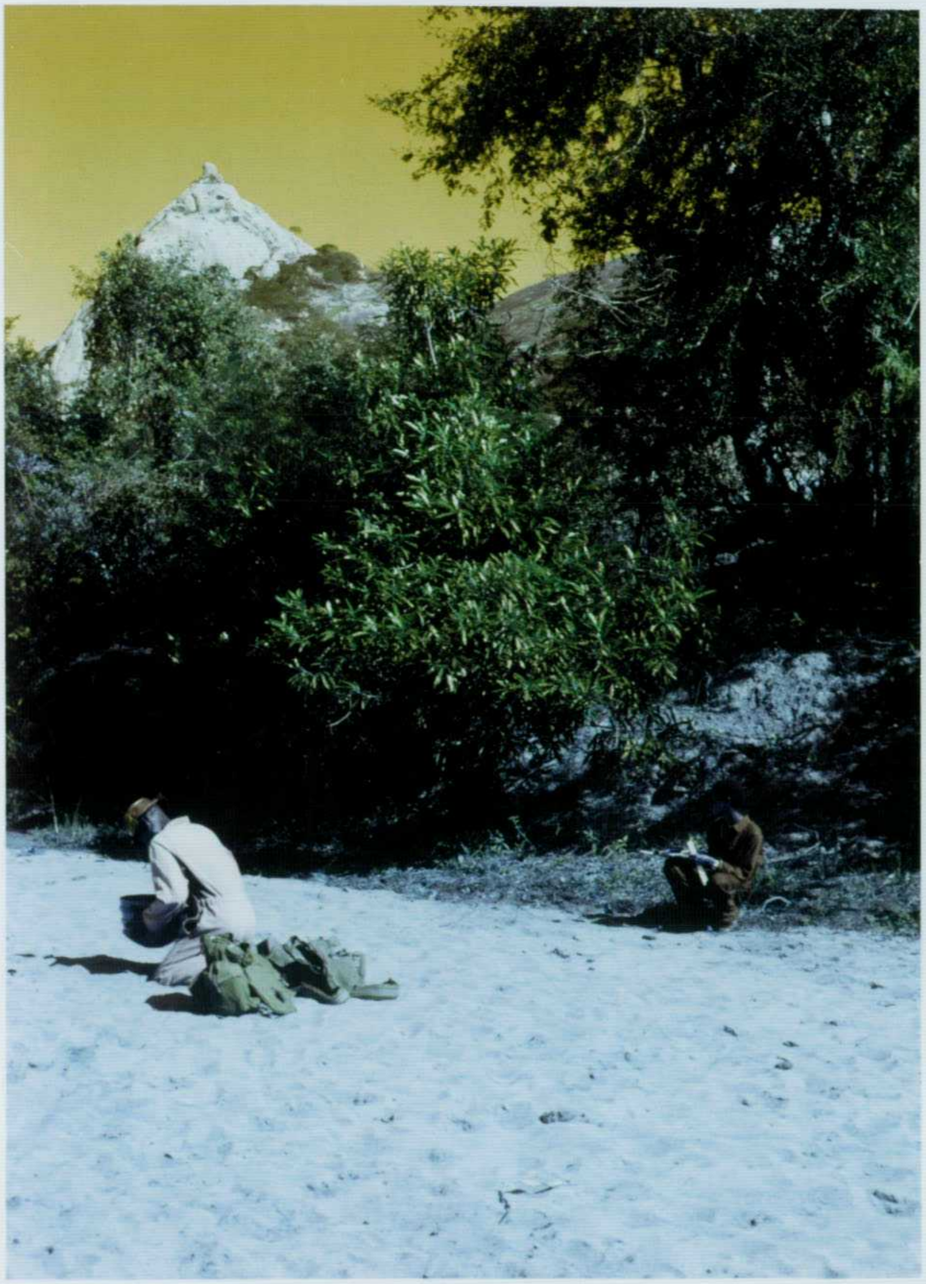
BRITISH GEOLOGICAL SURVEY
Overseas Directorate

WC/MP/87/17

A regional drainage geochemical exploration survey of the Makaha area, north-east Zimbabwe

P. N. Dunkley



Report MP/87/17
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November 1987

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SUMMARY AND RECOMMENDATIONS

During the period 1982-86 a team of geologists from the British Geological Survey carried out a programme of regional geological mapping and geochemical exploration in collaboration with the Zimbabwe Geological Survey under a Technical Co-operation agreement. This report describes the working methods and results of a stream sediment geochemical exploration survey over 860 km^2 of the Makaha area of north-east Zimbabwe, which formed part of this programme. The results of the survey are presented in a series of geochemical maps which are held on open file at the offices of the Zimbabwe Geological Survey and the British Geological Survey, and which should be consulted in conjunction with this report.

The area is mostly underlain by Archaean granite-greenstone terrain forming the north-eastern margin of the Rhodesian Craton. In the east of the area these cratonic rocks together with younger metasedimentary cover rocks have been involved in Pan-African tectono-thermal events associated with the Mocambique Orogenic Belt. Numerous small dissused gold mines are located within the greenstones, and pegmatites hosted in granodiorite in the south-west of the area have produced beryl and minor amounts of tantalite and cassiterite.

The Ruenya Gneiss outcrops in the extreme north-east and is considered to be the oldest rock unit, being contiguous with gneisses to the north of the area that have yielded Archaean ages (3.0-3.1 Ga).

The Makaha Greenstone Belt occupies much of the north-western and central parts of the area, and comprises the Lawleys Formation and Mudzi Greenstone Formation. The Lawleys Formation consists essentially of tremolite schists, hornblende schists and felsic rocks, with interbedded calc-silicate rocks, ironstones and actinolite schists. The Mudzi Formation overlies the Lawleys Formation and consists of the Rugamba Member, composed of a thin sequence of cherts and banded ironstones, which is overlain by the Susamoya Member, consisting of mixed felsic and basaltic rocks at the base that are overlain by a thick pile of basaltic volcanic rocks.

A large proportion of the area, particularly in the south and east, is underlain by granitic and tonalitic intrusive rocks which post-date the greenstones and are generally considered to be of late Archaean age. Remobilised granites occur in the east, within zones of higher metamorphic grade in the Mocambique belt. These are thought to be partly equivalent to the undeformed granitic and tonalitic rocks in the west, but also include paragneisses of problematical age and origin.

Metasediments of the Umkondo Group, consisting of mica schists with interstratified marbles, calc-silicates and quartzites, crop-out in an arcuate structure around the eastern side of Chirwa, and rest unconformably upon the Makaha Greenstone Belt.

Basic and metabasic intrusions of the Mashonaland and Umkondo dolerite suites occur throughout the area. In the west they are undeformed and have primary mineralogy, but towards the east they show increasing effects of metamorphism and deformation.

A total of 3297 stream sediment samples was collected during the survey, giving an average density of 3.83 samples per km^2. The -80 mesh fraction was analysed for Cu, Pb, Zn, Co, Ni, Mn and Li by atomic absorption spectro-photometry following digestion with hot concentrated hydrochloric acid, and

for As, Ba, Sn, Ta and W by X-ray fluorescence spectrometry. Analytical precision was monitored by the replicate analysis of samples, and by the regular analysis of standard samples.

Results were analysed statistically, and geochemical maps were plotted by computer. The analytical data for each element is presented in a series of single element plots, at a scale of 1:50 000, as transparent overlays to the published topographic maps. These illustrate element concentration by means of proportional symbols, and provide a rapid and visual means of assessing concentration ranges and broad variations related to lithology.

Geochemical anomalies are portrayed on multi-element anomaly maps at a scale of 1:100 000, as transparent overlays complementary to the north-western corner of the published geological map for the Makaha - Inyanga-North area. Because of difficulties in portraying 12 elements on a single plot, the anomalies are split into two element associations, and each is presented separately. During interpretation the influences of lithology on stream sediment chemistry were accounted for by classifying the analytical results into groups according to the dominant drainage basin lithology at each sample site. For each element and lithological grouping, graphs of log-concentration plotted against cumulative frequency on a probability scale were used to determine threshold values (T), above which concentrations are considered to be anomalous. Anomalous values (AV) were then standardised to produced standard anomaly values (SAV) that are directly comparable regardless of the element, concentration range, background lithology and map sheet.

The formula used for standardisation is: $SAV = ((AV - T)/T)100$.

A total of 21 geochemical anomalies are listed and briefly described at the end of the report, and recommendations are made for further investigation of these. The area is considered to have good potential for exploration and it is recommended that all the listed anomalies should be examined in more detail. Anomalous areas should initially be investigated by more detailed stream sediment surveys using higher sampling densities, and subsequently areas of continued interest should be examined by soil geochemical surveys, geological mapping and rock geochemical surveys.

The ground underlain by the Makaha Greenstone Belt is the most prospective part of the area, and is believed to have good potential for the discovery of new areas of gold mineralisation. Most of the old gold mines occur within the lower part of the Mudzi Greenstone Formation, either within mixed felsic-basic volcanic rocks of the Susamoya Member or ironstones of the Rugamba Member, although a few are also located within the uppermost parts of the underlying Lawleys Formation. The present survey has discovered a number of anomalies, scattered over a wide area, that are underlain by this part of the succession. Many of these do not appear to drain old workings and should therefore be given a high priority in follow-up work.

Of the elements determined in the present survey, Pb and As, and to a lesser extent Cu, W and Zn give the most useful response in areas of known gold mineralisation. In follow-up surveys it is recommended that Au should also be determined routinely to the ppb level, and orientation work should be undertaken at an early stage to ascertain the optimum sampling medium for these determinations.

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A REGIONAL DRAINAGE GEOCHEMICAL SURVEY OF THE MAKAHA AREA, NORTH-EAST ZIMBABWE

INTRODUCTION

This report describes the working methods and results of a regional drainage geochemical survey of the Makaha area of north-east Zimbabwe. The survey was undertaken as part of a regional geological mapping and mineral reconnaissance project carried out during the period 1982-86 by staff of the British Geological Survey (BGS) and Zimbabwe Geological Survey (ZGS), under a technical co-operation agreement funded by the Overseas Development Administration of the United Kingdom and the Ministry of Mines of Zimbabwe. The report is complementary to a series of geochemical maps held on open file at the offices of the BGS and ZGS.

THE AREA

The ground covered by the survey extends eastwards from longitude 32°30'E to longitude 32°55'E, and southwards from latitude 17°15'S to latitude 17°26'S, and has an area of 860 km^2.

Access

Access to the area is by metalled road to Mtoko and from there by dirt road to Makaha, a distance of about 45 km. An alternative access route, particularly to the south-east of the area, is provided by a dirt road leading northwards from Inyanga to Avila Mission, a distance of approximately 40 km.

The western part of the area is reasonably well served by dirt roads, although these become fewer in the south-west. In the east of the area there are few motorable roads, and to the south-east of the Ruenya River large tracts of country are accessible by foot only.

Drainage and relief

Drainage is dominated by the Ruenya River and its major tributary the Inyamasizi which flow northeastwards across the area (Fig. 1).

The area is one of rugged terrain which generally decreases in elevation from west to east. The highest hills are Nyakurgwe (approximately 1440 m.) in the south-west and Susamoya (1435 m.) in the north-west, and the lowest ground occurs in the extreme north-east adjacent to the Ruenya River, where the elevation is slightly below 600 m.

In the north-west the Makaha Greenstone Belt gives rise to the Susamoya Range which is characterised by high steep sided hills and ridges separated by broad valleys. At the eastern end of the greenstone belt the ground is generally lower but more dissected, with rivers flowing in steep-sided and narrow valleys. The adamellite intrusion of Chirwa Dome, with its twin peaks of Chirwa and Makate, dominates the topography at the northeastern end of the belt.

The southern half of the area is occupied by granitic terrain which is characterised by a series of bare round-topped hills and dwalas with narrow

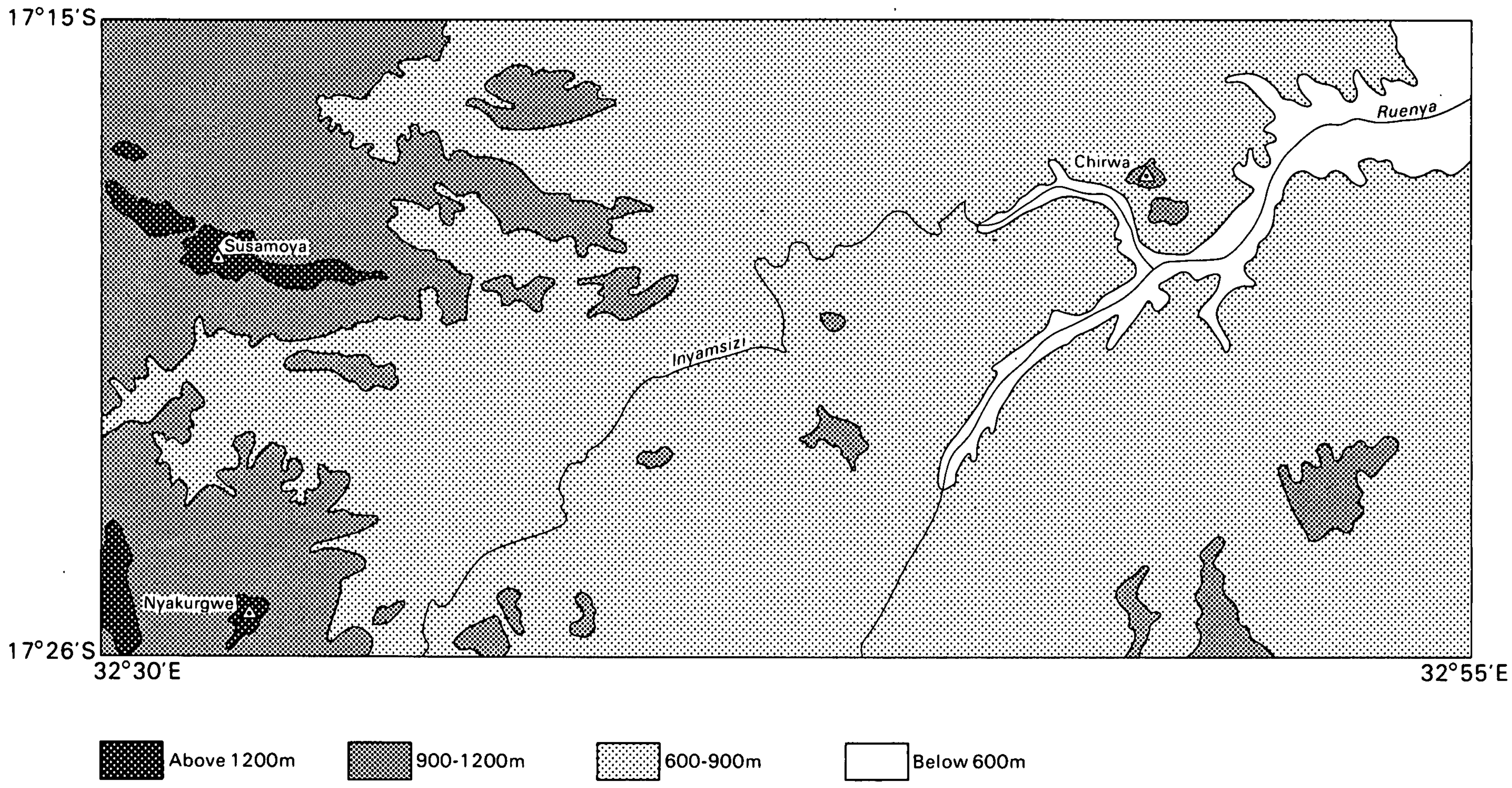


Figure 1: Relief and main drainage of the area.

valleys. Gneissic terrain in the extreme north-east of the area gives rise to less rugged undulating topography.

Climate and vegetation

The climate of the area is characterised by a dry season from May to November during which little rain falls, and a wet season from December to April when rainfall is intermittant but heavy. Mean annual rainfall varies between 350 and 950 mm, with greatest amounts falling on the higher ground in the south-west of the area. Data for Mtoko, the nearest weather station with complete records, are presented in appendix 1 and illustrate the marked seasonal nature of the rainfall.

The hottest part of the year is from September to April, with mean maximum monthly shade temperatures in the range 25 to 29 ^{o}C, and the coolest period is from May to August with mean maximum temperatures of 21 to 25 ^{o}C. However, temperatures in direct sunlight and in the lower ground in the east of the area are considerably higher.

Vegetation is varied but is dominated by woodland including the species <u>Brachystegia spiciformis</u> (Msasa), <u>B. boehmii</u> (Mfuti) and <u>Julbernardia globiflora</u> (Mnondo). <u>Colophosphermum mopane</u> (Mopane) and <u>Adansonia digitata</u> (Baobab) are prolific, particularly in the hotter and drier parts of the area, and <u>Acacia sp.</u> is widespread and very common in secondary bush developed upon previously cleared and cultivated ground.

Soils

The soils of the area are mostly fersiallitic (Thompson and Purves, 1978). These are moderately leached soils in which the dominant clay mineral is kaolinite, and in which there are appreciable amounts of free sesqui oxides of iron and aluminium, and usually reserves of weatherable minerals. Over granitic rocks these fersiallitic soils consist mainly of moderately shallow, greyish brown, coarse sands and sandy loams overlying sandy loams (type 5G of Thompson and Purves (<u>op. cit.</u>). Over siliceous gneisses and schists they are moderately deep, brown to reddish brown, fine to medium grained sandy loams, overlying sandy clays (type 5P of Thompson and Purves <u>op. cit.</u>). Over the Makaha Greenstone Belt and basic and ultra-basic intrusive rocks they consist of moderately deep to deep reddish brown granular clays (type 5E of Thompson and Purves <u>op. cit.</u>).

Lithosols occur in rugged hilly ground, and are very shallow and formed over weathering rock. In the rugged granitic terrain of the south of the area there are extensive pavements and steep hillsides of bare rock.

In rare cases calcretes of very limited lateral extent are developed over calcareous rocks and in some valley bottoms upon greenstone.

GEOLOGY

The area was mapped by Chunnet during the period 1970-71, although the Makaha Greenstone Belt had previously been described by Macgregor (1935). Stocklmayer (1980) incorporated the work of these geologists in Geological Survey Bulletin No.89 of the Inyanga-North - Makaha area, and which forms the basis of the following brief geological description, although modifications have been made in the light of new information obtained during recent geological mapping of the Rushinga - Nyamapanda area to the north by Barton et. al. (in press).

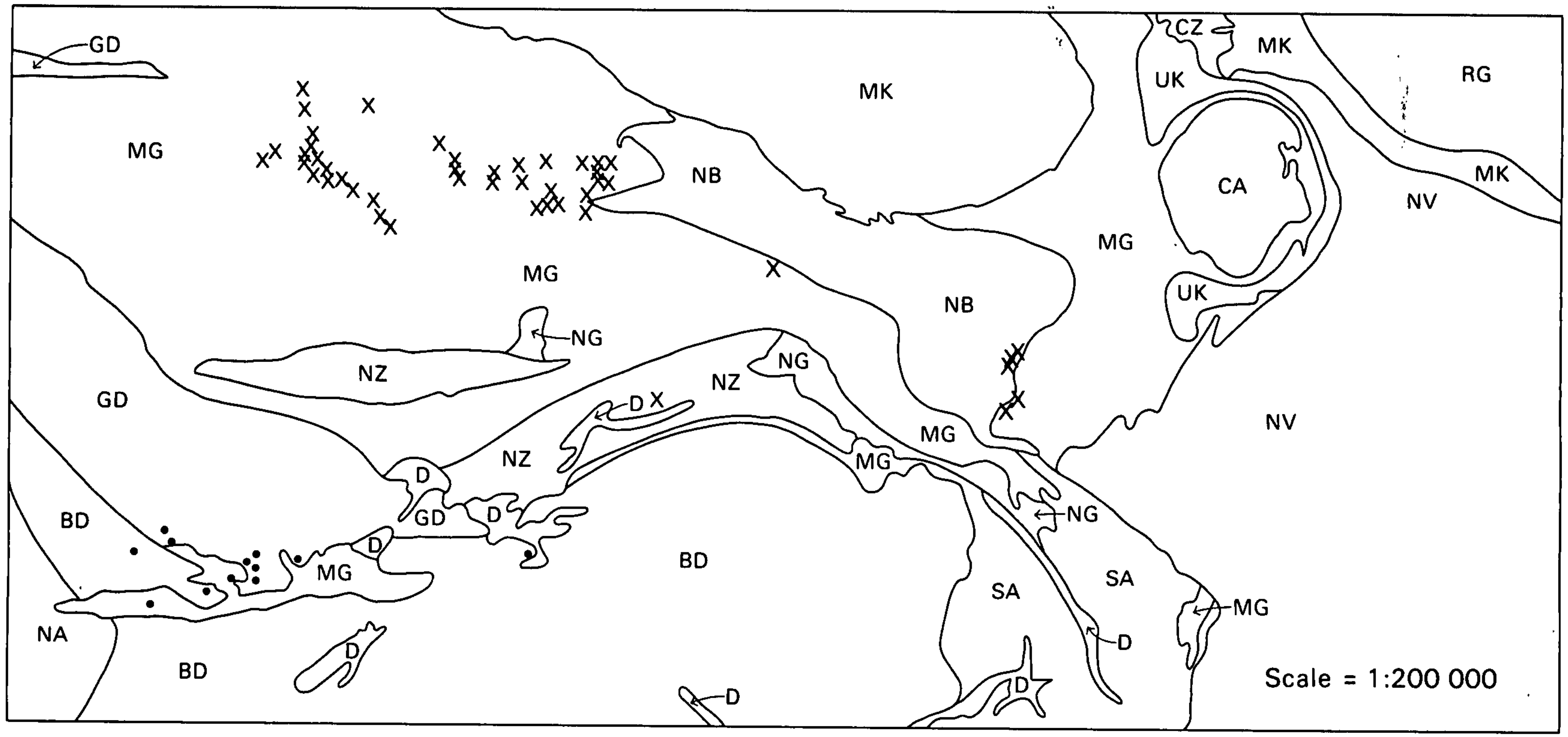
Most of the area is underlain by Archaean granite-greenstone terrain forming the north-eastern margin of the Rhodesian Craton. In the extreme east of the area these cratonic rocks together with younger metasedimentary cover rocks have been involved in Pan-African tectono-thermal events associated the Mocambique Orogenic Belt and give rise to gneissic terrain (Fig 2.).

Table 1. Summary of the main lithological units and sub-units in approximate order of age.

MAIN DIVISIONS	SUB UNITS/LITHOLOGIES
Dolerite sills and dykes	Mashonaland Dolerite Umkondo dolerite ?
Umkondo Group	Calc-silicate quartzite marble and mica schists
Remobilised Granites	Nyamvu Gneiss Chirwa Adamellite
Adamellites	Nyahove Adamellite Sawunyama Adamellite
Intermediate Granites	Nyamzizi Granodiorite Good Days Granodiorite Mtoko Granodiorite
Older Tonalites and Gneisses	Budjga Dome Suite
Mudzi Greenstone Formation	Basaltic volcanics Mixed basaltic and felsic volcanics
Lawleys Formation	Nyamazizi Member Chikwizo Member Nyamboe Member
Ruenya Gneiss	

The Ruenya Gneiss

The Ruenya Gneiss crops out in the extreme north-east of the area and consists essentialy of coarse-grained porphyroblastic gneisses, which Stocklmayer (1980) included with his Remobilised Granites. However, the BGS project has shown that these gneisses are contiguous with the Mudzi Metamorphic Suite to the north, which has yielded Archaean ages (3.0-3.1 Ga). The Ruenya Gneisses are therefore believed to be the oldest rocks in the area.



MAKAHA GREENSTONE BELT

MG Mudzi Greenstone Formation

NB Nyamboe Member } Lawleys Formation

CZ Chikwizo Member } Lawleys Formation

NZ Nyamzizi Member } Lawleys Formation

X Gold Mines (disused)

• Pegmatite Claims (Be-Li-Ta-Sn)

GRANITIC TERRAIN

CA Chirwa Adamellite

SA Sawunyama Adamellite

NA Nyahowe Adamellite

NG Nyamazizi Granodiorite

GD Good Days Granodiorite

MK Mtoko Granodiorite

BD Budjga Dome Suite

GNEISSIC TERRAIN

NV Nyamvu Gneiss

RG Ruenya Gneiss (basement?)

UK Umkondo Group

D Dolerite (& amphibolite)

Figure 2: Simplified geological map of the area.

The Makaha Greenstone Belt

The Makaha Greenstone Belt is composed of volcanic and sedimentary rocks and is subdivided into the Lawleys and Mudzi formations.

The Lawleys Formation consists essentially of tremolite schists, hornblende schists and felsitic rocks, with interbanded calc-silicate rocks, ironstones and actinolite schists, and is generally believed to represent a metamorphosed volcanic sequence. The formation crops out in three separate areas, respectively designated the Nyamzizi, Nyamboe and Chikwizo members. Although correlation between members is not possible a broadly generalised succession is recognisable in each member, in which basal felsic rocks are overlain by high-magnesian and ultramafic rocks which are in turn suceeded by basaltic volcanic rocks.

The Mudzi Greenstone Formation overlies the Lawleys Formation and comprises two members, the Rùgamba Member and the Susamoya Member.

The Rugamba Member occurs at the base of the formation in contact with the Lawleys Formation and is a thin but persistent unit composed of cherts, banded ironstones, ferruginous quartzites and ferruginous schists.

The Susamoya Member commences with a basal zone of mixed felsic and basaltic rocks which passes up into a thick sequence of basaltic volcanic rocks which are commonly pillowed, but converted to hornblende schists close to granite contacts. Talc schists and serpentinites also occur and are mostly found towards the base of the formation, often resting directly upon the underlying Lawleys Formation.

The Granitic Terrain

A large proportion of the area, particularly in the south and east, is composed of granitic rocks. Stocklmayer (1980) classified the rocks of this terrain into four main granitic groups, namely, Older Tonalite and Gneisses, Intermediate Granites, Adamellites and Remobilised Granites. The Older Tonalites and Gneisses, and the Intermediate Granites are thought to be broadly equivalent to The Suskwe Intrusive Suite mapped further to the north by the BGS project, and the Adamellites are probably equivalent to the Mutoko Intrusive Suite (c.f. Barton et al.).

Older Tonalites and Gneisses cover a large portion of the south and south-west of the area, where they are represented by the Budjga Dome Suite. This suite is composed of a complex assemblage of granodiorites, tonalites and adamellites which are mostly migmatitic and gneissic. Contacts with surrounding rock units are diffuse and indistinct so that age relationships are often contradictory. However, the presence of greenstone xenoliths indicates that the suite post-dates the Makaha Greenstone Belt, and there is abundant evidence to show that many of the components of this group pre-date the Intermediate Granite and Adamellite groups.

Intermediate Granites are apparently intermediate in age between the Older Tonalites and Gneisses and the Adamellites, and are intrusive into greenstone. They are mainly of granodiorite composition, and within the area of the geochemical survey there are three distinct masses, known as the Good Days Granodiorite, the Nyamzizi Granodiorite and the Mtoko Granodiorite. Pegmatites of economic significance are spatially associated with the Good Days Granodiorite and have produced beryl and lepidolite, and minor amounts of tantalite and tin.

Adamellites include the Sawunyama Adamellite and the Nyahove Adamellite. The former is developed in the south-east of the area and intrudes greenstone and some of the granites and gneisses of the Budjga Dome Suite, and contains abundant xenoliths of tonalite, granodiorite and gneiss. The Nyahove Adamellite crops out in the extreme west of the area and intrudes the Budjga Dome Suite.

Remobilised Granites occur within zones of higher metamorphic grade and can often be traced into virtually unaltered parent granitic rocks. However, in the east of the area, within the Mocambique orogenic belt, several gneissic units have no obvious unaltered parent rocks. These include the the Nyamvu Gneiss and the Chirwa Adamellite.

The Nyamvu Gneiss is extensively developed in the east of the area and consists of a complex and variable sequence of orthogneisses, paragneisses and schists, which were resolved by Stocklmayer (1980) into a granitic basement component overlain by a metasedimentary cover. The granitic component is composed of granodiorite and tonalite, which possibly represent lateral equivalents of the Ruenya Gneiss and, or, the Budjga Dome Suite. The overlying metasediments are of problematical age and origin. They have been tentatively correlated or compared with Shamvaian sediments (Johnson, 1968; Phaup, 1938), although they may possibly be equivalent, at least in part, to the Pfungwe and Mudzi metamorphic suites to the north and north-west, as described by Barton et al.

The Chirwa Adamellite occupies a domal structure centred on Chirwa Hill in the north-east of the area. The body is composed of a coarse-grained leucocratic adamellite core surrounded by darker more biotite-rich adamellite which becomes gneissic towards the periphery of the dome. The marginal adamellite is intruded by numerous large bodies of leucocratic adamellite believed to have differentiated from the core of the dome. The body is intruded into greenstone but there are no signs of a contact metamorphic aureole and contacts are sharp. A Rb-Sr model radiometric age of 2970 ma has been obtained from a whole-rock sample from the dome, whereas K-Ar dating of biotite yielded an age of 490 ma. The Chirwa Adamellite is thought to be part of the Suskwe Intrusive Suite (Barton et al.) of Archaean age, which was remobilised during the Pan-African tectono-thermal event.

The Umkondo Group

Metasediments of the Umkondo Group crop-out in an arcuate structure around the eastern side of Chirwa Hill, where they rest unconformably upon greenstones of the Makaha Greenstone Belt. In this area the group consists essentially of mica schists with interstratified marbles, calc-silicate rocks and quartzites.

Basic and metabasic intrusions

Basic and metabasic intrusions of the Mashonaland and Umkondo dolerite suites occur throughout the area. Large sills and minor dykes of dolerite are common in the west of the area, where they intrude the Granitic terrain and the Makaha Greenstone Belt. Dykes are fine to medium-grained whereas sills are generally medium to coarse-grained, sometimes becoming gabbroic. The majority are composed of sub-ophitic plagioclase and clinopyroxene, with accessory Fe-Ti oxides. Eastwards these intrusions show increasing effects of tectono-thermal events associated with the Mocambique Orogenic Belt, and in the eastern third of the area they are represented by hornblende-plagioclase amphibolite bodies which intrude the Sawunyama and Chirwa adamellites, the Nyamvu and Ruenya gneisses, and the Umkondo Group.

MINERALISATION

The following brief summary of metalliferous mineralisation is based largely on the work of Stocklmayer (1980).

Gold Deposits

Gold is the most important mineral to have been produced from the area. Between 1909 and 1965 a total of 65 mines declared a production of 3 415.33 kg of gold from 494 827 tonnes of ore, giving an average recovery grade of 6.9 g/t. An additional 12.38 kg were won from alluvial deposits, bringing total output from the area to 3 427.71 kg. In recent years there has been a revival in small-scale alluvial mining in the area.

The Makaha Greenstone Belt accounts for 97.5% of the declared production from the area. The Mudzi Greenstone Formation is by far the most important host to mineralisation and accounts for 95% of total production, whilst only 2.5% of production came from the Lawleys Formation. Most of the deposits hosted by the Mudzi Greenstone Formation take the form of pyritic shears and quartz veins, and are mainly located within the zone of mixed basaltic and felsic rocks towards the base of the formation. Relatively low-grade 'disseminated' mineralisation also occurs within banded-ironstones in the Rugambe Member, notably at Chipenguli Hill and Rugambi Hill. In the Lawleys Formation most of the mines lie within the Nyamboe Member, and only two are located in the Nyamzizi Member.

Several deposits contain minor chalcopyrite and arsenopyrite, and the Olympus and Old Umbrella mines have produced slightly over 70 t. of copper as a secondary product. Silver also occurs with the gold in many of the deposits and a few mines have declared minor production.

Pegmatite Deposits

Pegmatites containing beryl, lepidolite, spodumene, tantalo-columbite, cassiterite and traces of uranium are spatially associated with the Good Days Granodiorite. The most important pegmatites occur near the southern margin of the granodiorite, although a small number are found near the northern margin. Most are hosted within the Good Days Granodiorite, although several occur within the surrounding greenstones and Budjga Dome Suite.

Beryl is the most important mineral to have been produced from these pegmatites and during the 1950's and 1960's a total output of 504 tonnes was declared from 29 claims. Most of this production came from the Good Days and Jordywyitt mines, with lesser but significant amounts from the Ntabeni, Black Poll and Bertelite claims. The Good Days Mine also produced considerable amounts of lepidolite and a moderate amount of spodumene. In addition small amounts of tantalite and cassiterite were produced from several claims.

Base Metal Sulphide Deposits

Exploration work carried out by various mining companies under Exclusive Prospecting Orders have revealed numerous copper and zinc anomalies, but follow-up surveys indicate that most of these are of little economic interest. The most important deposit occurs at the Die Kinkel Claims to the south of Chirwa Hill. Here a mineralised quartz vein within the Nyamvu Gneiss contains an estimated 40 000 tonnes of ore grading 9.71% zinc and 42 g/t silver, with minor copper and lead. Several other claims in the vicinity of the Die Kinkel Claims contain minor copper mineralisation associated with quartz veins.

Molybdenite mineralisation occurs at the Ben Rich Claims to the south-west of Chirwa Hill. Here molybdenite is associated with pyrite and copper sulphides in an aplitic vein which strikes NW over a distance of 1100 m. The mineralisation is weak and grades are low, reaching a maximum of 0.08% MoS_2

GEOCHEMICAL ORIENTATION SURVEY

At the beginning of the BGS survey of the Rushinga-Nyamapanda area, in late 1982, a geochemical orientation survey was conducted by Ridgway (1983). The purpose of this orientation survey was to determine:

a) The best sediment size fraction to sample.

b) The analytical methods most suitable for detecting known types of mineralisation.

c) The density of sample spacing required to give the highest probability of locating mineral deposits of the type known to exist in the area, taking financial and time constraints into consideration.

Four areas of mineralisation were examined during the orientation work. One area is situated at Makaha, whereas the remaining three are situated to the north within the Rushinga-Nyamapanda area where the main BGS survey was conducted. The four areas are:

1. Ball Mine - Four Mile Prospect area: Scheelite with accessory Mo-Cu-Au mineralisation in veinlets and shears within gneisses of the Pfungwe suite, close to the contact with the Dindi greenstone belt.

2. Benson Mine: Pegmatites containing Be-Ta-Nb-Sn-Li-Cs mineralisation.

3. T.O.T. Claims, Chikwizo: Quartz vein containing weak Pb-Cu-Zn mineralisation.

4. Olympus-Umbrella mines area, Makaha: Greenstone-hosted Au-Cu mineralisation in quartz veins and shears.

The orientation survey indicated that the best anomaly to background contrast could be obtained by analysing the -100 mesh size fraction of the stream sediments. However, sieving to this size was found to be too time consuming and at many localities it was not possible to obtain sufficient sample. The minus 80 mesh size fraction was found to give acceptable anomaly to background contrast and sieving was much faster, and this size fraction was therefore chosen for the main survey.

It was decided to analyse the samples for Cu, Pb, Zn, Co, Ni, Mn, and Li by atomic absorbtion spectrophotometry, following digestion by hot concentrated hydrochloric acid, and to determine As, Sn, Ba, Pb, Ta and Ni by X-ray fluorescence spectrometry.

The orientation survey indicated that the mineral deposits under study could be detected at distances of 1 to 3 km, although this may have been affected by contamination caused by earlier working.

THE SAMPLING PROGRAMME

A total of 3297 samples was collected from the area, which is equivalent to an average sampling density of 3.83 samples per km^2.

Sample position and numbering.

At the beginning of the survey the positions of sample sites were determined and marked on the two 1:50,000 topographical maps of the area, and each map was allocated a set of pre-numbered sample envelopes. Prior to sampling the sample envelopes were shuffled, and were subsequently drawn randomly for use in the field on a daily basis. On completion of the sampling programme the samples were re-ordered consecutively prior to submission to the laboratory for analysis. The randomisation of sample numbers in this manner was taken as a precaution in case of changes in analytical precision or introduction of bias within the laboratory. Thus, for example, if bias was introduced for a short period during the analytical programme, this would not affect all the samples from any particular area or drainage basin.

Organisation of sampling teams

Three sampling teams were employed on the survey, and each was composed of 3 men. These included a team leader who was responsible for the location of sample sites from the map and for recording details for sample registration, and two samplers who actually collected the samples.

Sample collection

During the course of the survey all drainage channels were dry, thus enabling samples to be sieved on site.

Samples were made up of sediment taken at several different positions in the stream bed within a radius of up to about 5 metres, and at least 6 positions were sampled at each locality. Only the central or active parts of channels were sampled so as to avoid local material collapsed from banks. Samples were taken from just below the surface by scraping off the top layer with a plastic dust pan and using a plastic jug to scoop up the sample from below. The sediment was sieved through a stack of 3 wooden sieves with plastic meshes of sizes 10, 60 and 80 mesh. The -80 mesh fraction was collected in a wooden bowl at the base of the stack and then transferred to randomly selected pre-numbered sample envelopes (Kraft soil sample bags). Sample packets were usually filled to about two-thirds capacity, corresponding to a mass of about 100 grams.

Information, recorded on sample registration forms at the site of collection, included:

- Sample number.
- Map sheet number, e.g. 1732B3.
- Sample type. In this case drainage sample.
- Grid reference
- Name of sampler
- Date
- Traverse number
- Description of channel morphology, including depth, width, cross profile shape and description of sediment (ie. sandy or bouldery etc.)
- Description of unusual rock types found in float.

In addition, traverse numbers were recorded on sample packets at the time of collection.

Samples were taken to the Geological Survey offices in Harare at the end of each month, where they were sorted and stored in consecutive order prior to submission to the laboratory for analysis.

CHEMICAL ANALYSIS OF SAMPLES

The chemical analysis of samples was undertaken at the Institute of Mining Research, University of Zimbabwe.

Samples were submitted to the laboratory in batches of about 150. They were analysed for Cu, Pb, Zn, Co, Ni, Mn and Li by atomic absorption spectrophotometry (AAS) following digestion with hot concentrated hydrochloric acid for a period of 1 hour, and for As, Ba, Pb, Ni, Sn, Ta and W by X-ray fluorescence spectrometry (XRF).

Precision of the AAS analytical method was monitored by the regular analysis of control samples. Three 'known' control samples, designated BGS1, BGS2 and BGS3 were inserted into each analytical batch by the laboratory, and another three 'hidden' controls, designated A, B and C, were submitted to the laboratory under the guise of routine samples. During the analysis of the first 10 batches of samples the control samples were analysed routinely and the mean, standard deviation and coefficient of variation was calculated for each element, the values of which are given in appendix 2. Precision was set at mean$\pm$2SD and for the remainder of the survey the control samples were analysed routinely and results were plotted on precision monitoring charts of the type presented in appendix 3. Using this method only 1 in 22 determinations should fall outside mean$\pm$2SD, and fewer than 1 in 370 outside mean$\pm$3SD. Departures from these limits would indicate the introduction of unacceptable errors or bias.

Precision of the AAS analytical programme was also monitored by the method of Thompson and Howarth (1973), which takes into account the variation of precision with concentration. In this method precision is defined as twice the coefficient of variation expressed as a percentage (SDx200/mean), and may be examined for conformity to an arbitrary level by use of a precision chart such as that shown in appendix 4. Throughout the course of the analytical programme samples were re-analysed routinely and replicate analyses plotted on such charts.

Precision for the AAS analysis was generally good, except for Pb at low concentrations (below 10 ppm). At higher concentrations however, the precision for Pb was acceptable.

Precision of the XRF analytical method was monitored by the regular analysis of international rock standards and of 'in house' control stream sediment samples, the results of which are summarised in appendix 2. Although the XRF analytical precision for control samples appears to be acceptable a number of samples gave exceptionally high results (in the percent range) for all, or several elements. As some of these abnormal results were for elements that generally behave in a geochemically incoherent manner with respect to one another (for example exceptionally high Ni and Ta in the same sample) they were discarded from the data set. In addition, for a number of the XRF analytical batches all the elements for all samples were reported as having zero concentration. Whilst zero concentration may be expected for many determinations, particularly for elements with low analytical sensitivity, it is unlikely to be the case for all determinations in a single batch of samples, especially for elements such as Ni and Ba which normally occur in concentrations well above detection limit. Such spurious results throw some doubt on the reliability of the XRF data set as a whole, although the majority of analyses appear to be acceptable.

Detection limits for both the AAS and XRF analytical methods are presented in table 2. Detection limit is here defined as twice the standard deviation at zero concentration, and was calculated by regression of the means against the differences of duplicate analytical results (Thompson and Howarth, 1978).

Table 2: Analytical detection limits

Element	Det. Limit
Cu	1 ppm
Pb	9 ppm
Zn	3 ppm
Co	3 ppm
Ni	2 ppm
Mn	26 ppm
Li	1 ppm
Sn	4 ppm
W	4 ppm
Ta	5 ppm
Ba	54 ppm
As	10 ppm

ACQUISITION OF DATA

Four data subsets were compiled during the course of the survey, and these were eventually merged to form a single data set for interpretation and the generation of geochemical maps. A printed copy of the merged data set accompanies this report, and copies can also be obtained on magnetic diskette from BGS headquarters on request.

The four data subsets are as follows:

1. AAS analytical results. These were entered into the project's Cifer 1880 microcomputer in Harare.

2. XRF analyses were recorded on the PDP11 computer at IMR and on completion of the analytical programme the results were forwarded on magnetic tape to BGS headquarters in the U.K. Approximately 10% of the samples, or their analytical results, were mislaid in the XRF laboratory, and absent data values (-1) were therefore assigned to these samples and were not taken into account during subsequent statistical analysis. The elements Ni and Pb were analysed by both the XRF and AAS methods, but because of the loss of so many XRF analyses and the general uncertainty over the quality of the XRF data, only the AAS analyses for these two elements were used in the interpretation.

3. Information on the geology of sample sites was taken from the published 1:100 000 scale geological map. Each sample was given a two-tiered code denoting its underlying bedrock type and lithostratigraphic unit, as listed in appendix 5, and this was recorded on the project's microcomputer.

4. Grid references of sample sites were obtained by automated digitisation of sample locality maps at BGS headquarters. Important river courses were also digitised for automated plotting on the final geochemical maps.

INTERPRETATION AND PRESENTATION OF RESULTS

Each element is approximately log-normally distributed. This is borne out by the close similarity between the median and geometric mean values, as shown in the statistical summary presented in table 3, and by straight-line distributions produced in numerous log-probability plots during the interpretation, an example of which is shown in figure 3.

Table 3. Statistical summary of results for the entire data set

	Min Conc	Max Conc	Median	Arith Mean	Stand Dev	Geom Mean	Geom Mean (log)	Log Dev	N
Cu	*	345	28	36	29.9	24	1.382	0.421	3297
Pb	*	270	*	6	6.7	5	0.718	0.163	3297
Zn	3	388	38	41	18.7	38	1.576	0.189	3297
Co	*	113	13	17	13.2	12	1.092	0.385	3297
Ni	*	845	30	40	41.9	25	1.398	0.470	3297
Mn	70	8110	590	731	491.7	592	2.772	0.289	3297
Li	*	55	4	4	2.7	4	0.582	0.242	3297
Sn	*	1097	*	13	25.2	6	0.788	0.535	2991
W	*	98	*	10	12.4	5	0.707	0.491	2991
Ta	*	266	*	15	20.1	7	0.853	0.534	2991
Ba	*	2605	369	386	215.0	317	2.501	0.308	2991
As	*	211	*	8	7.6	7	0.824	0.223	2991

*Below detection limit. Values below detection limit were set to half the detection limit prior to statistical analysis.

The results of the survey are presented in a series of maps, which include:

a) Single element concentration maps at 1:50 000 scale.
b) Multi-element anomaly maps at 1:100 000 scale.

Single element concentration maps

Single element concentration maps were produced at a scale of 1:50 000 as transparent overlays to the topographic maps; the sampling density was too high for the data to be presented at 1:100 000 scale. These illustrate the level of a particular element at each sample site by means of a line, of length directly proportional to concentration, extending from the sample point. In addition to presenting the raw data in a visual form, these maps provide a rapid means of assessing the overall results for each element by indicating the concentration range and broad variations related to lithology, aswell as drawing attention to some of the more prominent anomalies.

In order to maintain general uniformity between the maps for each area and for each element, the background (median) level for each element is assigned a standard symbol size of 5 mm. For elements such as Pb, Sn, W and Ta the true median values are well below detection limits, and therefore the symbol sizes were standardised using a median value calculated only from values above detection; without doing this the maps would have been confused by a proliferation of very large symbol sizes representing the higher concentrations. For the other elements almost all analytical results are above detection and the true median is practically the same as that calculated using only values above detection.

Multi-element anomaly maps

Multi-element anomaly maps were produced at a scale of 1:100 000 as transparent overlays complementary to the northwestern corner of the Inyanga-North geological map. Because of difficulties in portraying 12 elements on a single plot, the anomalies are split into two element associations and presented separately. One map presents the anomalies for Cu, Pb, Zn, Co, Ni, Mn, Ba, W and As, whilst the other illustrates the anomalies for Sn, Ta, Li and W.

Lithological influences on stream sediment chemistry were accounted for by classifying the analytical results into groups according to the dominant drainage basin lithology at each sample site. The lithological classification used to subdivide the data is given in table 4. Sorting into these classes was achieved by computer, using the codes listed in appendix 5.

Table 4. Classification used to group the data according to dominant lithological influence on sample sites.

Umkondo Group	UK
Remobilised Granites (includes Ruenya Gneiss)	RG
Adamellites	A
Intermediate Granites	IG
Older Tonalites and Gneisses	OT
Mixed basaltic and felsic greenstones	BF
Basaltic greenstones	B
Lawleys Formation	LF
Dolerite, amphibolite and ultrabasic sheets	D

For each element and lithological grouping, graphs of log-concentration plotted against cumulative frequency on a probability scale were used to determine threshold values (Sinclair, 1976), above which concentrations are considered to be anomalous (Fig. 3). Threshold values were identified at inflexion points at high concentrations, and background concentration taken at the 50^{th} percentile (median) of the distribution. The practice, frequently adopted in the absence of well-defined inflexions in the log-concentration versus probability curves, of regarding the top 2.5% of high values as being anomalous was not followed; in the absence of such inflexions all values are considered to be sub-anomalous. Summary statistics for the data grouped according to influencing lithologies are given in appendix 6, and threshold and background values are presented in table 5.

Anomalous values, for each element and lithological group, were standardised by the method of Govett and Galanos (1974), thus resulting in anomaly magnitudes that are directly comparable regardless of element, concentration range, background lithology and map sheet.

The formula used for standardisation is:

$$\text{Standardised anomaly value} = \frac{(\text{Anomaly} - \text{Threshold})}{\text{Threshold}} * 100$$

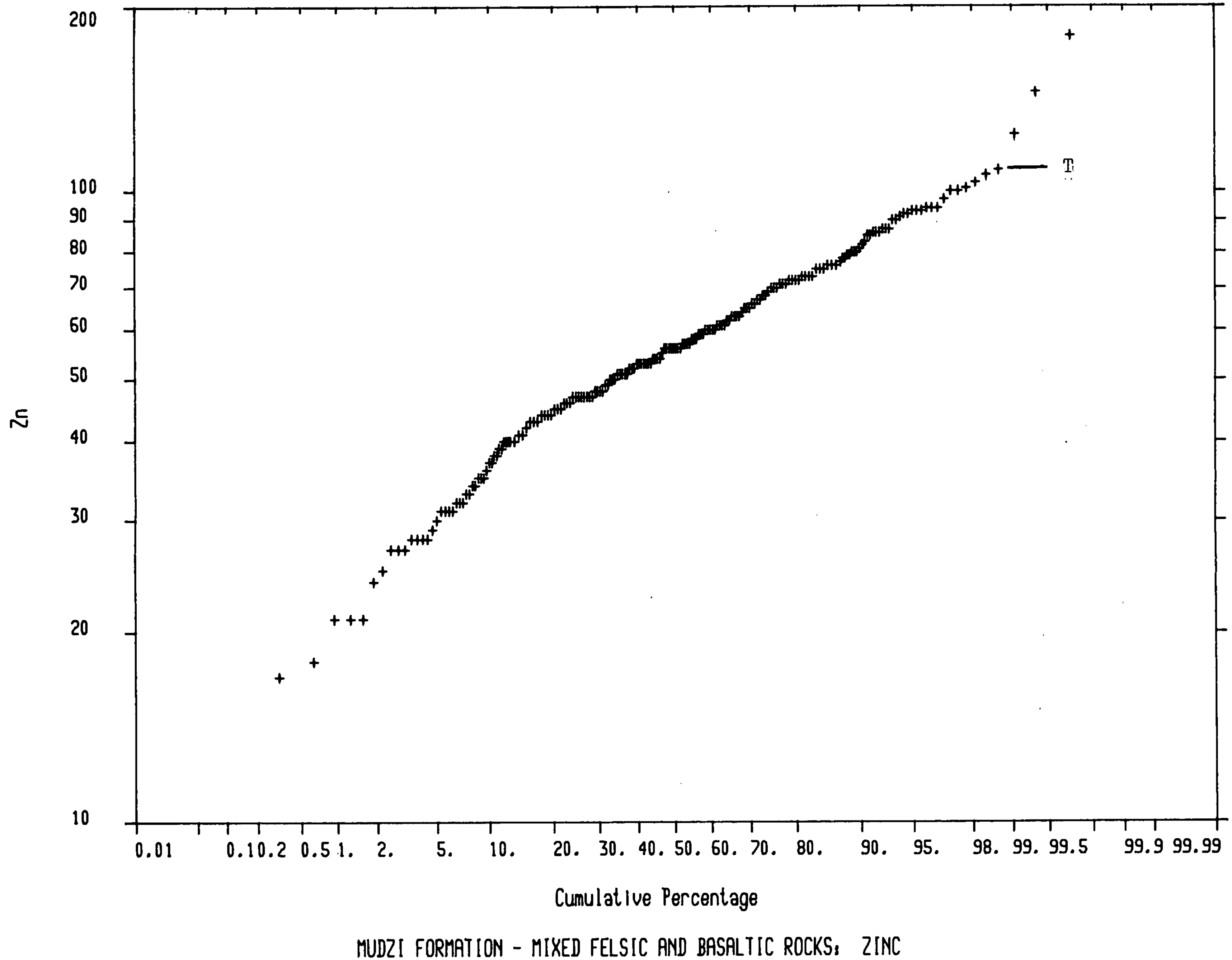


Figure 3: Example of a log probability plot. T = threshold (109 ppm).

Table 5. Threshold (upper) and background (lower) values in relation to lithological groups (see table 4 for explanation of letter codes).

Rock Group	Cu	Pb	Zn	Ba	Mn	Co	Ni	As	W	Sn	Ta	Li
UK	47	-	-	880	-	-	-	-	-	-	-	-
	20	*	33	460	480	11	20	*	9	17	18	5
RG	40	-	64	1170	-	16	58	26	41	65	70	-
	9	*	27	481	370	6	10	*	*	16	15	3
A	52	21	51	-	1140	19	77	-	32	49	70	9
	9	10	25	538	370	6	10	*	*	11	17	3
IG	104	21	88	1110	1470	35	88	24	52	74	83	-
	13	*	34	482	370	8	17	*	*	*	*	5
OT	103	21	88	1130	1540	25	61	26	38	52	73	11
	18	10	32	552	500	9	16	*	*	*	*	5
BF	101	16	109	510	2260	52	149	46	61	50	74	23
	63	*	56	235	1170	34	73	*	4	*	*	4
B	106	11	93	-	2150	53	149	28	53	64	79	11
	57	*	47	211	1100	31	61	*	4	*	*	4
LF	93	21	82	740	1451	46	169	29	-	55	58	-
	40	*	45	235	730	19	48	*	*	*	*	4
D	167	21	83	804	-	49	-	32	36	55	-	-
	41	*	41	489	810	16	40	*	4	4	15	3

* Below detection.

GEOCHEMICAL ANOMALIES

Numerous anomalies occur throughout the area, although only the more important ones are described here, and the grading of these is somewhat subjective. In the following section the anomalies are listed approximately in order of importance, and include single-site anomalies as well as groups containing several anomalous sites scattered over a broad area.

Most of the important anomalies occur within streams draining the Makaha Greenstone Belt. Many of these occur upon the basal parts of the Mudzi Greenstone Formation, either upon mixed felsic-basic volcanic rocks of the Susamoya Member or ironstones of the Rugamba Member, or immediately beneath the latter upon the upper parts of the Lawleys Formation.

Pegmatite related anomalies (Sn, Ta, Li) are relatively scarce, and no anomalies were discovered in association with the pegmatite occurrences in the vicinity of the Good Days Claims. The failure to detect anomalies in the main pegmatite belt probably results from the sampling procedure being generally ineffective for Sn and Ta, which mostly reside in heavy restite minerals. Heavy mineral concentrates generally provide a more reliable sampling medium for these elements, but the collection of such samples was not logistically feasible in the present survey.

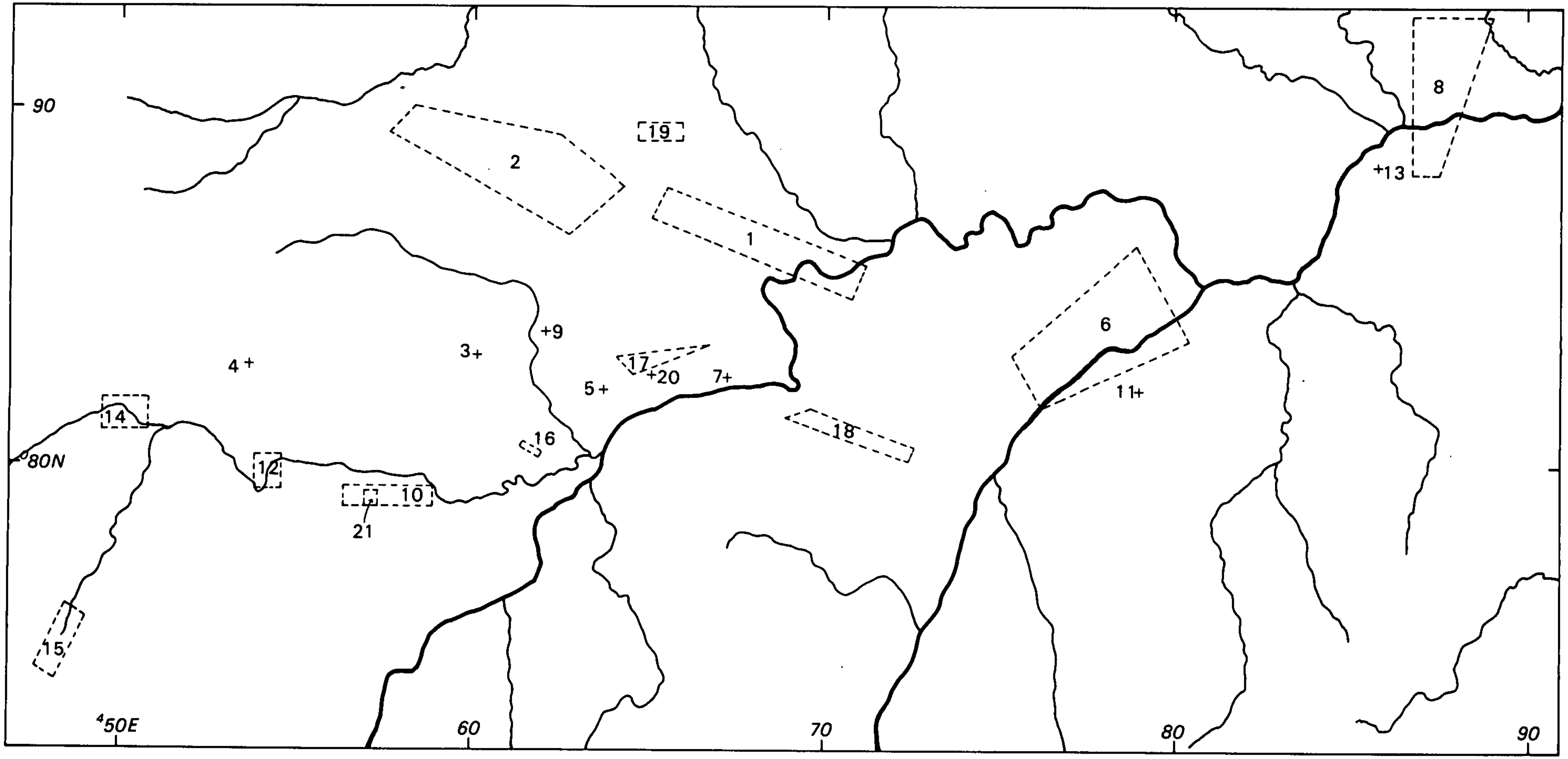


Figure 4: Distribution of geochemical anomalies.

Anomaly 1.

A group of several widely scattered but strong Pb-As anomalies occurs within small northerly flowing tributaries of the Manyuchi and Nyamzizi rivers to the west and south of Nyamboe Hill (46510875). These are underlain by the Nyamboe Member of the Lawleys Formation, and most occur a short distance downstream from the contact with the Mudzi Greenstone Formation.

Anomalous sites include:

Site	Grid Ref.	Pb	As	
17791	46890858	60	211	Element values in ppm.
17815	46590871	100	55	
18087	47000852	-	38	
18164	47000854	270	-	
18728	47100856	35	37	
	Threshold	21	29	
	Background	bd	bd	(bd = below detection)

Site 17791 occurs downstream from the O.M.A. Mine and may be anomalous as a result of contamination, whilst the other anomalous sites are not associated with known claims or workings.

These Pb-As anomalies are considered to be the most important in the area and should be given the highest priority in any follow-up surveys, since similar Pb-As anomalies are associated with known areas of mineralisation in the old mining area along strike to the north-west (see anomaly 2).

Anomaly 2.

A number of moderate to high Pb, As and Cu anomalies and moderate to weak W, Cu and Zn anomalies are associated with the old mining area between the Radnor Mine (45950892) and the Golden Sovereign Claims (46340871). These mainly occur within the northerly flowing headwaters of the Manyuchi River which drain mixed basic and felsic volcanic rocks and serpentine-talc schists of the Susamoya Member.

Anomalous sites include:

Site	Grid ref.	Cu	Pb	Zn	As	W
17000	46160875	-	-	-	-	84
17021	45900893	-	-	-	129	-
17302	46230810	110	150	-	92	-
17476	46270880	169	-	-	-	-
17479	45810894	-	-	180	-	-
*17484	46130874	-	-	-	-	98
17552	46150884	166	50	-	119	-
17691	46330874	345	35	-	-	68
	Threshold	101	16	109	46	61
	Background	63	bd	56	bd	4

*Site 17552 is situated at the contact between mixed felsic-basic volcanic rocks (upstream side) and serpentine-talc rocks (downstream side), a short distance downstream from the Koodoo Mine (Au-Cu). On the geochemical anomaly map it is not portrayed as being anomalous in Cu because the dominant lithological influence was wrongly assumed to be due to serpentine-talc schists (threshold 167 ppm Cu). If the mixed felsic-basic volcanic rocks (threshold 101 ppm Cu) further upstream are taken to be the dominant lithological influence, then the site has a standardised anomaly value of 64 for Cu.

Although the possibility of contamination by past mining activity should be considered, several of the anomalies of this group occur in streams that drain areas with no known claims or workings, and they therefore merit further attention.

Anomaly 3.

Two sample sites, situated about 0.5 km west of the Rodeo Claims (46100829), are strongly anomalous in Pb and Mn. The anomalies occur in two adjacent 1st order streams at the contact between the Nyamzizi Member of The Lawleys Formation and the Susamoya Member of the Mudzi Formation.

The anomalous sites are:

Site	Grid Ref.	Pb	Mn
17689	46020832	80	-
17950	46010831	-	8110
	Threshold	16	2260
	Background	bd	1170

Anomaly 4.

A single Ba anomaly (site 17920) occurs within a 1st order stream flowing over the Susamoya Member, close to a contact with the underlying Nyamzizi Member at grid reference 45370828. The site gave an analytical value of 2605 ppm Ba over a background of 235 ppm and a threshold of 510ppm.

Anomaly 5.

A single Cu anomaly (site 18120) is situated within a 1st order stream at grid reference 46370822. The site occurs at the contact between the Rugamba Member and the underlying Nyamzizi Member, and gave an analytical value of 310 ppm over a background of 40 ppm and a threshold of 93ppm.

Anomaly 6.

A broad zone of moderate to weak As anomalies and minor Pb anomalies occurs within easterly flowing tributaries of the Ruenya and Nyamzizi rivers, to the south-west of Chirwa (48080880). These anomalies are underlain by basaltic greenstones of the Mudzi Formation, except for one site (20159) which occurs upon the Lawleys Formation close to the contact with the Mudzi Formation.

Anomalous sites include:

Site	Grid Ref.	As	
20107	47690837	45	Threshold = 28
20147	47860858	42	Background below detection (10)
20176	47928525	45	
20186	47770842	53	
20287	47630823	43	
20159	47560834	48	Threshold = 29, Background below detection

These anomalies occur in streams that do not appear to drain known claims or workings.

Anomaly 7.

A prominant Ni-Co anomaly is situated 2 km east-north-east of the Dumfries Claims (46440818). The anomaly comprises two anomalous sample sites occuring on separate first order streams draining the Nyamzizi Member. A small dolerite body is marked on the published geology map very close to the sites, but the magnitude of the anomaly is much higher than the background concentrations of Ni and Co normally associated with dolerites elsewhere in the region. This is the most significant Ni anomaly in the area.

The anomalous sites are:

Site	Grid Ref.	Ni	Co
18073	46730825	840	100
18820	46720826	845	113
	Threshold	169	46
	Background	48	19

Anomaly 8.

A group of Zn anomalies occurs in the north-east corner of the area. The anomalies are mainly underlain by Ruenya Gneiss, although the most anomalous site (sample 20708) is situated on a contact between Nyamvu Gneiss and Mtoko Granodiorite.

Anomalous sites include:

Site	Grid Ref.	Zn	
20446	48790916	112	Threshold 64, Background 27.
20680	48690923	84	
20861	48770923	93	
20897	48690927	70	
20708	48700885	388	Threshold 88, Background 34.

The anomaly associated with sample 20708 is the largest Zn anomaly discovered by the survey and merits further investigation, especially when it is considered that several known base metal occurrences within the gneissic terrain in the east of the area did not produce geochemical anomalies in the present survey.

Anomaly 9.

A large single-site Sn anomaly occurs upon Nyamzizi Granodiorite at grid reference 46190839, approximately 1.5 km north-east of the Rodeo Claims. The site (17912) gave an analytical value of 1097 ppm Sn over a threshold of 74 ppm.

Anomaly 10.

A group of moderate to weak Cu anomalies occurs at the eastern end of the Good Days Granodiorite, approximately 2.5 km north-east of the Good Days Claims (45510774).

Anomalous sites include:

Site	Grid Ref.	Cu
18356	45790972	130
18369	45710784	138
18403	45780791	139
18453	45750791	180
18767	45710791	140
18827	45660791	171
18912	45660792	113
	Threshold	104
	Background	13

In the vicinity of the anomalies the Good Days Granodiorite contains abundant greenstone xenoliths. However, the anomalies are considered too high to be accounted for simply by the lithological influence of these xenoliths, as the Cu values exceed the threshold for basaltic greenstone elsewhere in the survey area, and in addition Ni values within the anomalous samples are very low.

Anomaly 11.

A single Ni anomaly occurs at grid reference 47880822 upon basaltic greenstones of the Mudzi Formation. The site (21079) gave an analytical value of 544 ppm Ni, over a background of 61 ppm and a threshold of 149 ppm.

The anomaly occurs less than half a kilometre east of the Nyarugo West Claims, which are reported to have weak copper mineralisation.

Anomaly 12.

A small Pb-Mn-Ba-Zn anomaly occurs upon Good Days Granodiorite approximately 3 km north-north-west of the Good Days Claims (45510774).

The anomalous sites are:

Site	Grid Ref.	Pb	Mn	Zn	Ba
18265	45430800	25	2800	99	1349
18741	45420794	40	2430	-	-
Threshold		21	1470	88	1110
Background		bd	370	34	482

Anomaly 13.

A single Cu anomaly occurs upon Nyamvu Gneiss on the eastern side of the Ruenya River at grid reference 48568859. The site (20959) gave an analytical result of 122 ppm Cu over a background of 9 ppm and a threshold of 40 ppm.

Anomaly 14.

A group of Pb-Mn anomalies is located on the Nyahunure River between 3.5 and 5 km south and south-east of the summit of Susamoya (45090853). The anomaly is underlain by Good Days Granodiorite.

Anomalous sites are:

Site	Grid Ref.	Pb	Mn
18542	44960817	-	5000
18625	45030816	30	-
18722	44730821	35	2000
18789	44980817	40	2050
18799	45060811	60	2400
18840	44870811	30	
Threshold		21	1470
Background		bd	370

Anomaly 15.

A group of weak Pb anomalies occurs to the north-east of Nyahove (44750748), upon the Nyahove Adamellite and its contact with basaltic greenstones of the Mudzi Formation.

Anomalous sites include:

Site	Grid Ref.	Pb		
18301	44840749	30	Threshold	21
18607	44820741	30	Background	10
18839	44850757	30		
18924	44850749	40		

Anomaly 16

A small Cu-Zn anomaly occurs between the Nyamatokwe and Nyanuri rivers approximately 1.5 km west of their confluence, and is underlain by the Nyamzizi Member of the Lawleys Formation.

Anomalous sites are:

Site	Grid Ref.	Cu	Zn
18388	46180804	124	86
18972	46160805	144	86
	Threshold	93	82
	Background	40	45

Anomaly 17

A group of Ni and minor Cu anomalies occurs upon mixed felsic and basic volcanics of the Mudzi Greenstone Formation approximately 1.5 km to the north of the Dumfries Mine.

Anomalous sites are:

Site	Grid Ref.	Ni	Cu
18031	46430830	215	104
18033	46470828	213	-
18316	46640834	336	-
	Threshold	149	101
	Background	73	63

Anomaly 18

A group of moderate Ni anomalies extends to the north and north-east of Nyaruhwe (47150795). The anomalies are underlain by the Nyamzizi Member of the Lawleys Formation and by the Nyamzizi Granodiorite, and occur in streams draining eastwards off a ridge of high ground culminating in Nyaruhwe. The top of the ridge is composed of serpentinite which is assumed to be the source of the anomalies.

Anomalous sites are:

On Nyamzizi Granodiorite.

Site	Grid Ref.	Ni
20099	47080811	173
20327	47220803	138
20357	47190805	148
	Threshold	88
	Background	17

On Lawleys Formation.

Site	Grid Ref.	Ni
20092	46980812	183
20226	46900814	228
20594	46980812	306
	Threshold	169
	Background	48

Anomaly 19.

A small group of weak Zn anomalies occurs in streams draining the eastern flanks of Budea (46430891). They are located upon the Nyamzizi Member a short distance downstream from its contact with the overlying Mudzi Formation.

Anomalous sites include:

Site	Grid Ref.	Zn
17836	46570895	92
17879	46530895	104
17941	46480895	104
17942	46480893	110
	Threshold	84
	Background	45

Anomaly 20

A single Zn-Cu anomaly occurs upon the Nyamzizi Member of the Lawleys Formation at grid reference 46500826, approximately 1 km north of the Dumfries Mine. The site (18121) gave analytical values of 104 ppm Cu over a threshold of 93 ppm and background of 40 ppm, and 130 ppm Zn over a threshold of 82 ppm and background of 45 ppm.

Anomaly 21.

A single Sn-Ta anomaly occurs at the eastern end of the Good Days Granodiorite. The site (18767) gave analytical results of 235 ppm Sn over a threshold of 74 ppm, and 266 ppm Ta over a threshold of 83 ppm. This sample is also anomalous in Cu (see anomaly 10).

RECOMMENDATIONS

The area is considered to have good potential for exploration and it is recommended that all the anomalies listed in the previous section should be examined in more detail. Anomalous areas should initially be investigated by more detailed stream sediment surveys using higher sampling densities, and subsequently areas of interest should be examined by soil geochemical surveys, geological mapping and rock geochemical surveys.

The ground underlain by the Makaha Greenstone Belt is the most prospective part of the area, and is believed to have good potential for the discovery of new areas of gold mineralisation. Most of the old gold mines occur within the lower part of the Mudzi Greenstone Formation, either within mixed felsic-basic volcanic rocks of the Susamoya Member or ironstones of the Rugamba Member, although a few are also located within the uppermost parts of the underlying Lawleys Formation. The present survey has discovered a number of anomalies, scattered over a wide area, that are underlain by this part of the succession, and except for anomaly 2, these do not appear to drain old workings and should therefore be given a high priority in follow-up work.

Of the elements determined in the present survey, Pb and As, and to a lesser extent Cu, W and Zn give the most useful response in areas of known gold mineralisation. In follow-up surveys it is recommended that Au should also be determined routinely to the ppb level, and orientation work should be undertaken at an early stage to ascertain the optimum sampling medium for these determinations. In addition to chemical determinations, it is recommended that heavy mineral concentrates from both soil and stream sediments should be examined for visible gold and scheelite (using a UV light for the latter). Heavy mineral concentrates, whether collected for visible examination or for chemical analysis, should preferably be obtained using automative separation techniques rather than traditional panning methods, in order to optomise precision.

In addition to those anomalies of interest with respect to gold mineralisation, several other anomalies are considered to be important. Within the greenstone belt the various Ni anomalies (anomalies 7, 11, 17 and 18) should be examined in more detail, with priority being given to anomaly 7. In the granitic terrain anomaly 8 (Zn) is considered to be the most important.

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APPENDIX 1: RAINFALL AND TEMPERATURE DATA FOR MTOKO.

RAINFALL

	1982	1983	1984	1985	MEAN*
JAN	171.6	96.2	95.2	327.0	169.4
FEB	141.4	87.0	90.9	194.4	141.5
MAR	32.6	9.7	18.7	185.9	90.9
APR	19.0	3.8	0.2	4.8	25.9
MAY	7.0	0.2	5.2	2.1	7.5
JUN	-	13.5	-	-	5.1
JUL	0.4	9.9	4.4	0.3	0.6
AUG	-	1.0	-	-	0.3
SEP	-	-	-	-	9.5
OCT	71.7	17.9	-	29.4	9.6
NOV	8.2	54.1	56.6	85.0	80.0
DEC	87.6	155.0	150.1	233.7	156.0
TOTAL	532.9	378.3	448.1	925.3	696.3

MEAN TEMPERATURE*

	MEAN MAX	MEAN MIN
JAN	26.4	17.1
FEB	26.3	17.0
MAR	26.4	15.7
APR	25.8	14.1
MAY	23.9	11.3
JUN	21.7	9.0
JUL	21.4	8.5
AUG	23.6	10.3
SEP	26.2	13.0
OCT	28.6	16.1
NOV	27.8	16.8
DEC	26.9	17.1
MEAN ANNUAL	25.4	13.8

*Mean rainfall and temperature based on records for previous 25 year period.

APPENDIX 2: ANALYTICAL PRECISION OF CONTROL SAMPLES

Values in ppm

COPPER (AAS)

Sample	Mean	SD	CV	N
BGS-1	74.2	1.46	1.97	40
BGS-2	13.5	1.73	12.85	41
BGS-3	44.0	1.19	2.70	39
A	66.1	2.17	3.28	30
B	13.7	1.56	11.36	30
C	42.9	1.27	2.95	30

LEAD (AAS)

Sample	Mean	SD	CV	N
BGS-1	8.9	0.83	9.28	40
BGS-2	20.0	1.55	7.72	41
BGS-3	14.0	0.93	6.60	39
A	0.2	0.68	290.96	30
B	20.2	2.14	10.59	30
C	6.4	1.83	28.48	30

ZINC (AAS)

Sample	Mean	SD	CV	N
BGS-1	126.1	2.87	2.28	40
BGS-2	23.4	1.61	6.88	41
BGS-3	73.8	2.06	2.79	39
A	54.5	2.14	3.94	30
B	23.3	1.37	5.87	30
C	107.2	6.22	5.80	30

COBALT (AAS)

Sample	Mean	SD	CV	N
BGS-1	31.1	1.41	4.53	40
BGS-2	12.4	0.62	5.04	41
BGS-3	22.2	0.81	3.64	39
A	48.1	3.49	7.25	30
B	12.5	1.28	10.21	30
C	31.5	1.92	6.10	30

NICKEL (AAS)

Sample	Mean	SD	CV	N
BGS-1	75.1	2.95	3.92	40
BGS-2	12.4	1.16	9.35	41
BGS-3	43.9	2.67	6.08	39
A	61.1	4.08	6.68	30
B	12.1	1.45	12.00	30
C	37.9	2.30	6.07	30

MANGANESE (AAS)

Sample	Mean	SD	CV	N
BGS-1	1334.8	15.19	1.38	40
BGS-2	649.0	14.28	2.20	41
BGS-3	992.0	17.84	1.80	39
A	2096.0	71.65	3.42	30
B	679.3	25.99	3.82	30
C	1573.7	43.35	2.75	30

LITHIUM (AAS)

Sample	Mean	SD	CV	N
BGS-1	6.4	0.66	10.47	40
BGS-2	5.6	0.63	11.19	41
BGS-3	6.0	0.63	10.51	39
A	4.5	0.97	21.47	30
B	5.8	0.95	16.28	30
C	3.7	0.58	15.62	30

ARSENIC (XRF)

Sample	Mean		SD	CV	N
AGV-1	1.5	(0.8)	1.24	83.22	37
MA-N	13.4	(13)	1.48	11.08	37
ST-5	34.4		1.57	4.56	36
SV-6	3.7		2.08	56.68	36

BARIUM (XRF)

Sample	Mean		SD	CV	N
AGV-1	1274.5	(1200)	13.47	1.06	35
MA-N	63.6	(42)	7.97	12.53	35
ST-4	731.2		22.55	3.08	35
SV-6	789.2		9.05	1.15	35

TANTALUM (XRF)

Sample	Mean		SD	CV	N
AGV-1	2.6	(1.4)	4.50	172.40	35
MA-N	304.8	(306)	2.46	0.81	35
ST-4	252.9		8.41	3.33	35
SV-6	26.8		3.24	12.09	35

TIN (XRF)

Sample	Mean		SD	CV	N
AGV-1	6.1	(3.6)	3.00	49.10	35
MA-N	921.4	(1050)	0.65	0.07	35
ST-4	244.5		2.73	1.17	35
SV-6	71.1		2.93	4.12	35

TUNGSTEN (XRF)

Sample	Mean		SD	CV	N
AGV-1	4.5	(0.53)	2.43	5.90	35
MA-N	71.9	(70)	2.98	4.14	35
ST-4	22.3		2.23	9.99	35
SV-6	89.7		15.47	17.24	35

* Values in parenthesis for the international rock standards AGV-1 and MA-N are working values proposed or recommended by Govindaraju (1984).

List of AAS control samples:

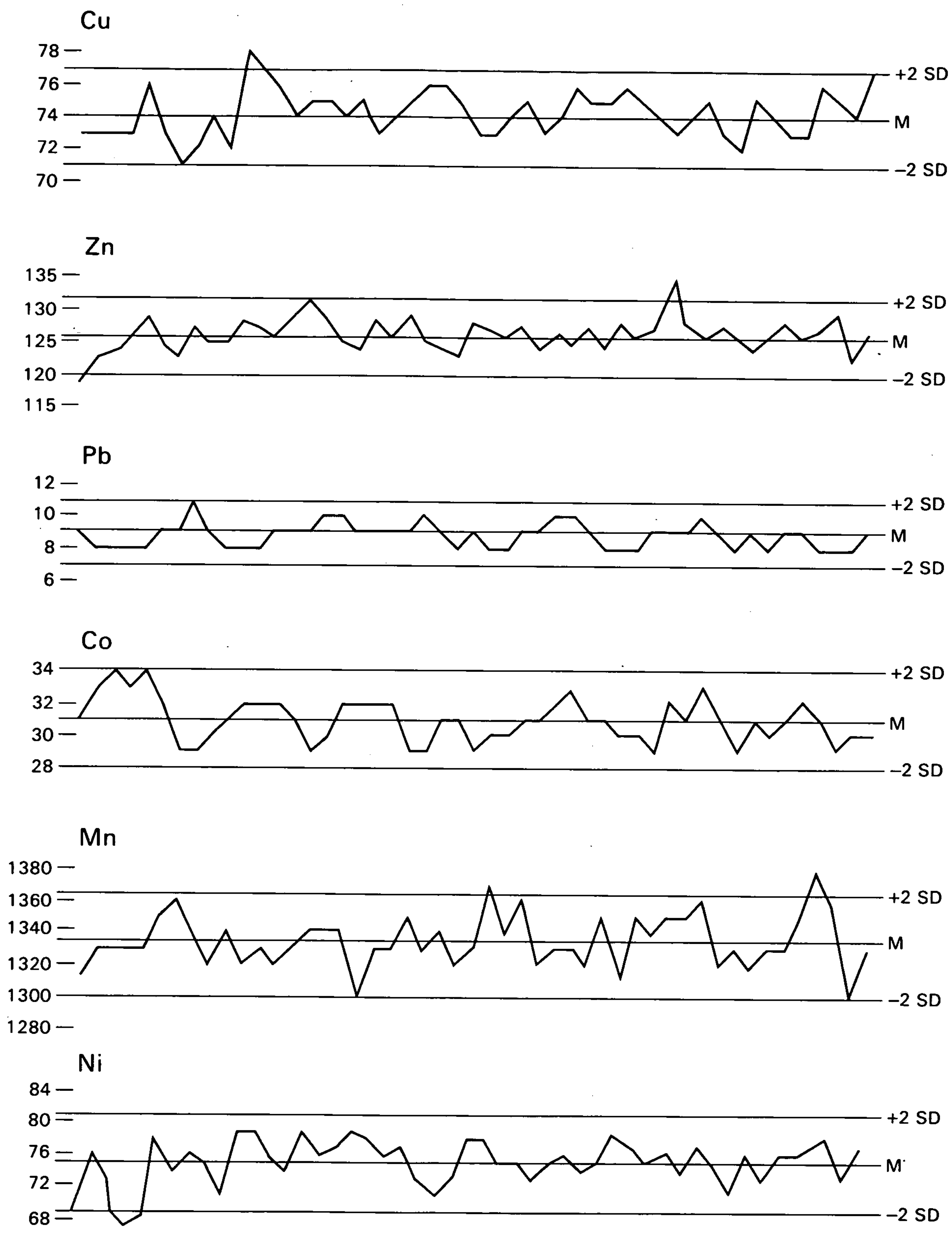
BGS-1, BGS-2, BGS-3: Stream sediment samples (BGS Zimbabwe Project). Inserted routinely into each analytical batch by laboratory.

A, B, C: Stream sediment samples (BGS Zimbabwe Project). 'Hidden controls' submitted to the laboratory under the guise of routinely collected samples. Controls BGS2 and B are splits of the same sample.

List of XRF control samples:

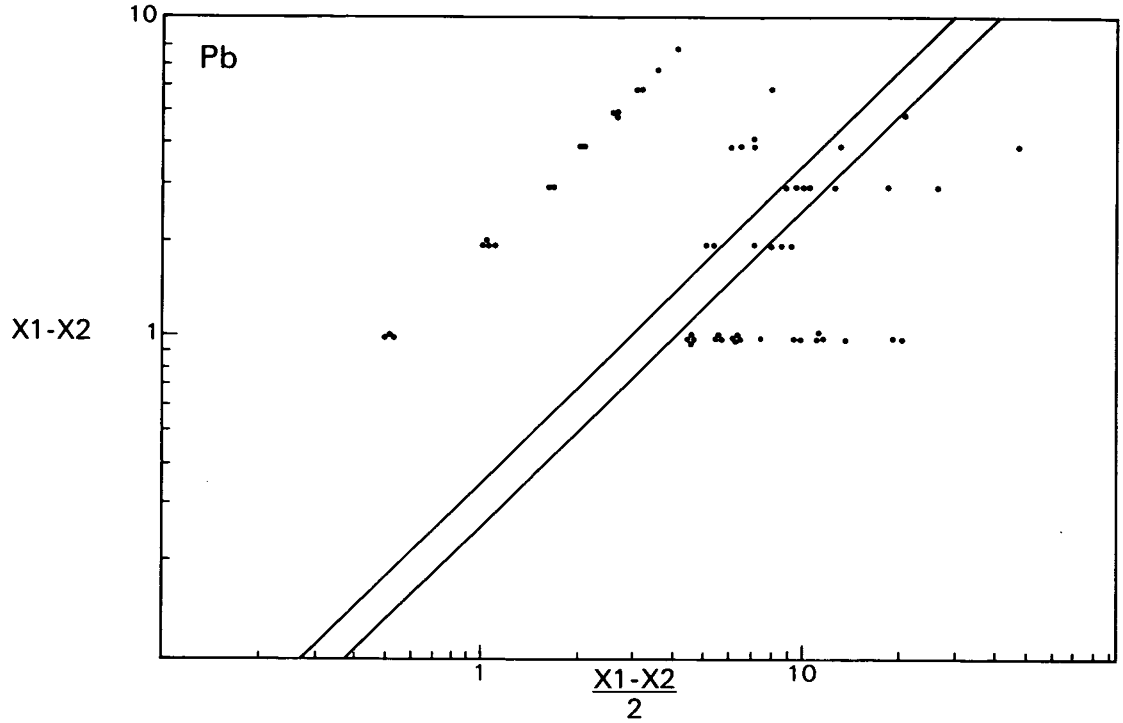
AGV-1: Andesite (USGS International rock standard).
MA-N: Granite (ARNT (France) International rock standard).
ST-5: Granite (Nottingham University standard).
ST-4: Stream sediment sample (BGS Zimbabwe Project).
ST-5: Stream sediment sample (BGS Zimbabwe Project).

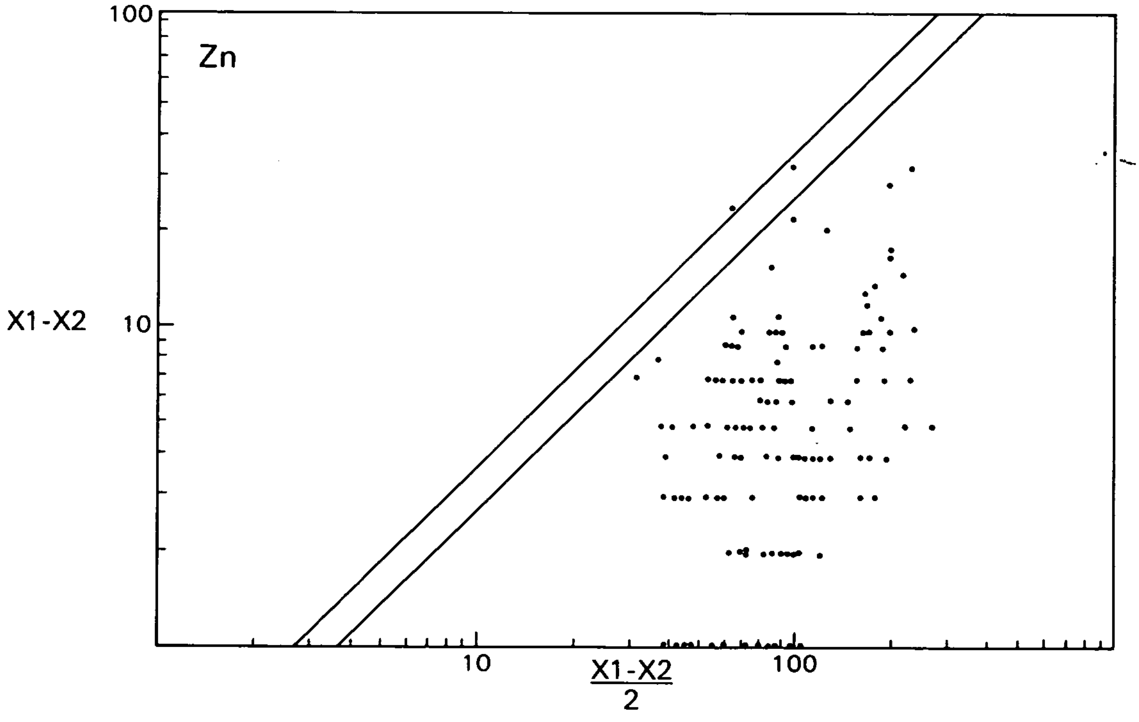
APPENDIX 3.



Example of control charts, for control sample BGS-1, analytical batches 14-26.
SD = Standard deviation, M = Mean, calculated from 40 replicate analyses.

APPENDIX 4:





Examples of precision monitoring charts, for replicate determinations (X1 and X2) showing the 90th and 99th percentiles as a function of concentration for an arbitrary precision of 20%. In these examples the precision for Pb is unacceptable (i.e. greater than 20%), whilst that for Zn is acceptable.

APPENDIX 5: LITHOLOGICAL CODES FOR BEDROCK TYPE AT SAMPLE SITES

MAIN UNIT	CODE	SUB UNIT	CODE
Umkondo Group	UK	Calc-silicate and mica schists	CS
Remobilised Granites	RG	Ruenya Gneiss	R
		Nyamvu Gneiss	NV
		Chirwa Adamellite	C
Adamellites	A	Nyahove Adamellite	N
		Sawunyama Adamellite	S
		Ultrabasic rocks	UB
		Dolerite	D
Intermediate Granites	IG	Nyamzizi Granodiorite	NG
		Good Days Granodiorite	GD
		Mtoko Granodiorite	MG
Older Tonalites and Gneisses	OT	Budjga Dome Suite	BS
		Dolerite	D
Mudzi Greenstone Formation	MG	Basaltic volcanics	B
		Ultrabsic rocks	UB
		Mixed basaltic and felsic rocks	BF
		Dolerite	D
Lawleys Formation	LF	Nyamazizi Member	NZ
		Chikwizo Member	CZ
		Nyamboe Member	NB
		Dolerite	D

APPENDIX 6: STATISTICAL SUMMARY AND THRESHOLD VALUES FOR SAMPLES GROUPED ACCORDING TO DOMINANT LITHOLOGICAL INFLUENCE.

LAWLEYS FORMATION

Number of samples = 390

Element	Min Conc	Max Conc	Median	Mean (Arith)	Stand Dev	Geom Mean	Log Dev	Threshold
Cu	5	144	40	44	20.9	39	0.216	93
Pb	*	270	*	5	14.7	4	0.167	21
Zn	13	130	45	47	15.7	45	0.144	82
Co	*	113	19	20	10.3	18	0.212	46
Ni	3	845	48	61	69.5	47	0.293	169
Mn	160	2610	730	794	342.3	727	0.185	1451
Li	1	13	4	4	1.8	4	0.188	-
Sn	*	69	*	11	13.7	5	0.519	55
W	*	60	*	12	13.4	6	0.515	-
Ta	*	111	*	11	16.8	5	0.523	58
Ba	*	1029	235	275	162.2	227	0.318	740
As	*	211	*	8	12.9	4	0.505	29

MUDZI GREENSTONE FORMATION: Mixed Basaltic and Felsic Rocks

Number of samples = 318

Element	Min Conc	Max Conc	Median	Mean (Arith)	Stand Dev	Geom Mean	Log Dev	Threshold
Cu	*	345	63	65	30.6	58	0.297	101
Pb	*	150	*	5	9.4	4	0.138	16
Zn	17	180	56	58	19.3	55	0.144	109
Co	*	56	34	33	10.2	31	0.183	52
Ni	8	336	73	80	38.9	72	0.201	149
Mn	180	8110	1170	1216	565.9	1120	0.180	2260
Li	*	55	4	5	4.0	4	0.253	23
Sn	*	80	*	12	14.9	6	0.530	50
W	*	98	4	12	14.9	6	0.514	61
Ta	*	85	*	12	17.0	5	0.542	74
Ba	*	605	235	236	106.4	206	0.257	507
As	*	129	*	9	12.1	5	0.530	46

* Below detection limit (see Table 2. for list of detection limits)

MUDZI GREENSTONE FORMATION: Basaltic Rocks

Number of samples = 765

Element	Min Conc	Max Conc	Median	Mean (Arith)	Stand Dev	Geom Mean	Log Dev	Threshold
Cu	5	138	57	57	21.8	51	0.223	106
Pb	*	30	*	4	1.7	4	0.083	11
Zn	14	107	47	48	15.5	46	0.146	93
Co	*	58	31	29	11.3	26	0.228	53
Ni	*	544	61	62	32.8	54	0.260	149
Mn	100	2650	1100	1080	442.1	976	1.343	2150
Li	1	21	4	4	1.9	4	0.178	11
Sn	*	89	*	12	15.3	6	0.528	64
W	*	69	4	12	13.1	6	0.508	53
Ta	*	170	*	16	19.7	7	0.576	79
Ba	*	1056	211	234	138.4	192	0.301	-
As	*	53	*	6	6.8	3	0.494	28

OLDER TONALITES AND GNEISSES: Budjga Dome Suite

Number of samples = 357

Element	Min Conc	Max Conc	Median	Mean (Arith)	Stand Dev	Geom Mean	Log Dev	Threshold
Cu	3	151	18	27	25.4	19	0.356	103
Pb	*	35	10	8	4.3	7	0.224	21
Zn	7	105	32	35	13.2	33	0.154	88
Co	*	31	9	9	5.2	8	0.275	25
Ni	*	94	16	19	13.7	14	0.381	61
Mn	100	5000	500	570	416.6	501	0.207	1540
Li	1	12	5	5	2.3	5	0.227	11
Sn	*	65	*	10	12.9	5	0.494	52
W	*	63	*	8	10.6	4	0.447	38
Ta	*	83	*	15	19.2	6	0.573	73
Ba	200	1373	552	577	189.2	549	0.136	1130
As	*	34	*	5	5.2	3	0.451	26

INTERMEDIATE GRANITES

Number of samples = 650

Element	Min Conc	Max Conc	Median	Mean (Arith)	Stand Dev	Geom Mean	Log Dev	Threshold
Cu	1	265	13	21	24.4	14	0.397	104
Pb	*	60	*	6	4.8	5	0.202	21
Zn	3	388	34	38	20.6	35	0.176	88
Co	*	42	8	10	7.6	8	0.348	35
Ni	*	235	17	24	23.9	15	0.471	88
Mn	80	5000	370	472	381.1	379	0.279	1470
Li	1	22	5	6	3.4	5	0.250	-
Sn	*	235	*	11	16.8	5	0.515	62
W	*	64	*	9	11.2	5	0.471	52
Ta	*	266	*	12	19.3	5	0.532	83
Ba	*	1349	482	477	183.1	430	0.230	1110
As	*	26	*	6	5.0	4	0.345	24

ADAMELLITES

Number of samples = 144

Element	Min Conc	Max Conc	Median	Mean (Arith)	Stand Dev	Geom Mean	Log Dev	Threshold
Cu	2	93	9	15	15.2	11	0.356	52
Pb	*	40	10	8	5.8	7	0.250	21
Zn	9	71	25	27	11.3	24	0.175	51
Co	*	23	6	7	4.5	5	0.324	19
Ni	*	173	10	18	24.2	10	0.479	77
Mn	120	2600	370	454	311.5	381	0.251	1140
Li	1	20	3	4	2.4	3	0.268	9
Sn	*	59	11	16	15.3	9	0.534	49
W	*	48	*	8	9.7	4	0.438	32
Ta	*	104	17	22	22.3	11	0.591	70
Ba	70	853	538	539	147.3	514	0.145	-
As	*	20	*	7	4.8	5	0.343	-

REMOBILISED GRANITES

Number of samples = 557

Element	Min Conc	Max Conc	Median	Mean (Arith)	Stand Dev	Geom Mean	Log Dev	Threshold
Cu	2	122	9	12	9.3	10	0.251	40
Pb	*	10	*	5	1.7	4	0.131	-
Zn	10	112	27	29	12.5	27	0.166	64
Co	*	23	6	6	2.8	6	0.211	16
Ni	*	125	10	13	10.1	10	0.254	58
Mn	70	1430	370	406	186.3	371	0.186	-
Li	1	11	3	3	1.7	3	0.237	-
Sn	*	94	16	19	16.9	11	0.524	65
W	*	84	*	8	10.7	4	0.447	41
Ta	*	175	15	22	24.0	10	0.593	70
Ba	*	1875	481	499	163.7	474	0.147	1170
As	*	36	*	7	6.8	4	0.478	26

UMKONDO GROUP

Number of samples = 40

Element	Min Conc	Max Conc	Median	Mean (Arith)	Stand Dev	Geom Mean	Log Dev	Threshold
Cu	6	78	20	24	14.0	20	0.254	47
Pb	*	10	*	5	2.0	4	0.132	-
Zn	20	58	33	34	9.4	33	0.117	-
Co	3	21	11	11	4.5	10	0.199	-
Ni	3	48	20	21	11.3	18	0.286	-
Mn	200	920	480	488	161.8	461	0.149	-
Li	2	16	5	6	3.2	5	0.238	-
Sn	*	43	17	17	12.5	11	0.487	-
W	*	62	9	16	17.0	8	0.522	-
Ta	*	77	18	22	23.8	10	0.624	-
Ba	108	1373	460	490	221.9	446	0.194	880
As	*	18	*	6	5.5	3	0.494	-

DOLERITE AND AMPHIBOLITE SHEETS

Number of samples = 76

Element	Min Conc	Max Conc	Median	Mean (Arith)	Stand Dev	Geom Mean	Log Dev	Threshold
Cu	7	258	41	54	51.4	37	0.377	167
Pb	*	50	*	7	6.8	5	0.239	21
Zn	15	104	41	47	21.1	42	0.200	83
Co	3	55	16	20	11.9	16	0.294	49
Ni	3	157	40	52	41.3	35	0.444	-
Mn	210	2335	810	859	442.0	748	0.237	-
Li	1	10	3	3	1.8	3	0.243	-
Sn	*	64	4	14	16.0	6	0.543	55
W	*	50	4	10	10.8	6	0.461	36
Ta	*	96	15	24	25.0	10	0.642	-
Ba	84	962	489	470	214.3	411	0.245	804
As	*	119	*	10	15.7	5	0.541	32