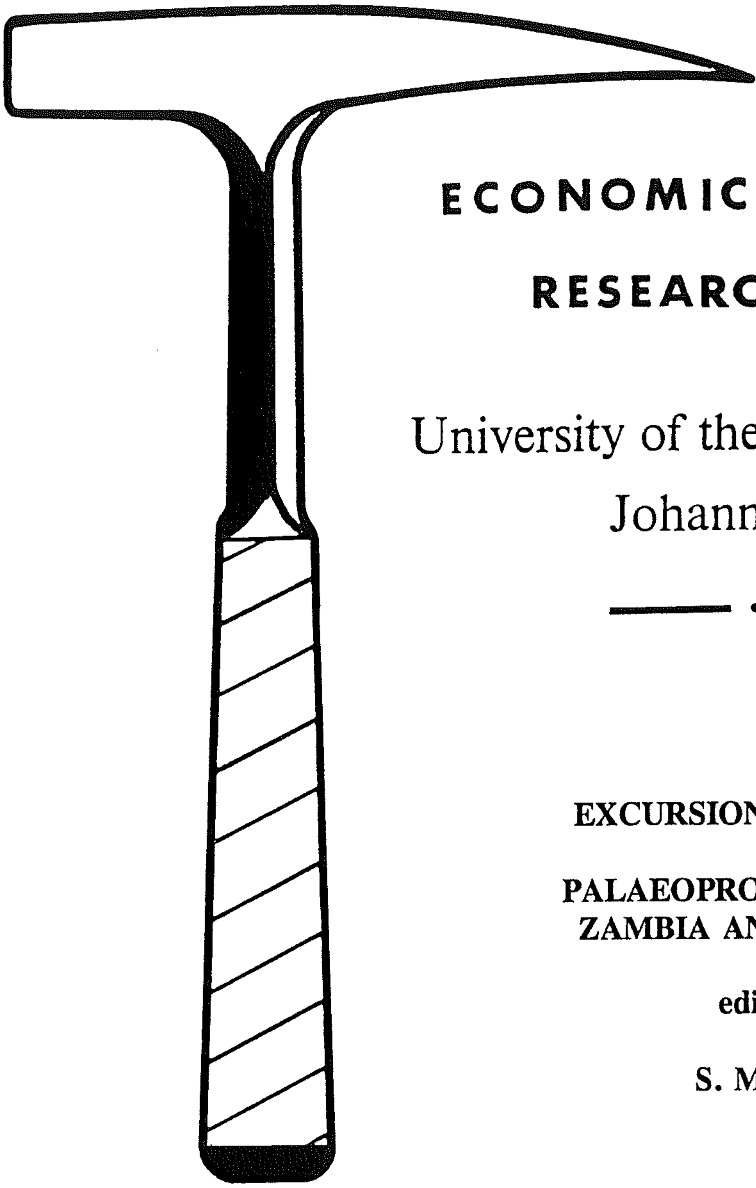


ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
Johannesburg

EXCURSION GUIDEBOOK:

PALAEOPROTEROZOIC OF ZAMBIA AND ZIMBABWE

edited by

S. MASTER

INFORMATION CIRCULAR No. 302

UNIVERSITY OF THE WITWATERSAND
JOHANNESBURG

UNESCO/IUGS
International Geological Correlation Programme

IGCP PROJECT 363:
LOWER PROTEROZOIC OF SUB-EQUATORIAL AFRICA

FIRST FIELD MEETING
(ZAMBIA/ZIMBABWE, 14-30 SEPTEMBER 1996)

EXCURSION GUIDEBOOK:
PALAEOPROTEROZOIC OF ZAMBIA AND ZIMBABWE

Edited by

SHARAD MASTER
Leader: IGCP Project 363
(Economic Geology Research Unit, Department of Geology, University of the Witwatersrand, P/Bag 3, WITS 2050, Johannesburg, South Africa)

ECONOMIC GEOLOGY RESEARCH UNIT
INFORMATION CIRCULAR No. 302

September, 1996

IGCP PROJECT 363:
LOWER PROTEROZOIC OF SUB-EQUATORIAL AFRICA

FIRST FIELD MEETING
(ZAMBIA/ZIMBABWE, 14-30 SEPTEMBER 1996)

EXCURSION GUIDEBOOK:
PALAEOPROTEROZOIC OF ZAMBIA AND ZIMBABWE

CONTENTS

oOo

Published by the Economic Geology Research Unit
Department of Geology
University of the Witwatersrand
1 Jan Smuts Avenue
Johannesburg 2001
South Africa

ISBN 1 86838 232 X

IGCP PROJECT 363:
LOWER PROTEROZOIC OF SUB-EQUATORIAL AFRICA

Pre-Conference Field Excursion:

Palaeoproterozoic of the Domes Area, Northwestern Zambia

14-17 September 1996

EXCURSION GUIDE

compiled by

Francis Tembo[1], Clement Namateba[2] and Sharad Master[3]
([1] Department of Geology, University of Zambia, P.O.Box 32379, Lusaka, Zambia
[2] Geological Survey Department, P.O. Box 50135, Lusaka, Zambia
[3] Economic Geology Research Unit, Department of Geology, University of the Witwatersrand, P/Bag 3, WITS 2050, Johannesburg, South Africa)

Excursion Leaders:

Francis Tembo (UNZA)
Clement Namateba (GSD)
Silishebo Mabuku (GSD)
Sharad Master (WITS)
Patrick Mumba (CBU/WITS)

_____oOo_____

GEOLOGY OF THE DOMES REGION, NW ZAMBIA

In the Domes Region of northwestern Zambia (Fig. 1), Palaeoproterozoic rocks are exposed as basement domes which form cores to younger Mesoproterozoic and Neoproterozoic supracrustals (Arthurs & Legg, 1974; Klinck, 1977). Neoproterozoic orogenesis played a major role in the deformational history of the Domes Region as indicated by the arcuate trend of the domes, paralleling the main structural trend of the Lufilian arc (Cosi et al., 1992). Within the individual domes, the geology is largely obscured by a thick soil cover and is only exposed along river and stream beds.

Lithology

The main lithologies which are common to all domes are gneisses, migmatites, aamphibolites, metagranites and quartz-kyanite-muscovite schists. The oldest gneisses are considered to be biotite and hornblende gneisses derived from both sedimentary and igneous protoliths. No detailed subdivision of the gneisses has been made up to now. Typical mineral parageneses in the gneisses are:

(a) Biotite + K-Feldspar + quartz + garnet + ore
(b) Biotite + epidote + sphene
(c) Hornblende + plagioclase + quartz + sphene + scapolite
(d) Biotite + quartz + epidote

The migmatites are closely associated with the gneisses from which they were derived. Relative to the gneisses, there is an increase in biotite in the melanosomes of the migmatites, whilst the palaeosomes comprise fine-grained gneiss and pegmatitic microcline granite. The metagranites are intrusive into the gneisses and are in part conssidered to be responsible for migmatisation. They comprise both massive and foliated varieties. The schists which are mainly found at the basement-cover contact have a mineral paragenesis dominated by the assemblage quartz + kyanite + muscovite ± epidote ± K-feldspar. Kyanite-bearing biotite schist occurs as lenses and bands within the gneisses. Amphibolites, which are interbanded with gneisses, form a minor component in the lithology of the basement of the Domes Region. A common mineral paragenesis in the amphibolites is Hornblende + plagioclase + quartz ± biotite ± epidote. The amphibolites are commonly converted to talc-chlorite schists in shear zones.

The Palaeoproterozoic structural and metamorphic history of the Domes Region is poorly understood due to strong overprinting by younger orogenic events, as well as due to a lack of detailed studies. Economic mineralization in the Domes Region occurs in Neoproterozoic Katangan metasedimentary rocks. The largest mineral deposits are the copper deposits at Lumwana in the Mombezhi dome (Macgregor, 1965; Benham et al., 1976). The main mineral production has been from the Kansanshi deposit, where copper, gold and silver have been mined (Anon, 1929; Tomkins & Freeman, 1977). Copper sulphide mineralization also occurs in basement rocks, but is of no economic importance. Other minerals prospected for in the region include uranium (Jay, 1960; Meneghel, 1981; Cosi et al., 1992), nickel, manganese and iron.

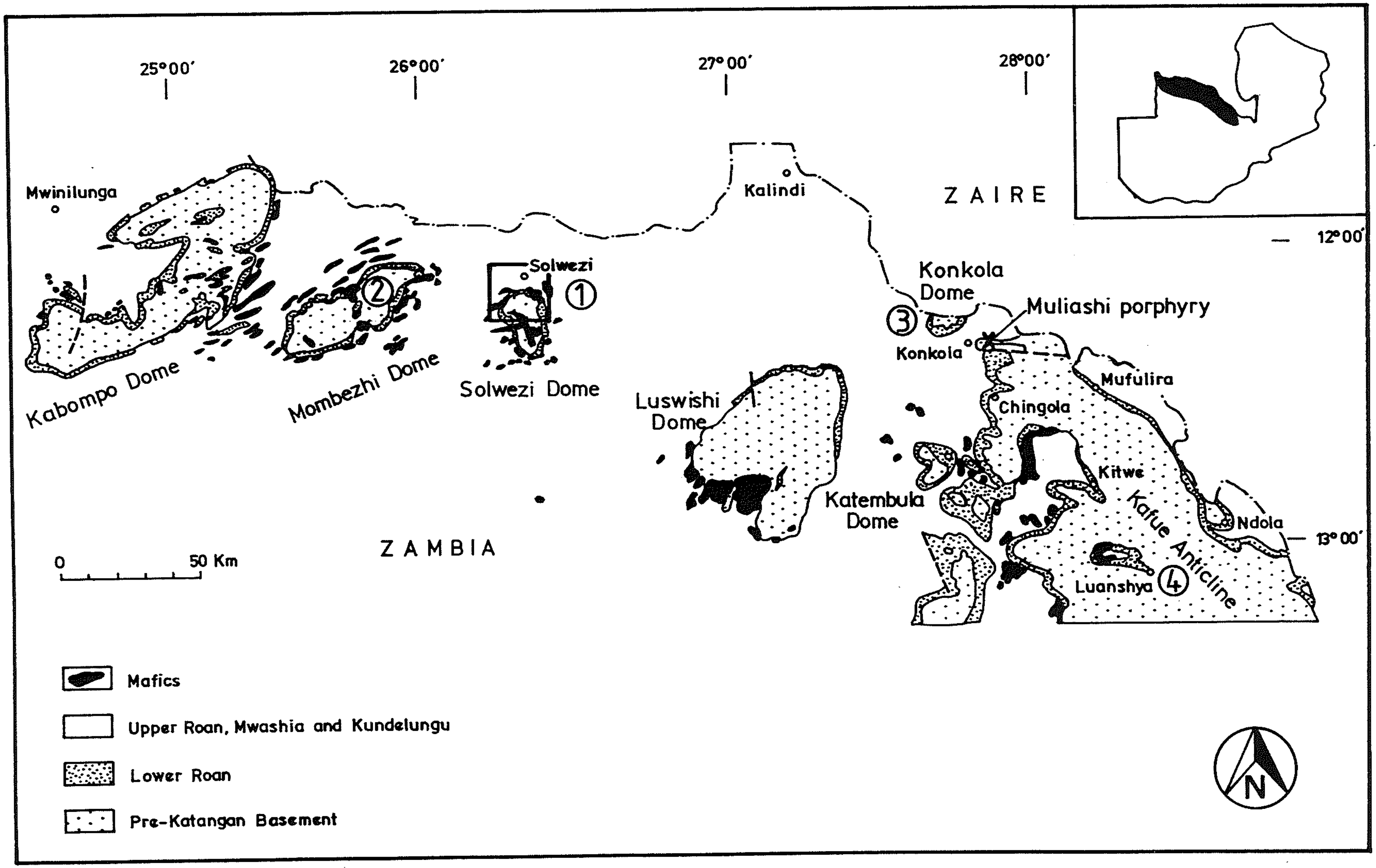


Figure 1: Regional geology of the Domes Area, Zambia (after Thieme & Johnson, 1981; Cosi et al., 1992).

EXCURSION STOPS

Day 1: The Solwezi Dome (Fig. 2)

Stop 1: Kansanshi Cu-Au open pit mine

The Kansanshi deposit is hosted by Kundelungu metasedimentary rocks of the Neoproterozoic Katangan Sequence, which include quartzites schists, graphitic slates, and limestones. Copper mineralization occurs in all rock types. The mineralization occurs as: (i) quartz-carbonate veins associated with breccias, and (ii) disseminations in quartzite and siltstone. Where altered, it forms the "Green wallrock", which consists of a fine crystalline mixture of albite and copper silicates (Manders, 1989).

The geological structure at Kansanshi is a shallow dome which is transected by a series of north-south trending near-vertical veins, which carry the highest grades of mineralization (Samani, 1982; Speiser, 1995). The lowest unit exposed in the Kansanshi open pit is the Upper Limestone which is about 5 to 20 m thick. The limestone is overlain by a quartzite which contains some conglomerate beds at the base. The quartzite is overlain by a 20 m-thick unit of garnet-mica schist which is interbedded with minor quartzites and graphitic schist. The uppermost unit is a graphitic argillite (containing quartz, mica and graphite) and its albitized equivalent, the Green wallrock. The metasedimentary succession is interpreted as as fining upward sequence deposited in a carbonate-clastic shoreline environment (Arthurs & Legg, 1974).

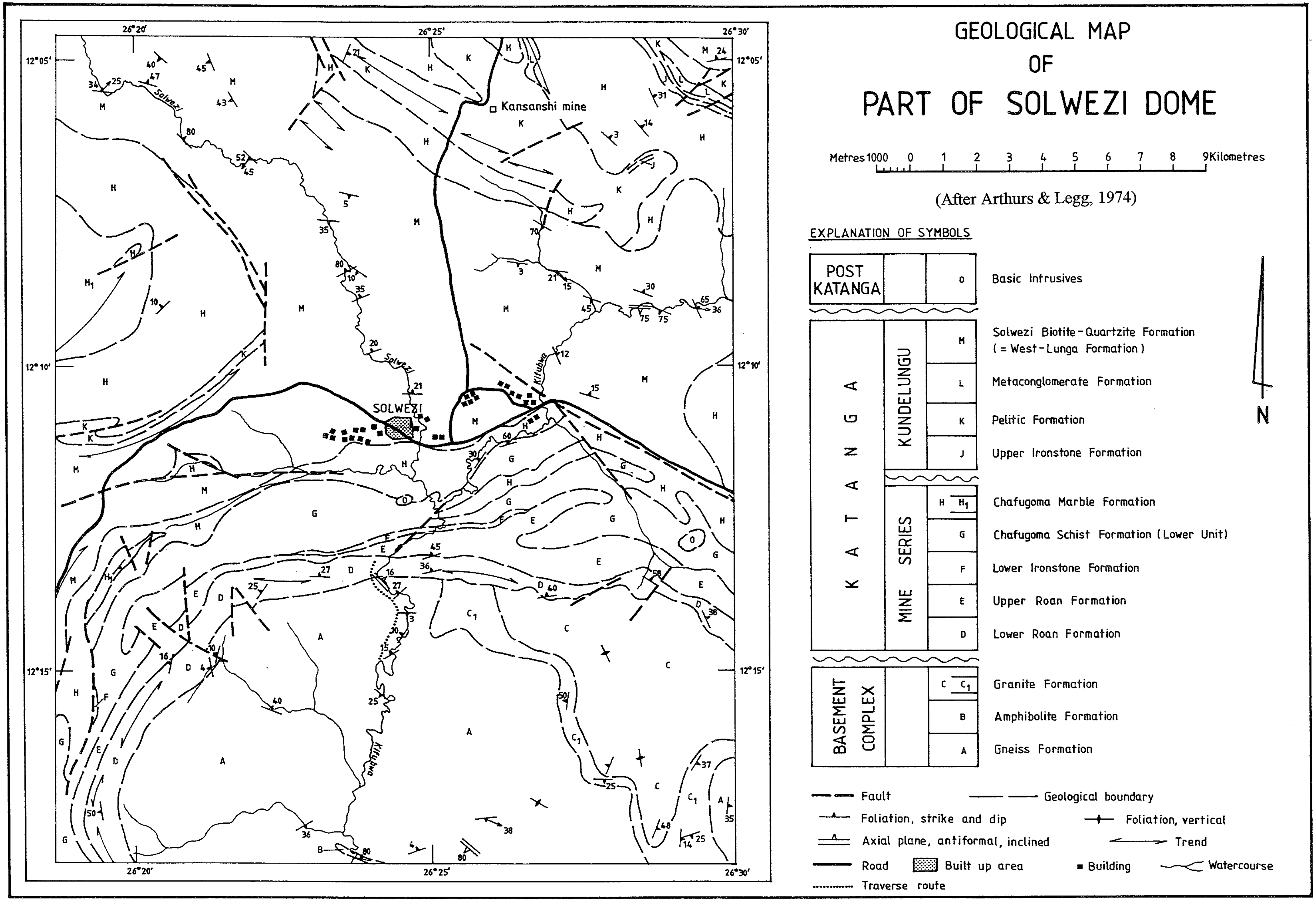
The three main ore types at Kansanshi are vein ore, Green wallrock and quartzite. Vein ore consists of quartz-carbonate veins containing copper sulphides in various states of oxidation. The vein ore has the highest copper grade of about 10 % Cu. The primary disseminated copper sulphide in the quartzite is chalcopyrite. Most of the copper is contained in the Green wallrock, in the form of copper silicates (chrysocolla, etc), mixed with albite. Gold is present in both the vein ore and in the quartzite, at an average grade of 2.2 g/t (Naish, 1981). The Green wallrock has an estimated Au content of 0.4 g/t.

Stop 2: Traverse along the Kifubwa River (total walking distance 6 km).

A geological traverse along the Kifubwa River in the northern part of the Solwezi Dome (Fig. 2), with exposures of quartzite and muscovite-kyanite schists at the contact between basement and Katangan cover. Basement gneisses and schists are also exposed along the river. Three units of the Basement Complex can be identified in the Solwezi Dome:

(i) Migmatitic gneiss, which outcrops widely in the central part of the dome along the Kifubwa River. The main rock type is a garnetiferous biotite gneiss in which pegmatitic leucosomes are well developed parallel to the gneissic foliation.

(ii) A poorly-exposed leucocratic two mica granite, covering the northern part of the dome. The granite consists of sodic plagioclase, perthitic microcline, quartz, biotite and muscovite.



GEOLOGICAL MAP
OF
PART OF SOLWEZI DOME
Metres 1000 0 1 2 3 4 5 6 7 8 9 Kilometres
(After Arthurs & Legg, 1974)
EXPLANATION OF SYMBOLS
POST KATANGA
O Basic Intrusives
KATANGA
KUNDELUNGU
M Solwezi Biotite-Quartzite Formation (= West-Lunga Formation)
L Metaconglomerate Formation
K Pelitic Formation
J Upper Ironstone Formation
MINE SERIES
H H1 Chafugoma Marble Formation
G Chafugoma Schist Formation (Lower Unit)
F Lower Ironstone Formation
E Upper Roan Formation
D Lower Roan Formation
BASEMENT COMPLEX
C C1 Granite Formation
B Amphibolite Formation
A Gneiss Formation
Fault
Geological boundary
Foliation, strike and dip
Foliation, vertical
Axial plane, antiformal, inclined
Trend
Road
Built up area
Building
Watercourse
Traverse route
N
Kansanshi mine
SOLWEZI
Solwezi
Kifubwa
26°20'
26°25'
26°30'
12°05'
12°10'
12°15'

Figure 2

(iii) Fine-grained gneiss, which is compositionally similar to the migmatitic gneiss, but is fine-grained, and has less well developed gneissic banding.

In the metasedimentary envelope of the Solwezi Dome, the lower units comprise muscovite-haematite quartzites and schists, while the upper units are dominantly calcareous marbles. The metasediments outcrop mainly along the dome rim although some wedges are observed in tectonic contact with basement rocks in the central part of the dome.

There are numerous outcrops of metabasic rocks both within and outside of the Solwezi Dome. Inside the dome, the metabasites occur as lozenge-shaped bodies within mega-shear zones. Outside the dome, the outcrop is too poor to ascertain the relationship between the metabasites and the metasediments.

Two main structural directions are observed in the Solwezi Dome- an older north-south direction, and a younger east-west direction. The older structures are attributed to north-directed thrusting during which the basement was isoclinally folded. The major structure of the dome, however, is a large wedge caused by thrusting from the west to the east during the second deformation phase.

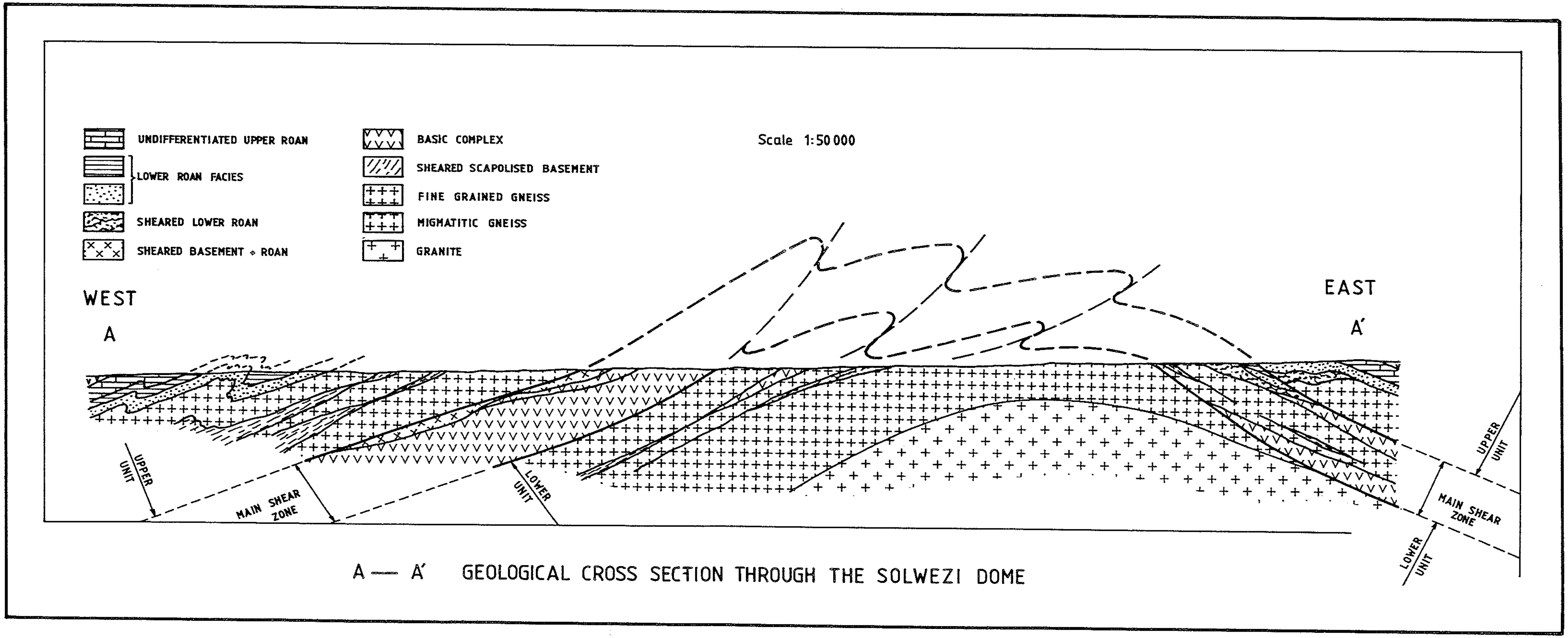
Day 2: Mombezhi Dome (Fig. 3)

Stop 1: Traverse along the East Lumwana River.
Exposures of migmatitic gneisses and schists, and metabasites, of the Mombezhi Dome.

Visit the Lumwana prospect and study drillcore of basement rocks at the Phelps Dodge camp.

The crystalline basement of the Mombezhi Dome comprises the following units:
(i) Migmatitic complex which is dominated by granite gneisses and intruded by syenite, microgranite stocks and dykes.
(ii) A sheared facies of the migmatitic complex which is made up of muscovite-phlogopite schists. The schists contain porphyroblasts of kyanite, quartz and feldspar. This rock-type represents major shear zones in the basement.
(iii) Metabasites, which are represented by scapolite-garnet metagabbros and hornblendites. The metabasites are commonly found in shear zones within which they are folded and sheared.

Structure
Some of the most important structural features in the Mombezhi Dome are major shear zones defined by blastomylonites derived from granitic gneisses and their cover sequence of metasediments and metabasites. These shear zones are folded into large east-west trending structures. The Katangan metasedimentary rocks in the Mombezhi Dome are invariably sheared, and have been transformed into tectonites associated with shear zones.



(From AGIP SPA Quarterly Report No. 20, 1984)

Figure 3: Geological cross-section through the Solwezi Dome, NW Zambia

Day 3: Kafue Dome and Kalulushi Core Shed

(a) Underground visit to Luanshya Mine. Exposures of multiply-deformed Lufubu Schists, which form the basement to the Katangan Sequence at Luanshya and Baluba East mines.

(b) Visit to Kalulushi core shed to examine drill core of basement rocks from the Copperbelt area, including the Samba "porphyry-type" copper deposit.

The Samba deposit, with reserves of > 50 Mt @ 0.5 % Cu, is the largest known concentration of copper mineralization in the pre-Katangan basement of the Zambian Copperbelt (Fig. 4) (Wakefield, 1978). The deposit, situated at 27°50'E, 12°43'S (Figs. 4 & 5), consists of disseminated pyrite, chalcopyrite and bornite in deformed pre-Katangan granodioritic and quartz monzonitic porphyritic intrusive rocks, with associated quartz-sericite and biotite-quartz-sericite schists (Figs. 6-8). Although the undated intrusive rocks at Samba were assigned a Mesoproterozoic (Muva) age by Wakefield (1978), it is equally likely that these rocks are of Palaeoproterozoic (Ubendian) age, and are related to other Palaeoproterozoic granitoids in the Kafue anticline and surrounding areas (e.g. Mufulira, Mokambo, Luina and Roan Antelope granites).

(c)Traverse along the Kitwe-Mufulira road to examine outcrops of Lufubu Schists, Muva quartzites, and the Mufulira Granite.

References

Anon (1929). The Kansanshi Copper Mine. Rhod. Min. Jour., 3, 105-107, 171.

Arthurs,J.W. & Legg,C.A. (1974). The geology of the Solwezi area. Explanation of degree sheets 1226, NW quarter and 1126, part of SW quarter. Rep. Geol. Surv. Zambia, 36, 48 pp.

Cosi,M., De Bonis,A., Gosso,G., Hunziker,J., Martinotti,G., Moratto,S., Robert,J.P. & Ruhlman,F. (1992). Late Proterozoic thrust tectonics, high pressure metamorphism and uranium mineralization in the Domes Area, Lufilian Arc, northwestern Zambia. Precambrian Res., 58, 215-240.

Jay,J.R. (1960). Geochemical prospecting studies for cobalt and uranium in Northern Rhodesia. Ph.D. thesis, Univ. London, 258 pp.

Klinck,B.A. (1977). The geology of the Kapompo Dome area. Rep. Geol. Surv. Zambia, 44, 27 pp.

MacGregor,J.A. (1965). The Lumwana copper prospect in Zambia. Ph.D. thesis, Rhodes Univ., Grahamstown, 171 pp. [Abstract in Snowball (1966), 14-15.].

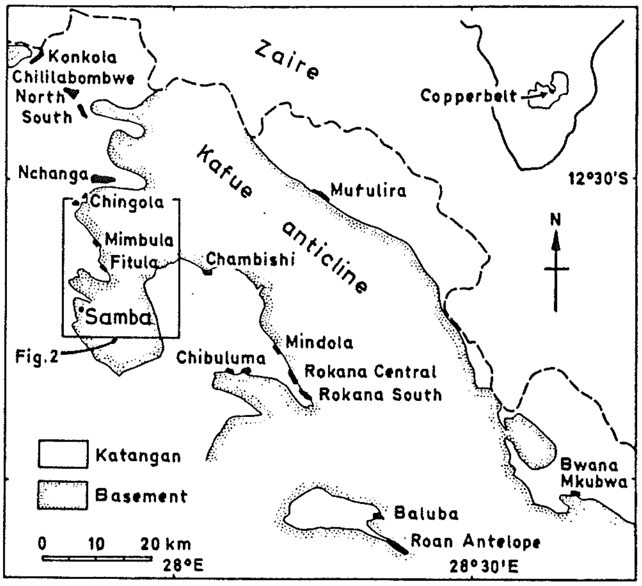


Fig. 4: Location map of Katangan orebodies, Zambian Copperbelt (after Wakefield, 1978)

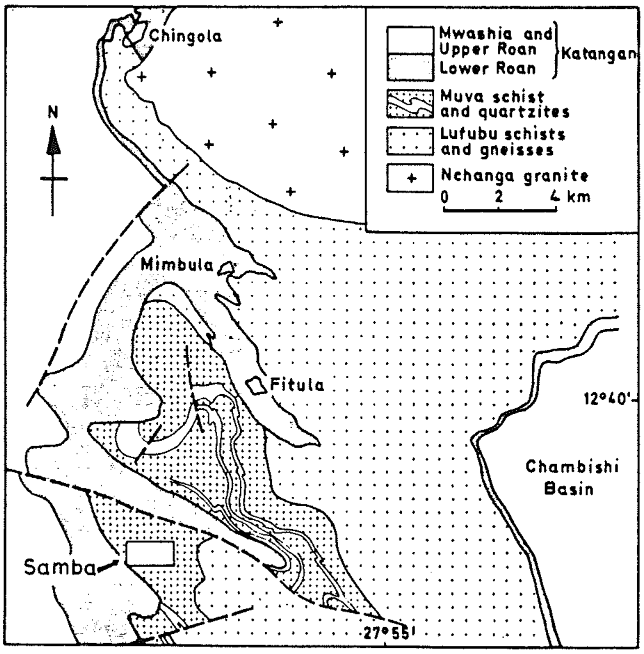


Fig. 5: Geological map of the area around Samba (after Wakefield, 1978)

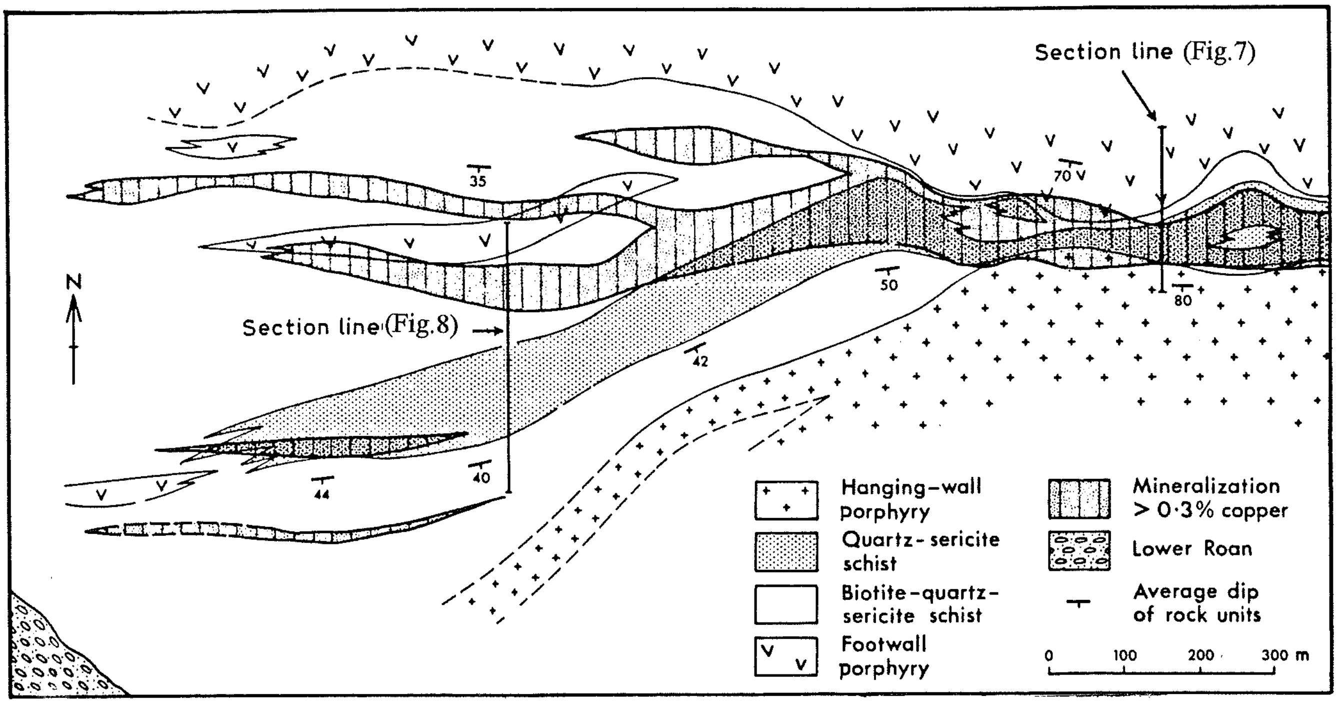


Fig. 6: Geological plan of Samba deposit at 100-m level (After Wakefield, 1978)

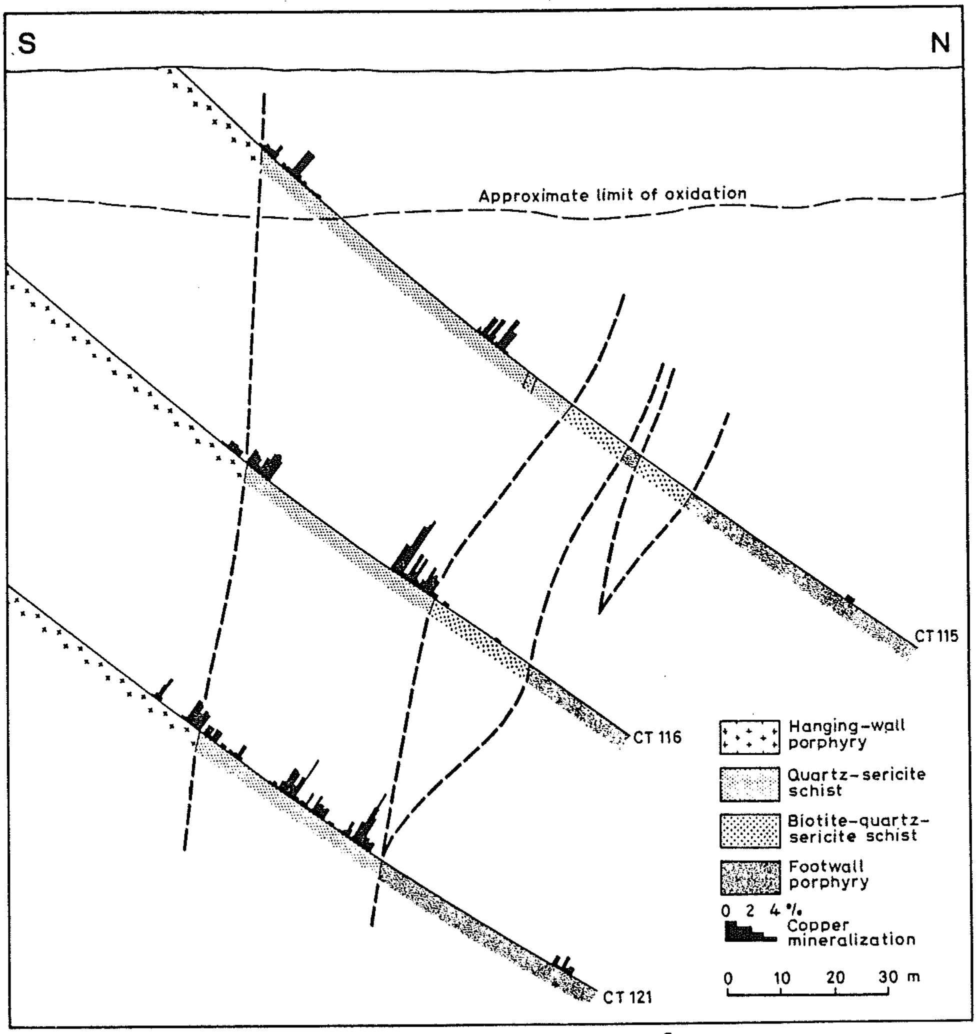


Fig. 7: Drill Section CT 115–116–121. Section line shown on Fig. 6

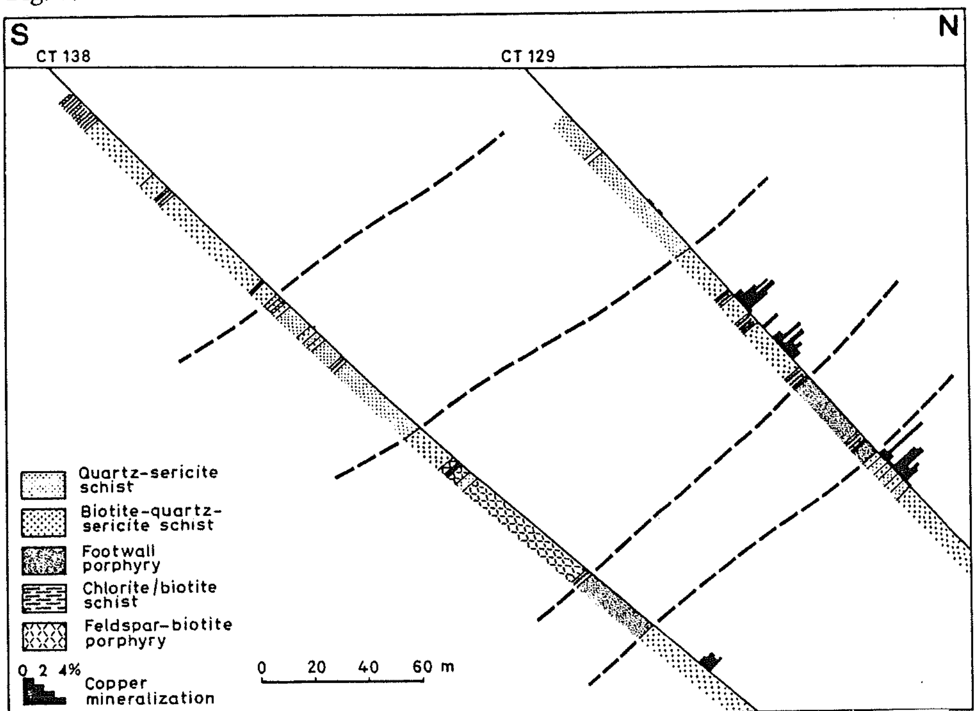


Fig. 8: Drill section CT 129–138. Section line shown on Fig

Wakefield (1978)

Manders,B. (1989). Albitization of graphitic shale and the mineralogy of cupriferous clays at Kansanshi, Zambia. Zambian Jour. Appl. Earth Sci., 3(2), 31-44.

Meneghel,L. (1981). The occurrence of uranium in the Katanga System of Northwestern Zambia. Econ. Geol., 76, 56-68.

Naish,E.J. (1981). The occurrence of gold in Kansanshi ores. Unpubl. Rept., Geology Department, Centralised Services Division, Nchanga Consolidated Copper Mines.

Samani,K. (1982). The relationship between mineralization and veins and joints at Kansanshi Mine. B.Sc. thesis, School of Mines, University of Zambia, Lusaka.

Snowball,G.J. (1966). Annotated bibliography and index of the geology of Zambia (formerly Northern Rhodesia) 1964-1965. Geol. Surv. Zambia, Lusaka, 47 pp.

Speiser,A. (1995). Diplom thesis, Georg-August-Universität, Göttingen, Germany. (Deals with Kansanshi mine, Zambia).

Tomkins,C.C. & Freeman,P.V. (1977). Interim report on Kansanshi Geology and Ore reserves. Unpubl. Rept., Nchanga Consolidated Copper Mines Limited.

IGCP PROJECT 363:
LOWER PROTEROZOIC OF SUB-EQUATORIAL AFRICA

Post-Conference Field Excursion No. 1:

Palaeoproterozoic of Central and Eastern Zambia.

20-24 September 1996

EXCURSION GUIDE

compiled by

Fred Kamona[1], Francis Tembo[1], Osbert Sikazwe[1],
Pete Siegfried[2] and Sharad Master[3]
([1] Department of Geology, University of Zambia, P.O.Box 32379, Lusaka, Zambia
[2] GEO Africa Prospecting Services (Pty) Ltd, P.O.Box 24218, Windhoek, Namibia
[3] Economic Geology Research Unit, Department of Geology,
University of the Witwatersrand, P/Bag 3, WITS 2050, Johannesburg, South Africa)

Excursion Leaders:

Clement Namateba (GSD)
Pete Siegfried (GEO Africa)
Fred Kamona (UNZA)
Patrick Mumba (CBU/WITS)
Silishebo Mabuku (GSD)
Francis Tembo (UNZA)
Sharad Master (WITS)
Ben Mapani (UNZA)

_____oOo_____

GEOLOGICAL BACKGROUND

Eastern Zambia is a complexly deformed polymetamorphosed region of the Mozambique Belt (Fig. 1). Geological work in the area has shown that at least three major deformation phases have affected the granitic-gneisses of the Archaean-Palaeoproterozoic Basement complex during the Ubendian (c. 2.0-1.8 Ga), Irumide (c. 1.3 Ga), and Mozambique (850-550 Ma) Orogenies (Johns et al., 1989). During the Ubendian Orogeny metamorphic conditions reached the granulite facies, producing granulites in the Chipata and Petauke areas (Vavrda, 1973, 1974; Vavrda & Vrana, 1972). The granulites were retrogressed to upper amphibolite facies during the Irumide Orogeny.

The metasedimentary rocks of the Mesoproterozoic Muva Supergroup consist mainly of quartzites, calc-silicates, schists and metavolcanics (Barr, 1972, 1973, 1974). These rock units have persistent NE-trending structures and were generally metamorphosed to amphibolite facies grade during the Irumide Orogeny. Later overprinting by the Mozambique orogeny which produced east-west structures and resulted in greenschist facies metamorphism.

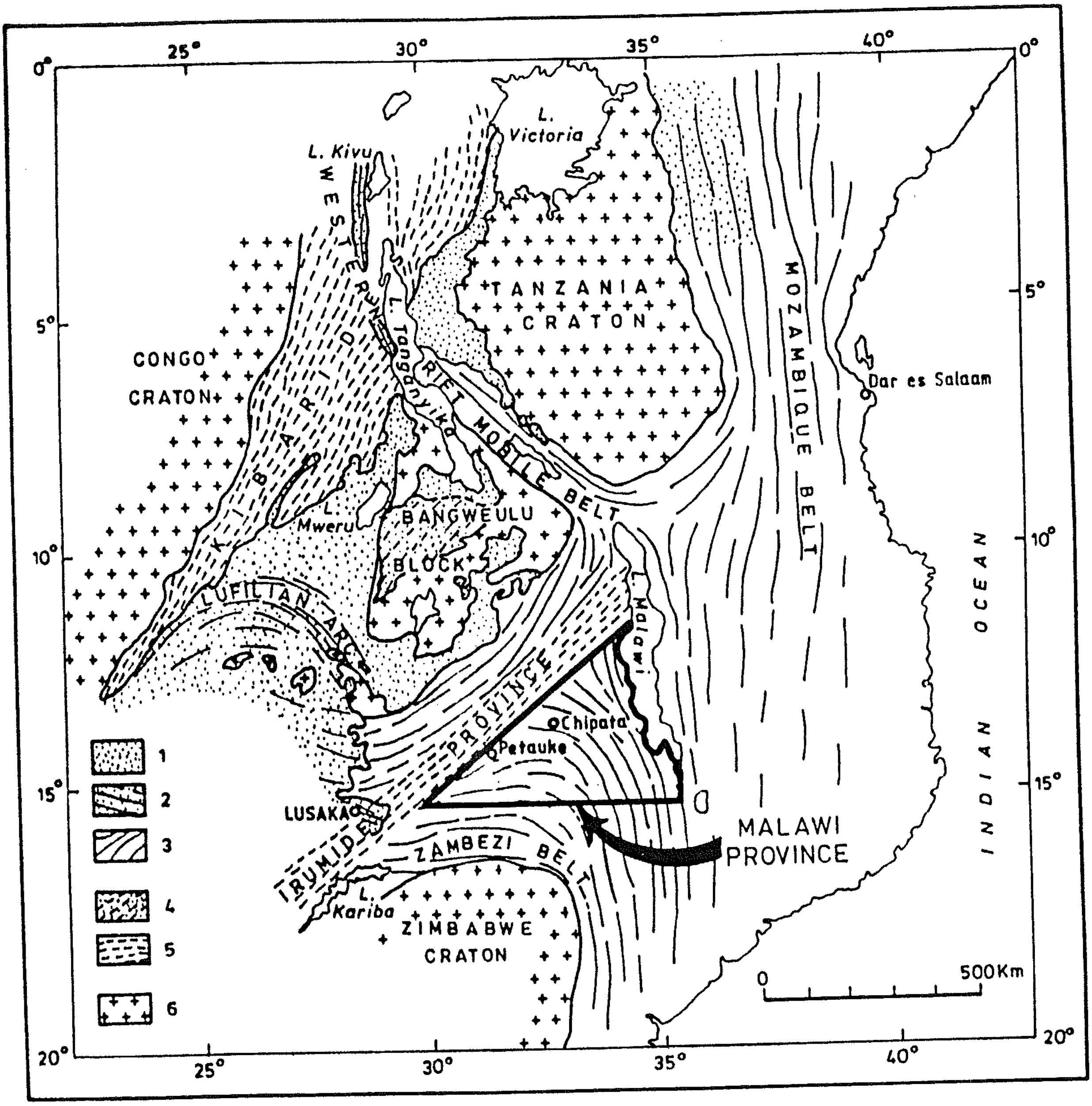
The Mwembeshi Dislocation Zone (de Swardt et al., 1965) is a prominent structure along which complex sinistral and dextral shear movements took place at the closing stage of the Lufilian Orogeny around 570 Ma. Numerous post-tectonic Pan-African granites intruded the basement rocks at around 500 Ma and are exposed over large areas of Eastern Zambia (Phillips, 1961, 1964, 1965).

No significant metal deposits have been found in Eastern Zambia, but numerous gold occurrences associated with secondary off-shoot structures of the Mwembeshi Dislocation Zone have been productive in the past (Andrews-Speed & Sliwa, 1984). Gem-bearing pegmatites are found in the Lundazi District, within the polymetamorphic Mozambique belt (Patney & Tether, 1988; Njamu, 1994). In the Petauke-Nyimba area, there are occurrences of Cu-Zn-Pb massive sulphides (Skowronski & Sliwa, 1986), as well as graphite deposits (Drysdall, 1960).

The route to be followed and the outcrops to be examined during the field workshop are indicated in Figure 2 which is based on the geological map of Zambia 1981. The detailed geological map of eastern Zambia in the Nyimba-Petauke-Chipata area is shown in Figure 3 (after Thieme & Johnson, 1981). During the fieldwork it is planned to obtain structural data at the various outcrops and to collect rock samples for age dating at collaborating institutions in the region and abroad.

Stop 1.1: Chinyunu Hot Springs

The Chinyunyu Hot Springs are located 60 km east of Lusaka at a fault contact between Basement Complex gneisses and Muva meta-volcanics. The spring water contains mainly NaCl, Na_2CO_3 and NaF at a temperature of 63°C (Legg, 1974). The water is heated at depth due to the geothermal gradient in the area and comes up to the surface as a fault spring.



Legend:
1. Neoproterozoic (tabular); 2. Neoproterozoic (folded);
3. Palaeo-Meso-Neoproterozoic fold belts;
4. Mesoproterozoic Kibaran belt;
5. Archaean-Palaeoproterozoic cratons.

Fig. 1. Geological sketch map of Proterozoic terrains in central-eastern Africa, showing the location of the Malawi Province in eastern Zambia (modified after Cahen et al., 1984).

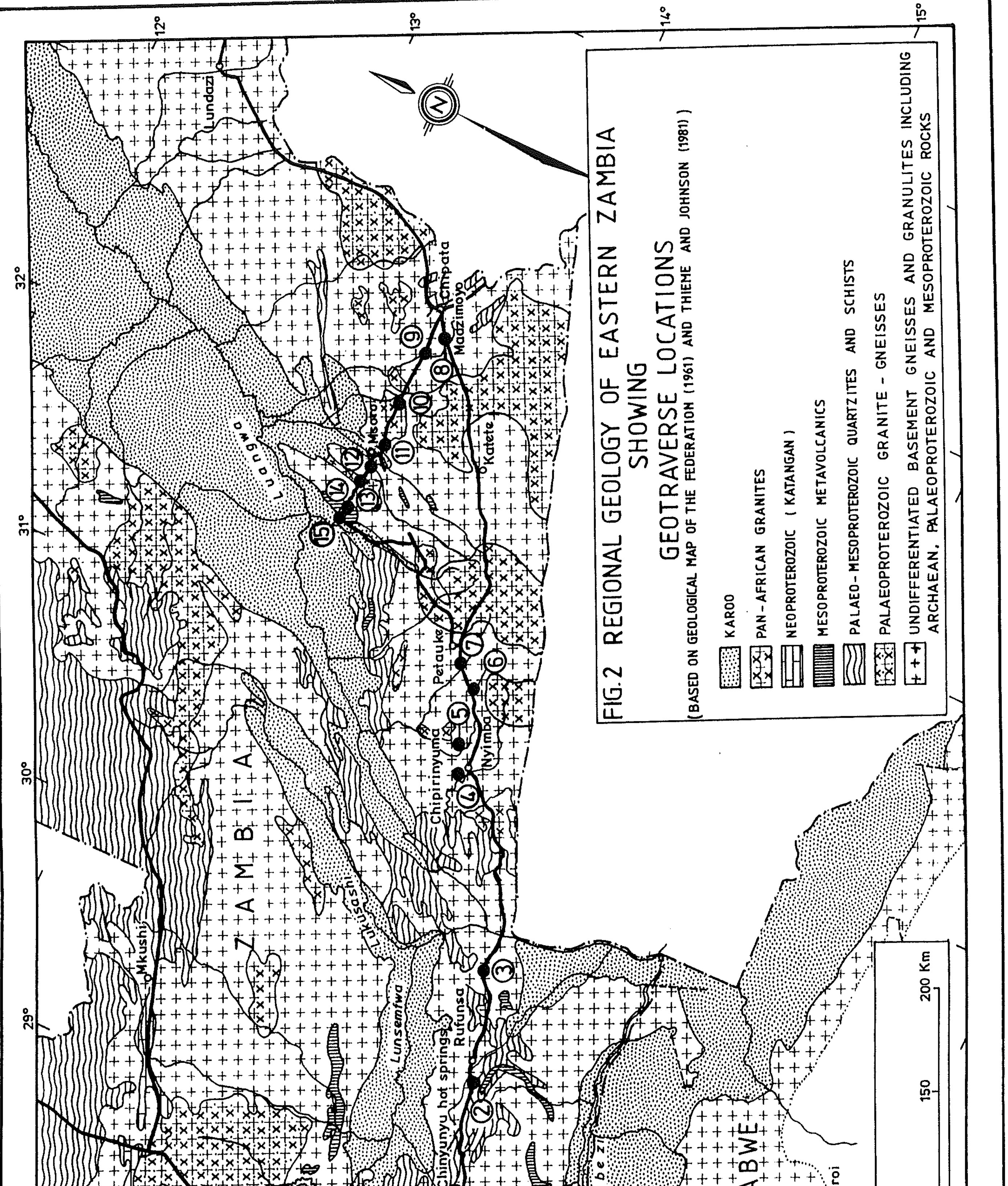


FIG.2 REGIONAL GEOLOGY OF EASTERN ZAMBIA SHOWING GEOTRAVERSE LOCATIONS
(BASED ON GEOLOGICAL MAP OF THE FEDERATION (1961) AND THIEME AND JOHNSON (1981))

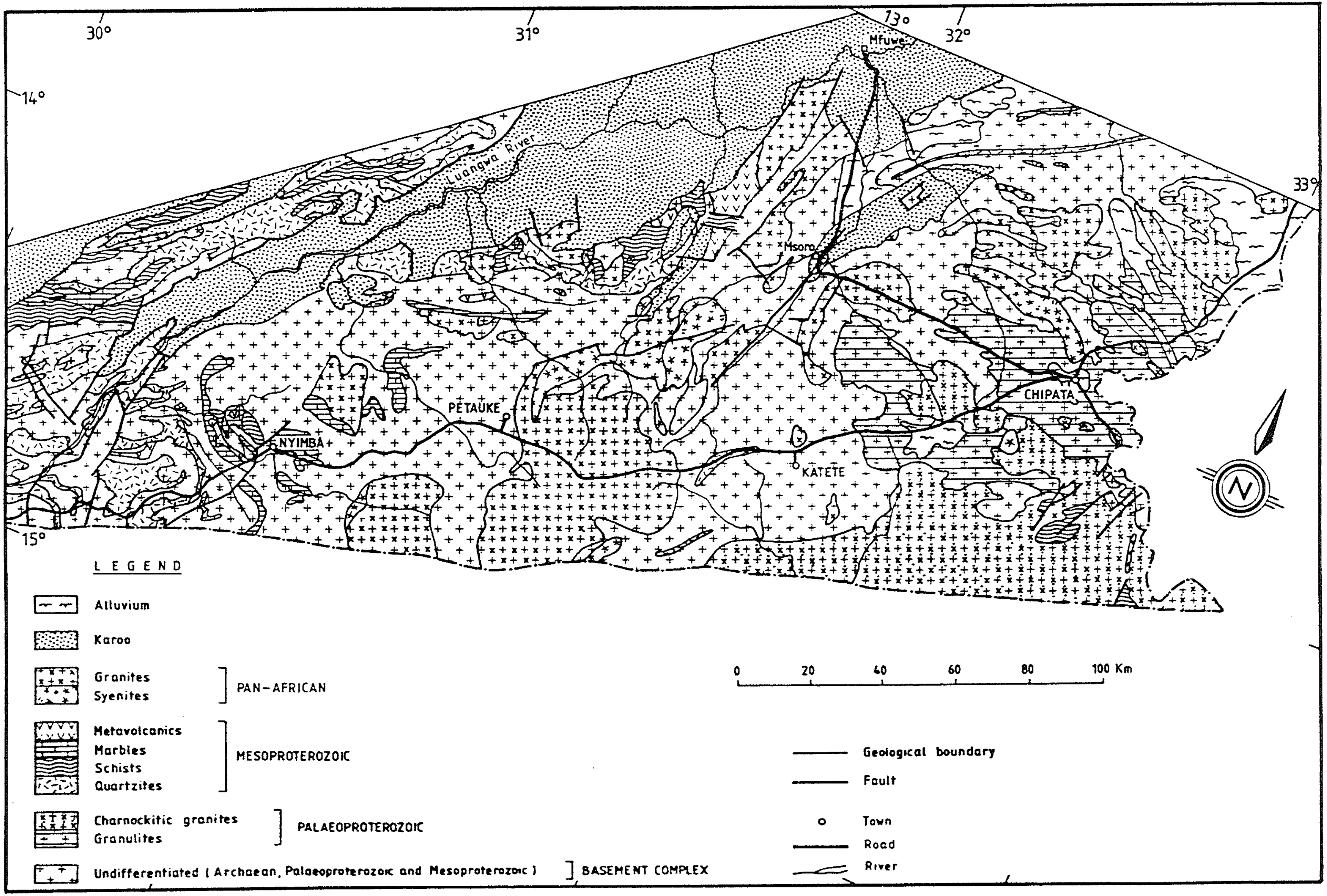


FIG. 3 GEOLOGICAL MAP OF NYIMBA — CHIPATA AREA (BASED ON THIEME AND JOHNSON, 1981)

Stop 2.1: Rufunsa Metaconglomerates

The Rufunsa metaconglomerate is located 105 km east of Lusaka. The deformed matrix-supported conglomerate, which consists of elliptical quartzite clasts ranging in size from pebbles to boulders in a matrix of quartz mica schist, is well exposed along the Great East Road. The conglomerate is probably tectonic in origin because of the monolithogical composition of the pebbles and boulders. They occur in the Kangaluwe Formation at the top of the Mpanshya Group. They were deformed during the Irumide orogeny (Barr, 1974) and have been termed as pseudo- or tectonic conglomerates.

Stop 3.1: Rufunsa Basement Gneisses

Rufunsa Basement Gneisses 205 km east of Lusaka. Large exposure of migmatitic, feldspar-biotite gneisses with minor garnet and amphibolitic pods. It is part of the Basement Complex believed to be Palaeoproterozoic or Archaean in age.

Stop 4.1: Nyimba-Chipirinyuma

Traverse across the Nyimba Terrain which consists of mixed metasedimentary and metavolcanic units of the Mvuvye Group. The succession, from the base upwards, consists of: amphibolite, calc-tremolite-marble, felsic gneiss, mixed amphibolite and metapelites, and metacarbonates. The rocks have been metamorphosed to upper amphibolite-facies grade, and are characterised by garnet-diopside-hornblende-plagioclase and muscovite-quartz-sillimanite assemblages.

Volcanogenic massive sulphide mineralisation occurs in the gneiss-amphibolite units. The main ore minerals are chalcopyrite, pyrhotite, pyrite, sphalerite and magnetite (Mountford, 1982; Skowronski & Sliwa, 1986)

DAY 2: THE PETAUKE-CHIPATA AREA

Stop 5.2: Vizhimumba Gneiss

Large foliated, coarse grained granite-gneiss outcrop of the Basement Complex east of Kapakasa Zn-Cu prospect near Vizhimumba. This gneiss has undergone polycyclic deformation during the Ubendian, Irumide and Mozambique orogenies. The gneiss forms the basement to the Mvuvye Group of Stop 4.1 and the protolith is believed to be of Archaean age.

Stop 6.2: Minga Quarry

Pink quartz-feldspar-magnetite gneisses are exposed here. They are probable equivalents of the Chipirinyuma gneisses.

Stop 7.2: Minga Graphitic Schist

Graphitic quartz-biotite schist of the Mvuvye Group. Similar schists are the host rocks to the graphite deposits of the Petauke District (Drysdall, 1960).

Stop 8.2: Madzimoyo Quarry

Outcrops of the Lutembwe River granulite consisting of leucocratic quartzo-feldspathic, hypersthene-bearing gneisses and banded sillimanite-garnet-biotite gneisses. The granulites have recently been dated at c. 3.0 Ga (Liyungu and Vinyu, 1996), and were involved in granulite facies metamorphism at around 2.1 Ga during the Ubendian Orogeny. Earlier Rb-Sr studies on these granulites yielded a poorly constrained age of ca. 2358 ± 200 Ma (Haslam et al., 1986).

DAY 3: THE CHIPATA-MSORO AREA

Stop 9.3: Lutembwe Granulite

Outcrops of Lutembwe granulite similar to those at Stop 8.3.

Stop 10.3: Ntimba Granite

Outcrops of the Pan-African Ntimba Granites intruded at c. 600-500 Ma into basement rocks.

Stop 11.3: Andalusite Gneisses

Contact-metamorphic aureole of andalusite gneisses produced by the intrusion of the Pan-African Ntimba Granite.

Stop 12.3: Msoro Calc-Silicates

Exposures of calc-silicate and metacarbonate rocks at the eastern margin of the Chindeni Mobile Belt. The Chindeni Mobile Belt is a 50 km wide zone of reworked basement rocks with predominantly NE-trending structures related to Pan-African deformation (Phillips, 1961). The syn- to post-tectonic granites within the Chindeni Zone trend north-east.

Stop 13.3: Pendwe Granite

Post-tectonic Pan-African granite similar to the Ntimba granite.

Stop 14.3: Longolo Stream

Meta-amphibolites with possible pillow structures cut by deformed aplitic dykes, sheared granite with feldspar augen, and recrystallized quartz stringers. The shear sense observed in the feldspar porphyroblasts is dextral.

Stop 15.3: Western Margin of Chindeni Mobile Belt

Outcrops of weathered amphibolites, and Pan-African granites with xenoliths of basement gneisses. Porphyroblastic Karoo basalts mark the summit of the western margin of the Chindeni Mobile Belt.

REFERENCES

BASEMENT COMPLEX, EASTERN ZAMBIA

Andrews-Speed,C.P., Sliwa,A. & Unrug,R. (1984). Primary gold occurrences in Zambia and their geological controls. In: Foster,R.F. (Ed.), Gold '82: The Geology, Geochemistry and Genesis of Gold Deposits. Spec. Publ. Geol. Soc. Zimb., No. 1. A.A.Balkema, Rotterdam, 493-505.

Barr,M.W.C.(1972). Short report on the Mpanshya Group of Central Zambia. 16th Ann. Rep. Res. Inst. Afr. Geol., Univ. Leeds, 3-7.

Barr,M.W.C.(1973). Altered lavas from Central Zambia. 17th Ann. Rep. Res. Inst. Afr. Geol., Univ. Leeds, 65-71.

Barr,M.W.C. (1974). The Pre-Karoo geology of the Rufunsa Area, Zambia, with special reference to structure and metamorphism. D. Phil. thesis, Univ. Leeds, 250 pp. Abstract in 18th Ann. Rep. Res. Inst. Afr. Geol., Univ. Leeds, 22-23.

Barr,M.W.C. (1976). Crustal shortening in the Zambezi Belt. Phil. Trans. R. Soc. Lond., A280, 555-567.

Barr,M.W.C. and Drysdall,A.R. (1972). The geology of the Sasare area: explanation of degree sheet 1331, SW quarter. Rep. Geol. Surv. Zambia, 30.

Cahen,L., Snelling,N.J., Delhal,J., Vail,J.R., Bonhomme,M. & Ledent,D. (1984). Geochronology and Evolution of Africa. Clarendon, Oxford, 512 pp.

de Swardt,A.M.J., Garrard,P. & Simpson,J.G. (1965). Major zones of transcurrent dislocation and superposition of orogenic belts in part of Central Africa. Geol. Soc. America Bull., 76, 89-102.

Drysdall,A.R. (1960). Graphite of the Petauke District, Eastern Province. Rep. geol. Surv. N. Rhodesia, 14, 28 pp.

Haslam,H.W., Rundle,C.C. and Brewer,M.S. (1986). Rb-Sr studies of metamorphic and igneous events in eastern Zambia. J. Afr. Earth Sci., 5, 447-453.

Johns,C.C., Liyungu,K., Mabuku,S., Mwale,G., Sakungo,F., Tembo,D., Vallance,G and Barr,M.W.C. (1989). The stratigraphic and structural framework of Eastern Zambia: results of a geotraverse. J. Afr. Earth Sci., 9, 123-136.

Legg,C.A. (1974). A reconnaissance survey of the hot and mineralised springs of Zambia. Econ. Rept. Geol. Surv. Zambia, No. 50, 60 pp.

Liyungu,A.K. and Vinyu,M.L. (1996). Constraints on the timing of the high grade Lutembwe quartz-feldspathic granulite, charnockitic enderbite and the relationship to the Chipata granite in the Mozambique Belt. In: A.F.Kamona, F.Tembo and B.S.E.Mapani (Eds.), Abstracts Volume of the First International Field Conference, IGCP 363: Palaeoproterozoic of Sub-Equatorial Africa. Geol. Soc. Zambia, Lusaka, p. 19.

Mountford,B.R. (1982). The Chipirinyuma massive sulphide deposit, Eastern Province, Zambia. In: Turner, D.C. (Ed.), Geochemistry in Zambia, AGID Rep. 9, 37-53.

Njamu,M.F. (1994). Kapirinkesa Hill pegmatite, Lundazi District, Zambia. Zambian Jour. Appl. Earth Sci., 8(1), 89-98.

Patney,R.K. & Tether,J. (1988). The gem-bearing pegmatites of eastern Zambia. Zambian Jour. Appl. Earth Sci., 2(2), 41-53.

Phillips,K.A. (1961). The Chindeni Mobile Belt. Ph.D. thesis (unpubl.), Univ. Cape Town.

Phillips,K.A. (1964). The geology of the Lusandwa River area: Explanation of Degree Sheet 1331, SE. Quarter. Rep. geol. Surv. Zambia, 13, 27 pp.

Phillips,K.A. (1965). The geology of the Petauke and Mwanjawantu areas: Explanation of Degree Sheet 1431, NW. Quarter and part of SW. Quarter. Rep. Geol. Surv. Zambia, 15, 31 pp.

Skowronski,A. and Sliwa,A.S. (1986). Proterozoic stratabound mineralization in eastern Zambia. Trans. geol. Soc. S. Afr., 89, 347-352.

Thieme,J.G. & Johnson,R.L. (1981). Geological Map of the Republic of Zambia, 1:1,000,000. Geol. Surv. Zambia, Lusaka.

Vavrda,I. (1973). The geology of the Chimwala Area: Explanation of Degree Sheet 1332 NE Quarter. Rep. Geol. Surv. Zambia, 49.

Vavrda,I. (1974). The geology of the Chipata area. Rep. geol. Surv. Zambia, 41, 22 pp.

Vavrda,I, and Vrana,S. (1972). Sillimanite, kyanite and andalusite in the granulite facies rocks of the Basement Complex, Chipata District. Rec. geol. Surv. Zambia, 12, 69-80.

IGCP PROJECT 363: LOWER PROTEROZOIC OF SUB-EQUATORIAL AFRICA

Post-Conference Field Excursion No 2:

The Palaeoproterozoic Magondi Mobile Belt, NW Zimbabwe

25-30 September 1996

EXCURSION GUIDE

compiled by

Sharad Master[1]

*([1] Economic Geology Research Unit, Department of Geology,
University of the Witwatersrand,
P/Bag 3, WITS 2050, Johannesburg,
South Africa)*

Excursion Leader:

Sharad Master (WITS)

_____oOo_____

INTRODUCTION AND OUTLINE OF GEOLOGY

The Magondi Supergroup is a mainly metasedimentary succession, with minor mafic and intermediate to felsic metavolcanics, which is found in the early Proterozoic Magondi Mobile Belt of western Zimbabwe (Figs. 1 & 2). It is subdivided into the Deweras, Lomagundi and Piriwiri groups, which were deposited between ca. 2.1 and 2.0 Ga (Pb-Pb, Rb-Sr), and metamorphosed between ca. 2.0 and 1.8 Ga (Table 1, after Treloar, 1988). In addition, lithologies of the Dete-Kamativi Inlier of NW Zimbabwe are also part of the Magondi Supergroup. The Magondi Supergroup is underlain by a Basement Complex consisting of Archaean granite-greenstone terrain (including a calc-alkaline magmatic arc succession) and gneisses of the Zimbabwe craton, and the earliest Proterozoic Great Dyke and related complexes that are intrusive into the Archaean rocks.

The Deweras Group, which unconformably overlies the granite-greenstone terrain of the Archaean Zimbabwe craton, comprises a redbed sequence, up to 1.3 km thick, of meta-arenites, rudites, pelites and minor carbonates and evaporites, together with enriched sub-alkaline mafic lavas and pyroclastic rocks. In the northern area, the Deweras Group is subdivided into the Mangula, Norah, Suiwerspruit and Chimsenga formations (Fig. 3). The Deweras Group was deposited in a continental strike-slip basin (Fig. 4), which has been compared with the Dead Sea strike-slip system (Master, 1995).

The Lomagundi Group, which overlies the Deweras Group unconformably, is subdivided into three formations (Fig. 5). The Mcheka Formation consists of basal conglomerates, grits and quartzites, followed by stromatolitic dolomites, phyllites, pockmarked quartzites, argillites and banded iron-formations.

The Nyagari Formation consists of striped slates, sandstones and intermediate volcanics, while the Sakurgwe Formation consists predominantly of greywackes. The overlying Piriwiri Group, which is considered the contemporaneous distal facies equivalent of the Lomagundi Group, is subdivided into three formations (Fig. 6). The Umfuli Formation consists of basal graphitic and pyritiferous slates with narrow bands of cherty manganiferous quartzite, followed by argillites and phyllites with minor interbedded greywackes. The Chenjiri Formation consists of phyllites and greywackes, with minor quartzites, chert, felsites, tuffs, agglomerates and andesites. The Copper Queen Formation consists of a monotonous sequence of phyllites and micaceous feldspathic quartzites, with a ferruginous marble near the base together with major stratiform Cu-Zn-Pb-Fe-Ag massive sulphides.

The tectonic setting of the Magondi Supergroup was in a rift-related continental back-arc basin which formed behind a magmatic arc produced by eastward subduction of oceanic lithosphere under the Zimbabwe craton (Fig. 7). The Magondi Supergroup was deformed into a thin- and thick-skinned fold-thrust belt and metamorphosed from greenschist to granulite facies during the ca. 2.0-1.8 Ga (Rb-Sr, K-Ar) Magondi Orogeny, which resulted from collision of the magmatic arc and closure of the back-arc basin. The western part of the Magondi belt was affected by tectonothermal events

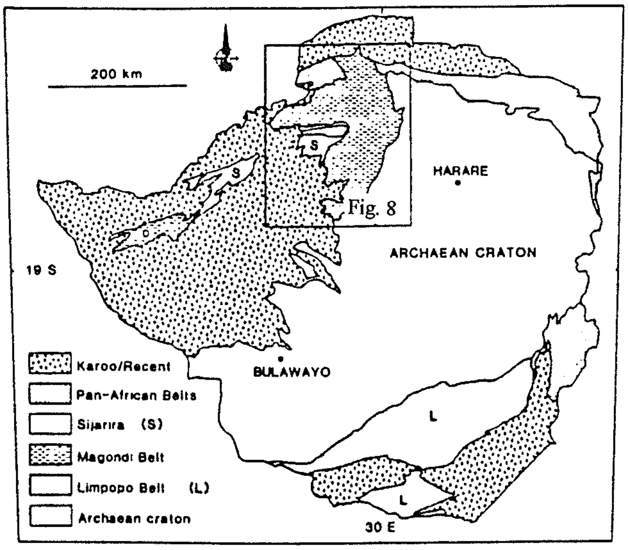


Figure 1: Simplified geological map of Zimbabwe showing the Magondi Belt positioned the the NW of the Archaean craton. The box indicates the position of Fig. 8.

Table 1: Geochronology of the Magondi Belt and related basement units (after Treloar, 1988).

Age (Ma)	Data	Event
400-650	K-Ar mica ages	Pan-African Zambesi thermal event
1659 (50) 1753 (65) 1905 (70) 1974 (70)	K-Ar Piriwiri slates	Magondi metamorphic age
1780 (280)	Rb-Sr Piriwiri granulites, Nyaodza	Magondi metamorphic age
1890 (260)	Rb-Sr Piriwiri granulites, Rukomeshe	Magondi metamorphic age
1980 (80)	Rb-Sr WR granites (includes Urungwe granite	Syn- to post-tectonic granites
2153 (125)	Rb-Sr WR Urungwe granite but note: 1211 (40) muscovite Rb-Sr 948 (40) muscovite K-Ar	Syn- to post-tectonic granite
2150 (100)	Rb-Sr pegmatites and late granites, Dett	Post-tectonic granites
2100 (200)	Pb-Pb galenas (Piriwiri Copper Queen massive sulphide)	Sedimentation age
2170 (100)	Rb-Sr basal Deweras lavas	Sedimentation age
2360 (90)	Rb-Sr Chipisa paragneisses	Early Proterozoic crustal forming event
2465 (53)	Rb-Sr Kariba paragneisses	
2460	Great Dyke	End Archaean

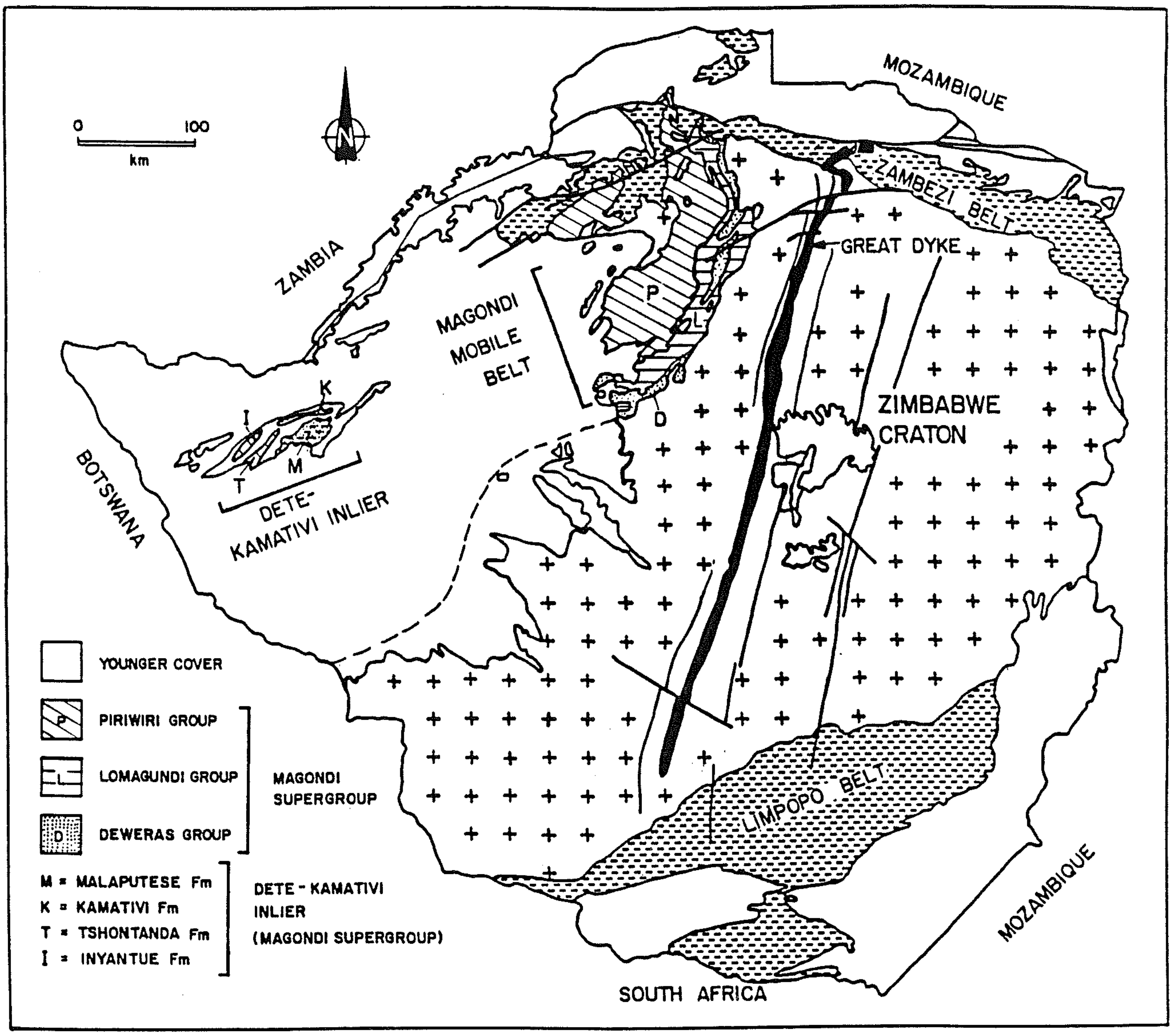


Figure 2: General map of Zimbabwe, showing the Magondi Supergroup and the Magondi Mobile Belt in relation to the Archaean Zimbabwe Craton and the Limpopo and Zambezi Mobile Belts. Note the fracture system on the Zimbabwe Craton, occupied by the Great Dyke and its satellite intrusions, which is parallel to the trend of the autochthonous Deweras Group in the Magondi Basin.

(after Master, 1991)

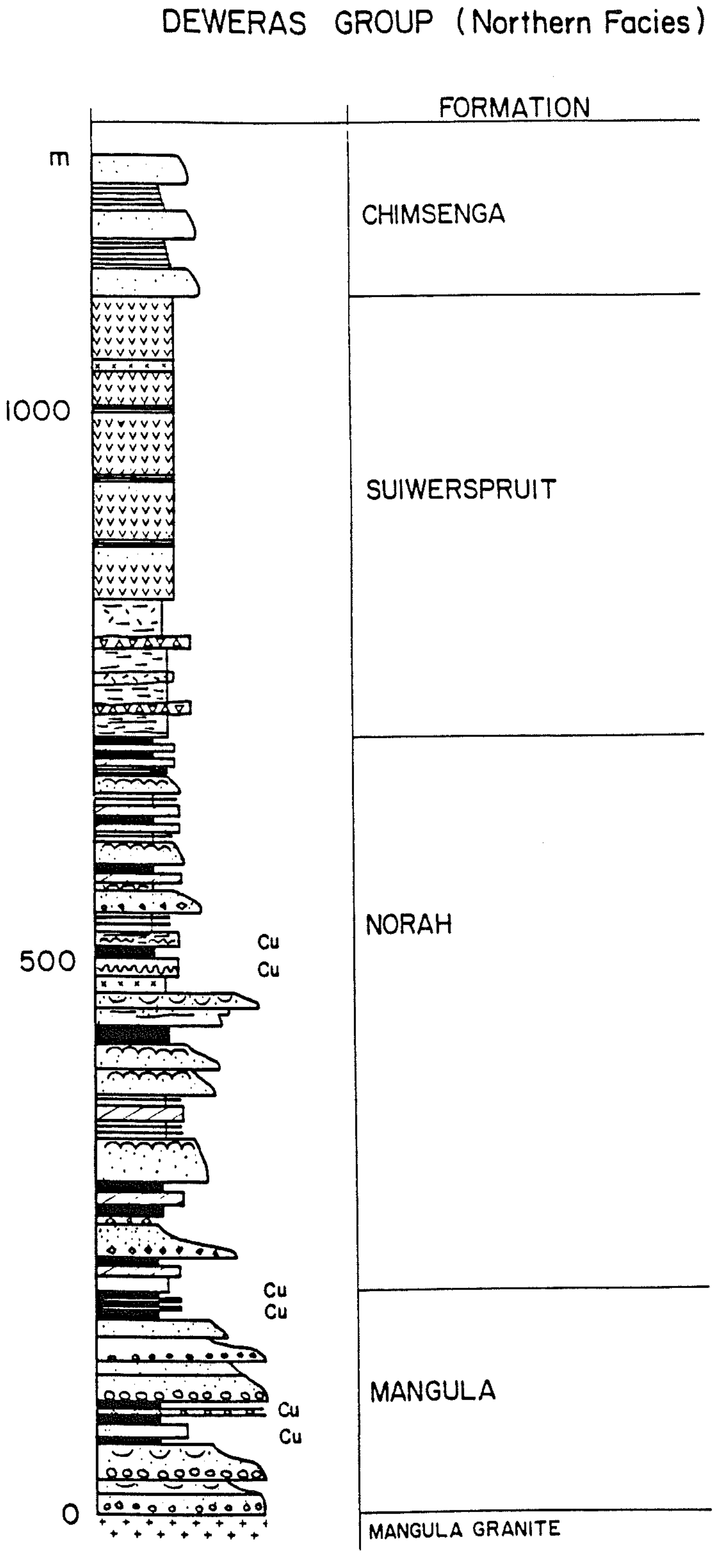
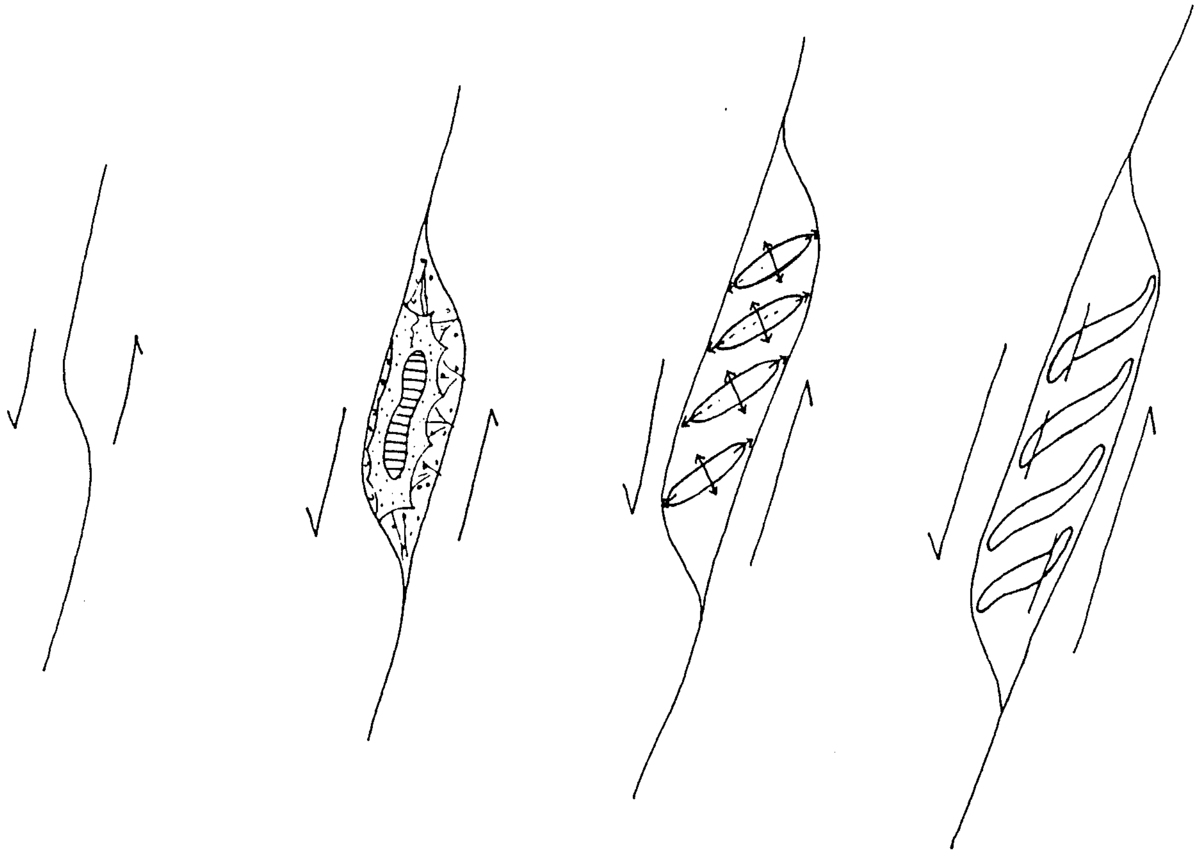


Figure 3: Generalised lithostratigraphy of the northern part of the Deweras Group (after Master, 1991)



TECTONIC SETTING OF THE DEWERAS GROUP

Figure 4: Tectonic setting of the Deweras Group: (a) releasing bend on sinistral strike-slip fault of the Great Dyke-Popoteke fault set, (b) Deweras Group sedimentation in a strike-slip basin, (c) formation of en echelon doubly-plunging synsedimentary anticlines, (d) sigmoidal recurving of the en echelon anticlines into shear direction, and cutting through of wrench faults.

(after Master, 1991)

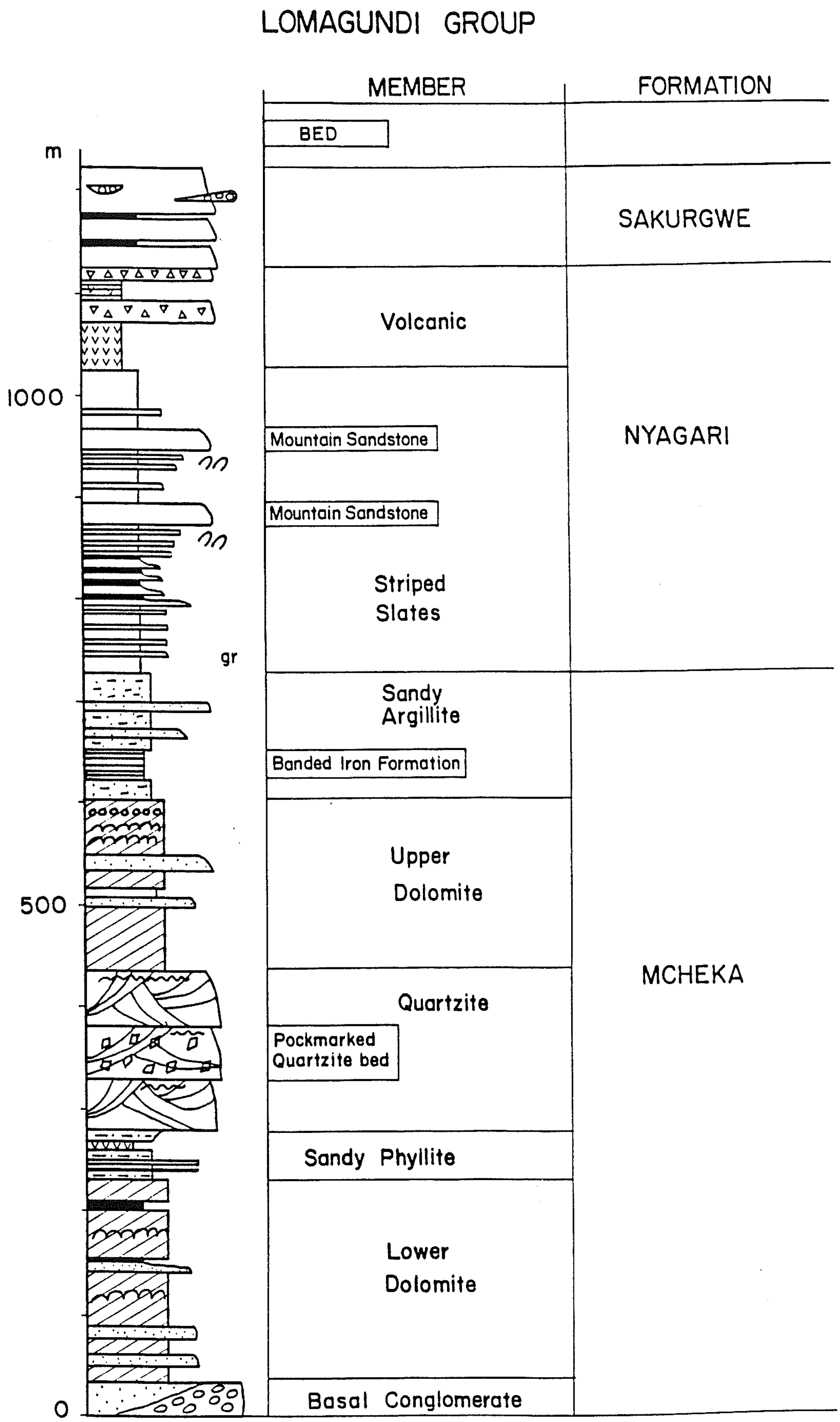


Figure 5: Generalised lithostratigraphy of the Lomagundi Group

(after Master, 1991)

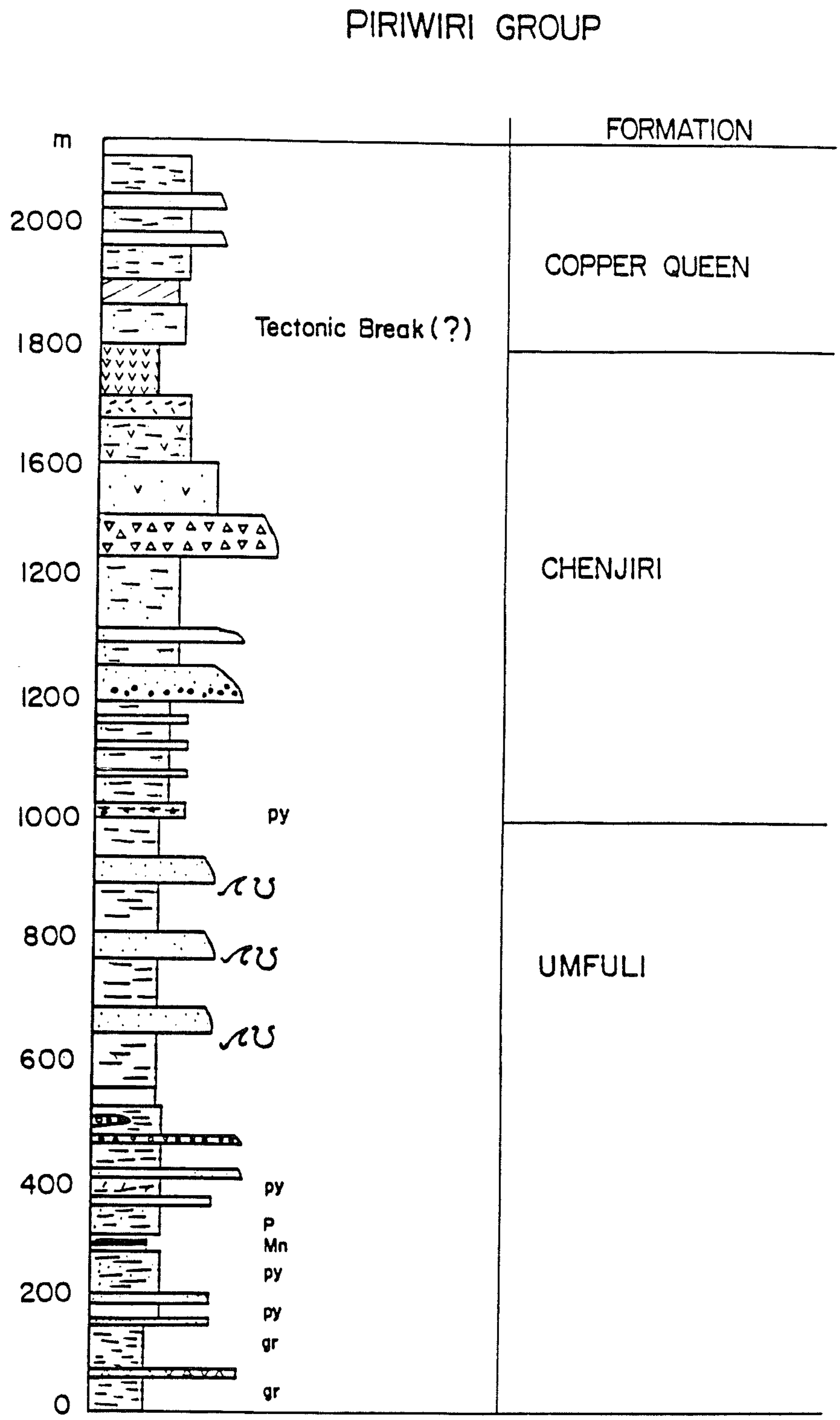
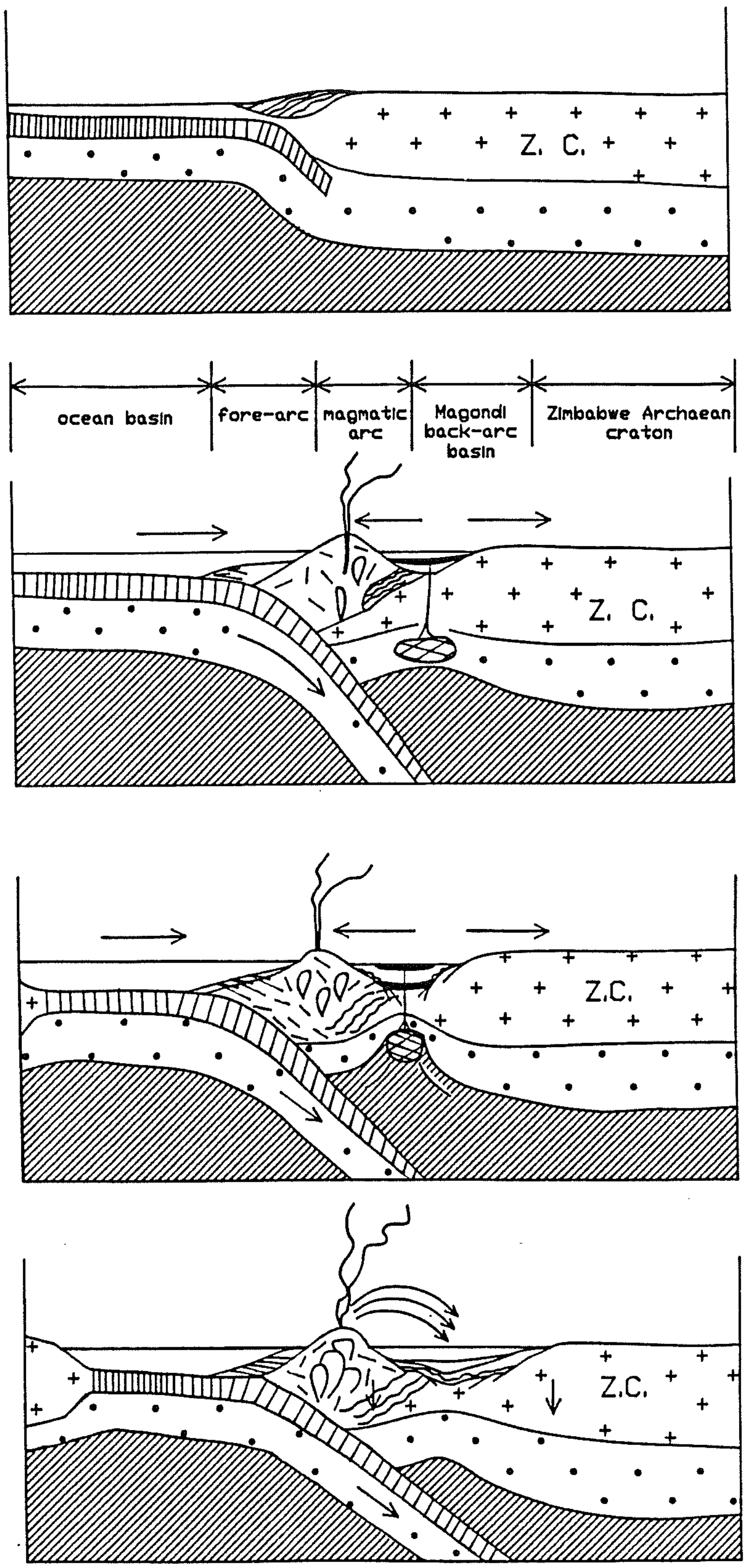


Figure 6: Generalised lithostratigraphy of the Piriwiri Group

(after Master, 1991)



c. 2.2 Ga

Initiation of Subduction

Thrusting and accretion of Kariba paragneisses on craton margin.

c. 2.1 Ga

Early back-arc rifting

Deweras Group basalts with I-type-MORB characteristics (mixed lithospheric source)

Later rifting

Deweras Group basalts with P-type-MORB characteristics (asthenospheric mantle plume source)

Thermal subsidence stage

Lomagundi & Piriwiri Group deposition. Calc-alkaline volcanic and pyroclastic input into basin from magmatic arc.

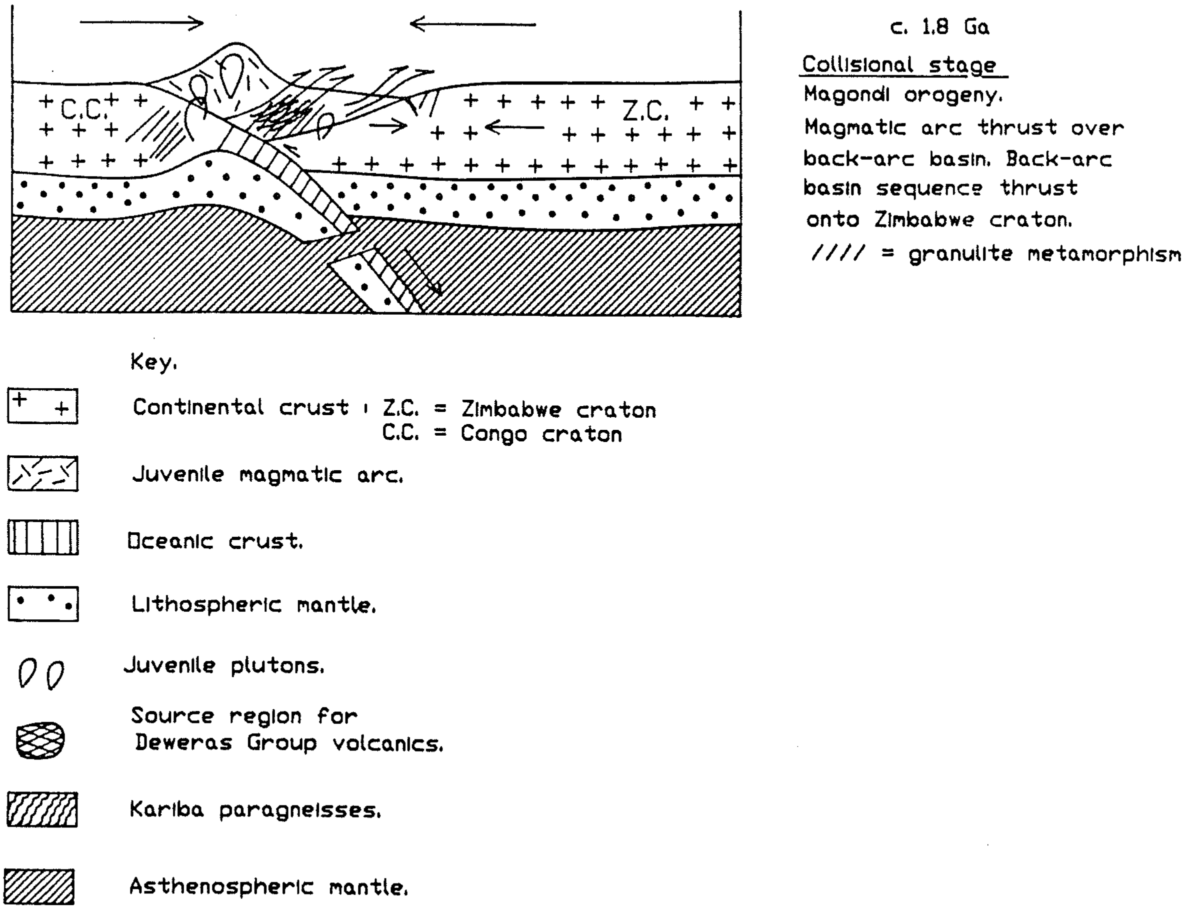


Figure 7: Schematic summary of the evolution of the Magondi Basin between 2.2 to 1.8 Ga, from the initiation of back-arc rifting, and the deposition of the Deweras, Lomagundi and Piriwiri Groups, to the Magondi Orogeny.

(after Master, 1991)

related to the mid-Proterozoic (1.3-0.9 Ga) Irumide Orogeny, and was also affected by the Pan-African (850-550 Ma) Zambezi Orogeny.

The Magondi belt was unconformably overlain by middle and late Proterozoic rocks of the Sijarira and Makuti Groups, which were deformed and meta- morphosed in the late Proterozoic to early Palaeozoic Pan-African Zambezi Orogeny. Post-orogenic molasse of Ordovician age was deposited in the Mid-Zambezi valley area. Following Pan-Gondwana glaciation, Permian and Triassic Karoo Supergroup rocks were deposited in rift basins in the Middle and Lower Zambezi Valley areas. This culminated with extensive Karoo flood basalt volcanism in the early Jurassic. Post-Karoo rifting initiated in the late Jurassic, and has carried on to the present day in the Zambezi Valley, which is still seismically active. Large areas of western Zimbabwe are covered with Permo-Triassic and Jurassic deposits, as well as by Tertiary and Quarternary aeolian deposits of the Kalahari. These younger deposits obscure the underlying rocks of the Magondi Belt, which is only exposed in the northwest, and in the Dete-Kamativi inlier in the west.

Excursion Stops

Day 1.

Stop 1 (Fig. 8): Kariba Dam Wall

Exposures of Kariba paragneisses, including “Kariba sillimanite quartzite”

In the northern part of the Magondi Belt, the basement consists of a succession of para- and orthogneisses which have been considered part of the "Zambezi Belt" (Thole, 1976; Broderick, 1981). These gneisses, which include the Urungwe, Escarpment, Chiroti, Chipisa, Kariba, Chitumbi, Mazamo and Chinemba gneisses, are extremely variable in texture and composition, and vary from foliated granitic leucogneisses to biotite gneisses to migmatites. There are also intercalations of hornblende-diopside calc-silicate gneisses. Some of the gneisses are associated with plugs and sills of tremolite-chlorite rock and para-amphibolites which are interpreted as metamorphosed volcanic tuffs (Thole, 1974). Granitoids consisting of plugs of granodioritic and tonalitic gneisses intruding the various paragneiss units have been recorded by Hitchon (1958), Wiles (1961), Loney (1969), Broderick (1976), Chenjerai (1988) and Bartholomew (in prep.). Granitic gneisses (the Tengwe and Kwetchi granites) have been described from the southern Hurungwe (Urungwe) area by Harper (1973). In the Copper Queen area, Leyshon (1973) has described several Pre-Magondi basement inliers (Copper Queen and Copper King domes), consisting of biotitic quartzo-feldspathic granite-gneiss which have been intruded by weakly foliated granites. A meta-granite in the Kariba area which is intrusive into paragneisses, was dated by Loney (1969) at 2050 ± 32 Ma (recalculated Rb-Sr whole rock). The Chipisa Paragneisses were dated by Loney (1969), and have yielded a recalculated age of 2443 ± 90 Ma. This imprecise result indicates a late Archaean to early Proterozoic age for the metamorphism that affected

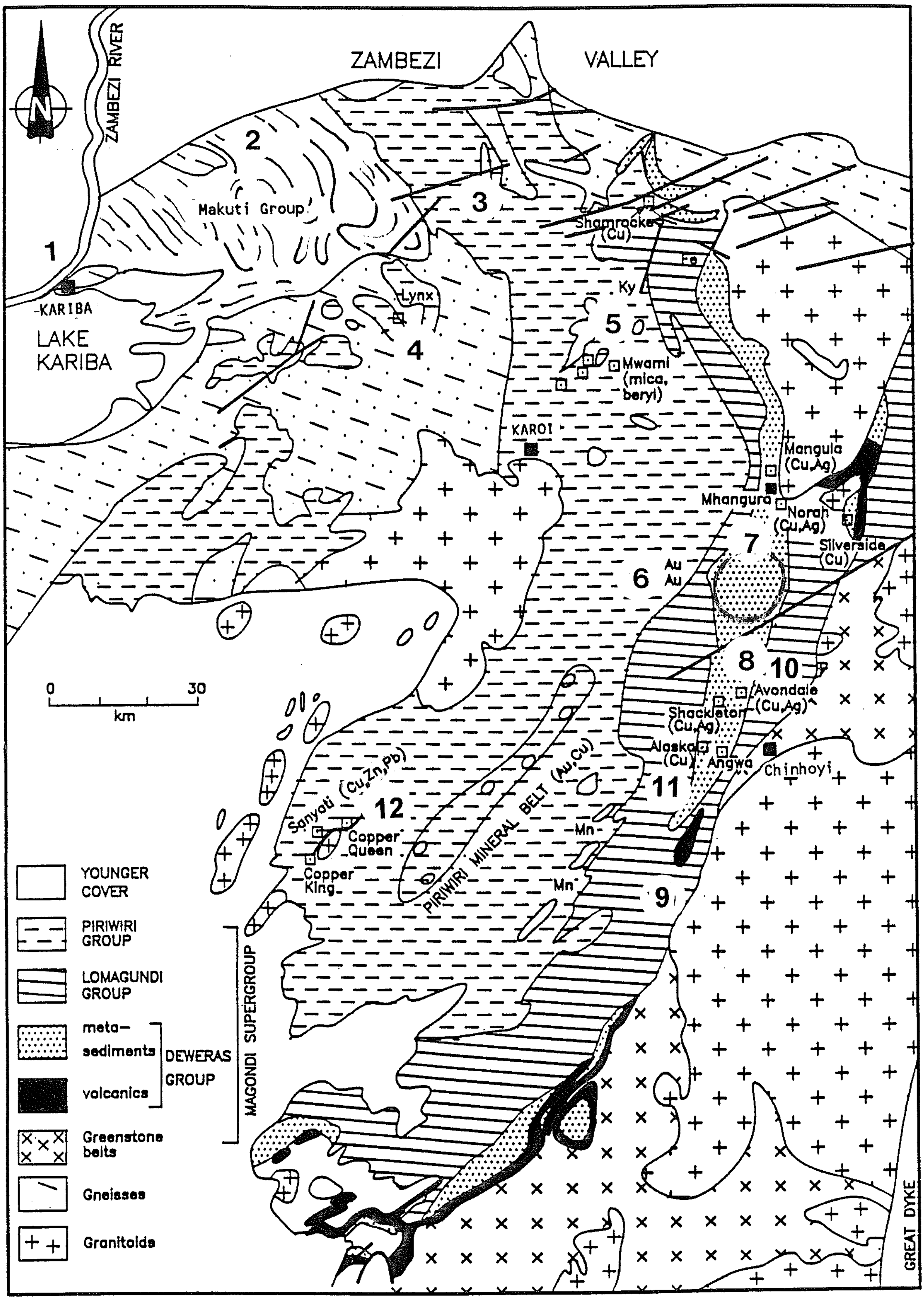


Figure 8: Geological map of the northern part of the Magondi Belt, showing the main excursion stops, and the location of the principal mines and mineral deposits hosted by rocks of the Magondi Supergroup (after Master, 1991).

these rocks. There are also some recent indications from U-Pb dating on zircons that the Chipisa gneisses are Late Archaean in age (Munyanyiwa and Kröner, unpubl. Data; pers. comm.)

The Kariba Paragneisses are a northern continuation of the Chipisa Paragneisses, and also consist of foliated biotite paragneisses with calc-silicate bands and thin leucogneisses (Hitchon, 1958; Loney, 1969; Kirkpatrick and Robertson, 1987; Broderick, 1976). There are also some porphyroblastic biotite gneisses containing euhedral microcline and microperthite porphyroblasts, which are associated with small plugs of adamellite and granodiorite (Hitchon, 1958; Broderick, 1976). Sillimanite quartzites occur interbedded within the Kariba Paragneisses, and are regarded as an arenaceous facies of the paragneiss. Loney (1969) obtained a (recalculated) age of 2368 ± 92 Ma for the Kariba Paragneisses. This imprecise age records the metamorphism, and must be regarded as a minimum age. The age of sedimentation of the protoliths is unknown, but was most probably late Archaean.

The paragneisses and their associated intrusive granitic orthogneisses and ortho-amphibolites record a major orogenic cycle that is imprecisely dated, but predates the 2.1 Ga Magondi Supergroup. Because most of the gneisses occur in the Hurunge District, and occupy an area that has been termed the 'Urungwe Subprovince' (Stowe et al., 1984), it was proposed by Master (1991) to call this orogenic cycle the Hurungwe Orogeny. The age constraints on this orogenic cycle are very poorly defined. The only dating of the paragneisses, by Loney (1969), indicates ages that span 2533 to 2276 Ma, i.e. late Archaean to early Proterozoic. Since the gneisses of the Hurungwe District can be correlated with the gneisses in the Guruve (Sipolilo) District, as appears probable from the mapping of Hahn et al. (1990), they must be late Archaean in age, since the Guruve gneisses were intruded by the 2470 Ma old Great Dyke (Worst, 1960; Wiles, 1968, 1972; Prost, 1982).

Interpretations of the metasedimentary paragneisses indicate that they were deposited in a marine environment. The biotitic and quartzo-feldspathic leucogneisses of the Urungwe and Escarpment Paragneisses may have been arkoses and greywackes, and together with the intercalated para-amphibolites (metamorphosed marls), may have been deposited in a shallow marine setting. In the overlying paragneisses, the lack of coarse clastic material, major carbonate units or arenites rules out a near shore or shallow shelf setting, and indicates a deeper marine depository. Thick sequences of fairly uniform biotite gneisses in the Chipisa Paragneiss may be meta-turbidites, and may have been deposited in a deep-sea fan setting similar to the Kuiseb Schists of the Khomas Trough in the Damara Belt (Kukla and Stanistreet, 1990).

The Hurungwe orogenic cycle may have involved subduction of oceanic crust underneath the Zimbabwe craton, with orogenic obduction of an accretionary wedge onto the western edge of the craton. If a latest Archaean age is accepted for the protoliths of the Hurungwe gneisses, then they may have been contemporaneous with the calc-alkaline rocks of the Bulawayan Upper Greenstones in the western part of the Archaean craton, for which a subduction related origin has been proposed by Condie and Harrison (1976), Wilson et al. (1978) and Watkeys (1984). In Watkeys' (1984) scheme, the Upper Greenstones represent an Andean-type magmatic arc, produced by eastward oblique subduction of oceanic crust as the Zimbabwe craton moved south-westward before colliding with the Kaapvaal craton in the Limpopo Mobile Belt. The Hurungwe belt of paragneisses may then represent a fore-arc trench complex formed on the leading edge of the Zimbabwe Archaean craton (Master, 1991).

Stop 2 (Fig. 8): Makuti Group exposures on Zambezi Escarpment

Exposures of the Late Proterozoic Makuti Group (Fig. 9) along the Zambezi Escarpment are flat-lying, but highly deformed and metamorphosed. Good examples of boudinage can be seen in quartzofeldspathic psammitic beds intercalated with pelitic and semi-pelitic schists. Brecciated dolomitic marbles are seen close to the escarpment fault. Munyanyiwa et al. (1996) interpret felsic gneisses and amphibolites from the Makuti Group as representing a bimodal rift sequence in an intraplate setting. Although Munyanyiwa and Blenkinsop (1992) ascribed the basic structure of the Vuti synform (Figs. 9 & 10), to two phases of deformation, more recent evidence suggests that there was an earlier phase of deformation that preceded their D1 event. This is manifested by the presence of an early schistosity that is folded by D1 folds, and possibly by rootless isoclinal folds, both in the Makuti Group (T.G. Blenkinsop, pers. comm., 1996).

Stop 3 (Fig. 8): Rukomeche River enderbites.

These granulites are metamorphosed equivalents of Piriwiri Group rocks, and have been dated by Treloar and Kramers (1989) at 1890 ± 260 Ma.

Stop 4 (Fig. 8): Lynx Graphite Mine.

The graphitic schists of the Piriwiri Group have in places been highly deformed and metamorphosed to high grades, and the resulting flake graphite has been exploited at the Lynx Graphite Mine and in several smaller prospects (Muchemwa, 1987) (Figs. 11 & 12). The mineralization at Lynx Graphite Mine is confined to a horizon of graphite schist which is interbedded with sillimanite and biotite gneisses and feldspathic psammites (Armstrong, 1975). The graphitic horizon has been traced geophysically and by trenching for a strike length of over a kilometre (Davies, 1982; Muchemwa,1987).

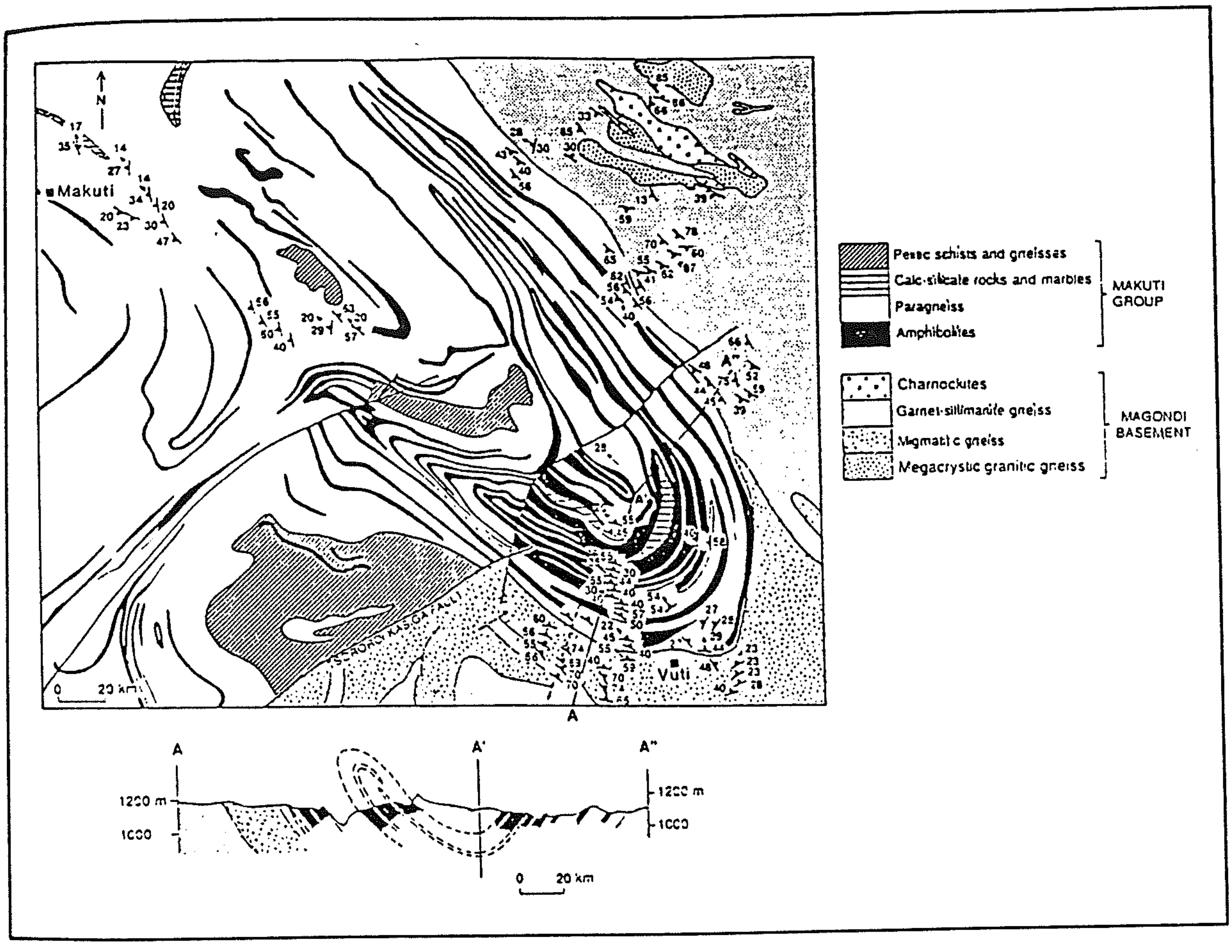


Figure 9: Geology of the Makuti Group and the underlying basement in the Vuti synform (after Munyanyiwa & Blenkinsop, 1992). Cross section A-A" shows refolding of the basement rocks.

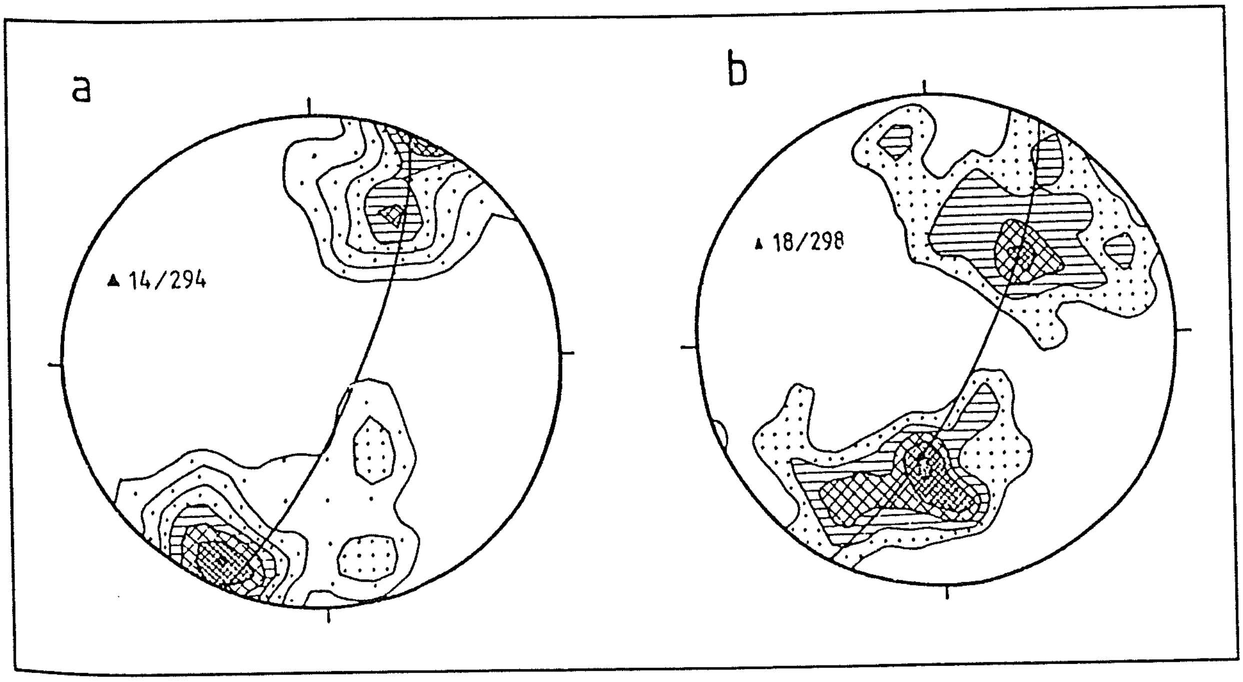


Figure 10: Lower hemisphere equal area contoured stereoplots of poles to (a) Magondi basement foliations (n=55); (b) Makuti Group foliations (n=131). Great circle is best-fit great circle, with plunge and bearing of plunge (after Munyanyiwa & Blenkinsop, 1992).

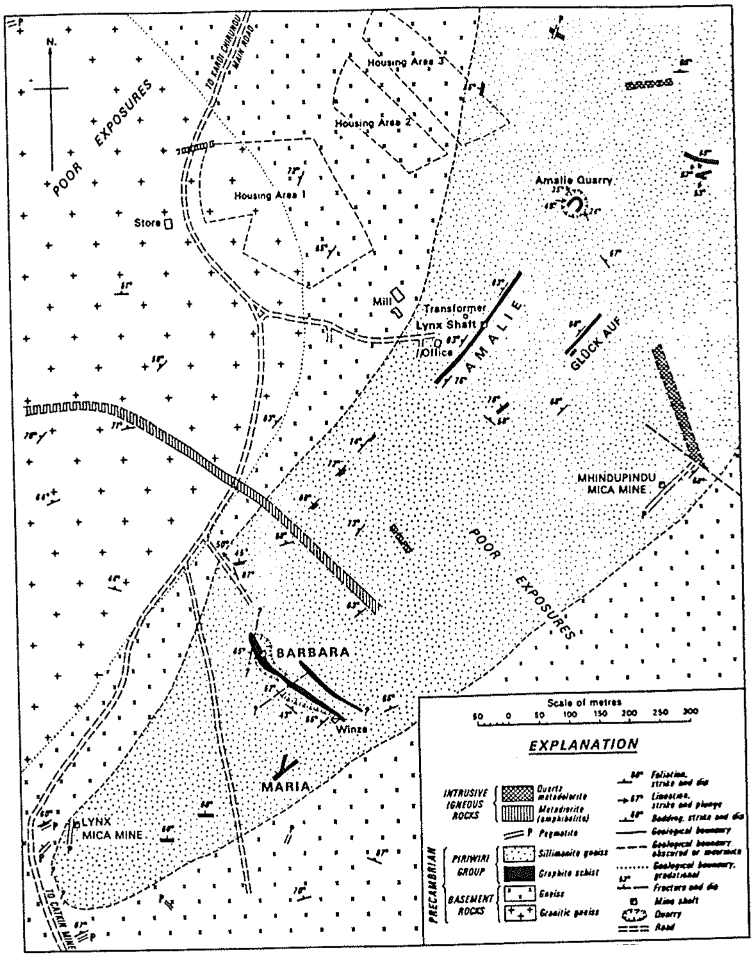


Figure 11: Geological map of the Lynx Graphite Mine
(after Armstrong, 1975; and Muchemwa, 1987)

Figure 12: Geological map of 3 Level South,
Lynx Graphite Mine
(after Muchemwa, 1987)

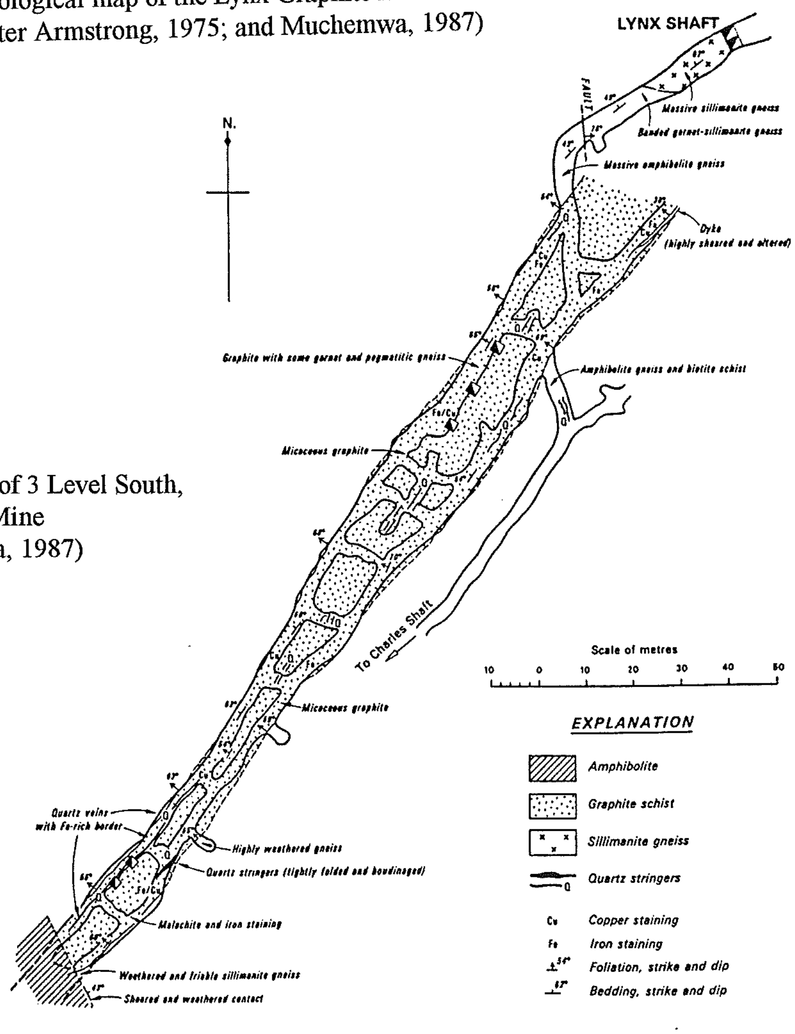


Figure Geological map of 3 level south, Lynx Graphite Mine

Day 2

Stop 5 (Fig. 8): Mwami (Miami) mica field

5.1 The Mwami mica field contains muscovite mica pegmatites (Figs. 13 & 14, after Wiles, 1961) related to regional metamorphism of the Piriwiri Group (Fig. 15). There are also mica and beryl pegmatites (with gem tourmaline and blue topaz) related to intrusive Miami granites (Pan-African age) (Fig. 16, after Treloar,1998).

5.2: Masterpiece Farm kyanite deposit

This is a deposit situated in a belt of Piriwiri Group graphitic schists, in which kyanite pseudomorphs after andalusite (chiastolite) occur (Fig. 17). The kyanites, which occur as single crystals and penetration twins (Figs. 18 a & b), were described by Workman and Cowperthwaite (1963).

Stop 6 (Fig. 8): D-Troop cluster of Au deposits along the Angwa River

6.1. The D Troop mine is one of several small gold mines and prospects along the Angwa River, in which gold mineralization is associated with a stockwork of N-trending quartz veins cutting phyllites and more sandy argillites of the Piriwiri Group. The veins appear structurally related to a NE-plunging anticline with minor drag folds. The gold is associated with pyrite. Most of the workings are shallow, and are confined to the oxide zone. The cumulative production from 1892 to 1984 was 556.22 kg Au at an average grade of 4.2 g/t (Bartholomew, 1990).

The D Troop mine is one of the most ancient authenticated mines in Zimbabwe. In the 1890's, when the old diggings were opened up by prospectors, an engraved bronze cup was found in the workings. This cup, which is now in the National Museum in Bulawayo, contains incised Indian designs which have been dated to ca. the 14th Century AD, i.e., during the height of the gold-based Monomotapa kingdom, which was centred on Great Zimbabwe.

In the16th Century, the Portuguese had taken control of the coastal areas of Mozambique, and took over the gold trade that was formerly run by Arabs based in the sultanates of Zanzibar, Pemba and Chilwa off the coast of East Africa. The Portuguese penetrated inland up the Zambezi and its tributaries, and built forts along the Angwa River, from where they controlled the gold mines of the D Troop cluster.

Figure 13: Longitudinal sections of mica shoots from the Mwami mica field (after Wiles, 1961)

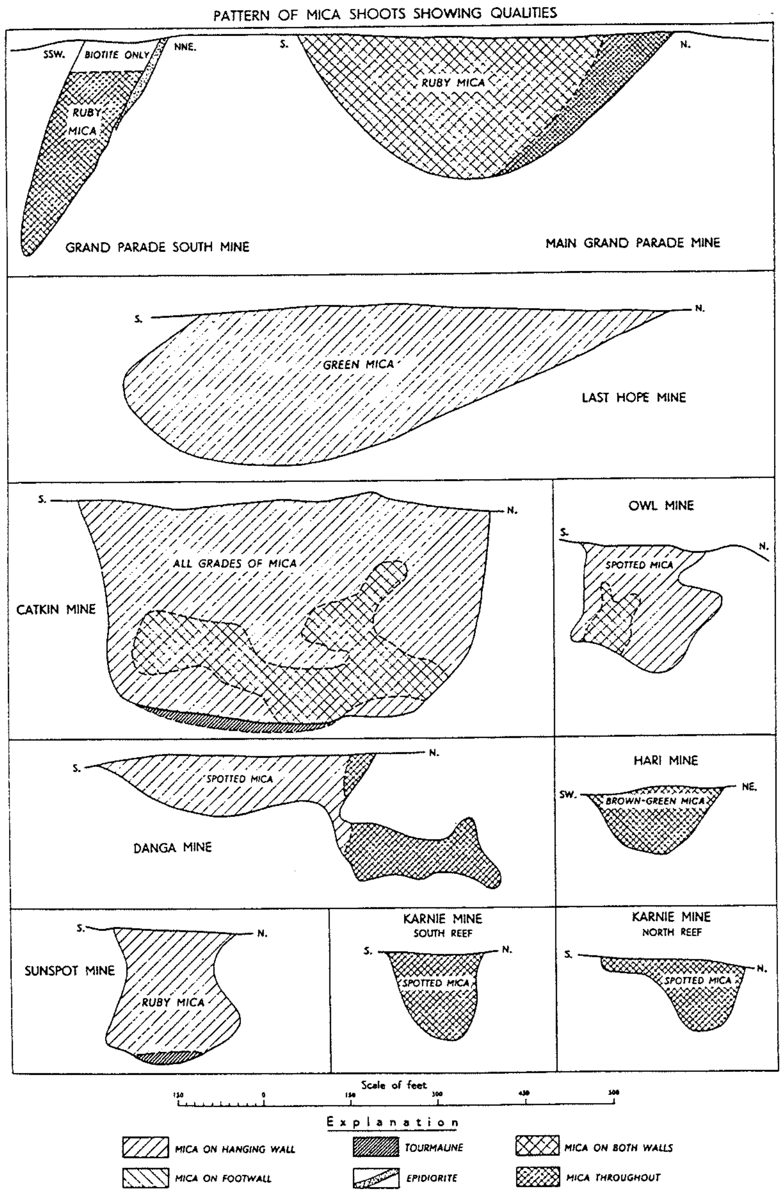
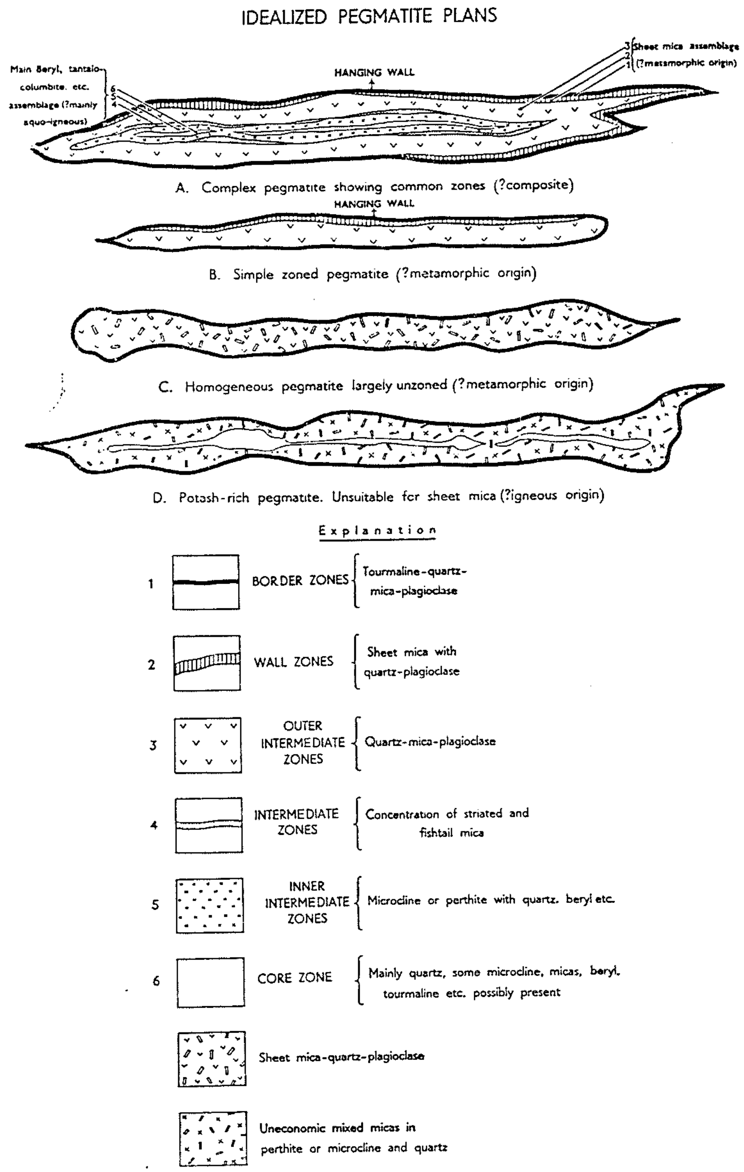


Figure 14: Idealised plans of pegmatites from the Mwami mica field



(after Wiles, 1961)

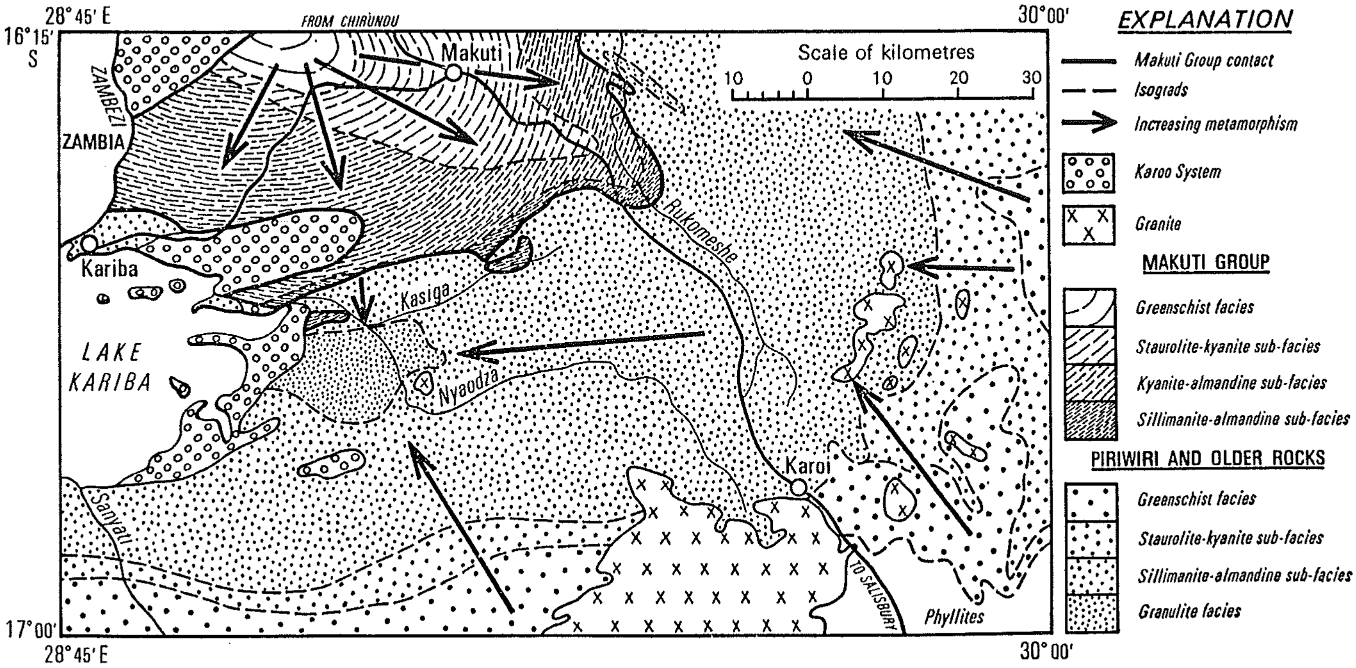


Fig. 15: Regional metamorphism around Makuti, Karoi and Kariba (after Broderick, 1976).

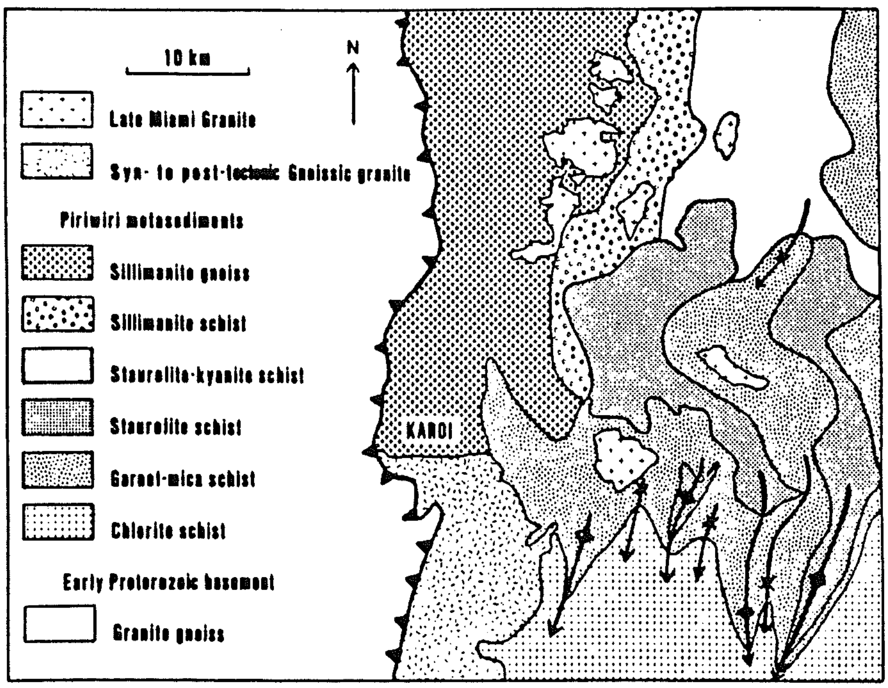


Fig. 16: Metamorphic map of the Mwami area (after Wiles, 1961; Treloar, 1988), showing post-metamorphic folding of the metamorphic isograds, and the late Miami Granite.

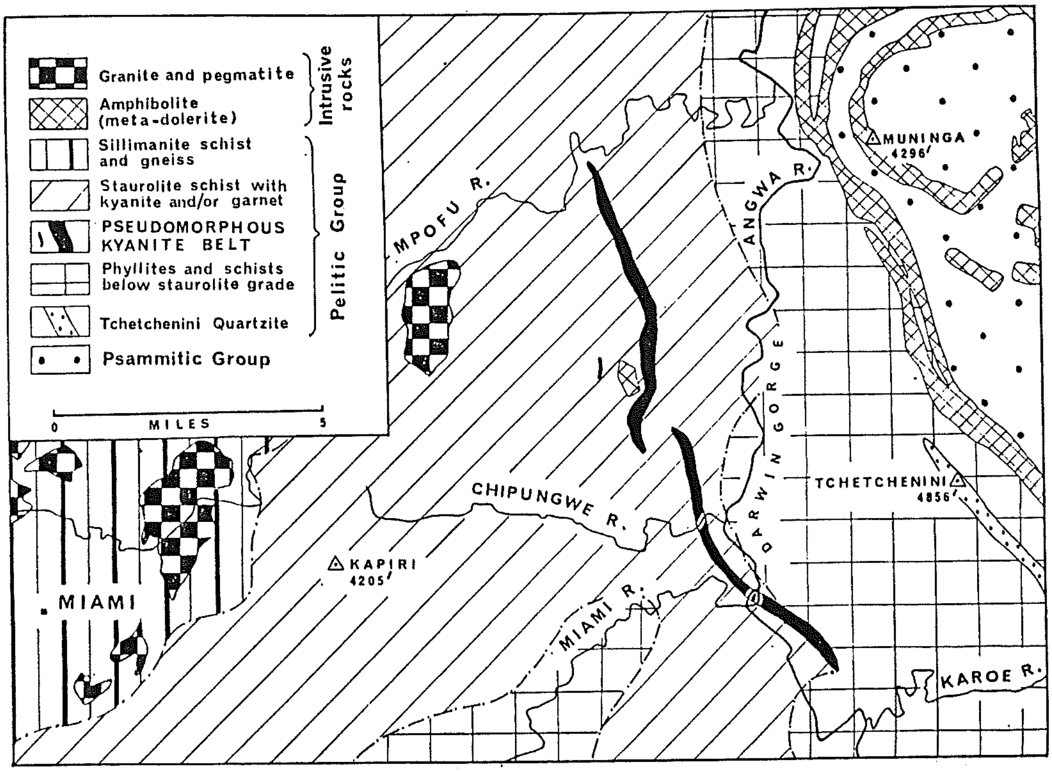


Fig. 17: Generalised geological map of the country east of Mwami, showing belt of pseudomorphous kyanite after chiastolite (after Workman & Cowperthwaite, 1963).

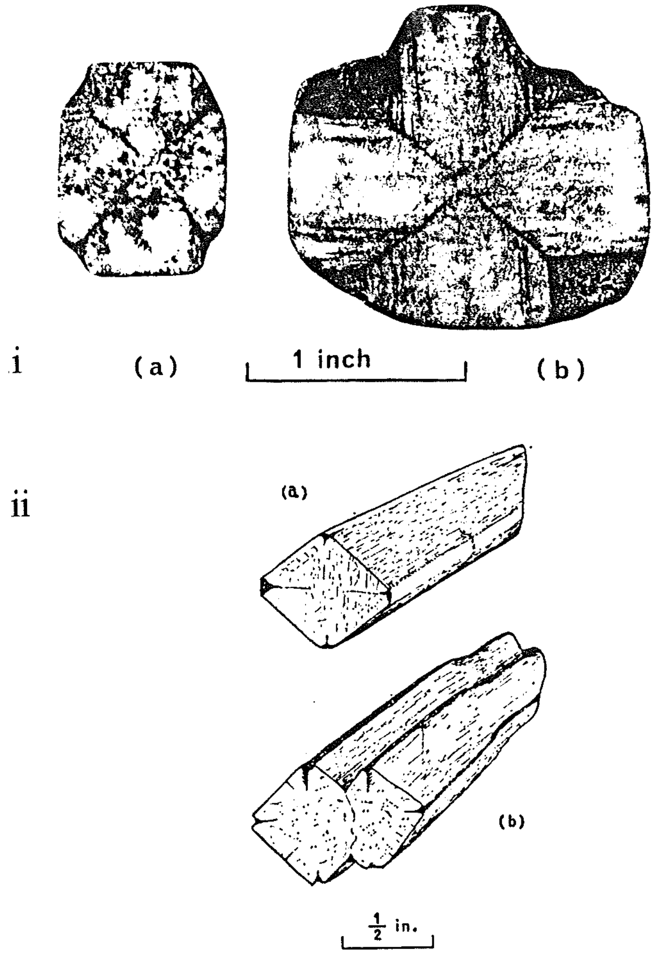


Fig. 18: (i a&b) Examples of chiastolite crystals now entirely converted to kyanite. (iia) a single crystal, (iib) a penetration twin. The specimens have been cut parallel to (001) to show the cross-sections (after Workman & Cowperthwaite, 1963).

6.2: Morocco Manganese Claims.

The Morocco claims, near D-Troop mine, contain manganese oxide mineralization in a thrusted zone of argillites separating Lomagundi Group rocks from Piriwiri Group phyllites. Individual bodies, averaging 45 m in length and 60 cm in width, are associated with brecciated concordant quartz veins (Kirkpatrick, 1976). 733 tonnes of ore grading 45% MnO_2 were declared from 1961-1966.

Day 3

Stop 7 (Fig. 8): Mangula Cu-Ag Mine, Mhangura

7.1. Underground visit to Mangula Mine, the largest copper-silver producer in Zimbabwe (Figs. 19-22). Mangula a stratabound sediment-hosted Cu-Ag-Au-Pt-Pd-(U,Mo) deposit hosted in red beds of the early Proterozoic (ca. 2.1 Ga) Deweras Group, which unconformably overlies the Archaean basement. The host rocks are arkoses, conglomerates and metapelites of the Mangula Formation, which were deposited in alluvial fan and braided stream environments. The rocks were deformed and metamorphosed to greenschist facies during the ca. 2.0-1.8 Ga Magondi Orogeny, as well as during the Irumide (ca. 1.3-0.9 Ga) and Pan-African Zambezi (ca. 550 Ma) orogenies.

Although Mangula was discovered in the 1920's, mining only commenced in 1957, and its original size is estimated to have been 60 million tonnes at an average grade of 1.2% copper and 20 g/t silver. Important by-product gold, platinum and palladium are recovered from the ores. Copper mineralization occurs over a stratigraphic thickness of about 200 m in the basal part of the Deweras Group. For mining purposes, the deposit is divided into eight parallel tabular orebodies separated by subgrade mineralization or barren zones, and extending along strike for 2 km. Most of the orebodies coalesce at depth and extend down-dip to about 900 m below surface.

The orebodies at Mangula Mine are hosted by alluvial fan and braided stream lithologies of the Mangula Formation. Although the mineralization is found in all rock types, there is a strong spatial association with lithologies of the distal fan facies association, in particular where there is an interfingering of permeable arkosic horizons with impermeable pelitic beds. The orebodies, which have an elongate tabular form concordant with the bedding, consist of disseminated chalcocite and bornite, with subordinate chalcopyrite and minor pyrite and molybdenite. The footwall of the orebodies are characterised by intense reddish haematitic alteration, accompanied by silicification and microclinization of arkosic arenites. In these zones, sedimentary structures such as cross-bedding are completely destroyed, and replaced by stratiform zones of haematite and magnetite bands and ellipsoids which are parallel to both bedding and cross-bedding. The magnetite ellipsoids may also contain minor copper sulphides and uraninite. The main source of the uranium, as revealed by fission track studies, was detrital zircon (together with minor allanite and apatite), that was concentrated in heavy mineral layers in the sediments. The magnetite ellipsoids have been shown to be flattened triaxial oblate ellipsoids, which are true strain

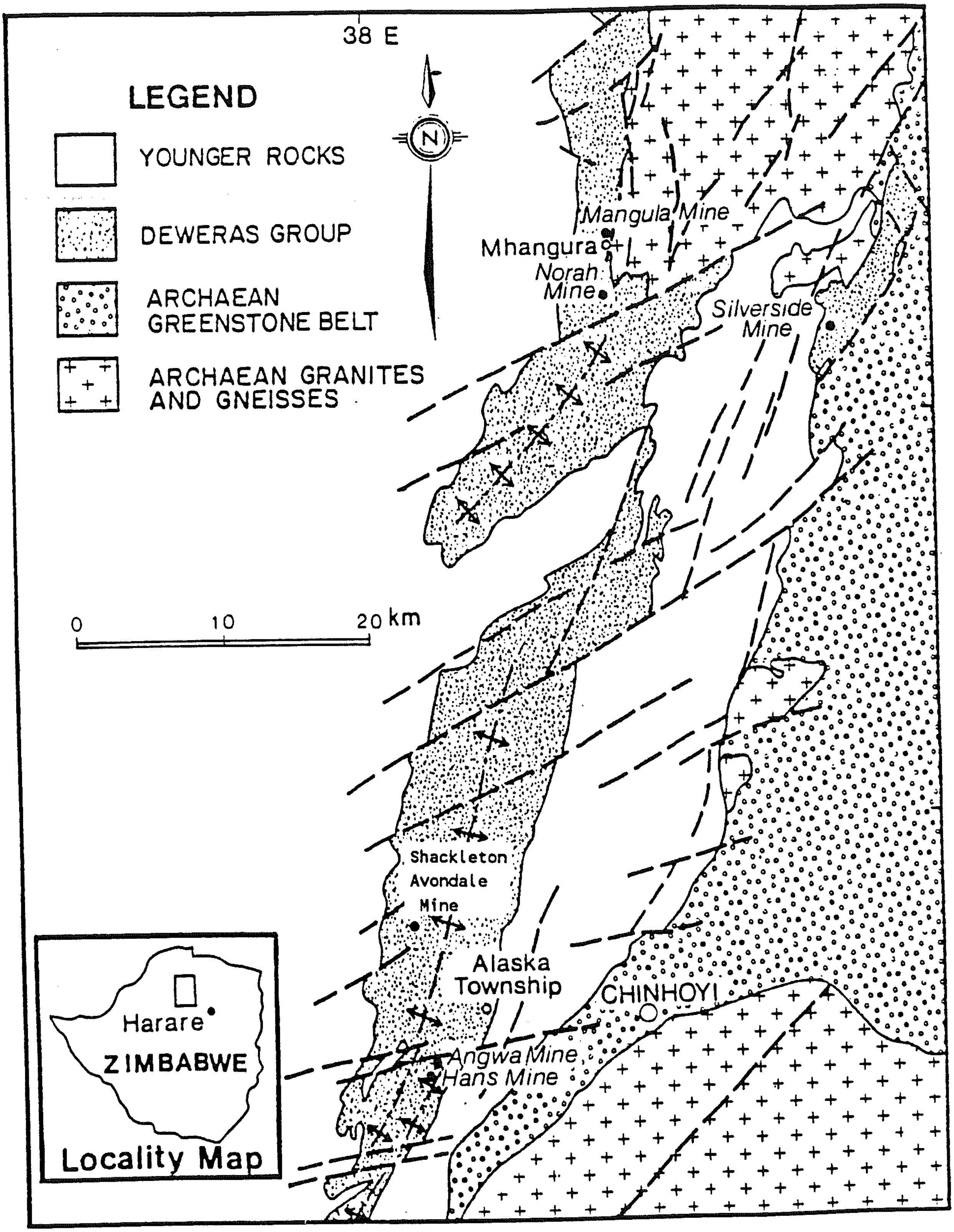
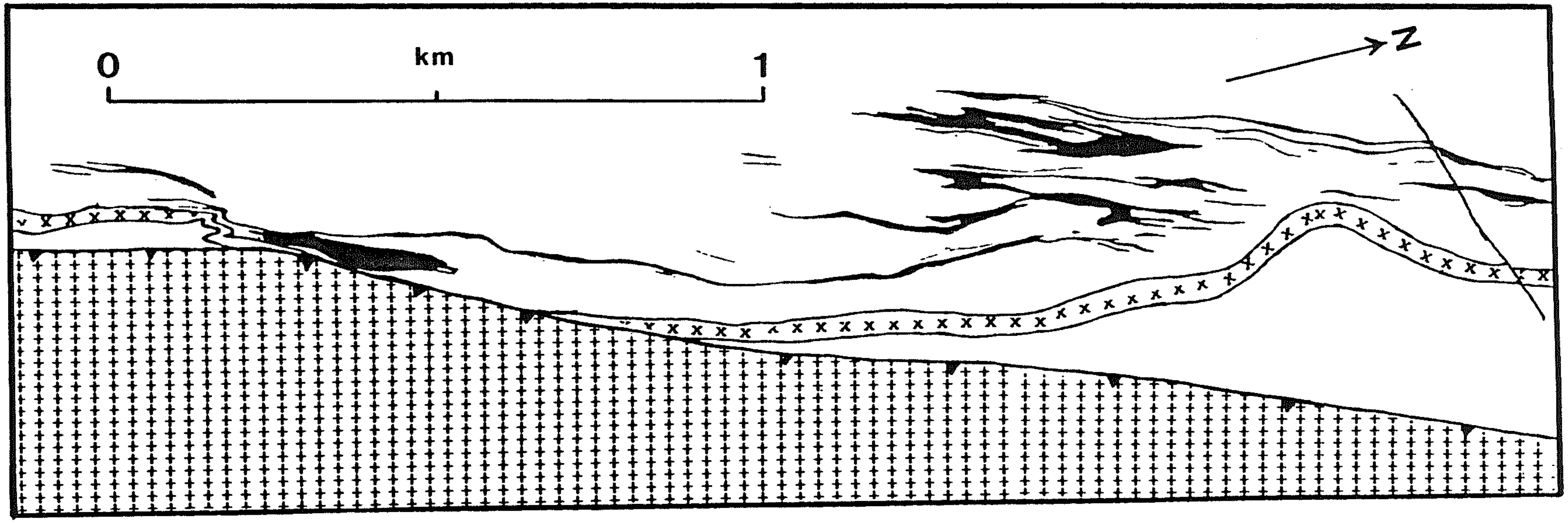


Figure 19: Locality map of the Magondi Copperbelt, showing the Deweras Group in relation to the Archaean granite-greenstone belt basement (after Master, 1991)

Figure 20

Plan of 5-00 Level, MANGULA MINE



+ = Mangula Granite, x = Mangula Metadolerite Dyke, black = orebodies, unornamented = Deweras Group metasediments (Mangula Formation)

(after Master, 1991)

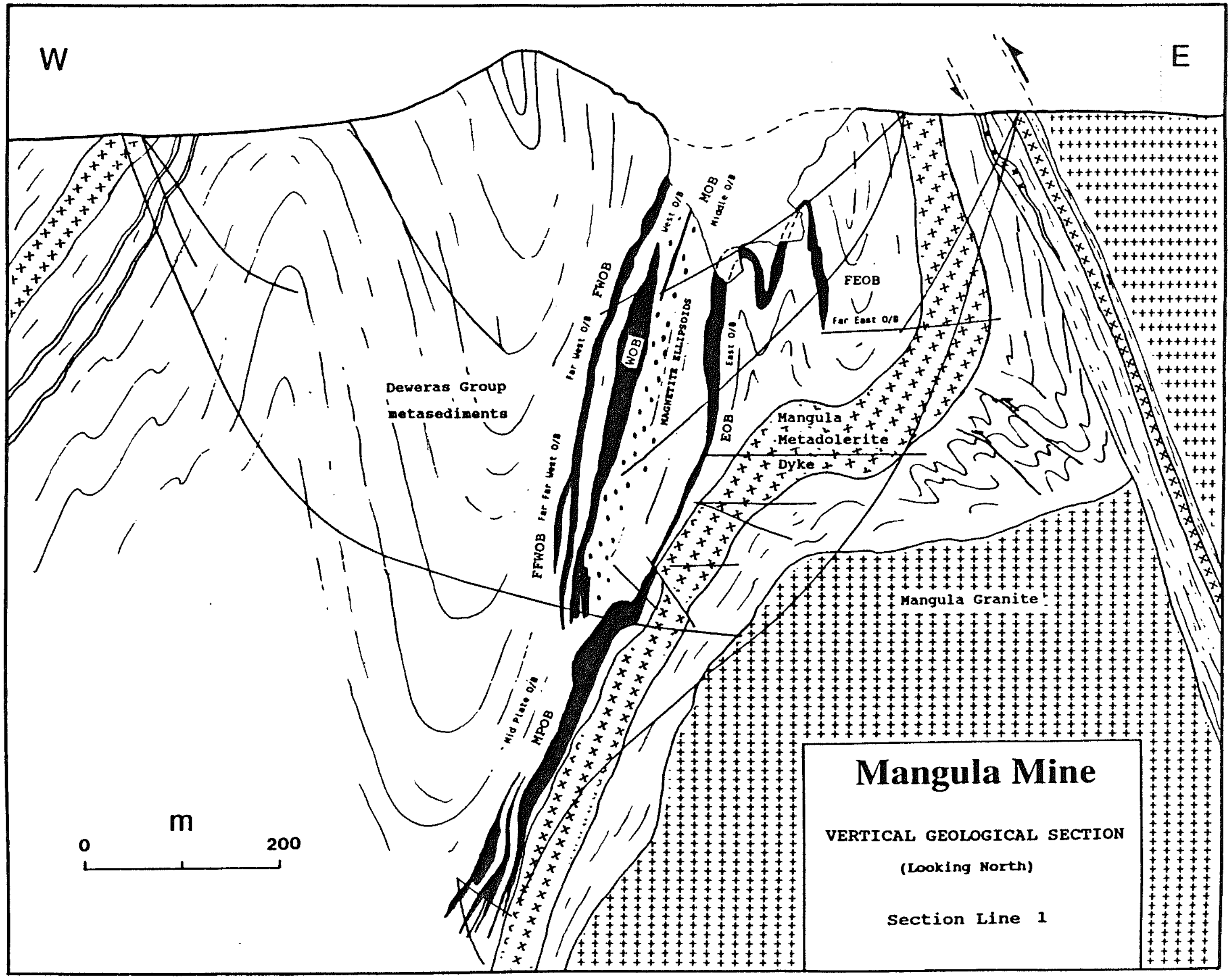


Figure 21: Vertical geological section of Mangula Mine, looking North (after Master, 1991).

ellipsoids formed by deformation of initially spherical reduction spots which are common in redbeds of all ages (Master, 1991). Oxidising metamorphic fluids generated by pressure solution during the first phase of deformation were responsible for very similar haematite-microcline alteration, especially around faults and veins.

The ore minerals are divided into primary (hypogene) minerals and secondary (supergene) minerals. The main primary sulphide minerals are chalcocite and bornite, with subordinate chalcopyrite and pyrite, minor digenite, molybdenite, and trace acanthite and wittichenite. The primary non-sulphides include native copper, native silver, native gold, magnetite, haematite, rutile, sphene, chromite, and uraninite. Silver and gold also occur as lattice-substitutions in copper sulphides. Platinum and palladium are also recovered as by-products from the sulphides, and no discrete platinum-group mineral has been identified as yet. There is no galena or sphalerite. The secondary minerals, which are restricted to the uppermost, oxidised parts of the orebodies, include malachite, chrysocolla, cornetite and pseudomalachite, together with minor azurite, turquoise, native copper, bornite, digenite, covellite, chalcopyrite, cupriferous wad, metatorbernite, uranophane and chalcanthite. There is a very strong correlation between Cu and Ag values, and a good correlation between Ag and Au values in the primary ores (Master, 1991). Au and PGE (Pt, Pd, Ir) are concentrated in sulphides and magnetites, and are highly depleted in the haematised and K-metasomatised alteration zones in the footwalls of the orebodies. The orebodies are zoned both vertically and laterally, having chalcocite cores surrounded by bornite-rich zones, passing out into narrow fringes of chalcopyrite and then into wide pyritic zones containing very minor sparsely disseminated pyrite (Fig. 22). Sulphur isotope values in the sulphides have a range in $\delta^{34}S$ of -2.3 to -16.0 permil CDT, and are interpreted to have resulted from thermochemical abiogenic reduction of sulphates at high temperatures (Master, 1991).

Copper mineralization occurs in several forms: (a) as even, banded or cloudy disseminations in arkose and schist; (b) as a replacement of detrital iron-titanium oxides on crossbed foreset laminae; (c) as syntectonic quartz-microcline-sulphide (-haematite-carbonate) veins occupying brittle fractures in competent lithologies; (d) as cleavage-parallel syntectonic quartz-microcline-sulphide veins in semi-pelitic schists. The ore textures are interpreted as the result of partial remobilization of pretectonic disseminated mineralization during polyphase deformation and metamorphism.

The stratabound mineralization at Mangula Mine, and the accompanying alteration, was produced by saline, slightly alkaline oxidising basin brines, which evolved through reaction with evaporites in the sequence, and which leached metals out of the redbeds, especially from detrital components like titanomagnetite, chromite, zircon, apatite and labile ferromagnesian minerals. The high copper and silver contents of the ores, the relatively low gold and platinoid contents, and the absence of lead and zinc are explained by the respective solubilities of these metals in the postulated ore fluids (Master, 1991). Sulphide precipitation occurred where mineralizing fluids encountered reduced beds and/or reduced fluids, and through replacement of pre-existing pyrite and magnetite.

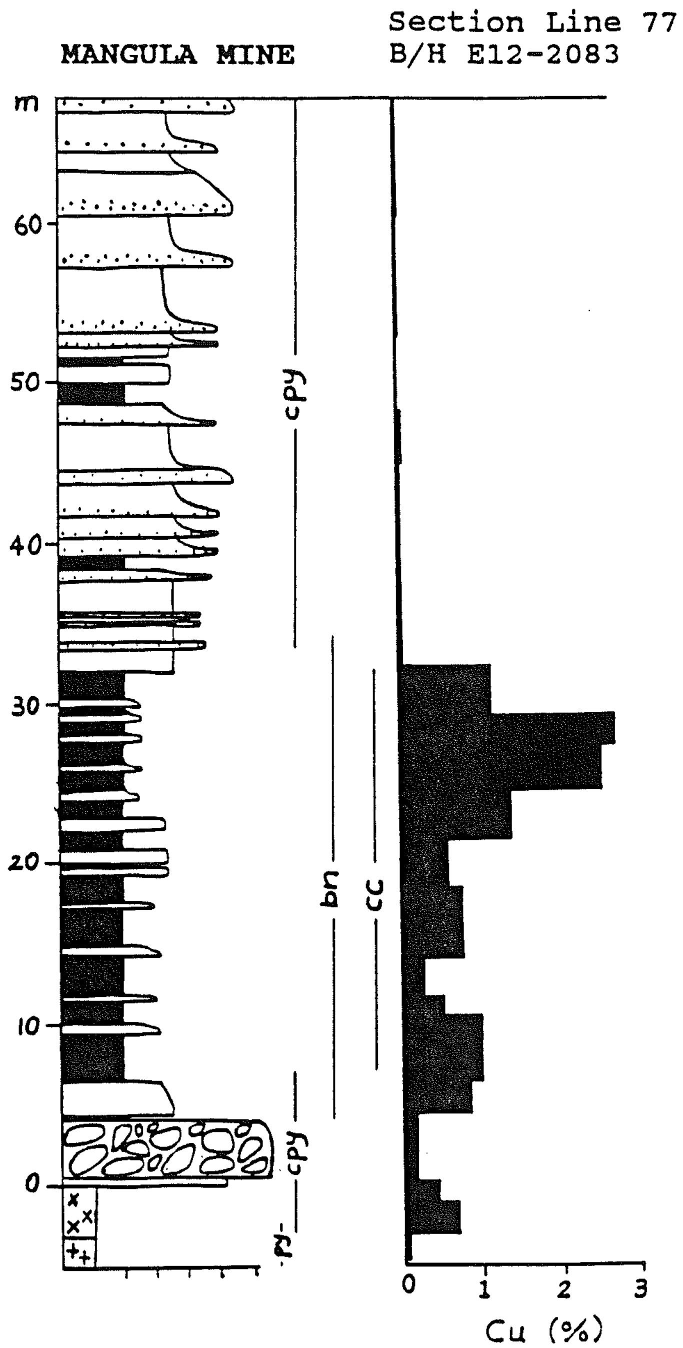


Figure 22: Mid Plate Orebody in borehole E12/2083 at Mangula Mine (after Master, 1991)

7.2: Highbury Meteorite Impact Structure

Exposures of Deweras and Lomagundi Group rocks which have undergone intense shock metamorphism and brecciation by a large meteorite impact, which produced a crater 20 km in diameter called the Highbury Impact Structure (Fig. 23). Shock metamorphic effects include the formation of Planar Deformation Features (PDFs) in quartz, which have an orientation characteristic of shock deformation at pressures exceeding 150 kbars (Fig. 25), and silica-rich impact glass (which has been partly devitrified). A granophyre exposed in the Ridziwi stream intrudes meta-arkoses and tremolitic marbles of the Deweras Group. This granophyre, which is interpreted to be an impact melt, has been dated at 1034 ± 13 Ma (Fig. 24, after Master et al., 1995).

Day 4

Stop 8 (Fig. 8): Shackleton-Avondale Cu-Ag Mine

Underground visit to Shackleton Mine (Fig. 26), which is hosted by metasedimentary rocks of the Deweras Group. In the Avondale section, will examine stratabound copper-silver orebodies hosted in conglomerates, arkoses and argillites. The orebodies at Shackleton and Avondale are in the form of elongate ore-shoots formed under impermeable and reducing argillite caps in doubly-plunging en-echelon anticlinal trap structures associated with a major sinistral wrench fault which was the feeder for the mineralizing brines (Fig. 27).

The Avondale sequence is separated from the overlying Shackleton sequence by the Dolomitic Argillites. Fresh exposures of these will be studied on 10 Level. The dolomitic argillites consist of thinly bedded dolomite horizons alternating with clastic ripple-marked dolomite and upward-fining marly arenite units. Thin pink anhydrite layers may overlie persistent chemically precipitated dolomite beds. The anhydrites are also reworked clastically into ripples. The ripple-marked dolomites exhibit the whole range of sedimentary structures indicative of tidal flat environments, including single, bifurcated and trifurcated flaser bedding, lenticular and wavy bedding, and starved ripples. Such structures are indicative of time-velocity asymmetry in the depositional environment, with alternating periods of ebb and flood flow (during which ripple marks form), separated by highstands and lowstands during which shale drapes form. Such processes are characteristic of a shoreline environment, which in this case was on the shores of a saline playa lake which deposited evaporites (carbonates and sulphates).

The Avondale orebody is associated with two or three argillite horizons (known as the Hangingwall, Middle and Footwall argillites), which occur with plane-bedded arenites interbedded with trough crossbedded arenites and conglomerates (Fig. 28). Mineralization is erratic, and may vary in its stratigraphic position with respect to the argillites- sometimes it is associated with one argillite, sometimes with another, and in other cases with

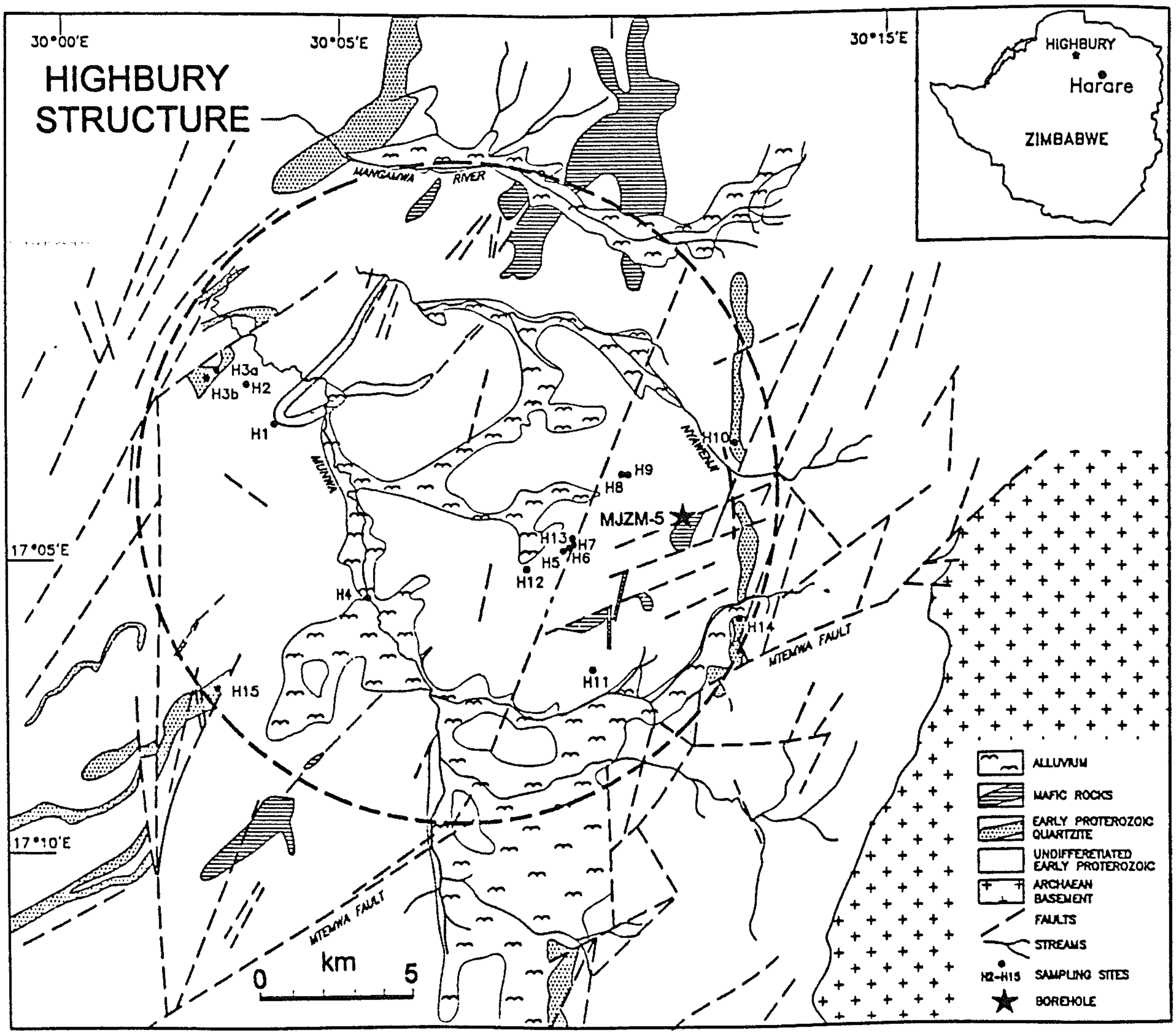


Figure 23: Simplified geological map of the Highbury Structure (dashed circle), after Stagman (1961) [6].

Figure 24: U-Pb plot of Munwa granophyre zircons. Euhedral (igneous) concordant zircons have an age of 1034±13 Ma. Older xenocrystic detrital zircons (5.1, 5.2) show Pb-loss at the same time. Some younger zircons (eg. 12) show a Pb-loss (thermal) event at c. 216 Ma (Karoo?).

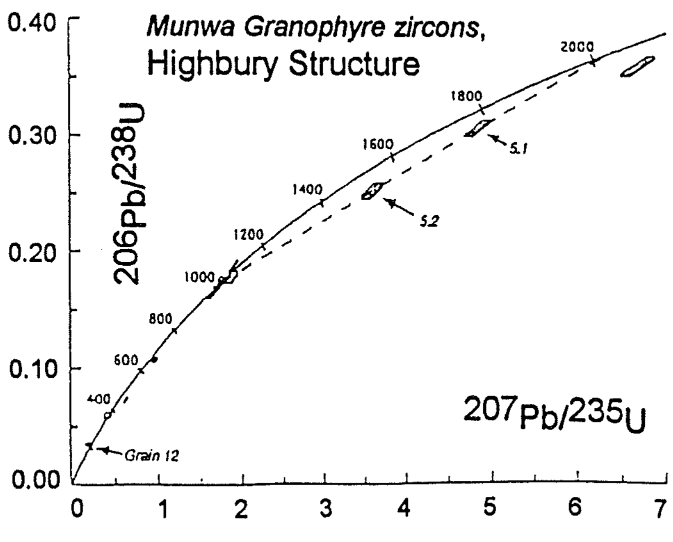
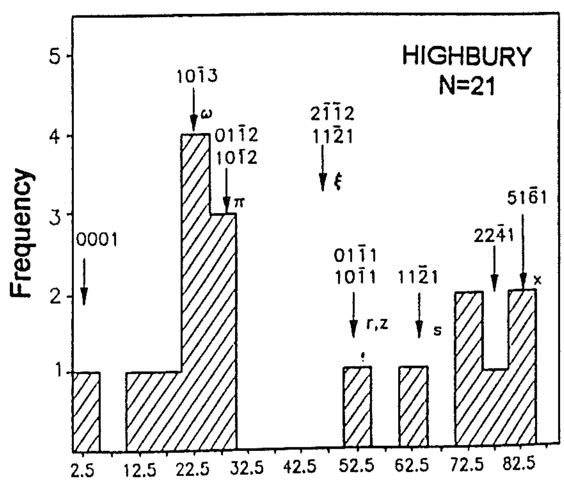


Figure 25: Histogram of orientations of PDFs in Highbury quartz (angle in degrees wrt 0001)



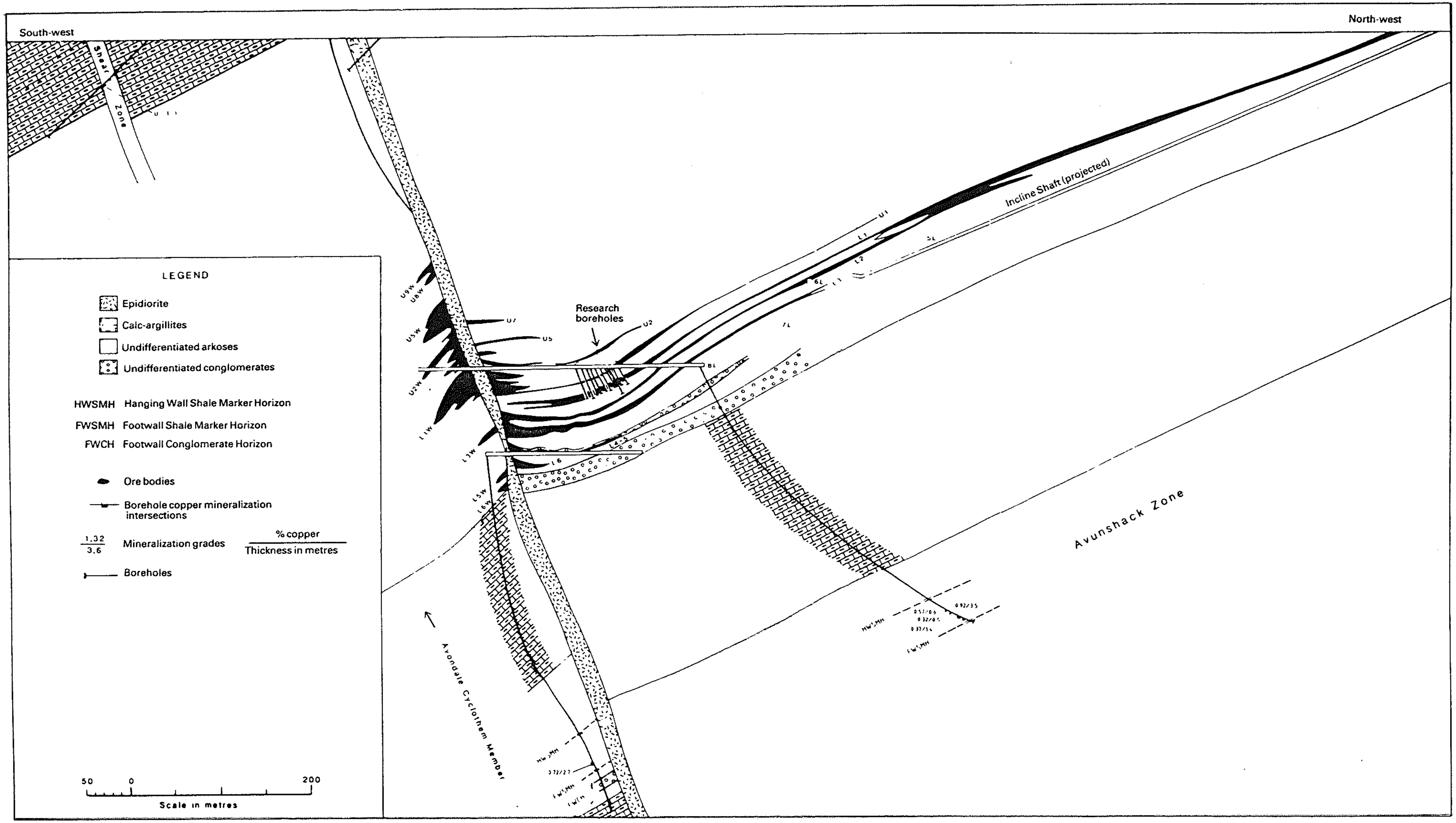


Figure 26: Longitudinal section of Shackleton Mine (after Newham, 1986).

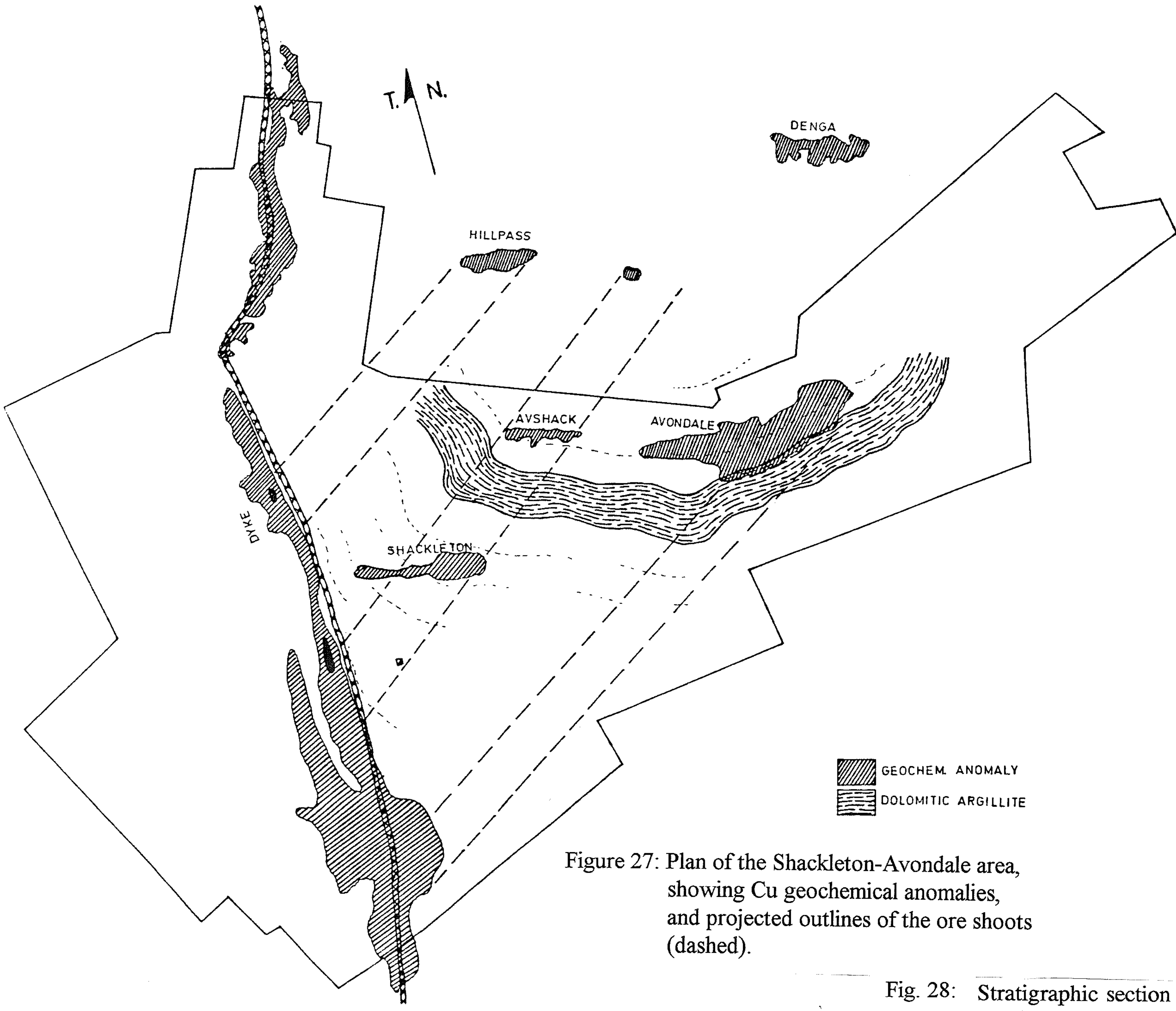


Figure 27: Plan of the Shackleton-Avondale area, showing Cu geochemical anomalies, and projected outlines of the ore shoots (dashed).

AVONSHACK 10 L

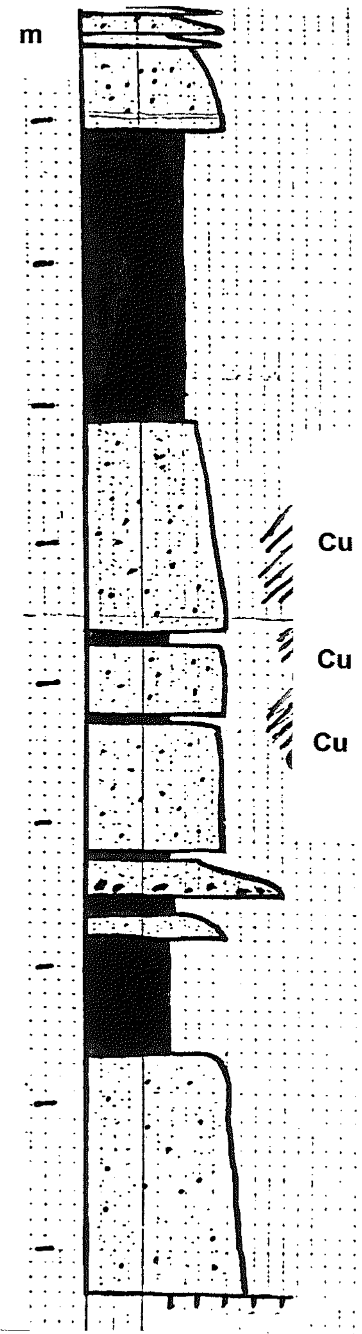


Fig. 28: Stratigraphic section through the Avonshack ore body on 10 Level, Shackleton Mine

two or three argillites. The exact controls on the position of the mineralization are still unknown. The Avondale conglomerates are oligomictic, with mainly shale intraclasts and small granite clasts, which do not get beyond the pebble to cobble range in size. The argillite horizons are commonly mudcracked, and provide abundant intraformational clasts for the overlying conglomerates. Some of these clasts are imbricated, and show palaeocurrents trending towards the east. In the immediate footwall, stratigraphically below the Avondale ore horizons, there occur large-scale crossbedded arkosic arenites, which have been proven to be aeolianites. These have interbedded interdunal pan sediments consisting of mud-cracked argillites.

Stop 9 (Fig. 8): Muchi River thrust front

The thrust front of the Magondi Belt is exposed along the Muchi River (Fig. 29). Here Lomagundi group quartzites are thrust over the Archaean basement.

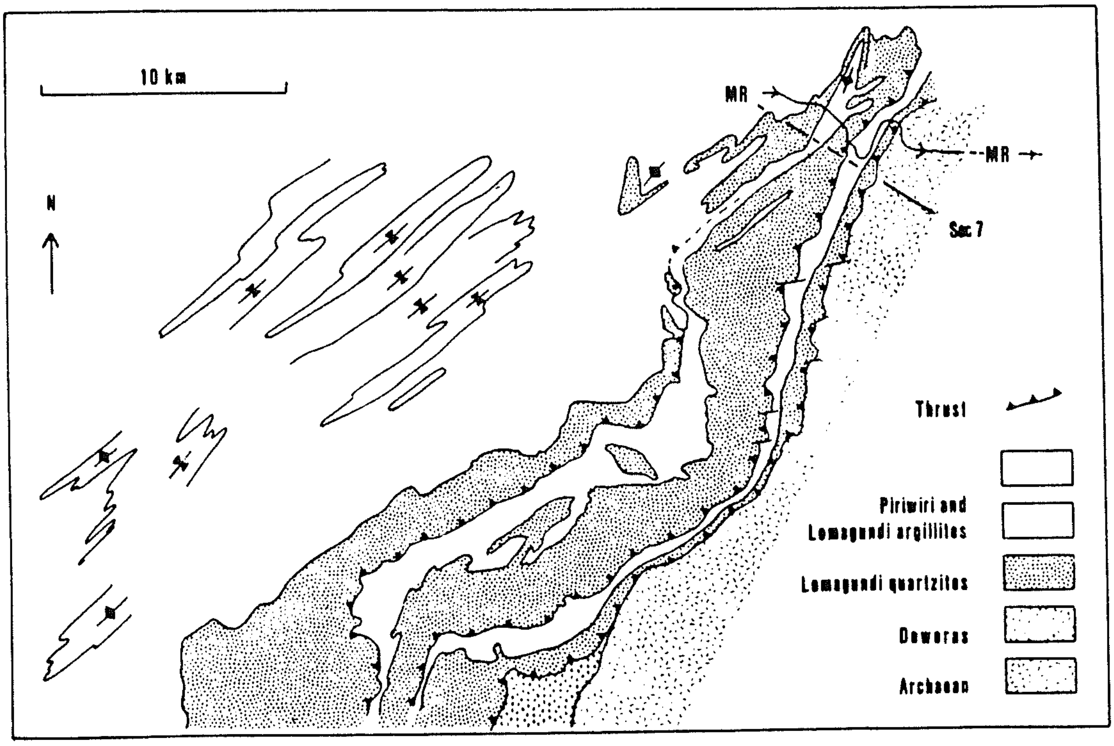


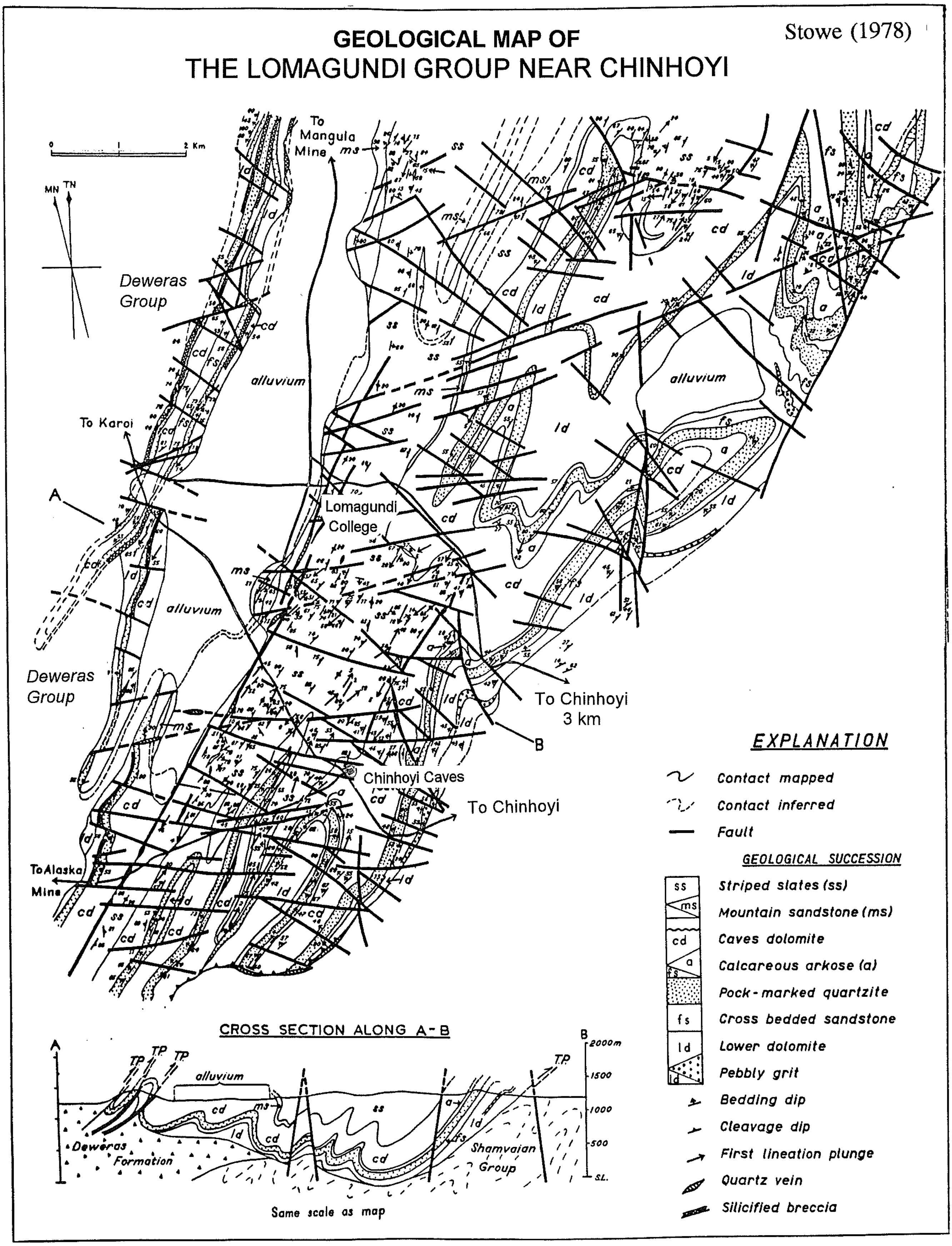
Figure 29: Map of the basal thrusts and overlying fold belt in the southern part of the Magondi Belt (after Tennick & Phaup, 1976; Treloar, 1988). MR = Muchi River

Day 5

Stop 10: Chinhoyi Caves (Fig. 30)

The spectacular Chinhoyi Caves, one of the biggest tourist attractions in Zimbabwe, are karstic features developed in the Lomagundi dolomites. The caves are situated along a

Figure 30: Geological map of the Lomagundi Group near Chinhoyi (after Stowe, 1978).



large fault zone in the dolomites. The Wonder Hole is a large karst sinkhole with circular outline, in the bottom of which is a 90 m-deep lake filled with clear, blue water.

10.1: Road Traverse, Lomagundi Group

Road traverse of lithologies of the early Proterozoic Lomagundi Group, along the Chinhoyi-Lomagundi College Road. This area was mapped by Stowe (1978) (Fig. 30). Along this traverse there are exposures of stromatolitic dolomites and Pockmarked Quartzite of the Mcheka Formation, and graphitic shales, Striped Slates and Mountain Sandstone of the Nyagari Formation.

Stop 11: Deweras Group aeolianites in Angwa River, on the road between Chinhoyi Caves and Alaska Mine. Large-scale planar crossbedded arkosic sandstones of the Deweras Group display small-scale features that are diagnostic of aeolianites, including cm-scale inversely-graded ripple-cross-laminated “subcritically-climbing translatent strata” (Hunter, 1976), wedge-shaped massive grainflows (avalanche deposits), and pinstripe lamination. These are among the oldest authenticated aeolianites in the world (Master, 1995).

Stop 11.1: Visit to the Alaska Mine quarry, from which oxidised copper ore, mainly malachite, was mined for centuries by the indigenous population in the pre-colonial era.

The mineralization at Alaska Mine (Fig. 31) occurs in highly sheared dolomites and intercalated sandstones and siltstones of the Lomagundi Group, and consists mainly of oxidised malachite ore, with some hypogene chalcocite or djurleite which occurs as pseudomorphs after pyrite, and minor chalcopyrite (McCann, 1928; Stagman, 1961; Newham, 1986). Sulphur isotopes of the sulphides range in $\delta^{34}S$ from +8.1 to -2.0 permil CDT (von Rahden and de Wet, 1984). The malachite occurs as paint-like films along cleavage planes and fractures. Other oxide minerals recorded are chrysocolla, cornetite, plancheite, shattuckite dioptase, cuprite and tenorite. Native copper occurs as dendritic crystals, and as sheets along fractures and faults. J.B.E. Jacobsen (1964) described the geology of the deposit, and interpreted the host rocks to be part of an allochthonous nappe that was bounded at the base by a major breccia zone. The nappe consisted of several imbricately stacked thrust sheets, in what would today be termed a duplex structure (Fig. 32). Newham (1986) reinterpreted the structure to be a simple syncline, as shown in his idealised cross-section of the deposit. This is at total variance with the detailed mapping of Jacobsen (1964) (Figs. 31 & 32), as well as with maps produced by the mine in 1970.

Examination of a sample from the sandstone orebody, which contains ‘chalcocite' pseudomorphs after pyrite, revealed convincing evidence for the timing of the mineralization.The ‘chalcocite’ was shown by XRD to be the first occurrence in Zimbabwe of the closely related mineral djurleite ($Cu_{31}S_{16}$) (Master, 1991). The djurleites, pseudomorphous after cubic pyrite, are deformed into parallelepipeds, and appear diamond-shaped in cross section. The host rock is a highly sheared metasiltsone,

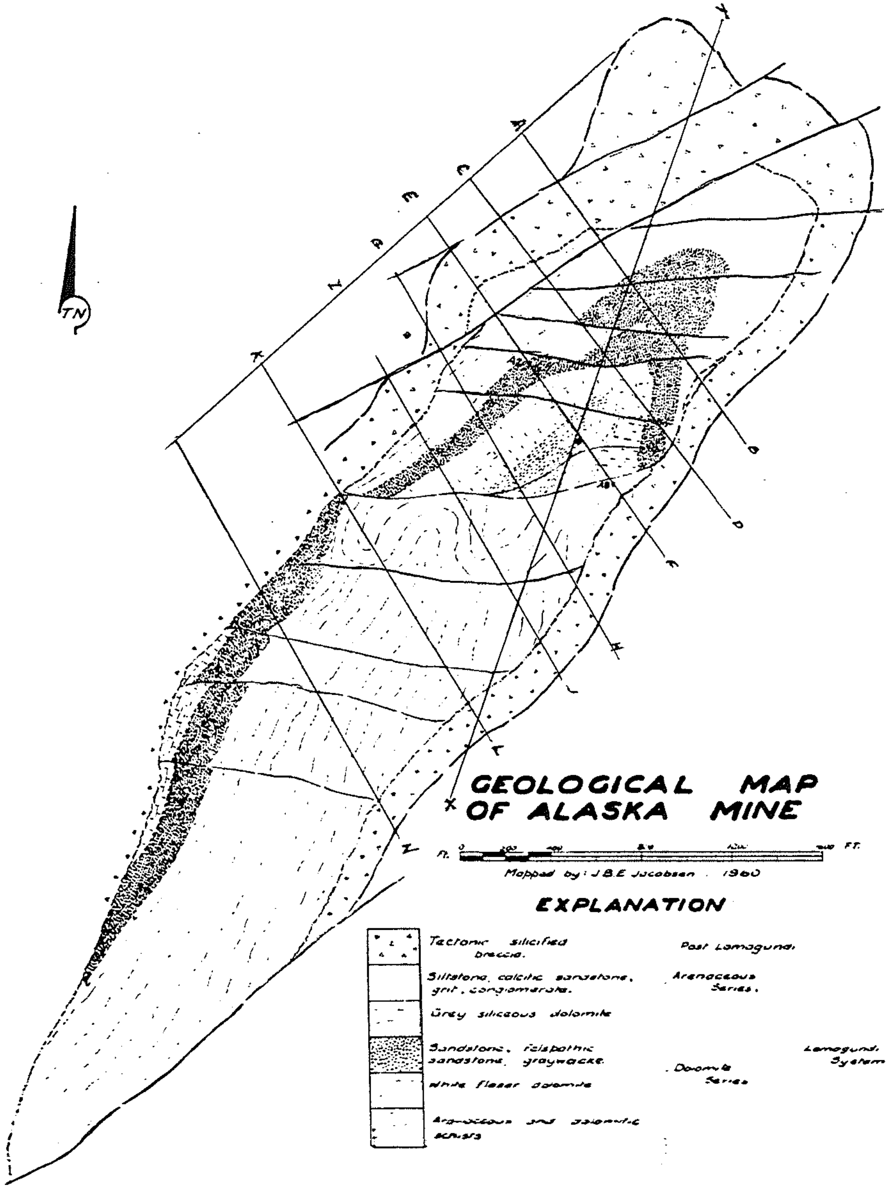


Figure 31: Geological map of Alaska Mine (after Jacobsen, 1964).

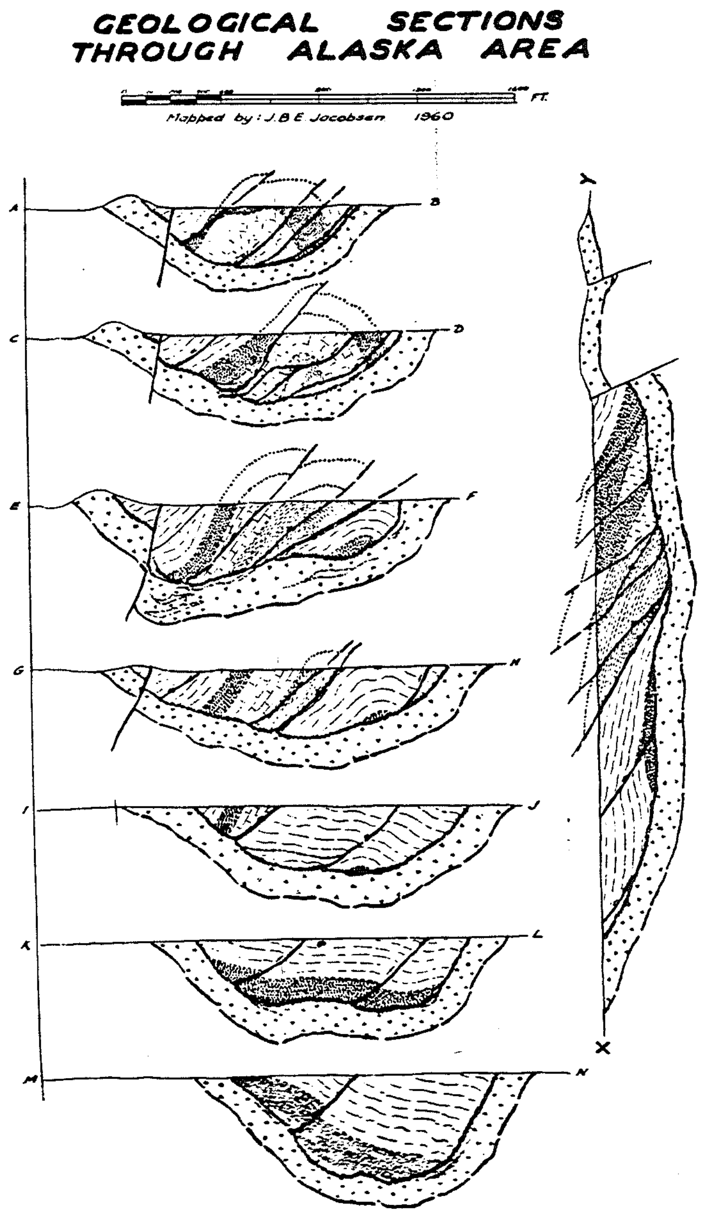


Fig. 32: Geological sections through Alaska Mine (after Jacobsen, 1964). The section lines are shown in Fig. 31.

which has shear planes with talcose partings, and which have a strong slickensided striation lineation, with steps at right angles to this. Fibrous minerals growing in the lee of the slickenside steps are oriented parallel to the lineation. The long axes of the deformed djurleite pseudomorphs are also aligned parallel to the lineation, and they appear to have stretched during simple shear. The djurleite pseudomorphs have quartz-rich pressure shadow fringes, indicating that the replacement took place after these fringes had formed around the earlier euhedral pyrites. If the djurleite replacement had taken place before any deformation, there would be no pressure shadows around the djurleites, but instead, because of the low grain boundary energy and strength of chalcocites, they would have been totally flattened into parallelism with the cleavage. The deformed pseudomorphs with pressure shadows indicate that the replacement must have happened syntectonically. A first increment of deformation produced a schistosity in the rock, and formed quartz pressure shadows around rigid pre-existing pyrite crystals. The rock was then infiltrated syntectonically by copper-bearing solutions moving along permeable cleavage and fracture planes, which replaced the pyrite by djurleite. The djurleites, with their inherited quartz pressure shadow fringes, then underwent further deformation, in which they behaved plastically, and suffered rotation and flattening by simple shear. A similar example of chalcocite pseudomorphs after euhedral pyrite has been recorded from the Klein Aub Mine in Namibia (Borg, 1987), but in this case the replacement was post-tectonic, since the chalcocites, with their quartz pressure shadows, are undeformed.

Stop 11.2: Halite casts, Nyagari Formation

At 32 km along the road from Alaska to Sanyati, there is a roadcut with exposures of siltites of the Nyagari Formation, of the Lomagundi Group, which contain halite casts in the form of hopper crystals.

Day 6

Stop 12: Sanyati Mine (Cu-Zn-Pb-Ag Massive Sulphide deposits)

The Sanyati polymetallic Cu-Zn-Pb-Ag massive sulphide deposits are situated about 100 km SW of Chinhoyi. They are expressed on surface as a line of spectacular malachite-stained ferruginous gossans which extend from the Copper King Dome to the Copper Queen Dome, over a strike length of about 25 km (Fig. 33). The deposits, including the Copper Queen, Copper King, Copper Joker and Copper Straight prospects, which are all developed along the same strike, were first pegged in 1910, and briefly worked for copper in 1918-1919. They subsequently went through a checkered history, including a major share fiasco in the 1920's), before being acquired by MTD in the 1950's. The deposits were taken over by ZMDC when MTD withdrew from Zimbabwe in 1985. In 1994 Reunion Mining (Zimbabwe) formed a joint venture with ZMDC to mine the oxidised part of the deposit. The only prospect that has been extensively drilled and developed underground is the Copper Queen prospect (J-Lines) (Fig. 34), where about 14.2 million tonnes of ore, grading at about 1.2% Cu, 3.2 % Zn and 0.9% Pb, was proven.

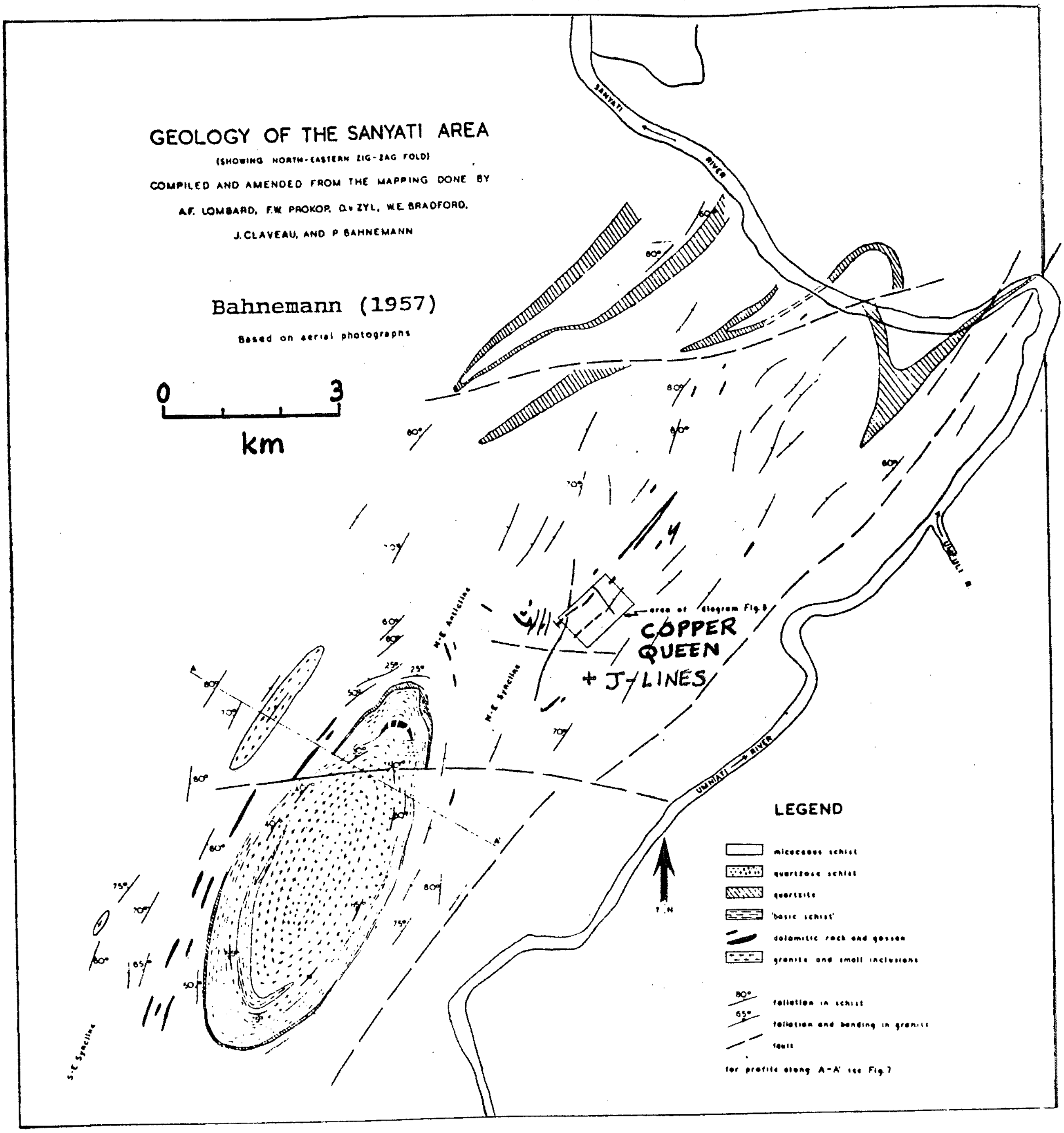
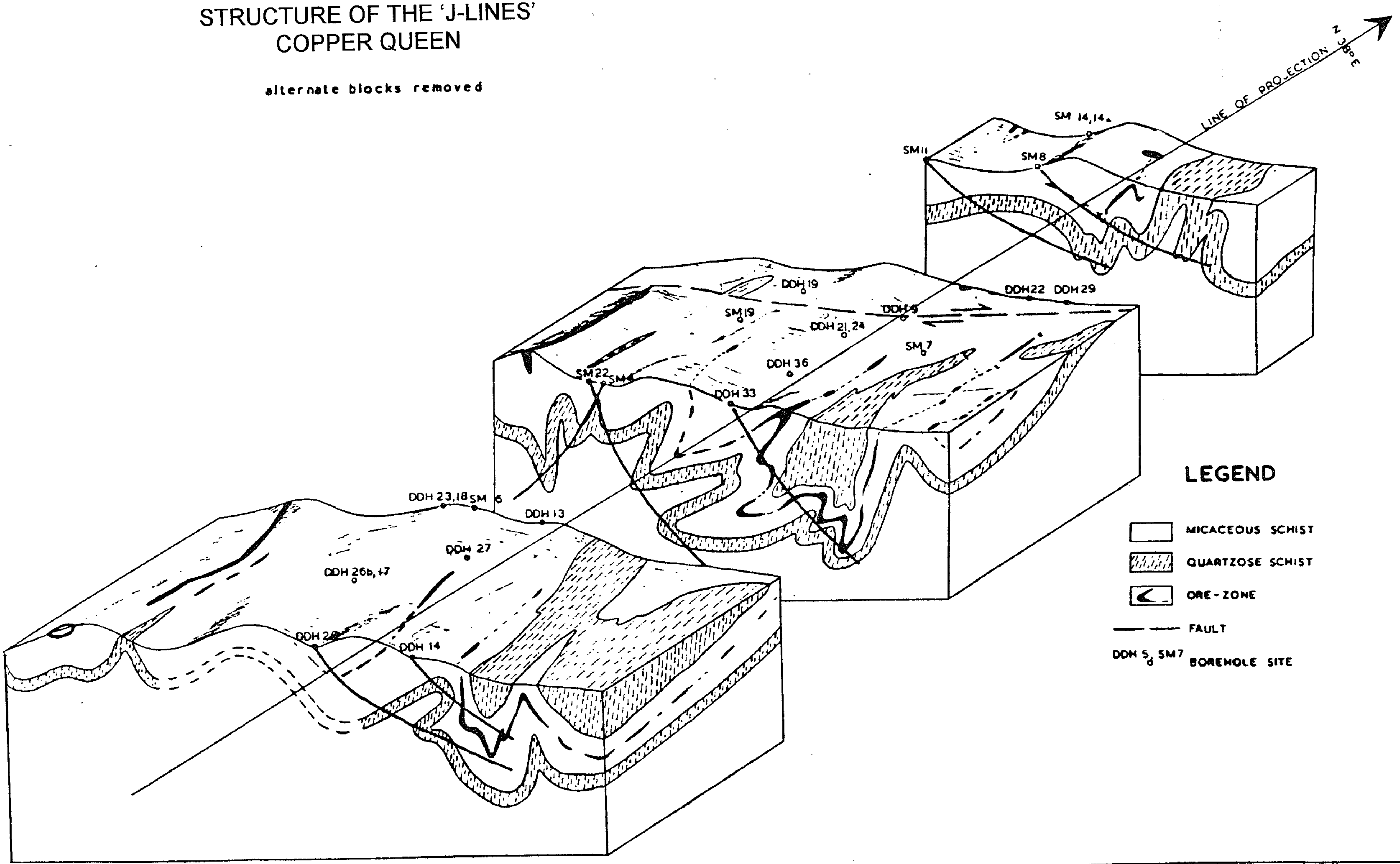


Fig 33: Geological sketch map of the Sanyati area (after Bahnemann, 1957).

Figure 34: (Bahnemann, 1957)

STRUCTURE OF THE 'J-LINES'
COPPER QUEEN

alternate blocks removed



The mineralization is closely associated with a band of tremolitic ferruginous dolomite marble which is surrounded by phyllites, schists and feldspathic quartzites. The hypogene ore minerals consist mainly of pyrrhotite, sphalerite, chalcopyrite, galena, arsenopyrite and pyrite, with minor magnetite, cubanite, valeriite and marcasite. Bahnemann (1957, 1961) suggested that the Sanyati deposits were skarn deposits related to emplacement of the Copper Queen and Copper King domes, but the style of mineralization shows great similarities with the class of sediment-hosted volcanogenic massive sulphide deposits referred to as "Besshi-type VMS" deposits. The continuity of the gossans over 25 km indicates that the Sanyati deposits have the potential to be a major ore district.

References

Armstrong,I.H. (1975). Geology of the Lynx Graphite Mine. B.Sc. Spec. Hons. thesis (unpubl.), Univ. Rhodesia.

Bahnemann,K.P. (1957). The ores of the "J-Lines", Sanyati Copper Mine, Southern Rhodesia. M.Sc. thesis (unpubl.), Univ. Pretoria.

Bahnemann,K.P. (1961). The ores of the "J-Lines", Sanyati Copper Mine, Southern Rhodesia. Trans. geol. Soc. S. Afr., 44, 193-220.

Bartholomew,D.S. (1990). Gold deposits of Zimbabwe. Geol. Surv. Zimbabwe, Mineral Resources Series No. 23, 75 pp.

Bartholomew,D.S. (in prep.). The geology of the Doma North area. Bull. Geol. Surv. Zimbabwe.

Borg,G. (1987). Controls on stratabound copper mineralization at Klein Aub Mine and similar deposits within the Kalahari Copperbelt of South West Africa/Namibia and Botswana. Ph.D. thesis (unpubl.), Univ. Witwatersrand, Johannesburg, 107 pp.

Broderick,T.J. (1976). Explanation to the geological map of the country east of Kariba. Geol. Surv. Rhod. Short Rept. No. 43, 98 pp.

Broderick,T.J. (1981). The Zambezi Metamorphic Belt in Zimbabwe, 739-743. In: Hunter,D.R. (Ed.), Precambrian of the Southern Hemisphere. Elsevier, Amsterdam, 822 pp.

Chenjerai,K.G. (1988). A preliminary report on the geology north of Chenanga. Annals Geol. Surv. Zimbabwe, Vol. XIII 1987, 1-7.

Condie,K.C. and Harrison,N.M. (1976). Geochemistry of the Archean Bulawayan Group, Midlands greenstone belt, Rhodesia. Precambrian Res., 3, 252-271.

Davies,B.J. (1982). Geophysical prospecting methods for graphite at the Lynx Mine area. M.Sc (Expl. Geophys.) thesis (unpubl.), Univ. Zimbabwe.

Hahn,L., Steiner,L., Bosum,W., Damaske,D., Höhndorf,A., Kreuzer,H., Ott,G., and Resch,M. (1990). Geology and mineral prospecting in the Makonde and Guruve Districts, Zimbabwe. Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Technical Cooperation Project No. 8421703, File No. 106842, 295 pp.

Harper,G. (1973). Metamorphism in the southern Urungwe district, norththwestern Rhodesia. Spec. Publ. geol. Soc. S. Afr., 3, 127-130.

Hitchon,B. (1958). The geology of the Kariba area. Geol. Surv. N. Rhod., Report no.3.

Jacobsen,J.B.E. (1964). The geology of the Alaska Mine, Southern Rhodesia, 353-366. In: Haughton,S.H.(Ed.), The Geology of Some Ore Deposits in Southern Africa, II, Geol. Soc. S. Afr., Johannesburg, 739 pp.

Kirkpatrick,I.M. (1976). The geology of the country around Tengwe, Lomagundi District. Bull. Geol. Surv. Rhod., 75.

Kirkpatrick,I.M and Robertson,I.D.M. (1987). A geological reconnaissance of the Makuti-Kariba road-1968. Ann. Geol. Surv. Zimbabwe, vol. XII 1986, 1-7

Kukla,P.A. and Stanistreet,I.G. (1990). The Khomas Hochland accretionary prism of the Damara orogen, Central Namibia. Abstract, Geocongress '90, Geol. Soc. S. Afr., Cape Town, 309-312.

Leyshon,P.R. (1973). Two granite-gneiss domes in the Copper Queen area, Rhodesia. Spec. Publ. geol. Soc. S. Afr., 3, 97-109.

Loney P.E. (1969). The geology of the Kariba District, Rhodesia, with special reference to geochemistry and amphibolite petrochemistry. Ph.D. thesis (unpubl.), Leeds Univ. Abstract in 14th ann. Rep. res. Inst. Afr. geol., Univ. Leeds (1970), p.19.

Master,S. (1991). The origin and controls on the distribution of copper and precious-metal mineralization at the Mangula and Norah mines, Mhangura, Zimbabwe. Ph.D. thesis, Univ. Witwatersrand, Johannesburg, 385 pp.

Master,S. (1995). Alluvial fan, aeolian dune and evaporitic playa lake sedimentation, and syn-sedimentary tectonics in the Deweras Group (Zimbabwe): a 2 Ga-old analogue of the Dead Sea strike-slip basin. Centennial Geocongress Geol. Soc. S. Afr., 3-7 April 1995, Rand Afrikaans University, Johannesburg, South Africa, Extended Abstracts, II, 834-837.

Master,S., Armstrong,R.A., Brandt,D., Ferraz,M.F.F., Gumede,T., Koeberl,C., Reimold,W.U., Robertson,D.J., Woldai,T. and Zeil,P. (1995). New geological, geophysical and remote sensing data from the Highbury impact structure, Zimbabwe. Lunar and Planetary Science, XXVI, 903-904.

McCann,W.S. (1928). Unpubl. Rept. on Alaska Mine. Quoted in Tyndale-Biscoe and Stagman, 1958.

Muchemwa,E. (1987). Graphite in Zimbabwe. Geol. Surv. Zimbabwe Min. Res. Series No. 20, 15 pp.

Munyanyiwa,H. and Blenkinsop,T.G. (1992). The relationship between Magondi Mobile Belt (Ubendian) and the Zambezi Mobile Belt (Pan-African) in northern Zimbabwe. Extended Abstracts, 16th Colloq. Afr. Geol., Mbabane, Swaziland, 224-226.

Munyanyiwa,H., Hanson,R.E., Blenkinsop,T.G. and Treloar,P.J. (1996, in press). Geochemistry of amphibolites and quartzofeldspathic gneisses in the Pan-African Zambezi belt, northwest Zimbabwe: evidence for bimodal magmatism in a continental rift setting. Precambrian Res., 79.

Newham,W.D.N. (1986). The Lomagundi and Sabi metallogenic provinces of Zimbabwe, 1351-1393. In: Anhaeusser,C.R. and Maske,S. (Eds.), Mineral Deposits of Southern Africa, II, Geol. Soc. S. Afr., 2335 pp.

Prost,A.E. (1982). A preliminary report on the geology of the country north of Centenary. Ann. Zim. Geol. Surv., VII 1981, 20-27.

Stagman,J.G. (1961a). The geology of the country around Sinoia and Banket, Lomagundi District. Bull. Geol. Surv. S. Rhod., 49, 107 pp.

Stowe,C.W., Hartnady,C.J.H. and Joubert,P. (1984). Proterozoic tectonic provinces of Southern Africa. Precambrian Res., 25, 229-231.

Treloar,P.J. (1988). Geological evolution of the Magondi Mobile Belt, Zimbabwe. Precambrian Res., 68, 55-73.

Treloar,P.J. and Kramers,J.D. (1989). Metamorphism and geochronology of granulites and migmatitic granulites from the Magondi Mobile Belt, Zimbabwe. Precambrian Res., 45, 277-289.

Tyndale-Biscoe,R. and Stagman,J.G. (1958). Copper deposits in Southern Rhodesia. Joint Meeting, East-Central, West-Central and Southern Reg. Comm. Geol., C.C.T.A., Leopoldville, 181-195.

von Rahden,H.V.R. and de Wet,J.J. (1984). Copper mineralization at the Shackleton Mine, Zimbabwe: syngenetic or epigenetic? In: Wauschkuhn,A. et al. (Eds.), Syngenesis and Epigenesis in the Formation of Mineral Deposits, 192-211. Springer-Verlag, Berlin Heidelberg.

Watkeys,M.K. (1984). The Precambrian geology of the Limpopo Belt north and west of Messina. Ph.D. thesis (unpubl.), Univ. Witwatersrand, Johannesburg, 349 pp.

Wiles,J.W. (1961a). The geology of the Miami Mica Field. Bull. Geol. Surv. S. Rhod., 51, 235 pp.

Wiles,J.W. (1968). Some aspects of the metamorphism of the Basement Complex in the Sipolilo District. Trans. geol. Soc. S. Afr., Annex., 71, 79-88.

Wilson,J.F., Bickle,M.J., Hawkesworth,R.J., Martin,A., Nisbet,E.G. and Orpen, J.L. (1978). The granite-greenstone terrains of the Rhodesian Archaean craton. Nature, 271, 23-27.

Workman,D.R. and Cowperthwaite,I.A. (1963). An occurrence of kyanite pseudomorphing andalusite, from Southern Rhodesia. Geol. Mag., 100, 456-466.

Worst,B.G. (1960). The Great Dyke of Southern Rhodesia. Bull. Geol. Surv. S. Rhod., 47.

oOo