAWKES, ROSE AND WEBB (1979)

BASALT		GRANITE		SHALE		QUARTZITE	ULTRAMAFICS		SOILS		ELEMENT	
0,6	0,53	4,8	3,9	4,0			0,001	0,03	1		U	1
2,2	2,7	17	20	12	12	5,5	0,003	0,004	13	13	Th	2
0,15	0,05	0,1	0,3	0,18	1,0	0,3	0,02	1,2	--	0,8	Bi	3
5	4	20	18	20	25	10	0,1	1	2 - 200	17	Pb	4
1	1	2	1,5	2	1,8	1,6	0,5	0,1	--	1	W	5
0,5	0,48	3,5	3,5	2	3,5		1	0,018	--	--	Ta	6
250	330	600	840	700	550	170	2	0,4	100-3000	300	Ba	7
0,001		0,001		0,01			0,001	n.a.	--	0,001	Te	8
0,2	0,1	0,2	0,2	1,0	1-2	1,0	0,1	0,1	5	2	Sb	9
1	1,5	3	3,0	4	6	0,6	0,5	0,5	10	10	Sn	10
1	1,5	2	1,3	3	2,6	0,2	0,3	0,3	2	2,5	Mo	11
20	20	20	20	20	20		15	1	--	15	Nb	12
150	140	180	175	160	160	220	50	45	300		Zr	13
n.a.		n.a.		n.a.			--	n.a.	n.a.		Yt	14
465	465	285	100	300	300	20	?	5,8	50-1000	67	Sr	15
30	32	150	276	140	143	40	--	0,14	20-500	35	Rb	16
0,05	0,13	0,05	0,14	0,6	0,6	0,05	--	0,13	0,2	0,31	Se	17
2	1,5	1,5	2,1	15	12	1,2	1,0	1,0	1-50	7,5	As	18
100	94	40	51	100	100	40	50	58	10-300	36	Zn	19
100	72	10	12	50	42	10	10	42	2-100	15	Cu	20
150	130	0,5	4,5	70	68	2	2000	2000	5-500	17	Ni	21
50	48	1	1	20	19	0,33	150	110	1-40	10	Co	22
n.a.	86500	n.a.	14200	n.a.	47000	9800	n.a.	94300	n.a.	21000	Fe	23
2200	1500	500	390	850	850	nil	1300	1040	850	320	Mn	24
200	170	4	4,1	100	90	35	2000	2980	5-1000	43	Cr	25
250	250	20	44	130	130	20	50	40	20-500	57	Vn	26
9000		2300		4600			3000	n.a.	5000		Ti	27
n.a.		n.a.		n.a.			n.a.	n.a.	n.a.		Ca	28
n.a.	8300	n.a.	42000	n.a.	26600	10700	n.a.	34	n.a.	11000	K	29
n.a.	300	n.a.	300	n.a.			n.a.	300	n.a.	100-2000	S	30
n.a.	1100	n.a.	600	n.a.	700	170	n.a.	220	n.a.	300	P	31
n.a.		n.a.		n.a.			n.a.		n.a.		Si	32
n.a.		n.a.		n.a.			n.a.		n.a.		Al	33
n.a.		n.a.		n.a.			n.a.		n.a.		Mg	34
n.a.		n.a.		n.a.			n.a.		n.a.		Na	35
400	420	735	810	740	680	280	100	20	--	300	F	36
*	+	*	+	*	+	+	*	+	*	+		

APPENDIX 2

COMPOSITE OVERLAYS OF ANOMALOUS ELEMENT CONTENTS ON 1:50 000 SHEETS.

Appen 2



LEGEND

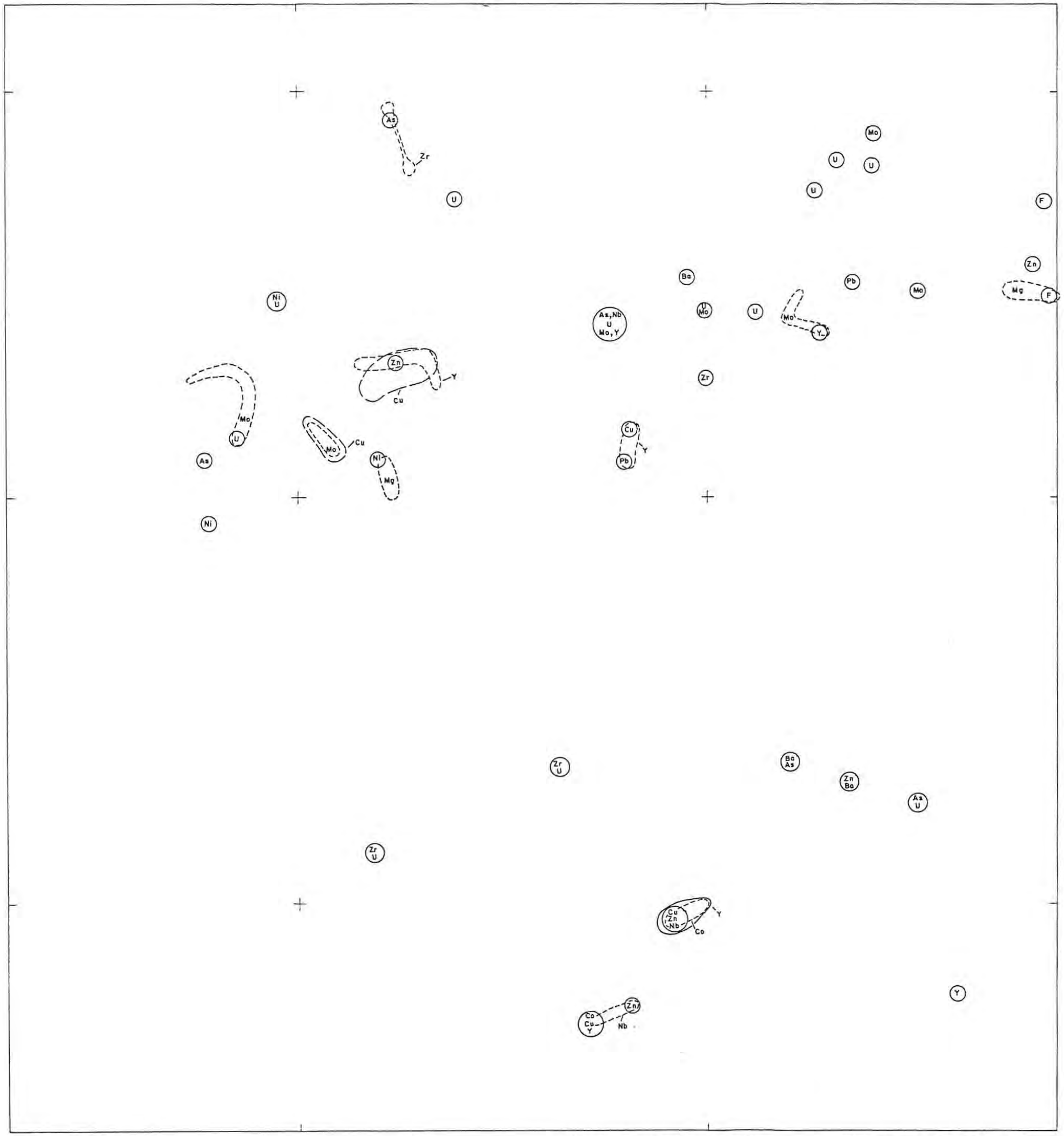
Cu	COPPER
Ni	NICKEL
Co	COBALT
Zn	ZINC
Pb	LEAD
Ba	BARIUM
Mg	MAGNESIUM
F	FLUORINE
As	ARSENIC
Zr	ZIRCONIUM
Nb	NIOBIUM
Y	YTTRIUM
U	URANIUM
Mo	MOLYBDENUM
2	ANOMALY REFERENCE NUMBER
A B	CHECK SAMPLING TRAVERSE LINE

DRAWN BY STK
MINERAL DEVELOPMENT DIVISION

FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230CB



LEGEND

Zr	ZIRCONIUM
Ni	NICKEL
As	ARSENIC
Mg	MAGNESITE
F	FLUORINE
Co	COBALT
Cu	COPPER
Zn	ZINC
Nb	NIOBIUM
Mo	MOLYBDENUM
Ba	BARIUM
Pb	LEAD
U	URANIUM
Y	YTTRIUM

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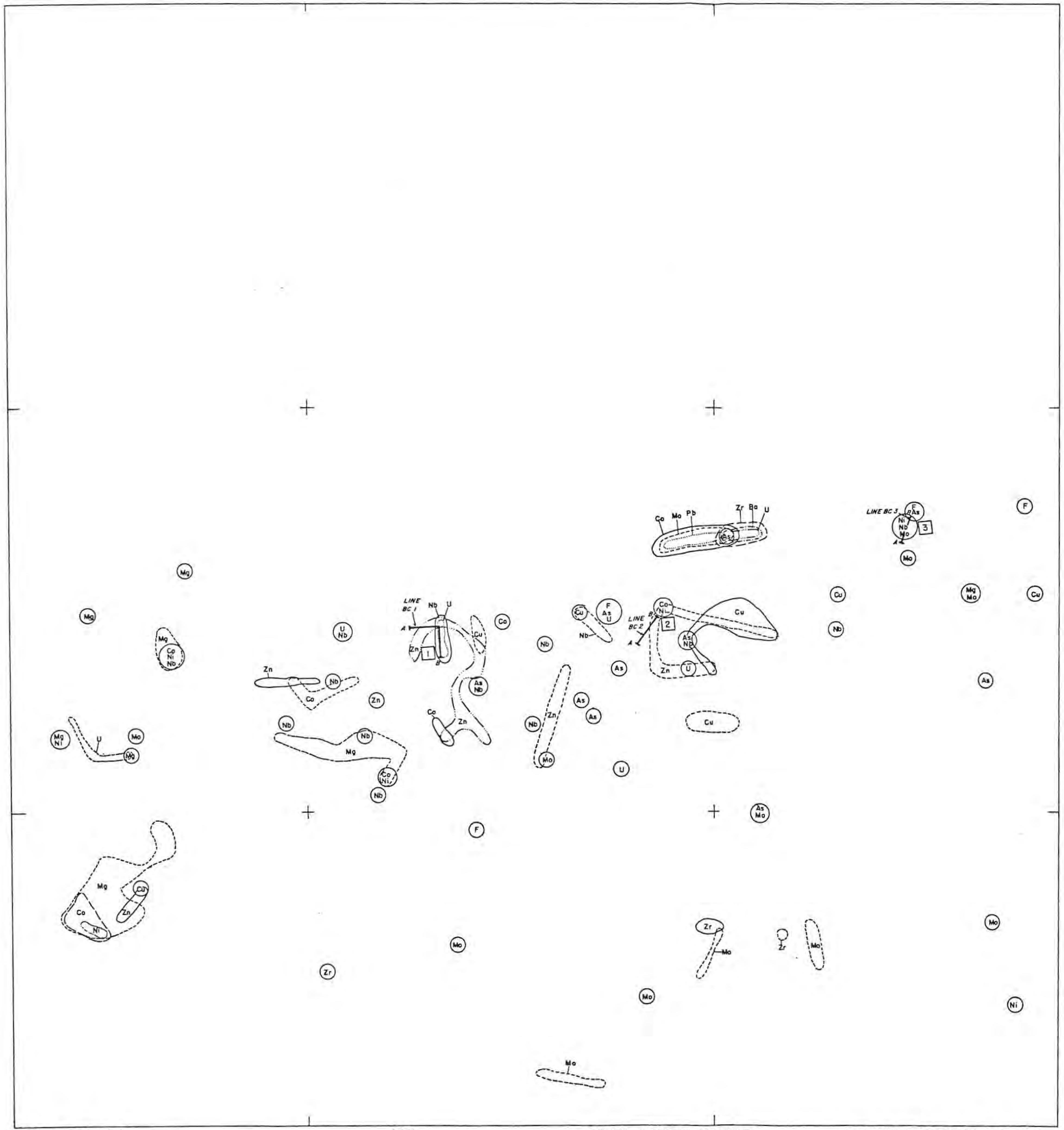
FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230 DA

Appendix 5



LEGEND

U	URANIUM
Pb	LEAD
Ba	BARIUM
F	FLUORINE
Zn	ZINC
Cu	COPPER
Mo	MOLYBDENUM
Nb	NIOBIUM
Zr	ZIRCONIUM
As	ARSENIC
Ni	NICKEL
Co	COBALT
Mg	MAGNESIUM
2	ANOMALY REFERENCE NUMBER
A B	CHECK SAMPLING TRAVERSE LINE

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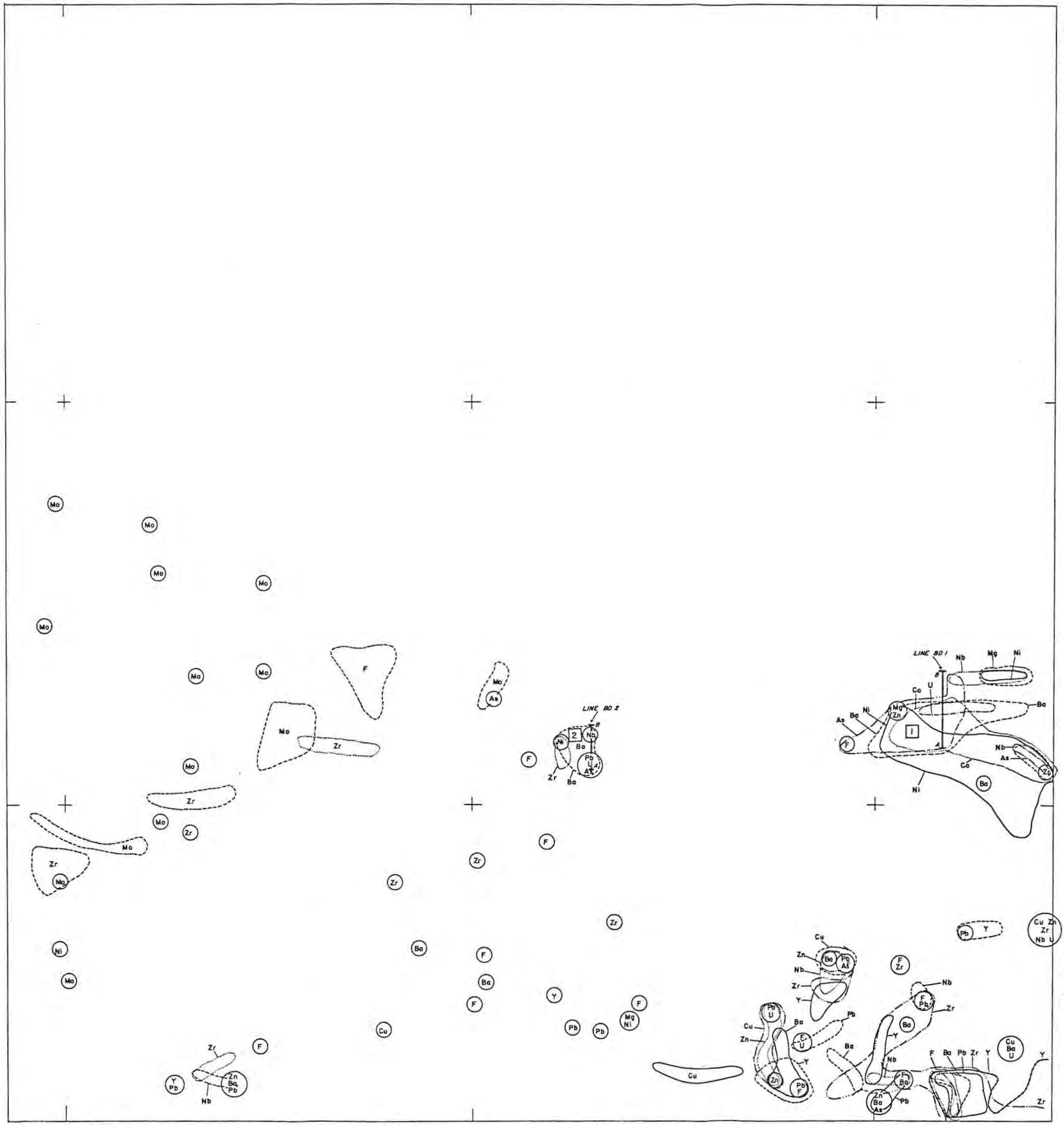
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230BC

Appen 2



LEGEND

U	URANIUM
F	FLUORINE
Pb	LEAD
Ba	BARIUM
Mo	MOLYBDENUM
Nb	NIOBIUM
Zr	ZIRCONIUM
Y	YTTRIUM
As	ARSENIC
Zn	ZINC
Cu	COPPER
Ni	NICKEL
Co	COBALT
Mg	MAGNESIUM
2	ANOMALY REFERENCE NUMBER
A—B	CHECK SAMPLING TRAVERSE LINE

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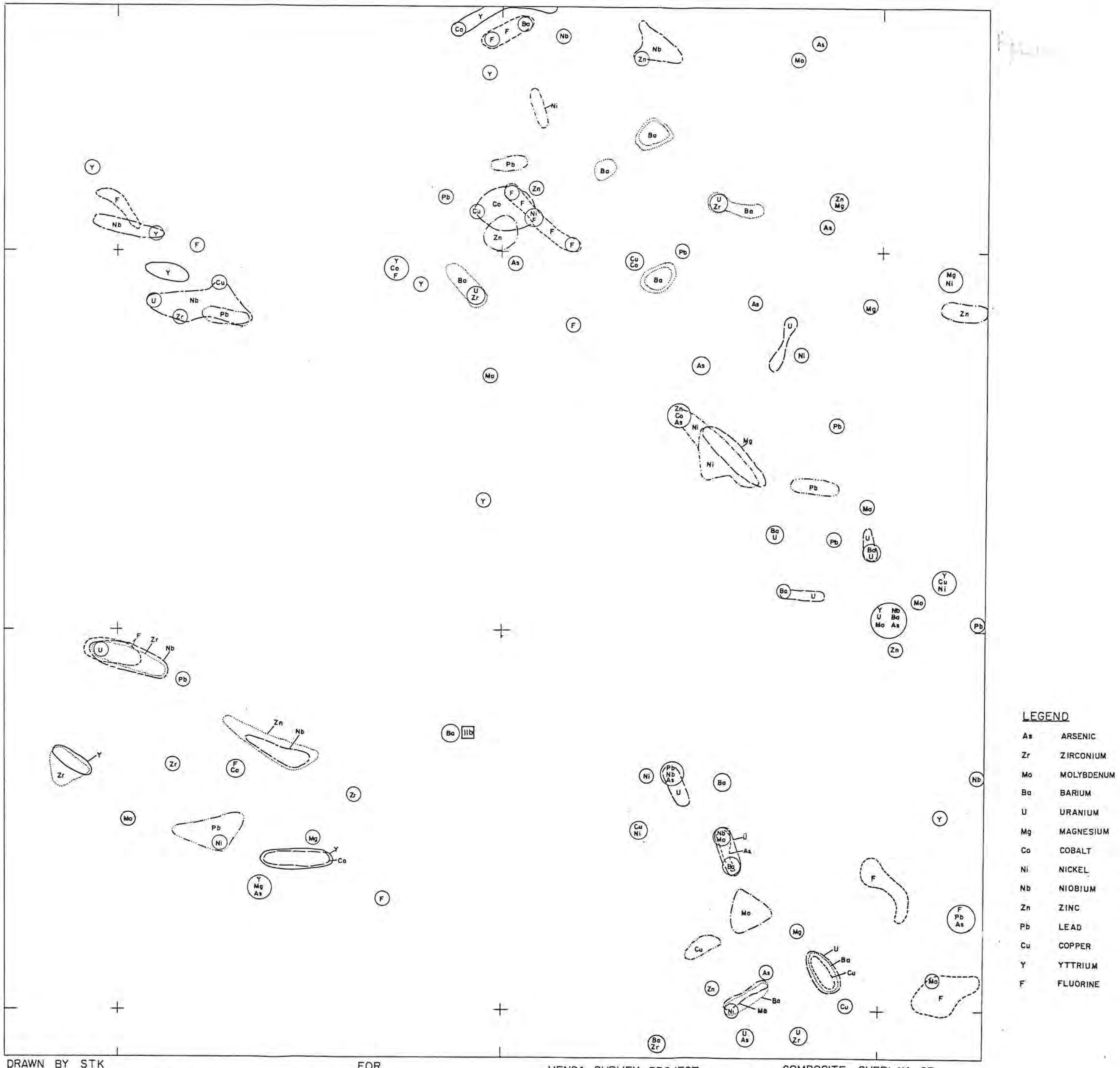
MINERAL DEVELOPMENT DIVISION

FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230BD



LEGEND

As	ARSENIC
Zr	ZIRCONIUM
Mo	MOLYBDENUM
Ba	BARIUM
U	URANIUM
Mg	MAGNESIUM
Co	COBALT
Ni	NICKEL
Nb	NIOBIUM
Zn	ZINC
Pb	LEAD
Cu	COPPER
Y	YTTRIUM
F	FLUORINE

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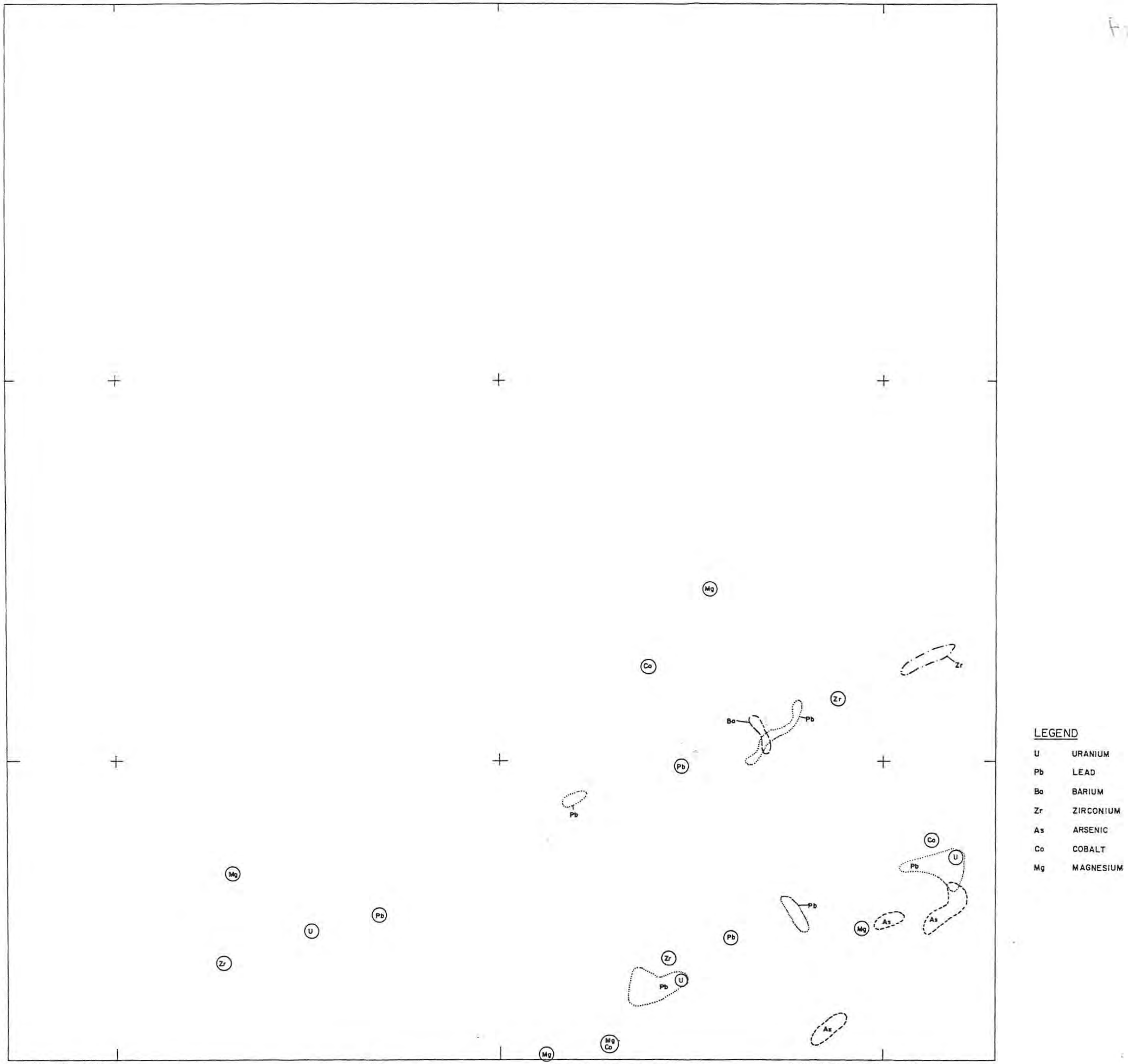
MINERAL DEVELOPMENT DIVISION

FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2330AB



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MINERAL DEVELOPMENT DIVISION

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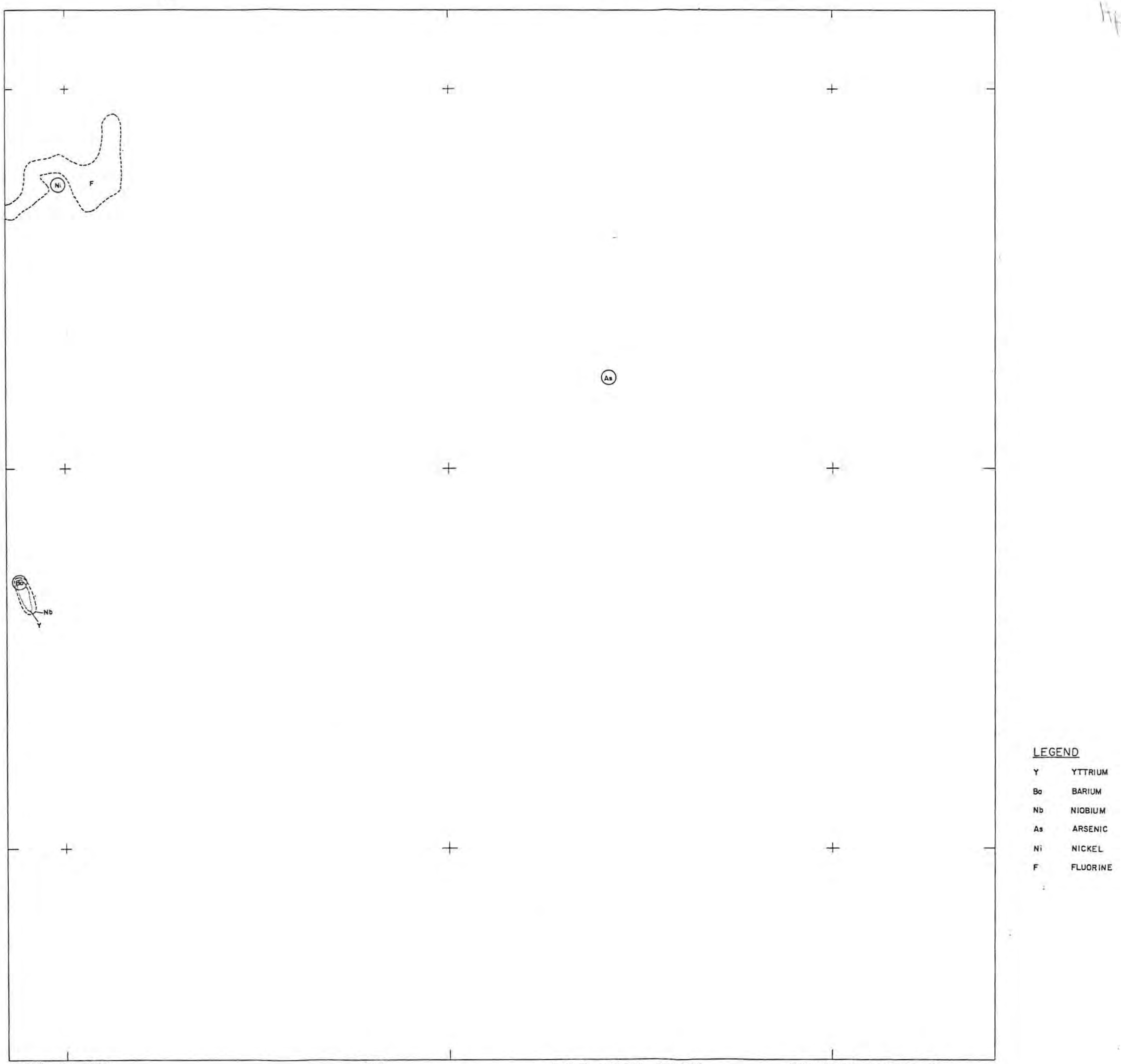
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230AD

[illegible]



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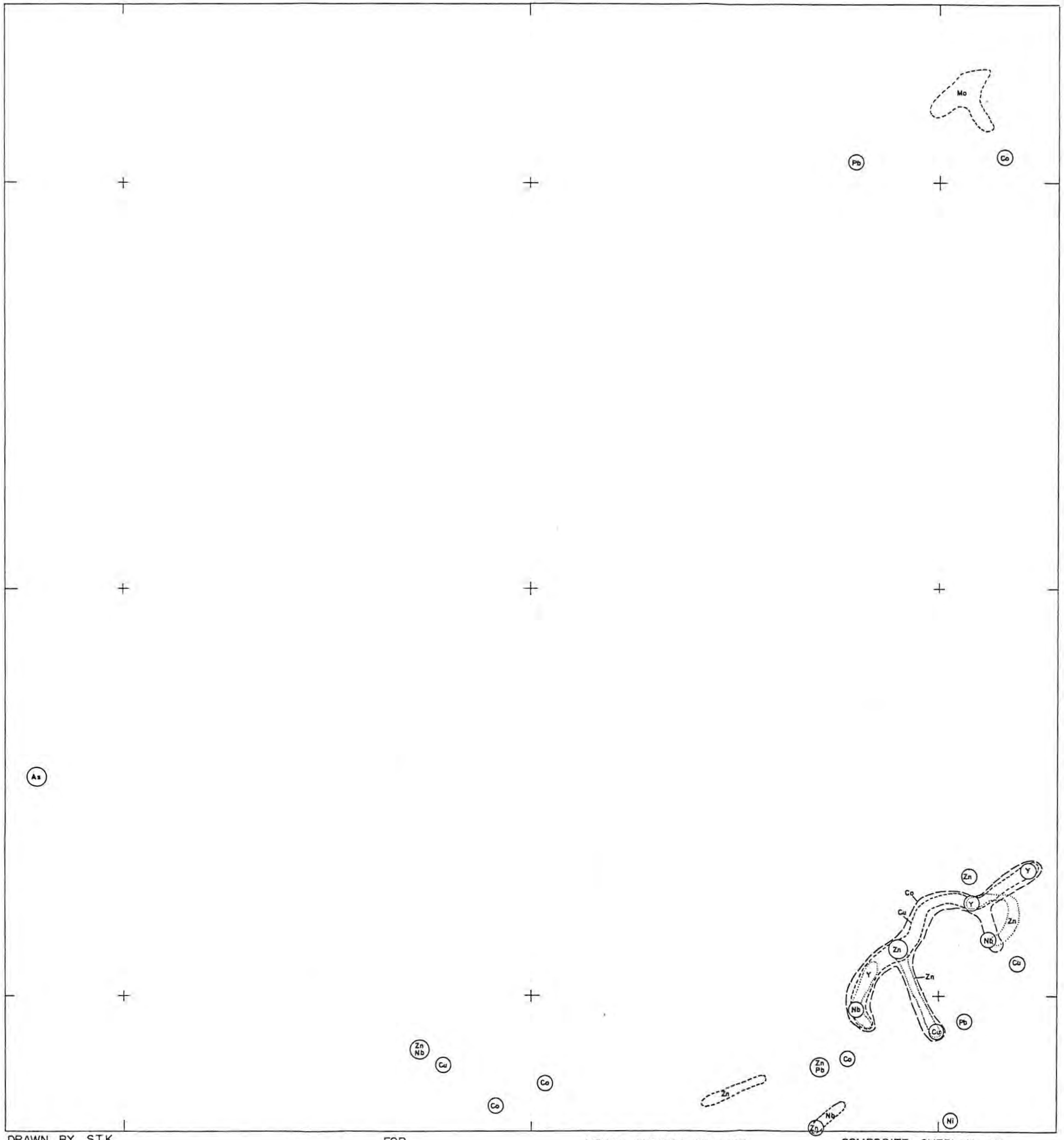
MINERAL DEVELOPMENT DIVISION

FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230DB

Appen 3



LEGEND	
Pb	LEAD
Mo	MOLYBDENUM
Nb	NIOBIUM
Y	YTTRIUM
As	ARSENIC
Zn	ZINC
Cu	COPPER
Ni	NICKEL
Co	COBALT

0 1 2 3 km

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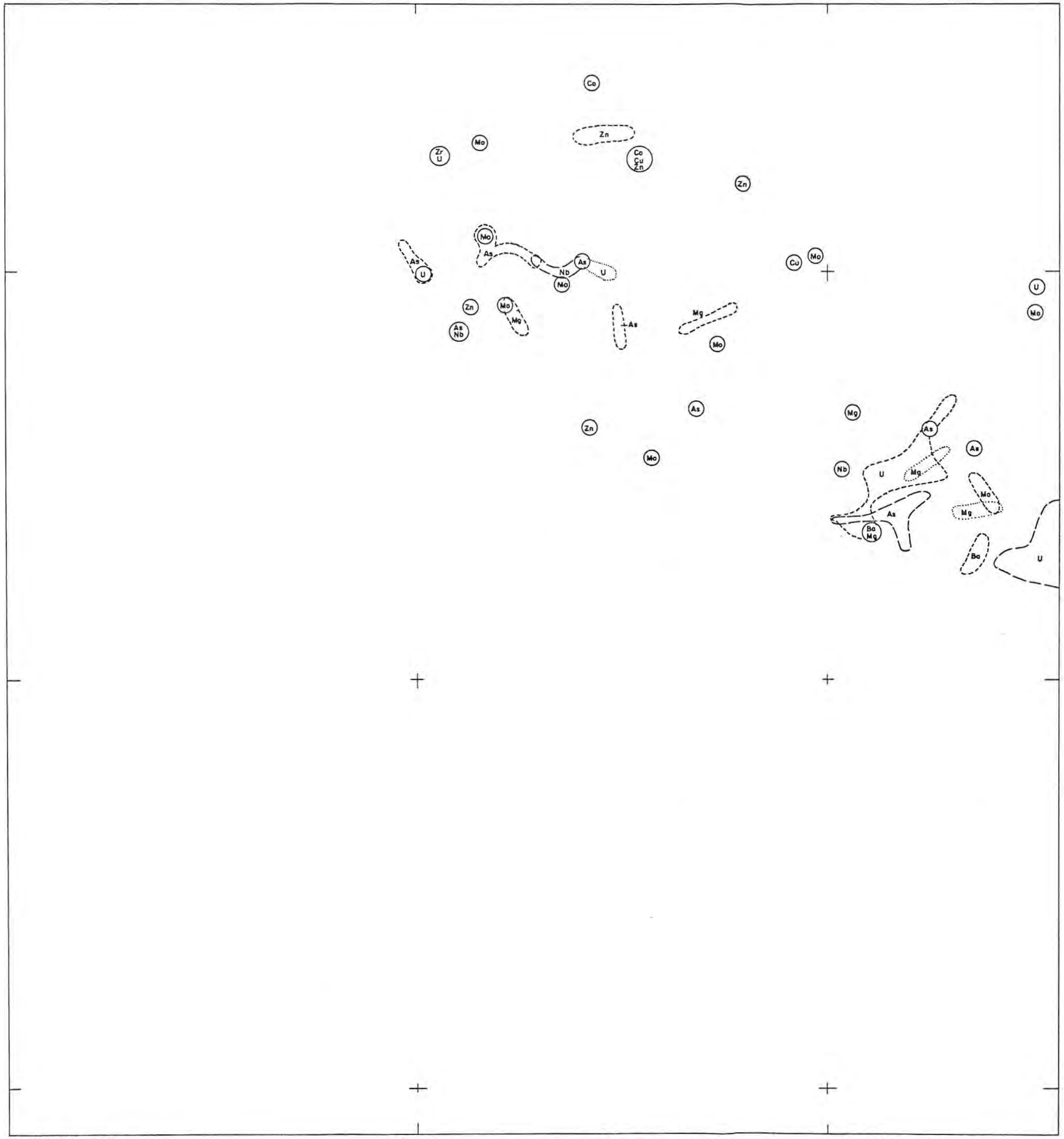
MINERAL DEVELOPMENT DIVISION

FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230CD



LEGEND

U	URANIUM
Ba	BARIUM
Mo	MOLYBDENUM
Nb	NIOBIUM
Zr	ZIRCONIUM
As	ARSENIC
Zn	ZINC
Cu	COPPER
Co	COBALT
Mg	MAGNESIUM
Pb	LEAD

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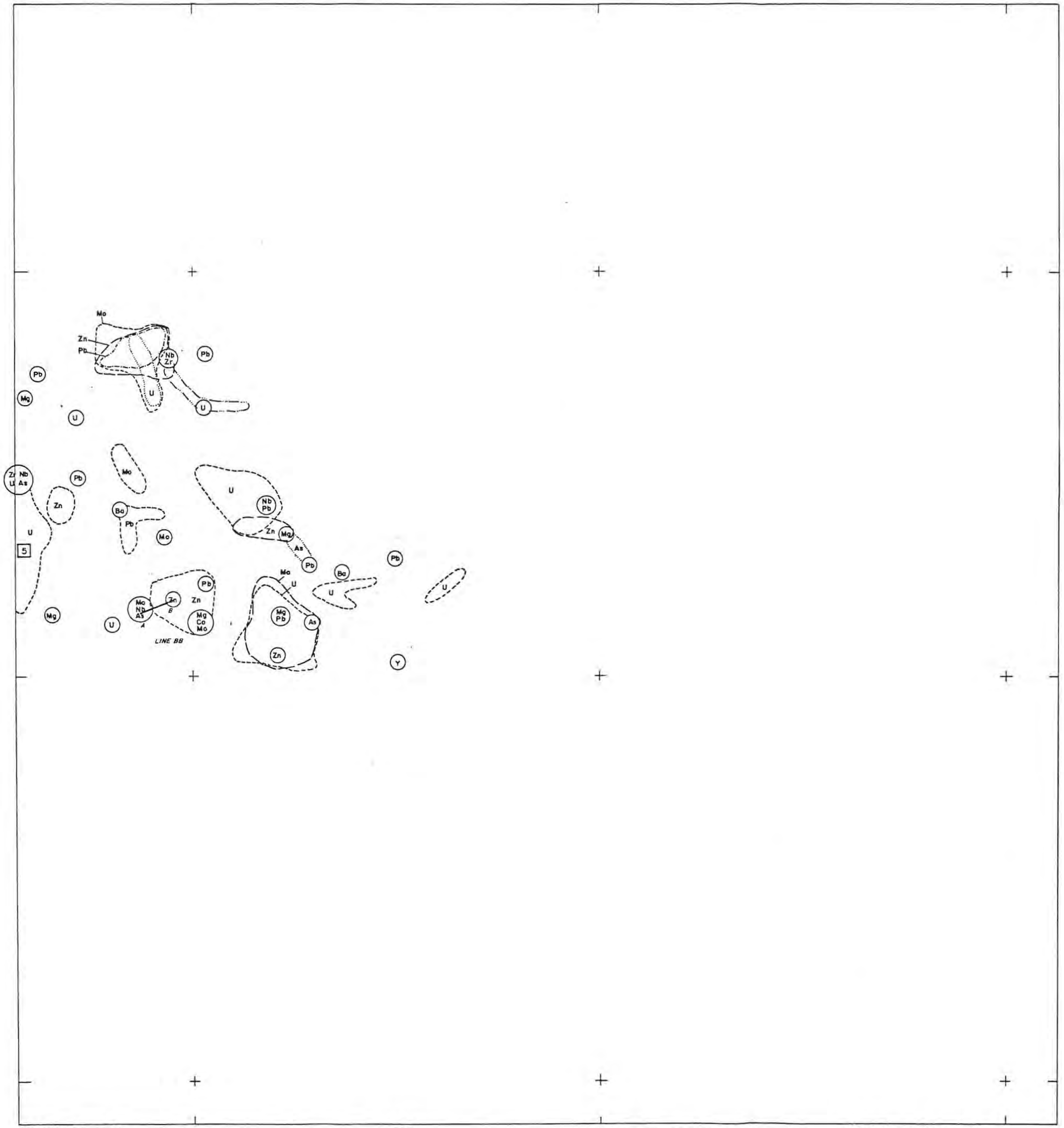
FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2329BA

Appendix



LEGEND

U	URANIUM
Ba	BARIUM
Mo	MOLYBDENUM
Nb	NIOBIUM
Zr	ZIRCONIUM
As	ARSENIC
Zn	ZINC
Cu	COPPER
Co	COBALT
Mg	MAGNESIUM
Pb	LEAD
Y	YTTRIUM
2	ANOMALY REFERENCE NUMBER
A B	CHECK SAMPLING TRAVERSE LINE

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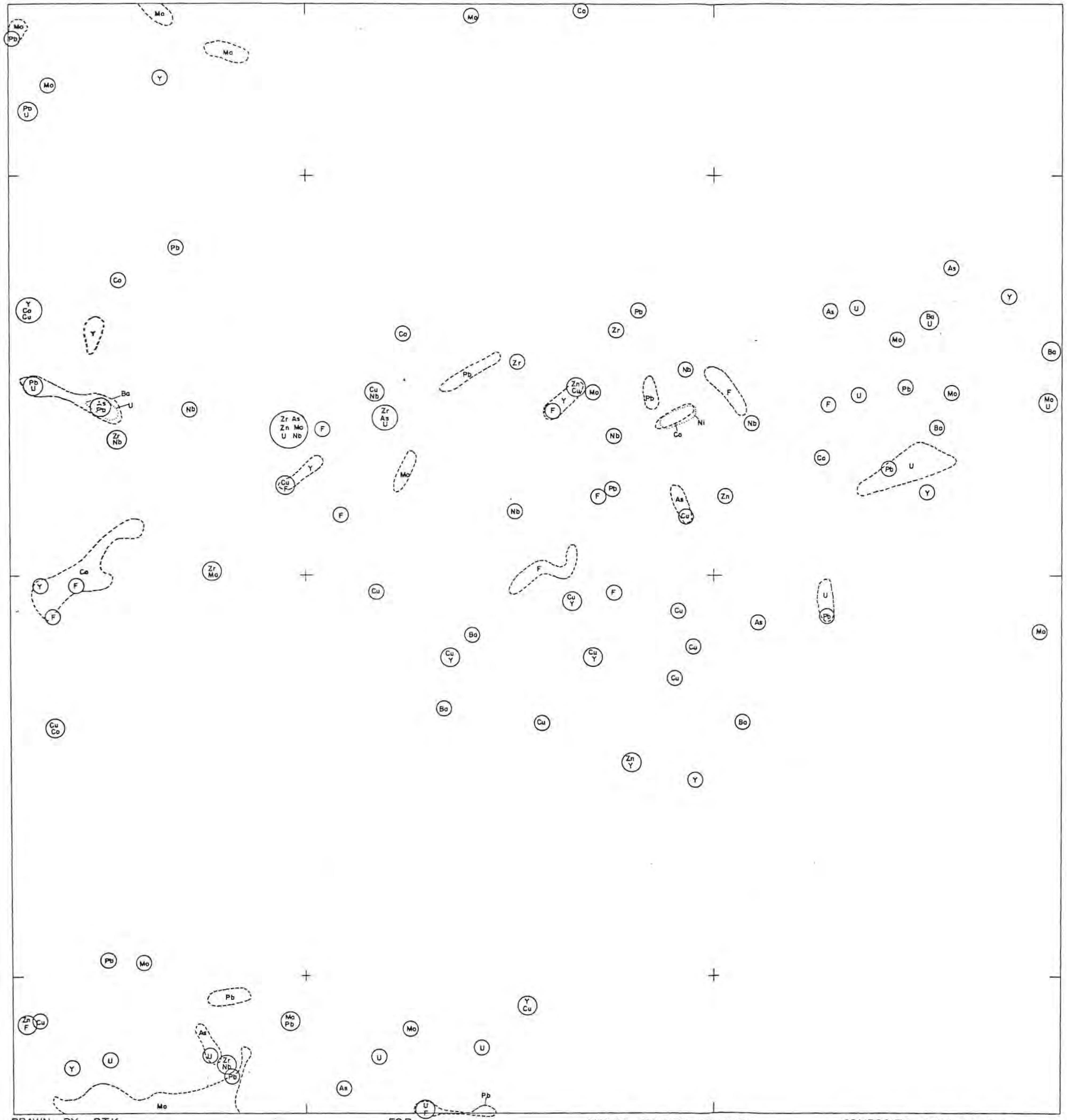
MINERAL DEVELOPMENT DIVISION

FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2329BB



LEGEND

U	URANIUM
Co	COBALT
Cu	COPPER
Y	YTTRIUM
Mo	MOLYBDENUM
Pb	LEAD
Zn	ZINC
As	ARSENIC
Ni	NICKEL
Ba	BARIUM
Nb	NIOBIUM
Zr	ZIRCONIUM
F	FLUORINE

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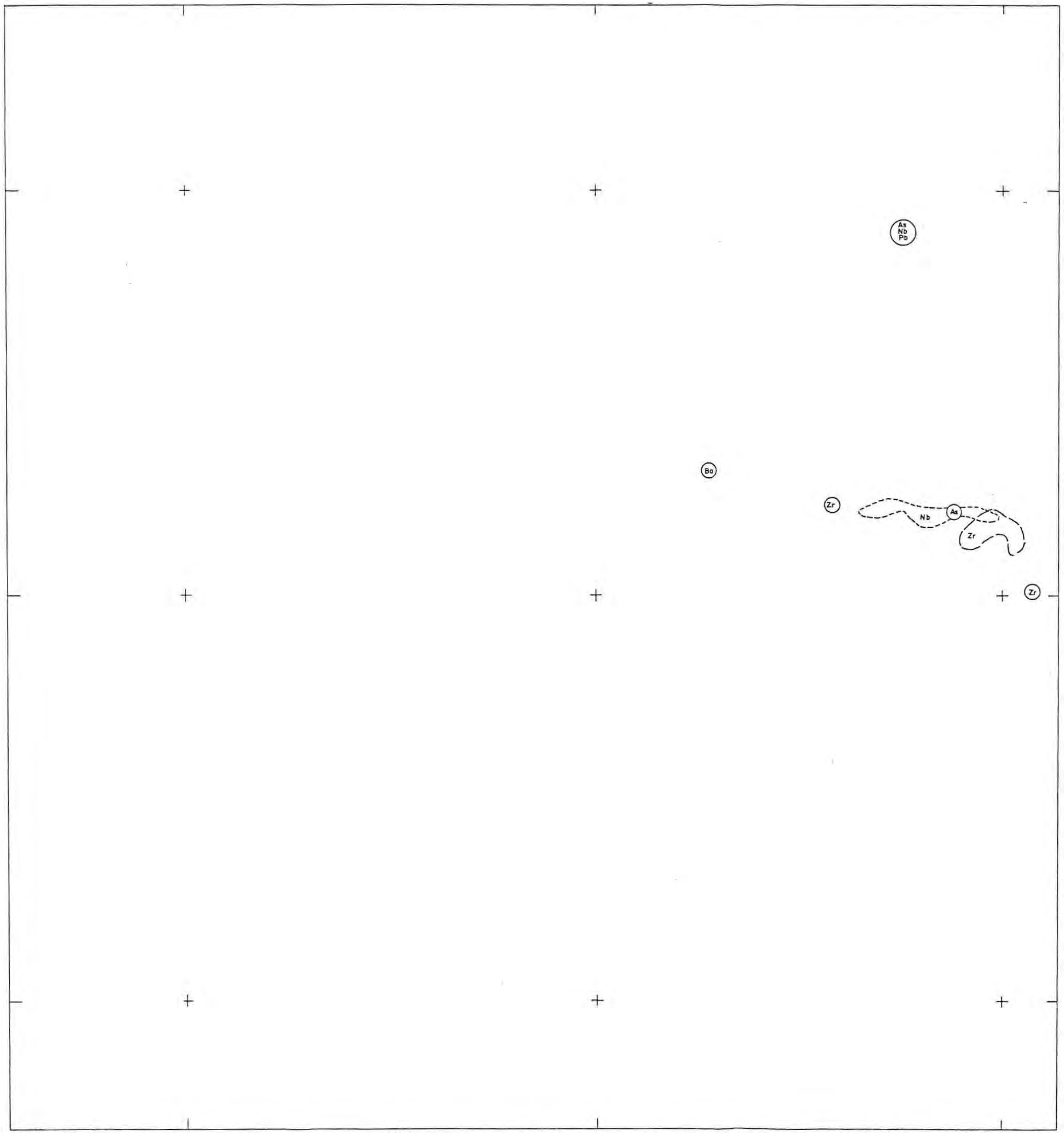
FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230DC



LEGEND

Pb	LEAD
Ba	BARIUM
Nb	NIOBIUM
Zr	ZIRCONIUM
As	ARSENIC

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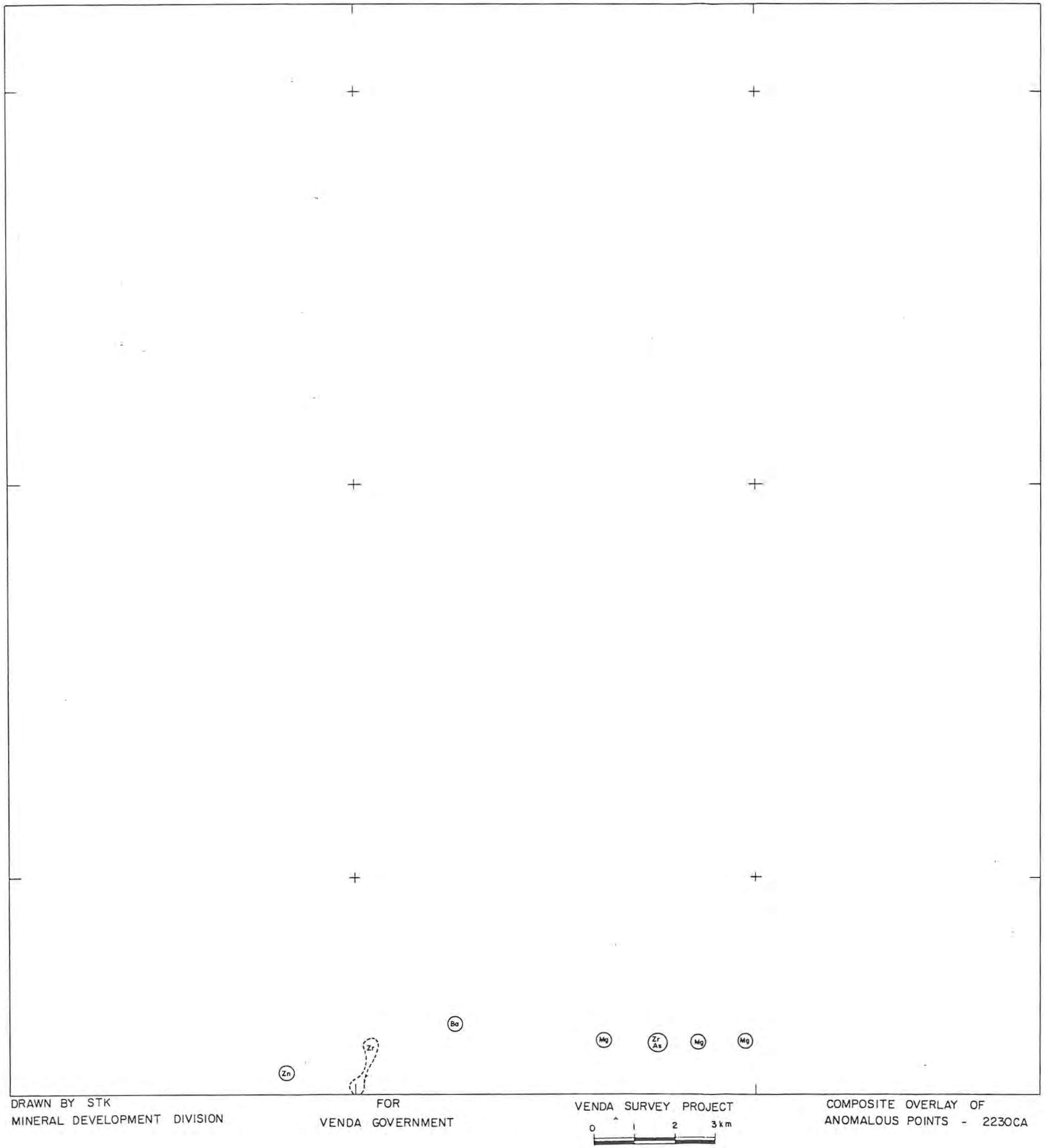
MINERAL DEVELOPMENT DIVISION

FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2229DD

Appendix



LEGEND

Zn	ZINC
Zr	ZIRCONIUM
Ba	BARIUM
Mg	MAGNESIUM
As	ARSENIC

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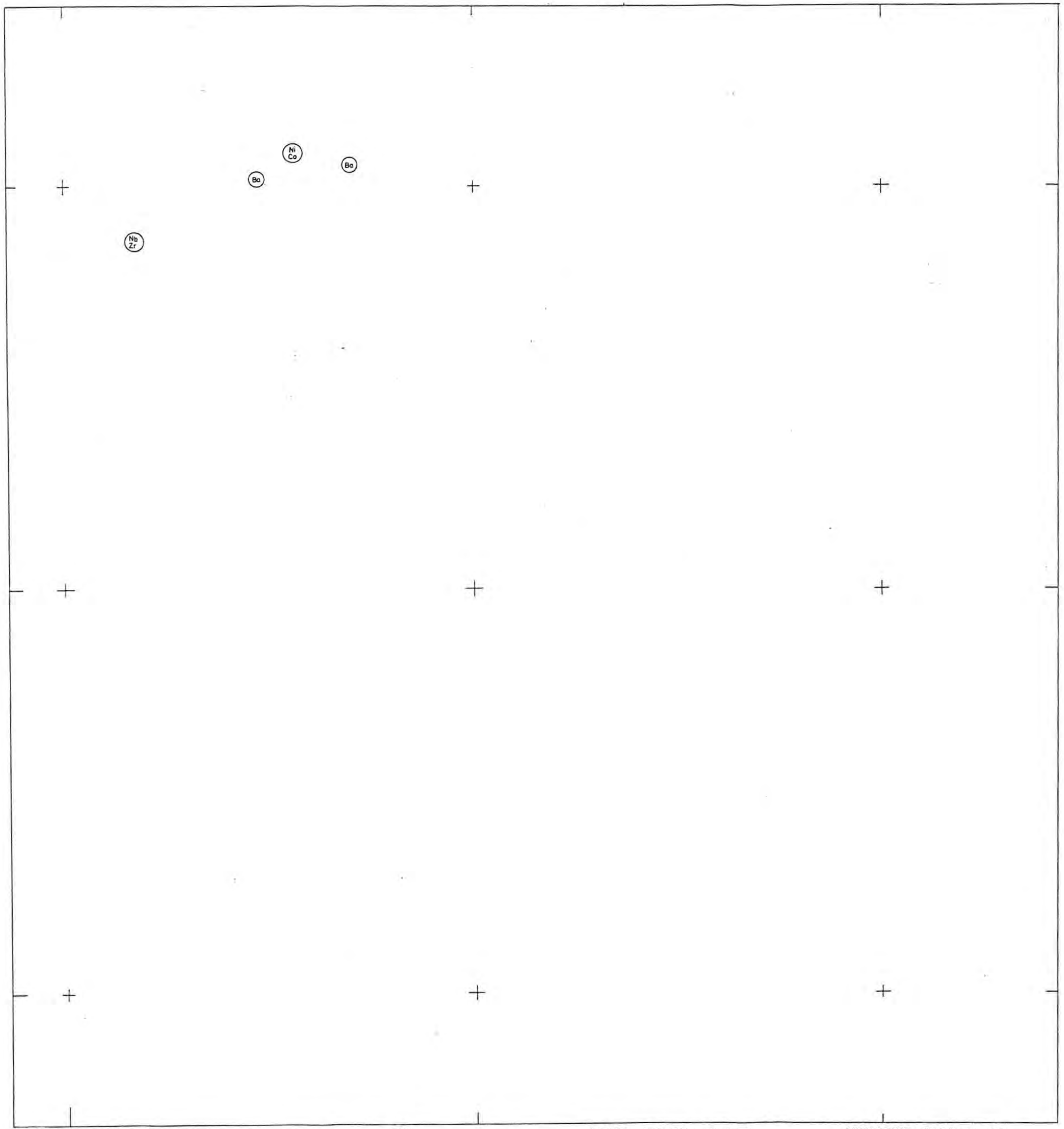
FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230CA

Appen



LEGEND

Co	COBALT
Ni	NICKEL
Zr	ZIRCONIUM
Nb	NIOBIUM
Ba	BARIUM

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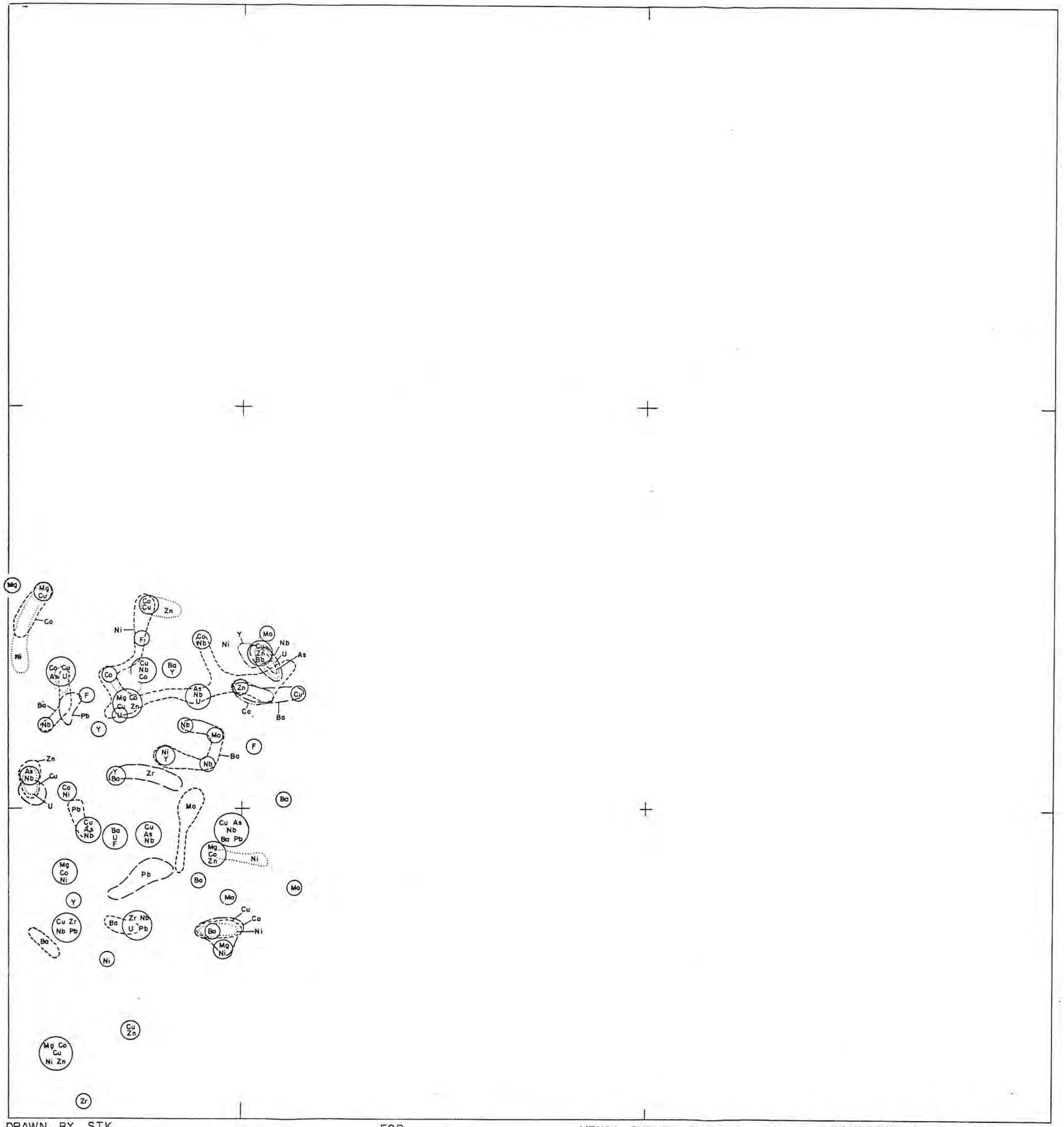
FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230DD

Append



LEGEND

Ni	NICKEL
Pb	LEAD
Mo	MOLYBDENUM
Y	YTTRIUM
F	FLUORINE
U	URANIUM
Ba	BARIUM
Nb	NIOBIUM
Zr	ZIRCONIUM
As	ARSENIC
Zn	ZINC
Cu	COPPER
Co	COBALT
Mg	MAGNESIUM

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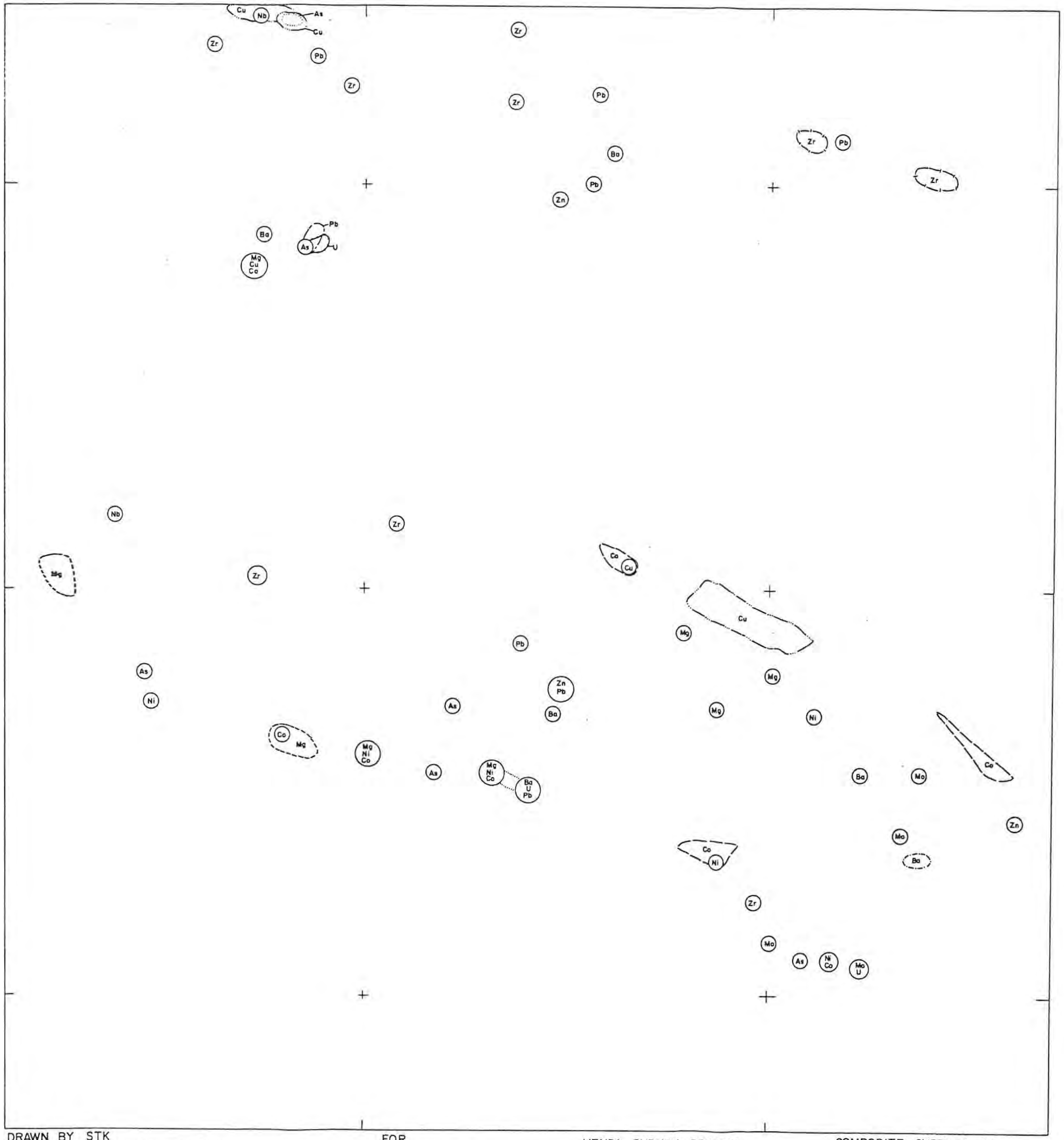
FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2231AC



LEGEND

U	URANIUM
Pb	LEAD
Ba	BARIUM
Mo	MOLYBDENUM
Nb	NIOBIUM
Zr	ZIRCONIUM
As	ARSENIC
Zn	ZINC
Cu	COPPER
Ni	NICKEL
Co	COBALT
Mg	MAGNESIUM

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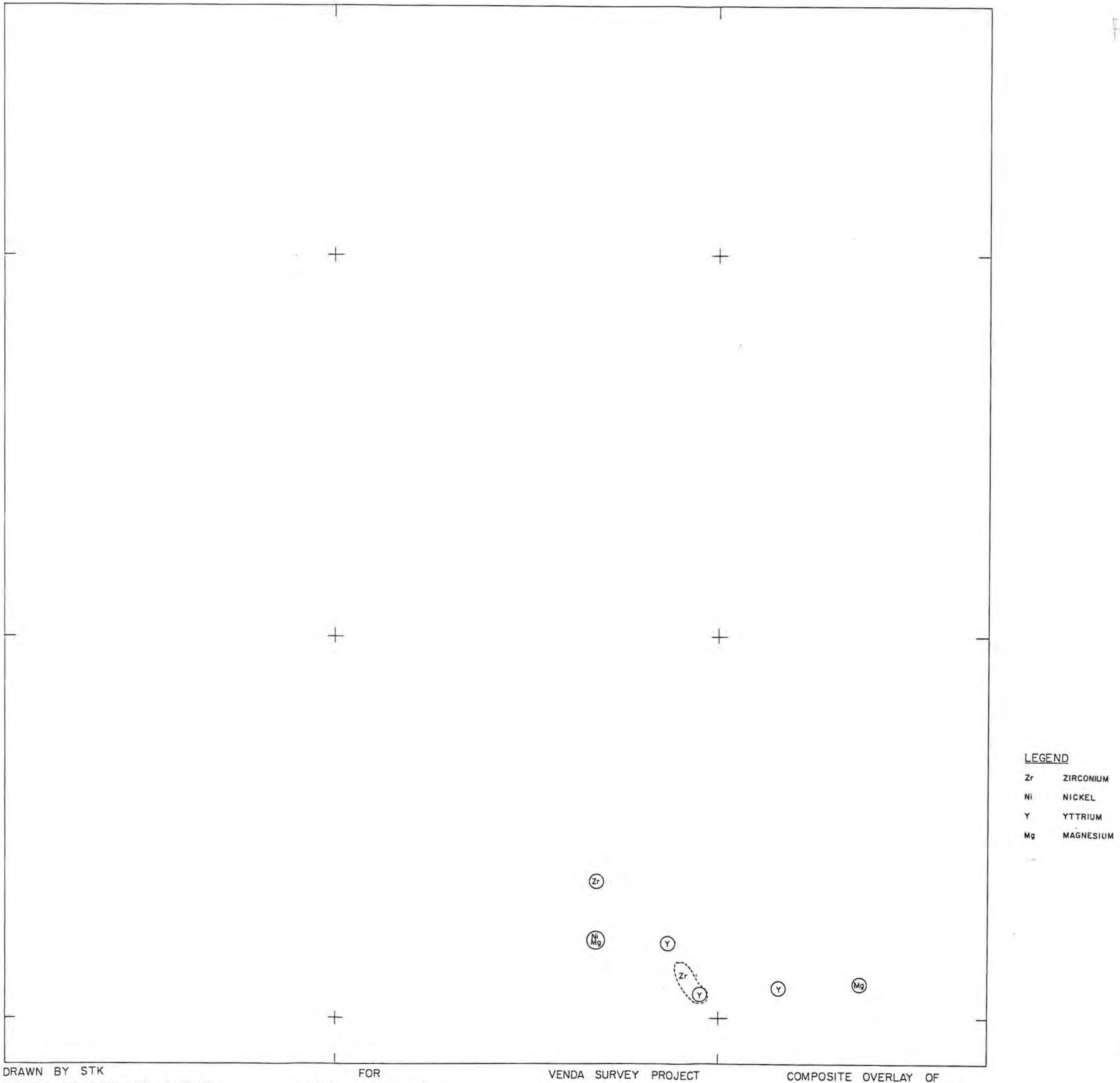
MINERAL DEVELOPMENT DIVISION

FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2230CC



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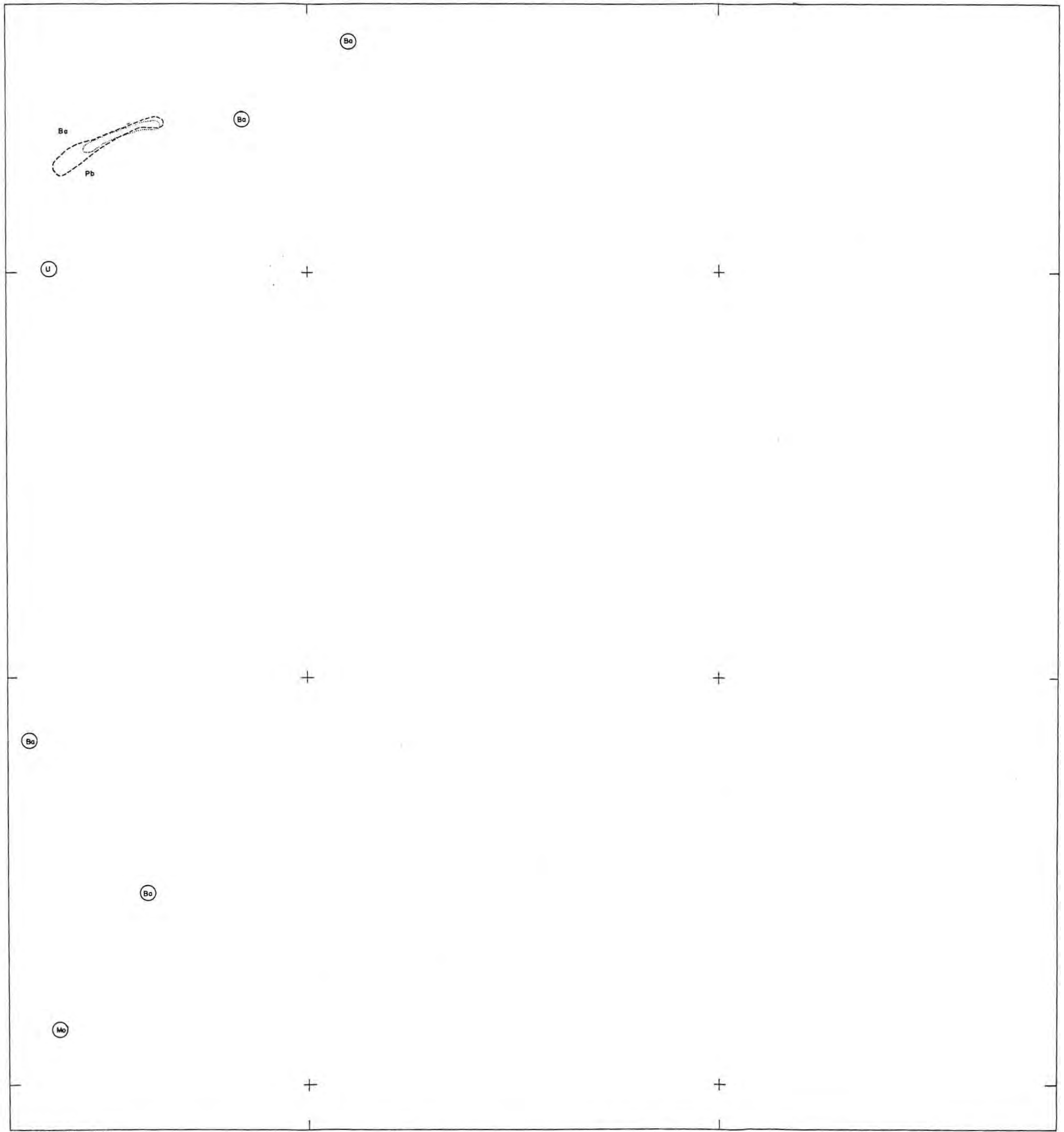
MINERAL DEVELOPMENT DIVISION

FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2330AA



LEGEND

Ba	BARIUM
Mo	MOLYBDENUM
Pb	LEAD
U	URANIUM

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FOR
VENDA GOVERNMENT

VENDA SURVEY PROJECT
0 1 2 3 km

COMPOSITE OVERLAY OF
ANOMALOUS POINTS - 2330BA