Geological Society of Zimbabwe Macgregor Memorial Lecture 2022

Geological Evolution and Metallogeny of the Palaeoproterozoic Magondi Belt, Zimbabwe and Botswana

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Part 1

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Bulawayo 24 October 2022

My main collaborators: Sarah Glynn (Wits), Michael Wiedenbeck (Potsdam), Richard Armstrong (Canberra), Jan Kramers (Johannesburg), Andrey Bekker (Riverside), Axel Hofmann (Johannesburg

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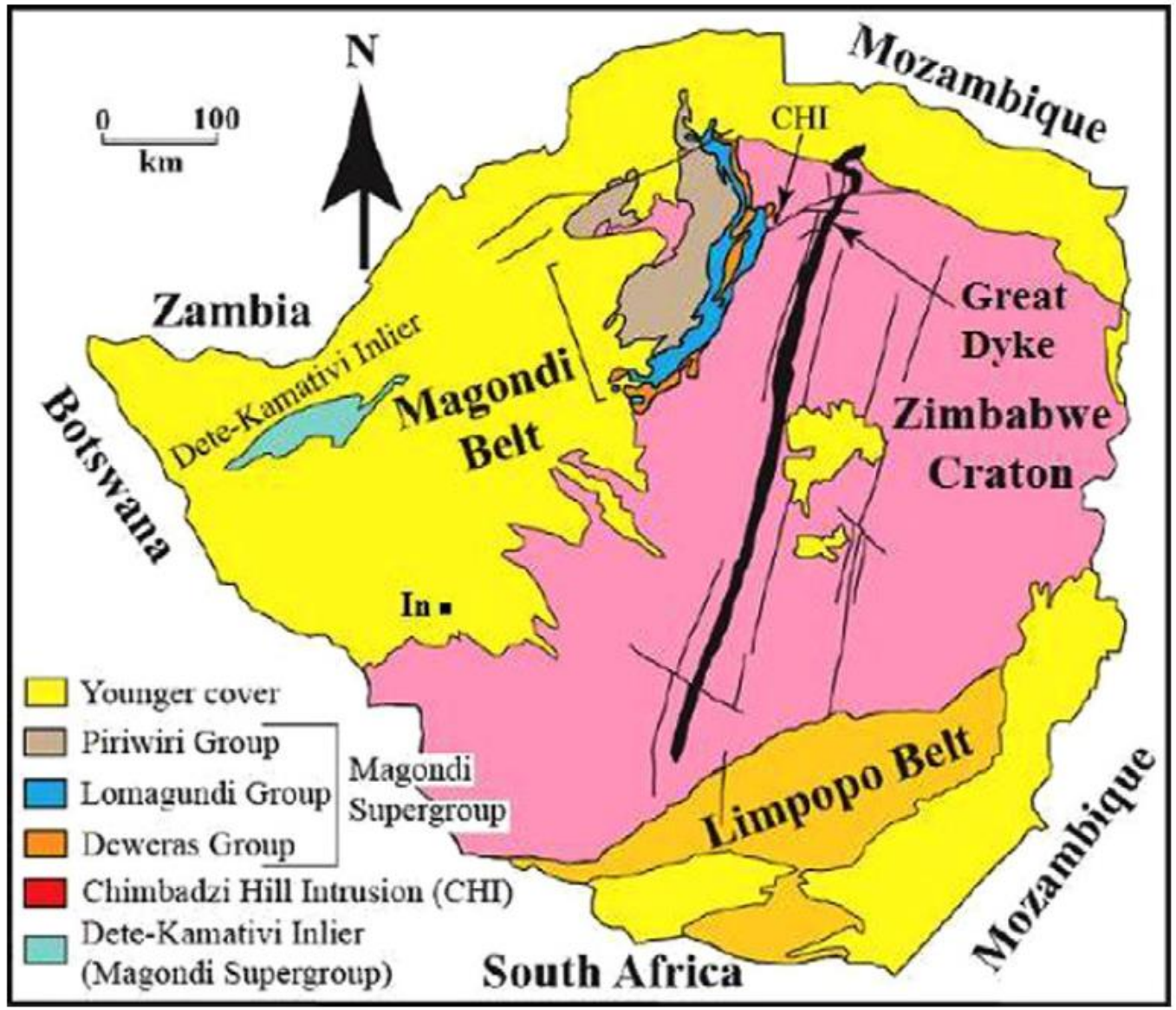
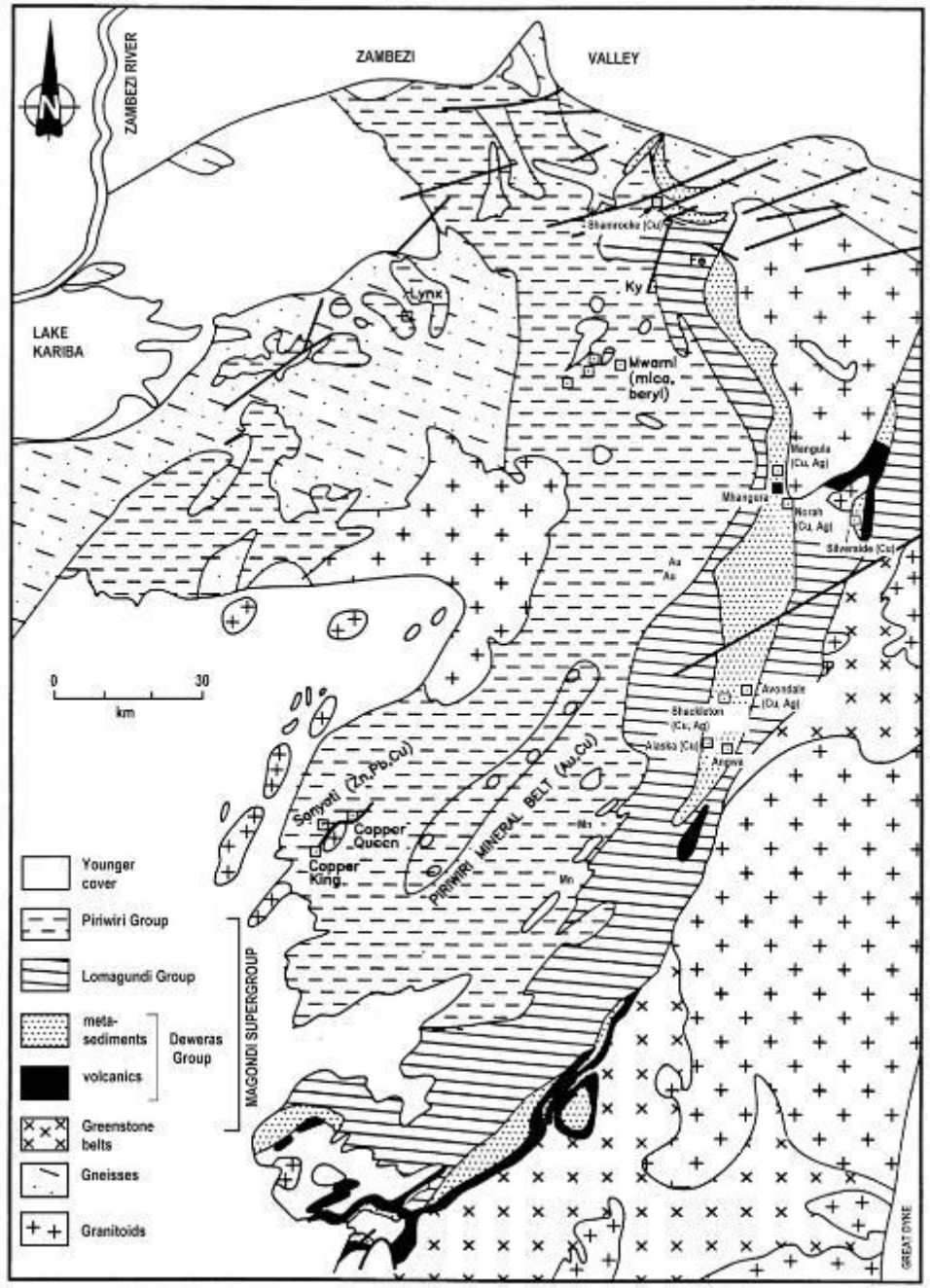
SEG Tim Nutt Memorial Fund
GFZ, Potsdam, Germany


Air Alliance

Simplified Geology, Zimbabwe Craton



Master et al. (2010), Precambrian Research

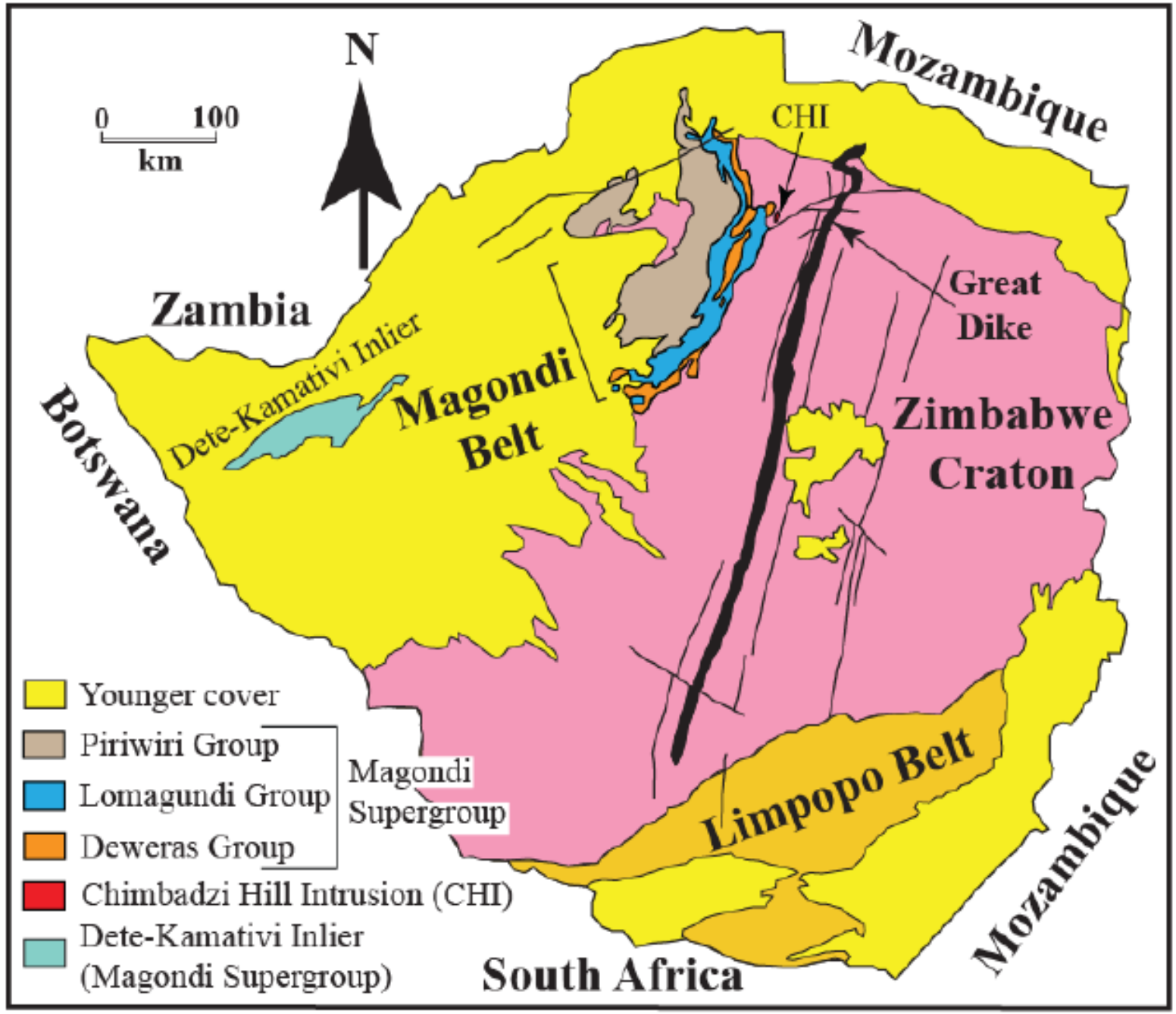

ZAMBEZI
VALLEY
ZAMBEZI RIVER
LAKE
KARIBA
Lynx
Shamrocke (Cu)
Ky
Fe
Mwami
(mica, beryl)
Mangula
(Cu, Ag)
Mhangura
Norah
(Cu, Ag)
Silverside (Cu)
As
As
Avondale
(Cu, Ag)
Shackleton
(Cu, Ag)
Alaska (Cu)
Angwa
PIRIWIRI MINERAL BELT (Au,Cu)
Sanyati (Zn,Pb,Cu)
Copper Queen
Copper King
Mn
Mn
0
30
km
Younger cover
Piriwiri Group
Lomagundi Group
meta-sediments
volcanics
Deweras Group
Greenstone belts
Gneisses
Granitoids
MAGONDI SUPERGROUP
GREAT DYKE

Generalised stratigraphy, lithology and environments of the Magondi Supergroup.

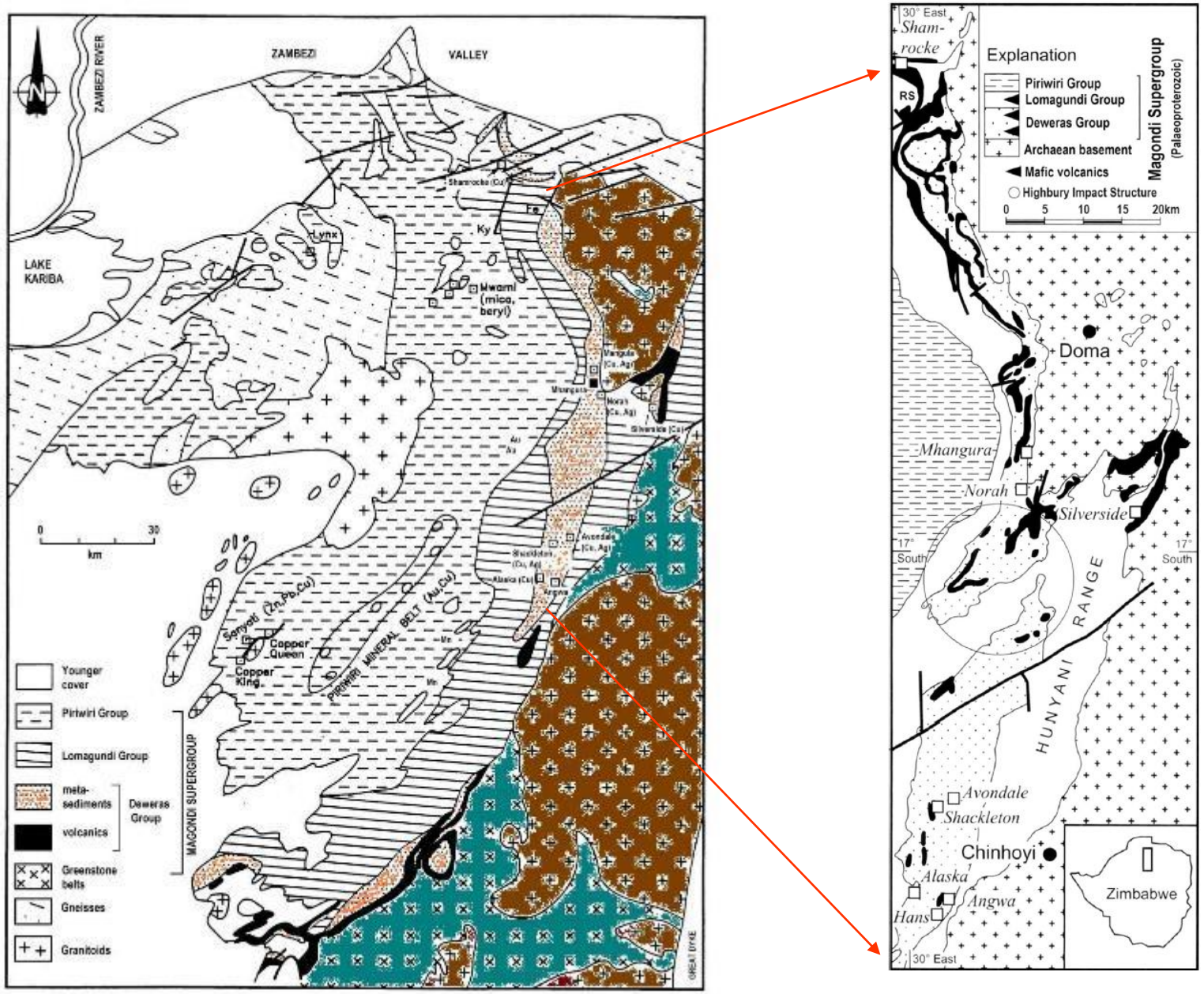
Group	Lithology	Environment
Piriwiri	graphitic schists, wackes, cherts, siltites, phyllites, greywackes, agglomerates, andesitic to felsic lavas, tuffs and agglomerates, dolomites, massive sulphides, Mn beds	Deep marine, distal shelf, continental slope, submarine fan
Lomagundi	conglomerates, arkosic arenites, orthoquartzites, stromatolitic dolomites, banded iron-formation, striped and graphitic slates, felsites, agglomerates, wackes.	Marginal marine (peritidal) and shallow storm-dominated shelf
	---------- unconformity ----------	
Deweras	conglomerates, arkosic arenites, siltites, argillites, dolomites, evaporates, basaltic lavas and pyroclastics	Continental alluvial fans, braided streams, playa flats, aeolian dunes,playa lakes

---------- unconformity ----------

Basement Complex (Archaean granite-greenstone terrain of Zimbabwe Craton)


N
0 100
km
Mozambique
CHI
Zambia
Great
Dike
Dete-Kamativi Inlier
Magondi
Belt
Botswana
Zimbabwe
Craton
Younger cover
Piriwiri Group
Lomagundi Group
Deweras Group
Magondi
Supergroup
Chimbadzi Hill Intrusion (CHI)
Dete-Kamativi Inlier
(Magondi Supergroup)
Limpopo Belt
South Africa
Mozambique

Deweras Group- basal part of Magondi Supergroup, unconformably overlying Archean granite-greenstone terrain of Zimbabwe Craton



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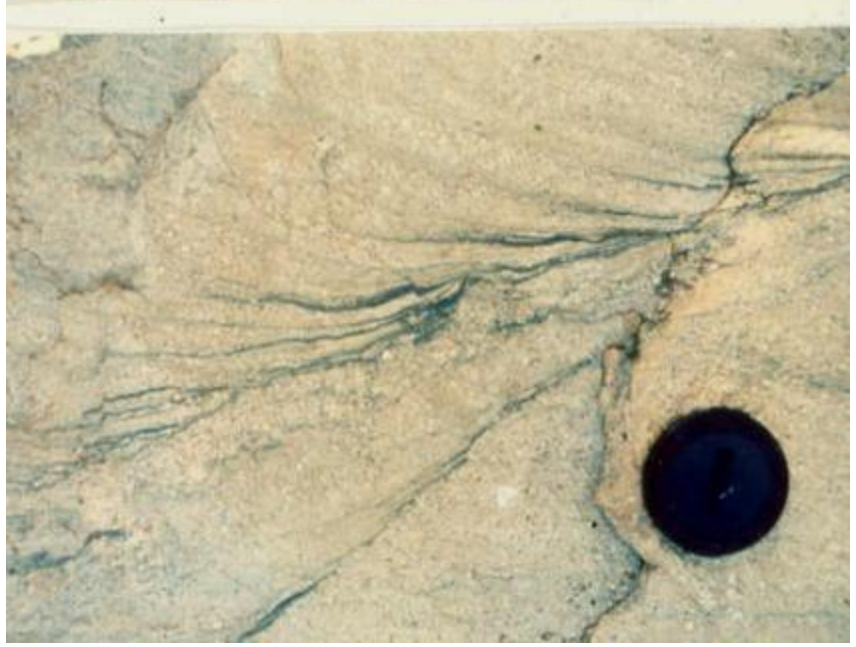
	---------- unconformity ----------	
Deweras	conglomerates, arkosic arenites, siltites, argillites, dolomites, evaporites, basaltic lavas and pyroclastics aeolian dunes	Continental alluvial fans, braided streams, playa flats, playa lakes
	---------- unconformity ----------	
Basement Complex	(Archaean granite-greenstone terrain of Zimbabwe Craton)	

- The **Deweras Group**, the basal part of the Paleoproterozoic **Magondi Supergroup**, unconformably overlies the Neoarchaean granite-greenstone terrain of the Zimbabwe Craton.

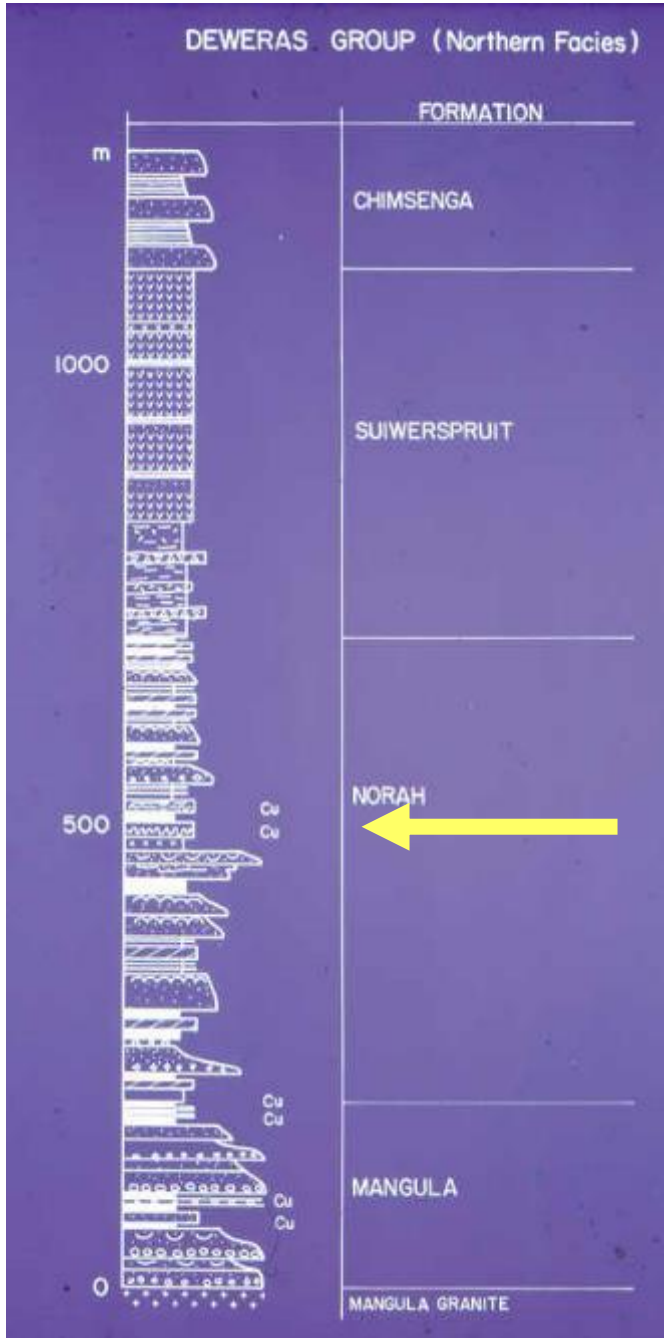
- It comprises a red bed sequence, up to 1.3 km thick, of meta-arenites, rudites, pelites and minor dolostones and sulfate evaporites, together with subalkaline basaltic lavas, pyroclastic rocks, and sills (Master et al., 2010, Prec. Res.).



Fluvial, trough-crossbedded arkoses in Deweras Group with abundant detrital magnetites on trough-crossbed foresets.

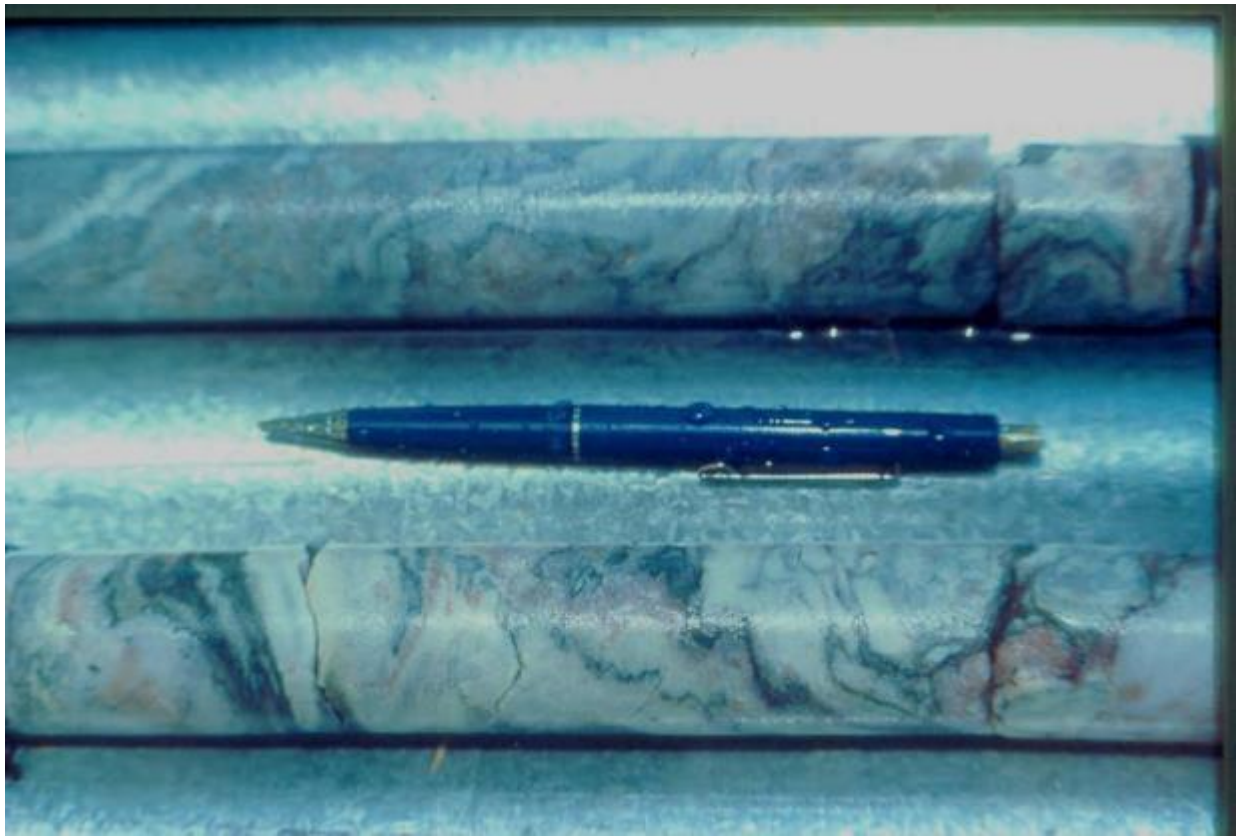
Braided river environment,

Mangula Formation

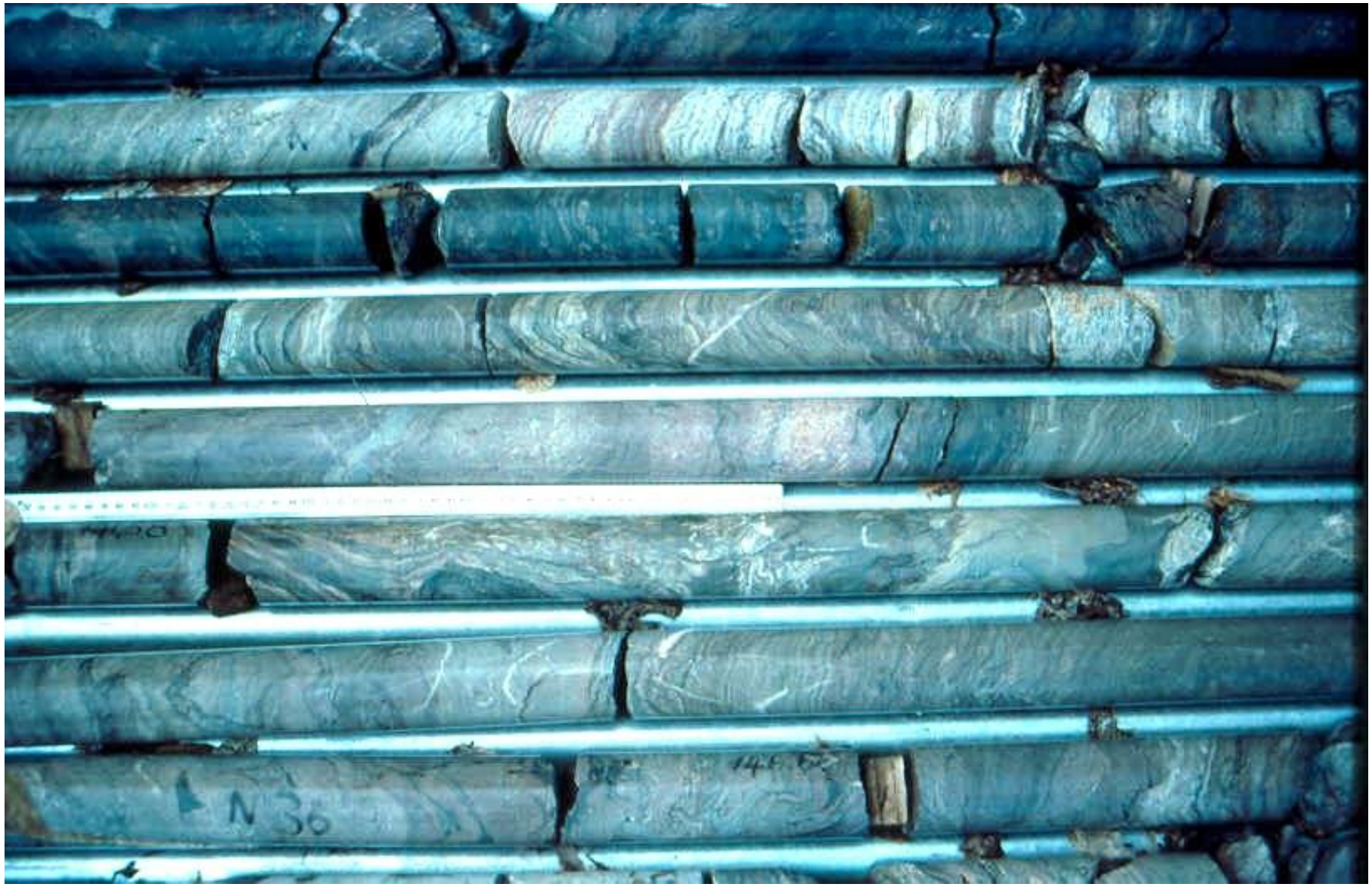


Norah Formation

Playa lake facies-
Anhydrite-bearing dolomite



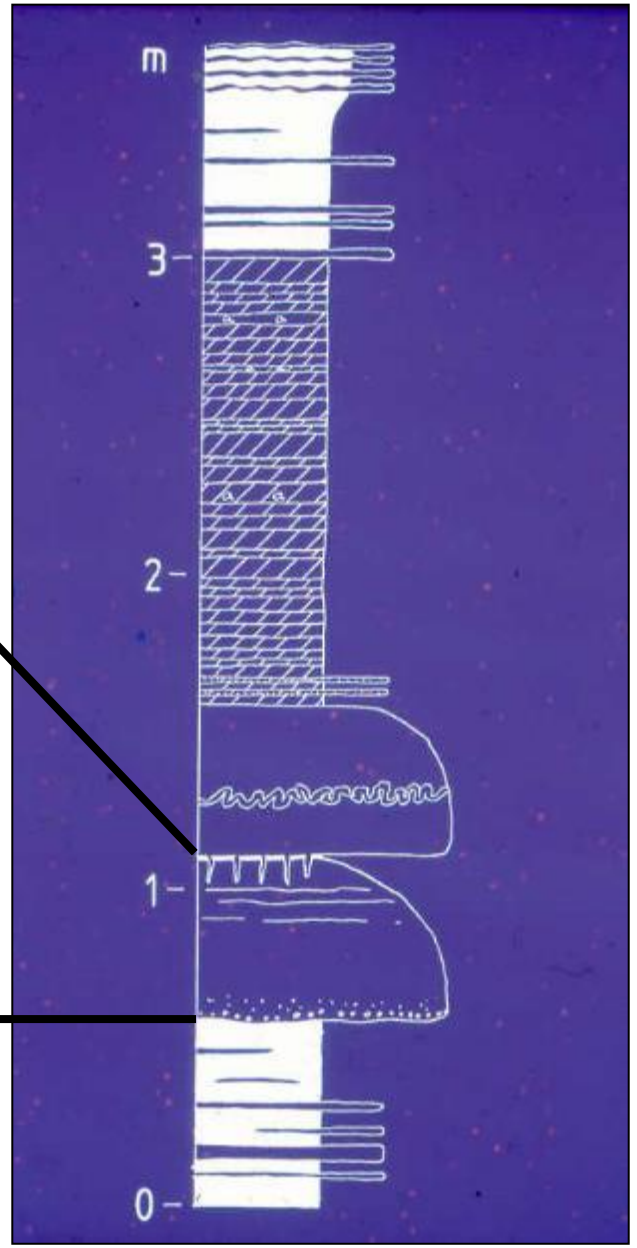
Norah Formation playa flat and playa lake beds-
arkoses interbedded with anhydrite-bearing dolomites



Norah Formation, Deweras Group

Playa Flat Facies

Graded beds going from conglomerates with angular rip-up clasts of dolomite to subaerially mudcracked shales

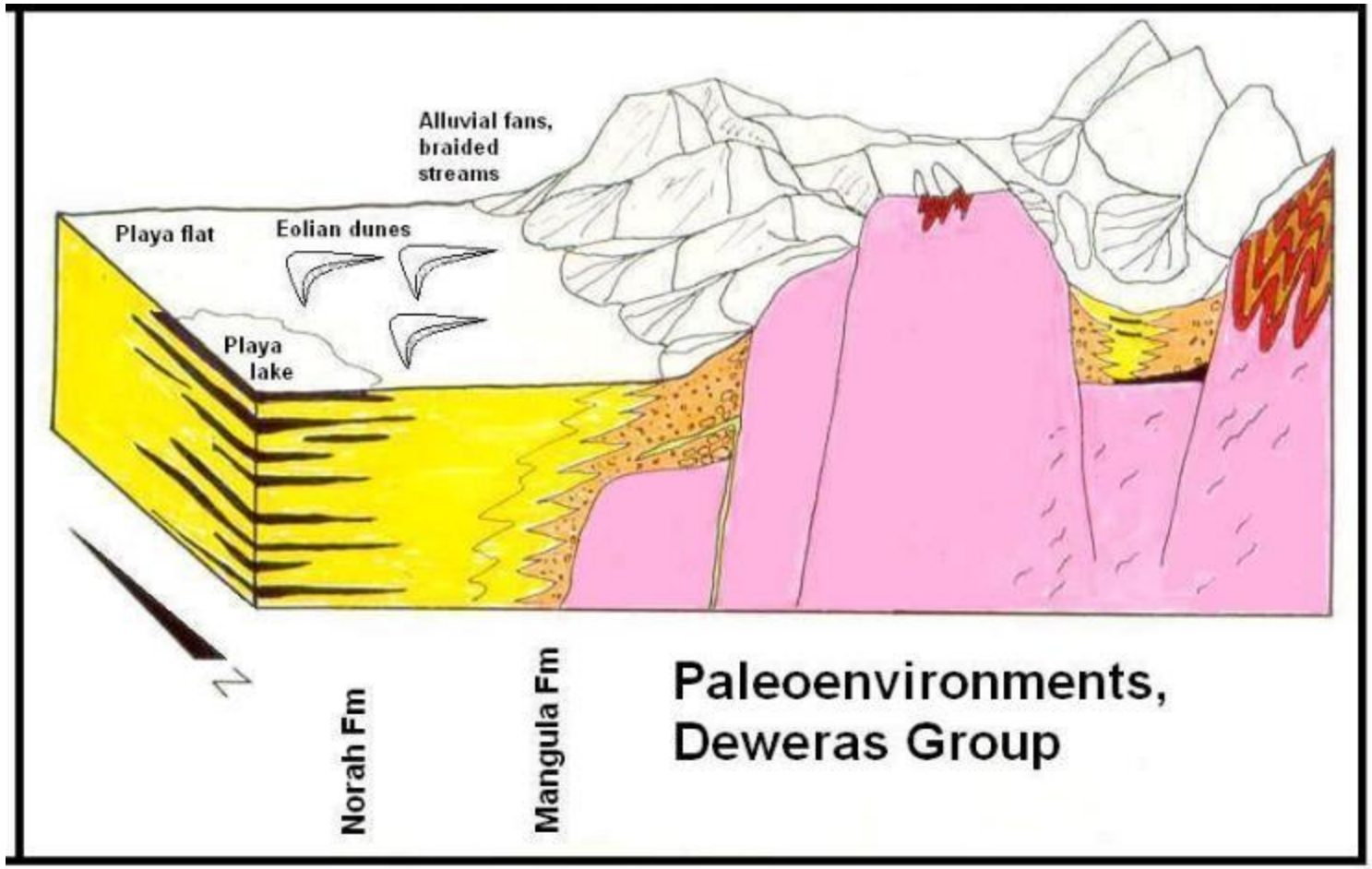


2.1 Ga-old preserved anhydrite evaporites

Ripple cross-laminated reworked dolomite-anhydrite, formed on the shores of an ephemeral continental playa lake, overlying eolian facies, Deweras Group at Avondale Mine, 10 L Haulage

Depositional environments

The **Deweras Group** was deposited in rift-related continental alluvial fan, braided stream, playa flat, playa lake and eolian environments.



Age of Deweras Group

- Detrital zircon SHRIMP U-Pb dating gives a **maximum age of 2171 ± 11 Ma** for the basal Deweras sedimentary rocks, which are overlain by **ca. 2070 Ma** Lomagundi Group rocks (Glynn et al., 2012, IMSG Meeting Abstr., Johannesburg).

Youngest detrital zircon from basal Deweras Group sedimentary rocks is dated at 2171 ± 11 Ma, giving maximum age of Deweras Group.

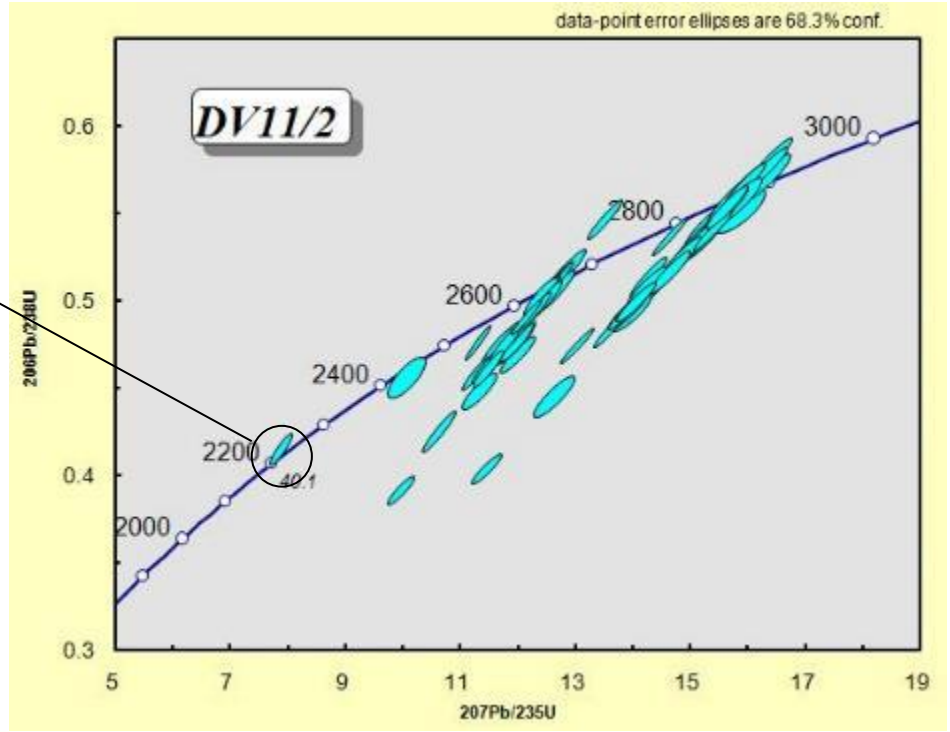


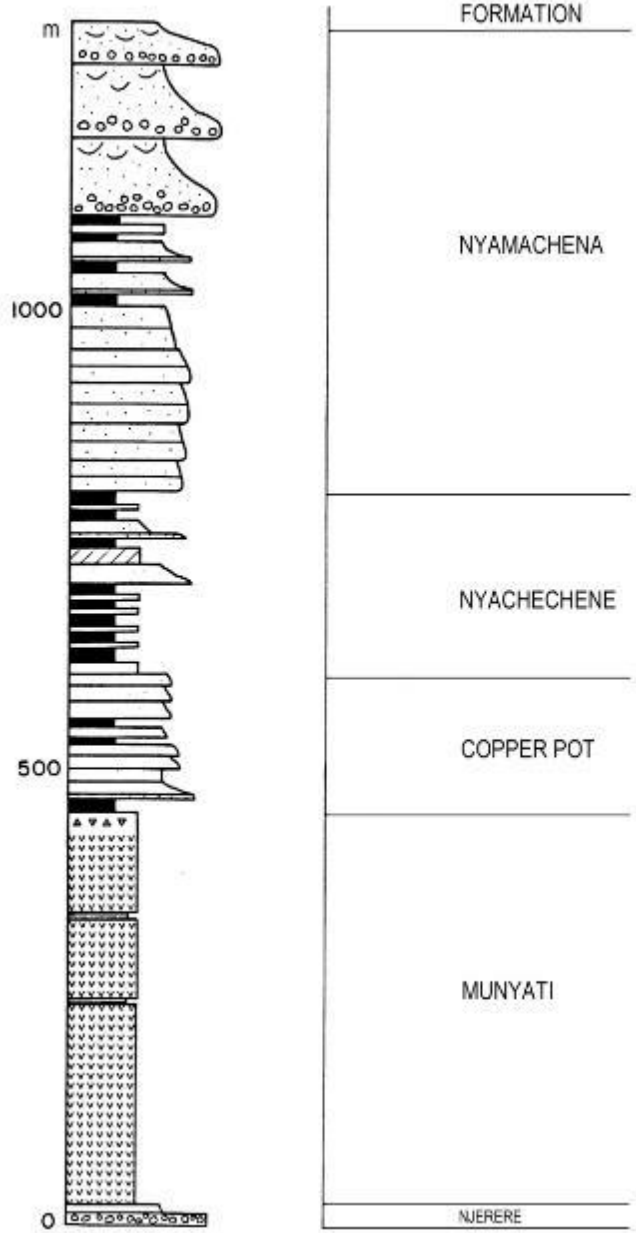
Table 3: Summary of the geochronology of the Magondi Belt

Rock Sequence	Age (Ma)	Method	Ref.	Interpretation
Dete-Kamativi				
Granite	2000 ± 80	Rb-Sr WR	1	Postorogenic intrusion
Granodiorite	2159 ± 100	Rb-Sr WR	1	magmatic arc intrusion
Gweta paragneiss	<2125	U-Pb zircon	2	detrital zircon (maximum age)
Kubu Is. Granite	2039.2 ± 1.4	U-Pb zircon	3	syntectonic intrusion (min. age)
Hurungwe Granite	1997.5 ± 2.6	U-Pb zircon	4	syntectonic intrusion (min. age)
Piriwiri Group				
granulites	1890 ± 260	Rb-SR WR	5	metamorphism
granulites	1780 ± 280	Rb-Sr WR	5	metamorphism
granulites	1960-1940	zrc Pb evap.	6	metamorphism
phyllites	1753 ± 65	K-Ar WR	7	metamorphism
phyllites	1659 ± 50	K-Ar WR	7	metamorphism
Sanyati Massive				
Sulphides	2122 ± 14	Pb-Pb galena.	8	Deposition
Arenite	2140 ± 8	U-Pb zircon	9	detrital zircon (maximum age)
Lomagundi Group				
Striped Slates	1905 ± 70	K-Ar WR	7	metamorphism
Striped Slates	1974 ± 70	K-Ar WR	7	metamorphism
Dolomite	2150 ± 50	Pb-Pb	10	deposition
Arenite	2629 ± 10	U-Pb zircon	9	detrital zircon (maximum age)
Arenite	2643 ± 11	U-Pb zircon	9	detrital zircon (maximum age)
Deweras Group				
Microcline veins	550 ± 110	Rb-Sr WR	11	metamorphism
Galena in vein	c. 2000	Pb-Pb model	12	metamorphism
Dolomite	c. 2000	Pb-Pb	13	metamorphism
Mafic lavas	2050 ± 100	Rb-Sr WR	14	deposition/metam. overprint
Arkose	2623 ± 13	U-Pb zircon	9	detrital zircon (maximum age)
Chimbazi Hill				
Intrusive complex	2262 ± 2	U-Pb baddel.	15	Exensional phase intrusion

Summary of Geochronology: **Deposition** c. 2.2 Ga-> 2.0 Ga

Deformation and Metamorphism: c. 2.0 Ga; also 1.0; 0.55 Ga

DEWERAS GROUP (Southern Facies)



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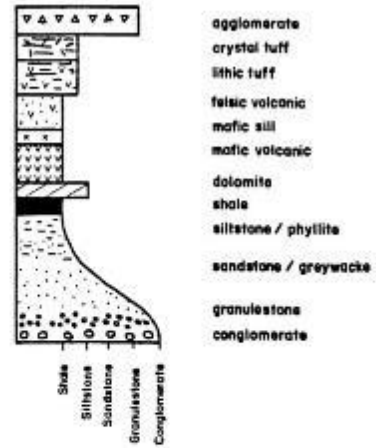
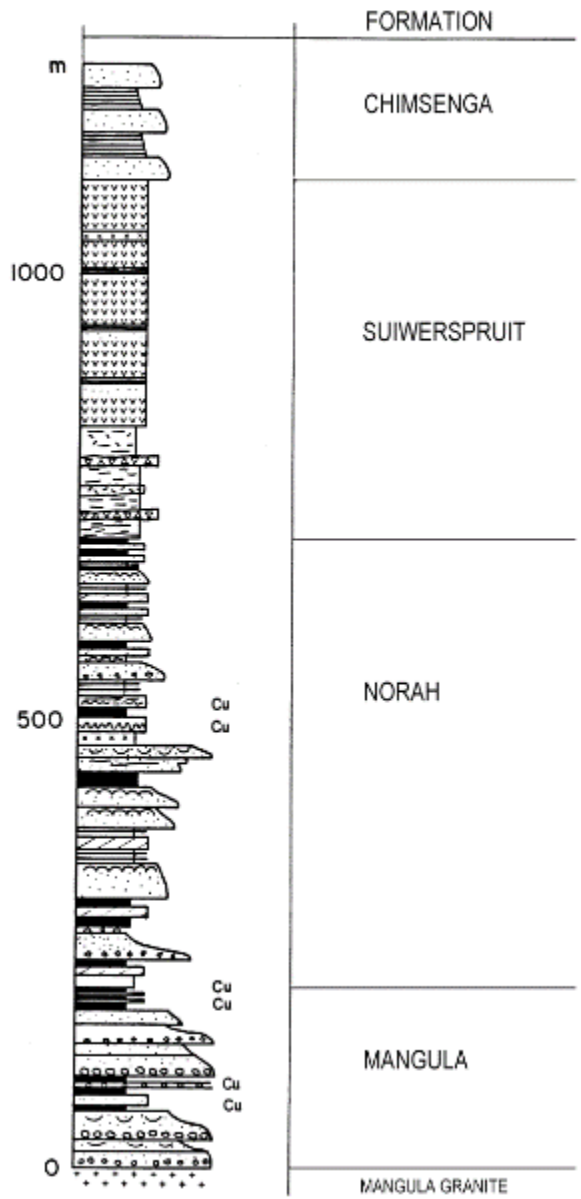


- Trough crossbeds
- Large-scale festoon crossbeds
- Pock marks
- Ripple marks
- Sole marks
- Flame structures
- Load casts
- Desiccation cracks
- Enterolithically folded anhydrite beds
- Stromatolites
- Oolites
- Conglomerate lenses

cu	copper sulphides
py	pyrite
gr	graphite
mn	manganese oxides
p	phosphate (collophanite)

DEWERAS GROUP (Northern Facies)



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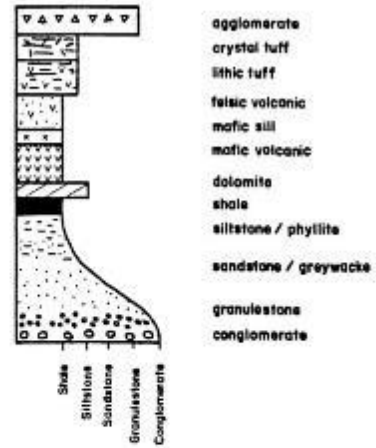
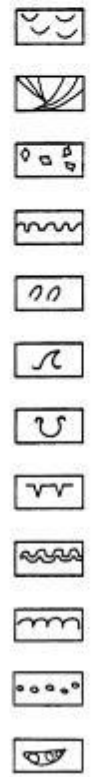




Trough crossbeds

Large-scale festoon crossbeds

Pock marks

Ripple marks

Sole marks

Flame structures

Load casts

Desiccation cracks

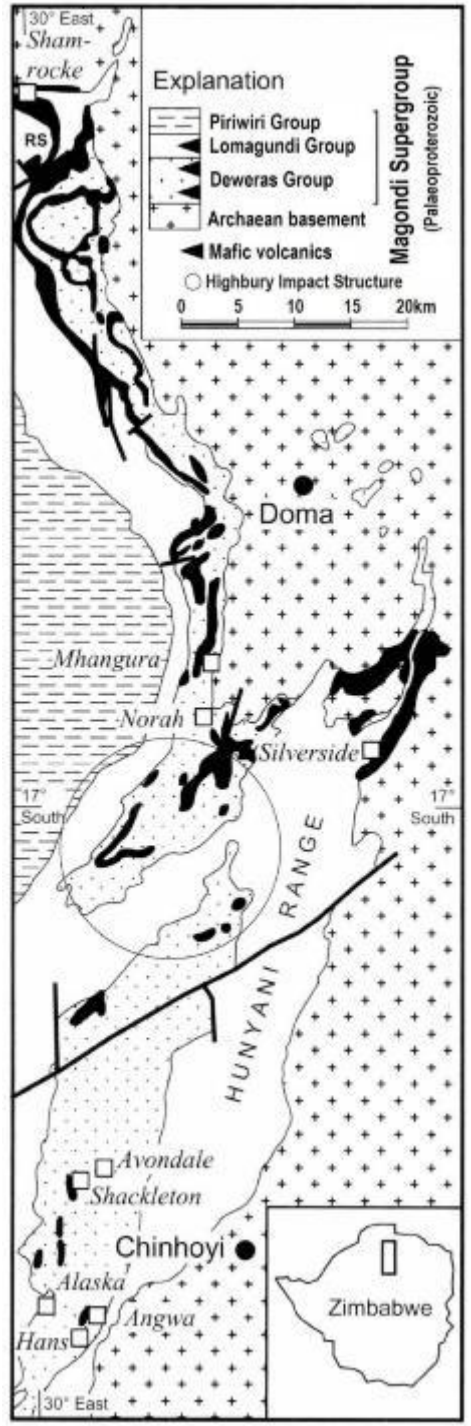
Enterolithically folded anhydrite beds

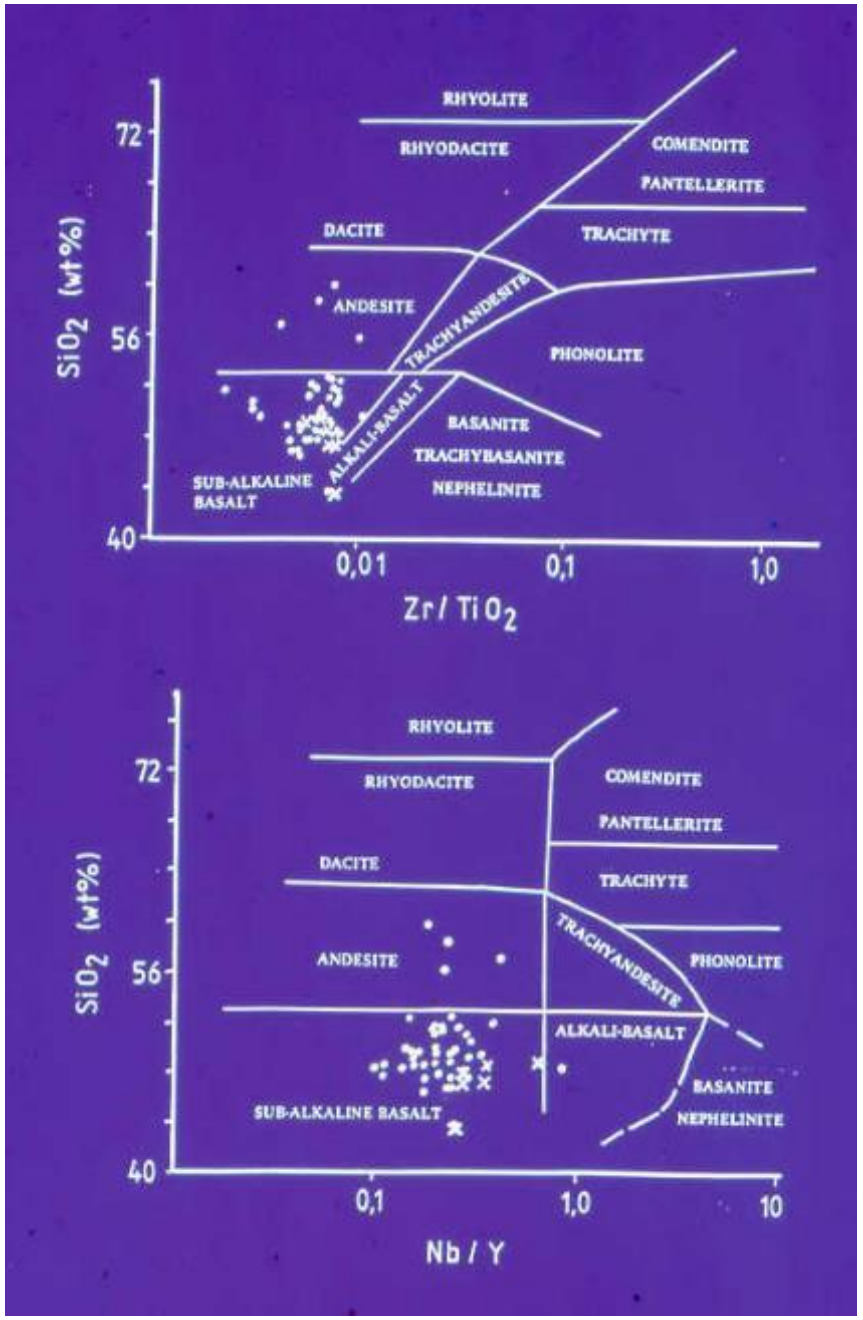
Stromatolites

Oolites

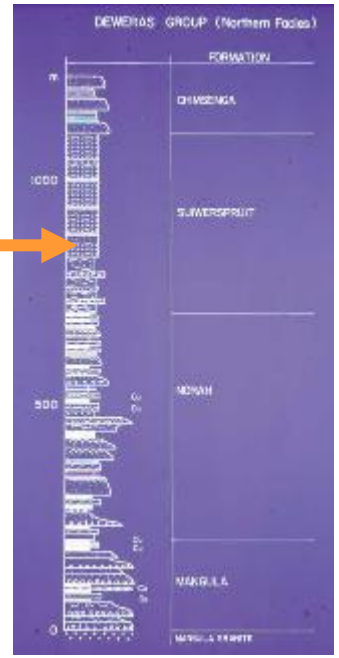
Conglomerate lenses

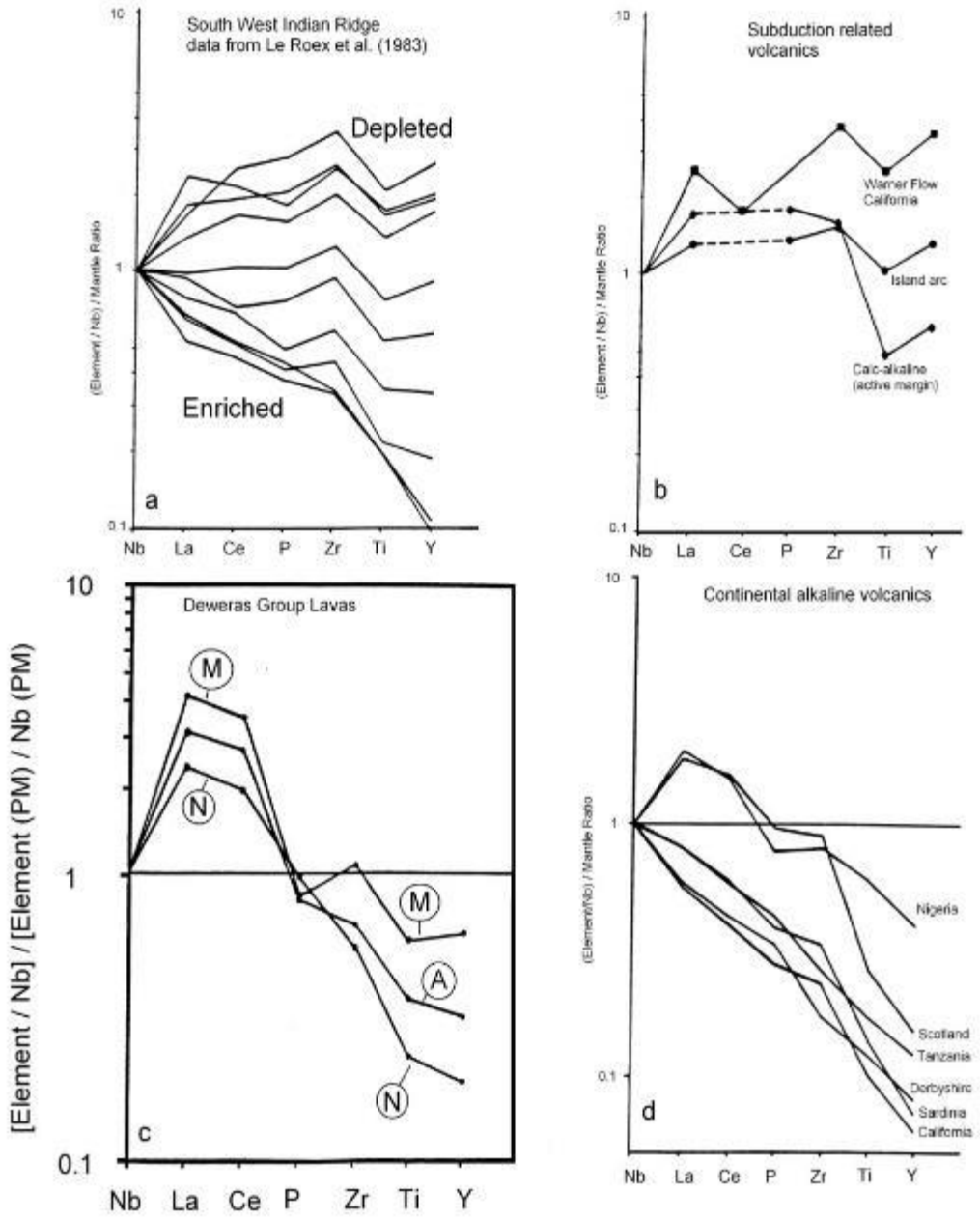
cu	copper sulphides
py	pyrite
gr	graphite
mn	manganese oxides
p	phosphate (collophanite)


30° East
Sham-
rocke
RS
Explanation
Piriwiri Group
Lomagundi Group
Deweras Group
Archaean basement
Mafic volcanics
Highbury Impact Structure
0 5 10 15 20km
Magondi Supergroup
(Palaeoproterozoic)
Doma
Mhangura
Norah
Silverside
17°
South
17°
South
RANGE
HUNYANI
Avondale
Shackleton
Chinhoyi
Alaska
Angwa
Hans
30° East
Zimbabwe



Deweras lavas: subalkaline continental rift tholeiites





Deweras Volcanics are continental tholeiites, and showed enriched mantle-normalized trace element patterns, with La and Ce anomalies attributed to crustal contamination.

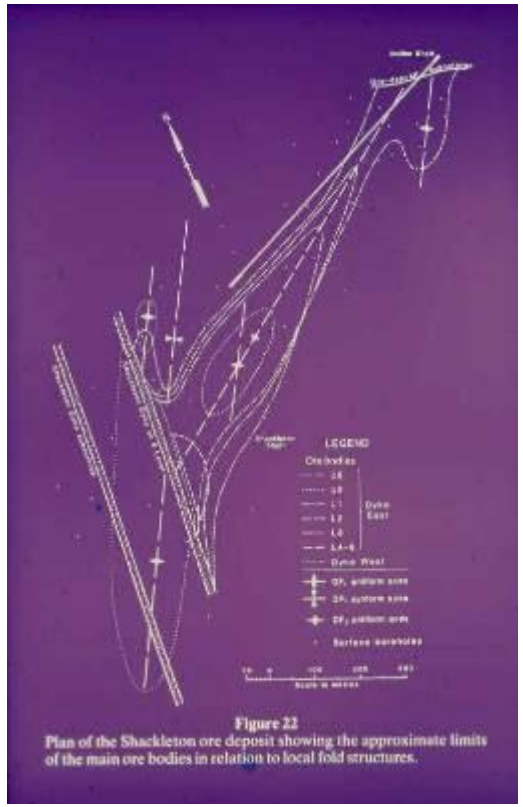
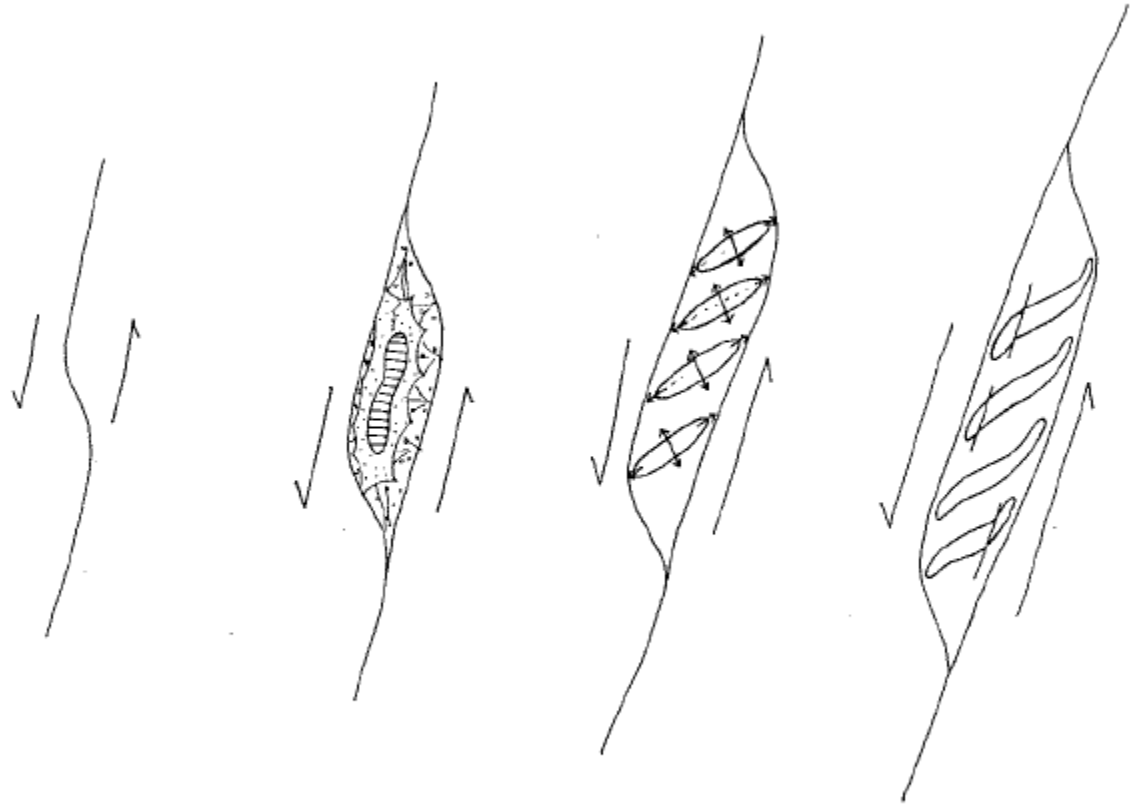
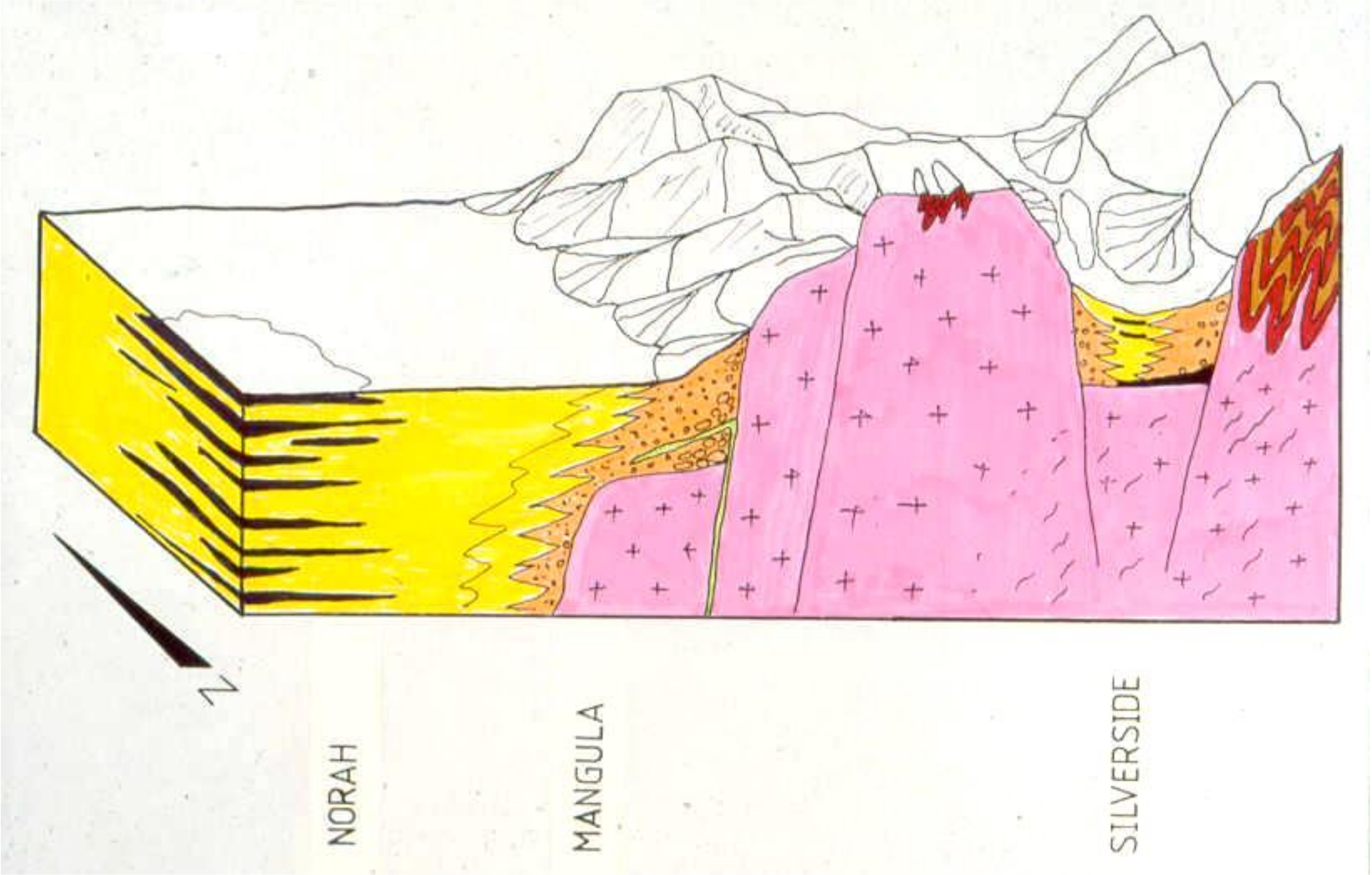


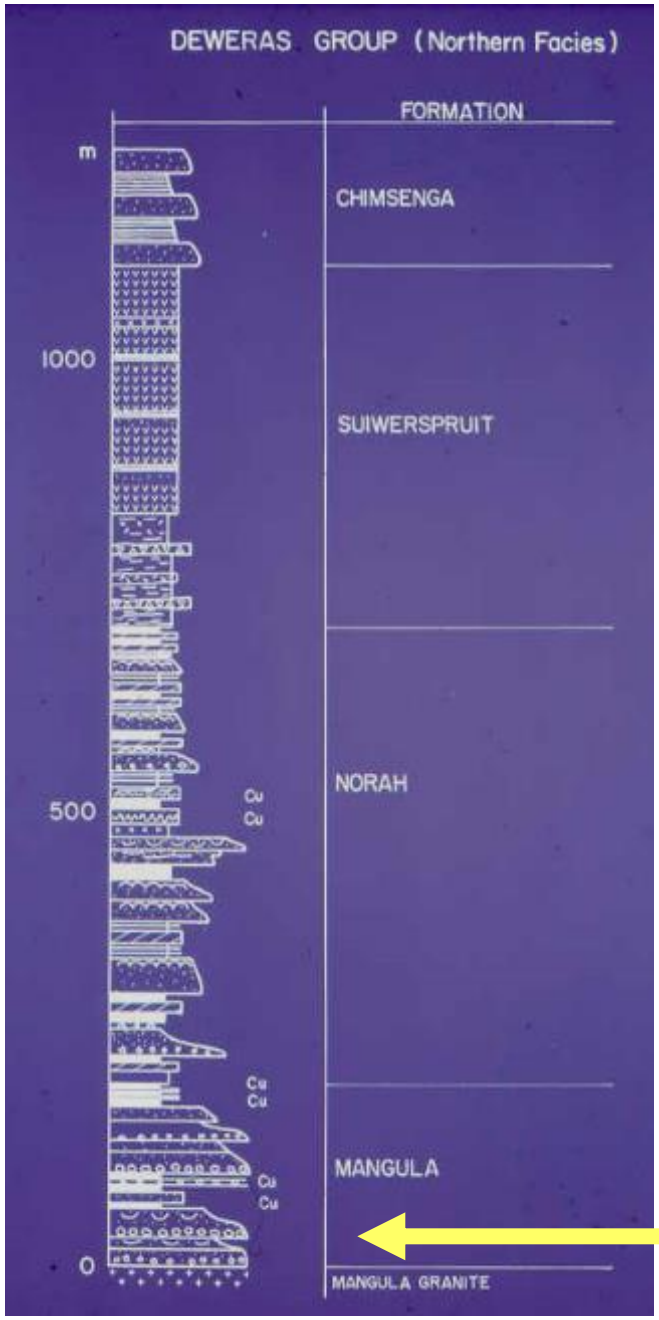
Figure 22
Plan of the Shackleton ore deposit showing the approximate limits of the main ore bodies in relation to local fold structures.

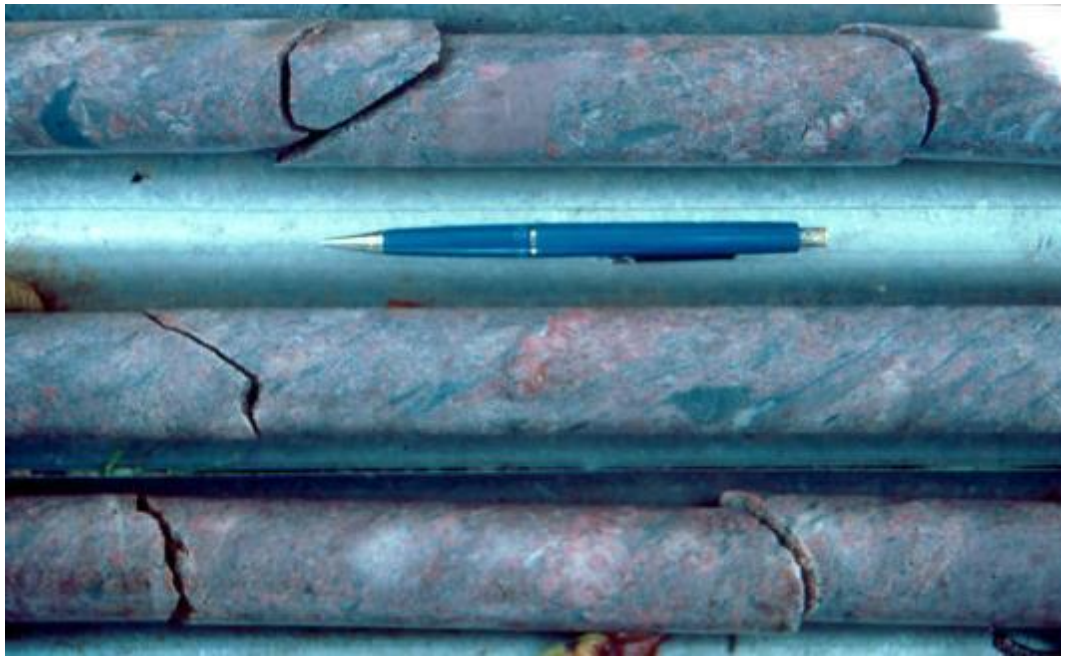


TECTONIC SETTING OF THE DEWERAS GROUP

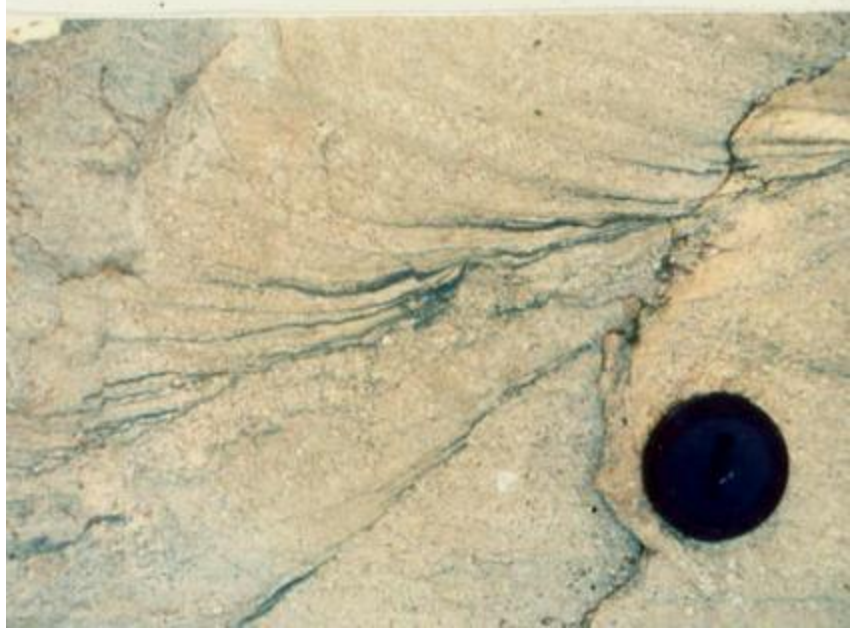


Palaeoenvironments, Deweras Group





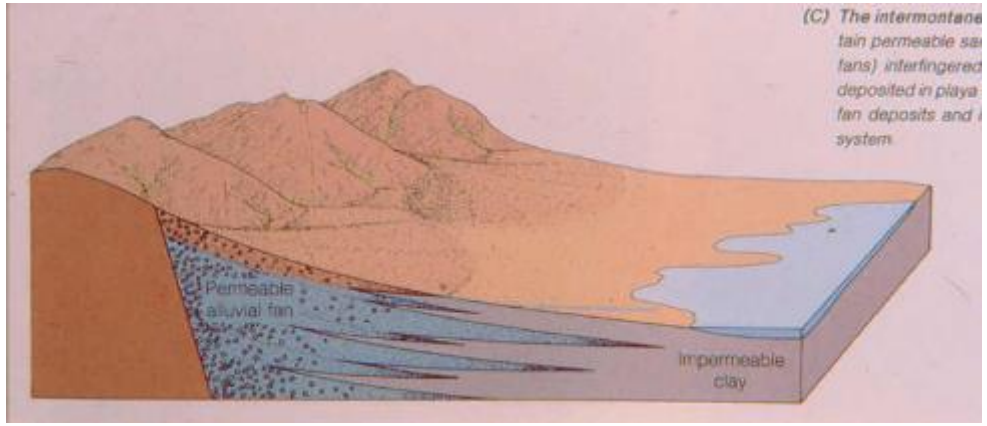
Drillcore showing pink granite clasts in fluvial conglomerates, Mangula Formation



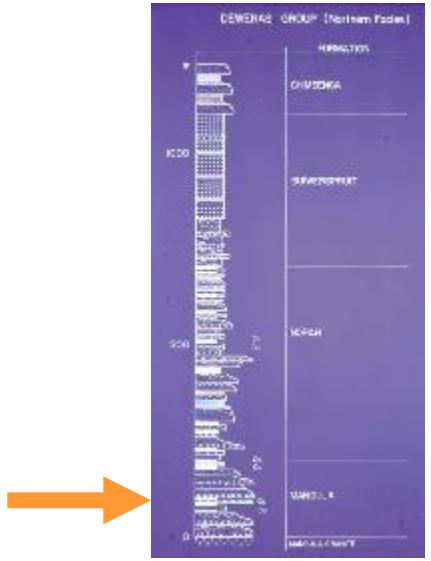
Arkoses in Deweras Group with abundant detrital magnetites on trough-crossbed foresets. The magnetites are enriched in Cu, Ag, Au, PGE, and are regarded as an intrastratal source of metals for sediment-hosted Cu deposits

Unaltered trough crossbedded arkose, Deweras Group, with detrital magnetite in foreset laminae.

Alteration of trough crossbedded arkose by oxidizing K-rich fluids in footwall of Mangula orebody. Relict crossbedding can still be seen, replaced by haematite, and zones of magnetite/haematite alteration.

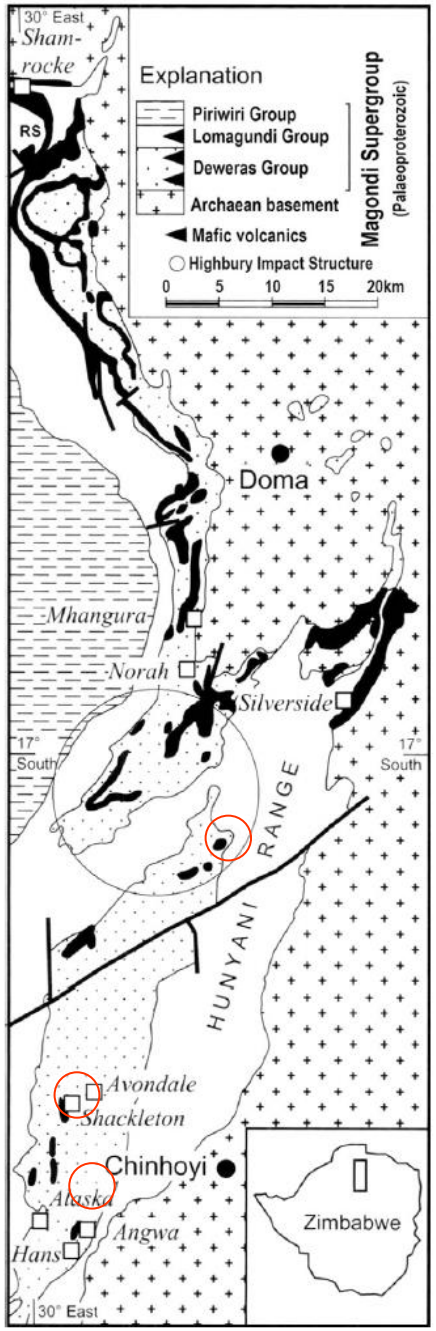


Alluvial depositional environment for Mangula Formation, Deweras Group: alluvial fans



Aeolian facies

- Three aeolianite localities are found over a region 33 km long and 5 km wide. These occurrences may be part of a continuous wedge-shaped body of sandstone, containing about 3.3 km^3 of aeolianite, representing a small sand sea, or erg.



Master & Eriksson, 2014, GSA Abstr.

Inversely graded arkosic sandstones of aeolian dune origin, Angwa River

Inversely graded sandstones, Deweras Group (Angwa River)

Deweras Group aeolianites- proof of a continental environment

Inversly-graded aeolian ripples, 2.2 Ga Deweras Group, Zimbabwe

Aeolian ripples- inversely grade

Inversely-graded ripple lamination in Jurassic Navajo sandstone aeolianites, Glen Canyon, Arizona

Mud-cracked argillites overlying aeolianite, 2.2 Ga Deweras Group, Zimbabwe

Fafa sandstone, Mali: Fluvial (wadi?) arenite with intraformational rip-up clasts of mudcracked argillites

Intraformational argillite clasts

Fafa sandstone, Mali: Fluvial (wadi?) arenite with intraformational rip-up clasts of mudcracked argillites

Mud-cracked argillites overlying aeolianite, 2.2 Ga Deweras Group, Zimbabwe

GSA 2014

19-22 October | Vancouver, BC, Canada

2.17-2.07 Ga eolianites and evaporitic continental playa sedimentary rocks from the Deweras Group, Zimbabwe: the world's oldest desert?

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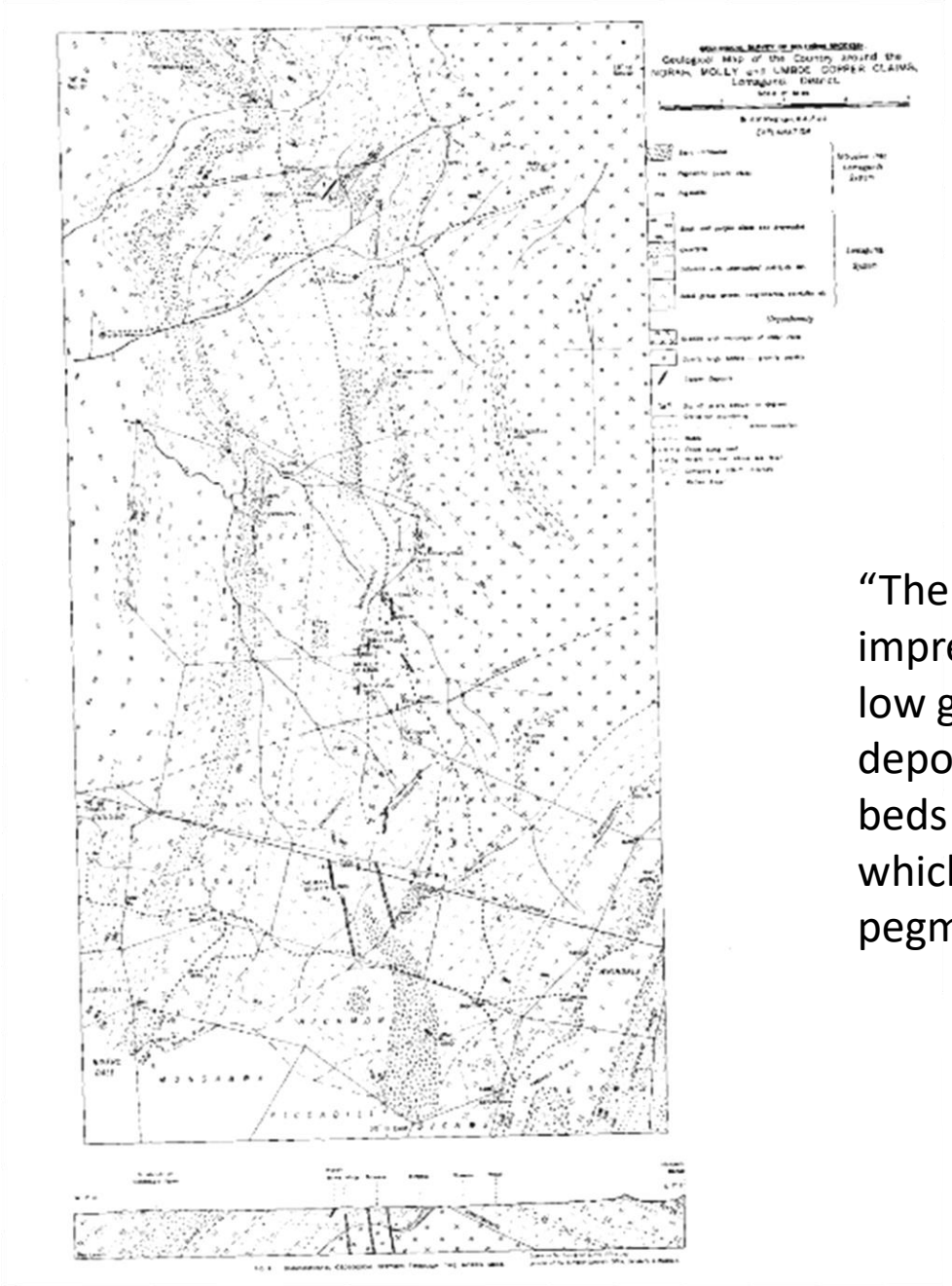
[2] Department of Geosciences, Virginia Tech, **Blacksburg**, VA 24061,USA.
kaeson@vt.edu

Magondi Copperbelt : Stratabound sediment-hosted copper-silver mineralization in the Deweras Group-

Mangula Mine, Mhangura: 60 Mt @ 1.2% Cu, 12 g/t Ag



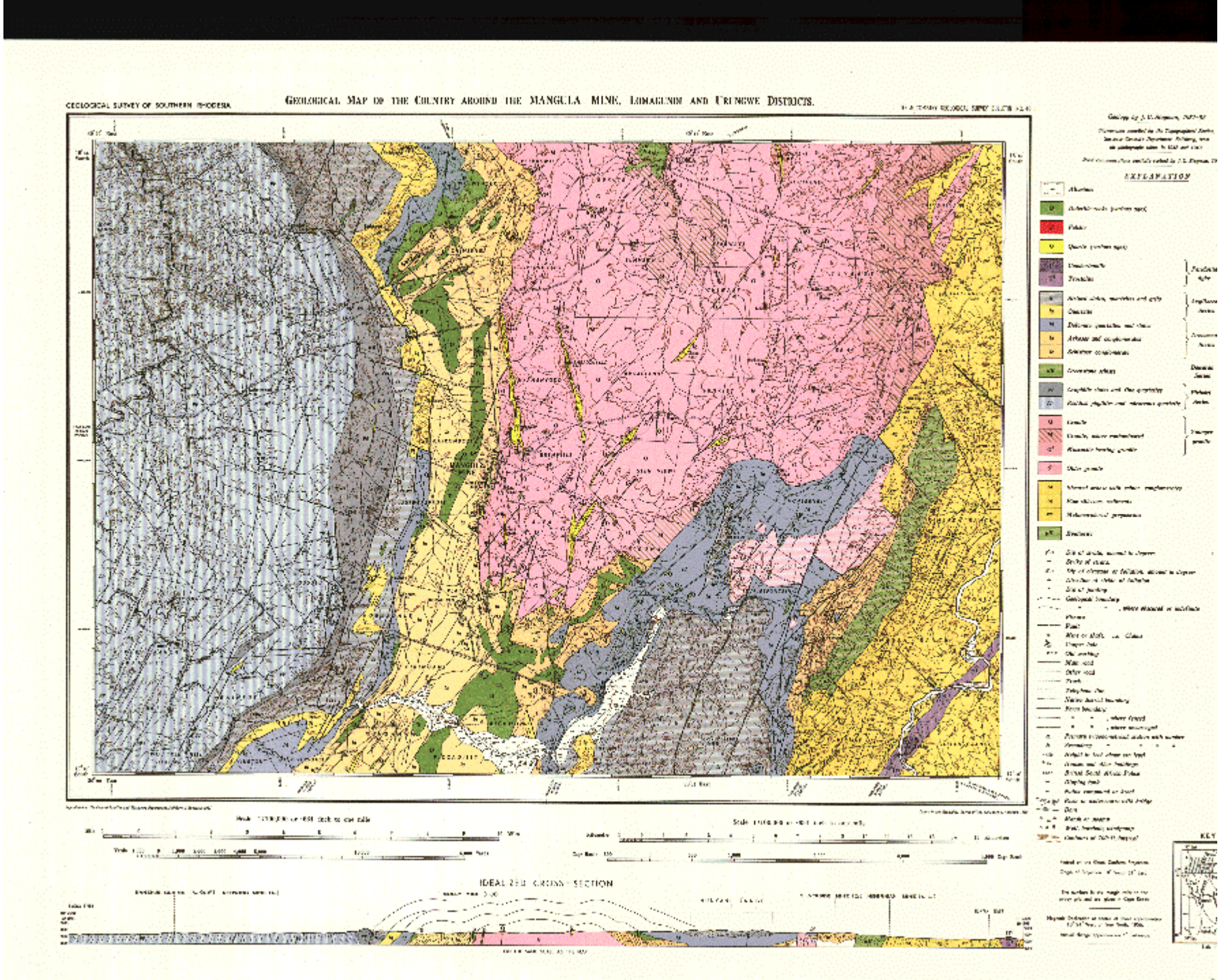
Macgregor, A.M. (1931)
Geology of the Country around the Molly, Norah and Umboe Copper Claims. Short Report, Geol. Surv. S. Rhod.

“The copper deposits in the area are all impregnations in arkose and are all of low grade. …The copper in the three deposits has been introduced into the beds of arkose by volatile substances which accompanied the quartz and pegmatites during their invasion’

L LECTURE

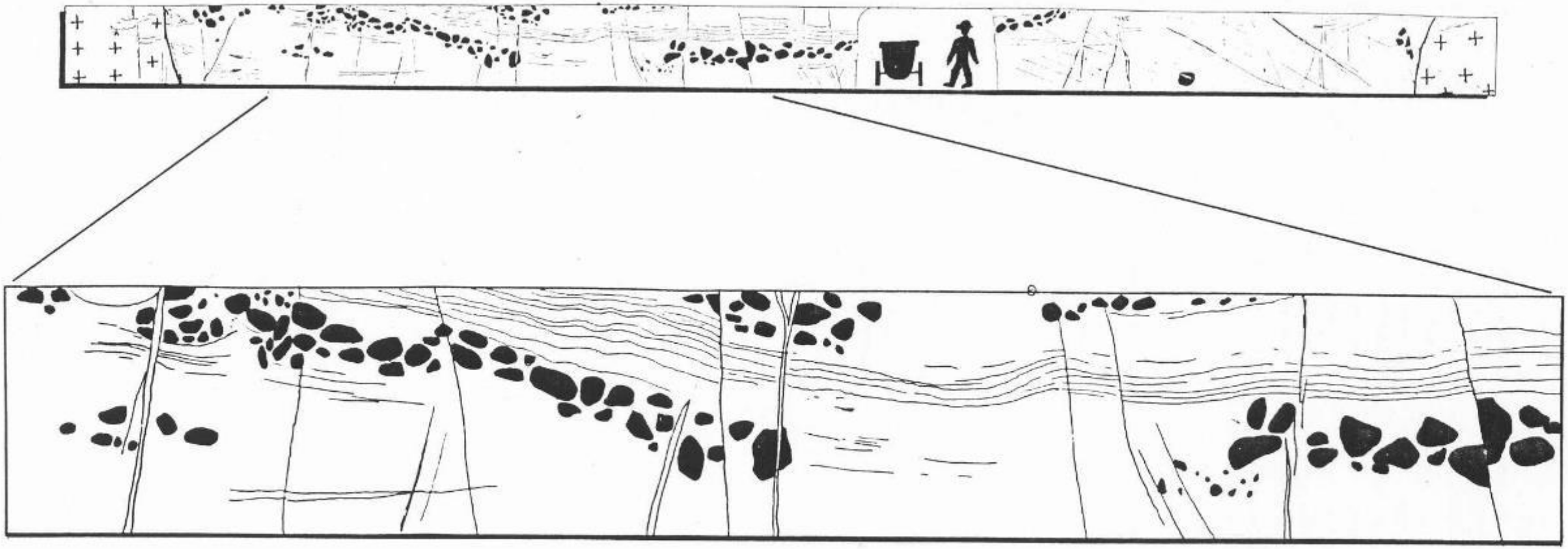
liths and a Tripartite Subdivision of the

Alexander Macgregor



Stagman, J.G. (1959)

Geological Map of the Country around the Mangula Mine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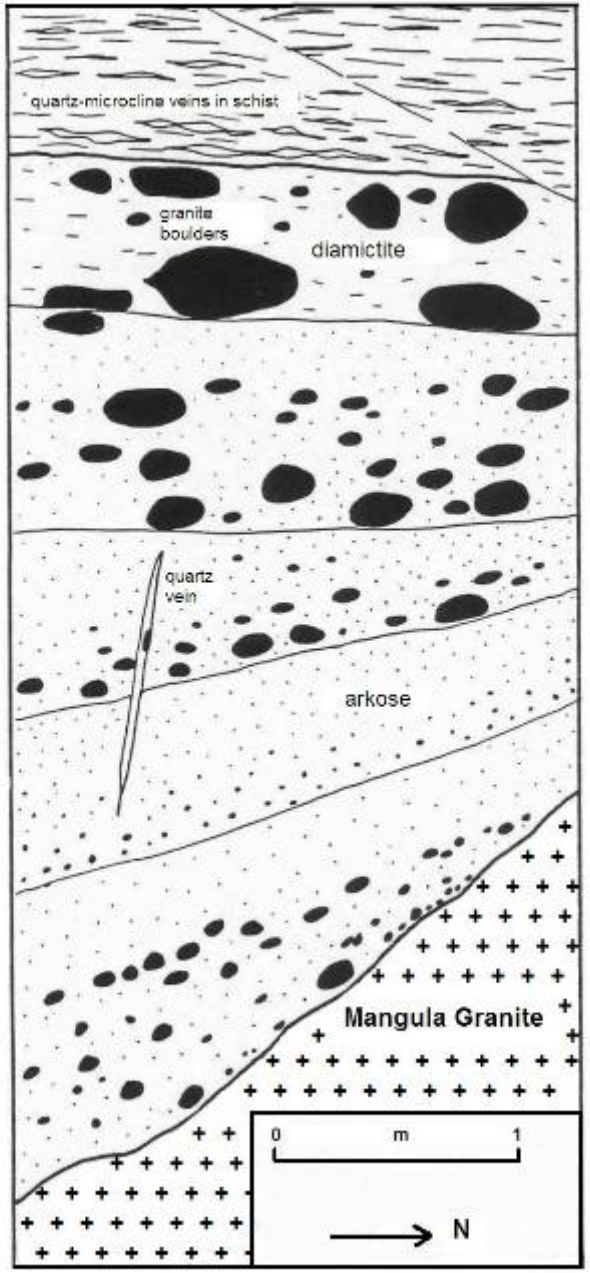
m



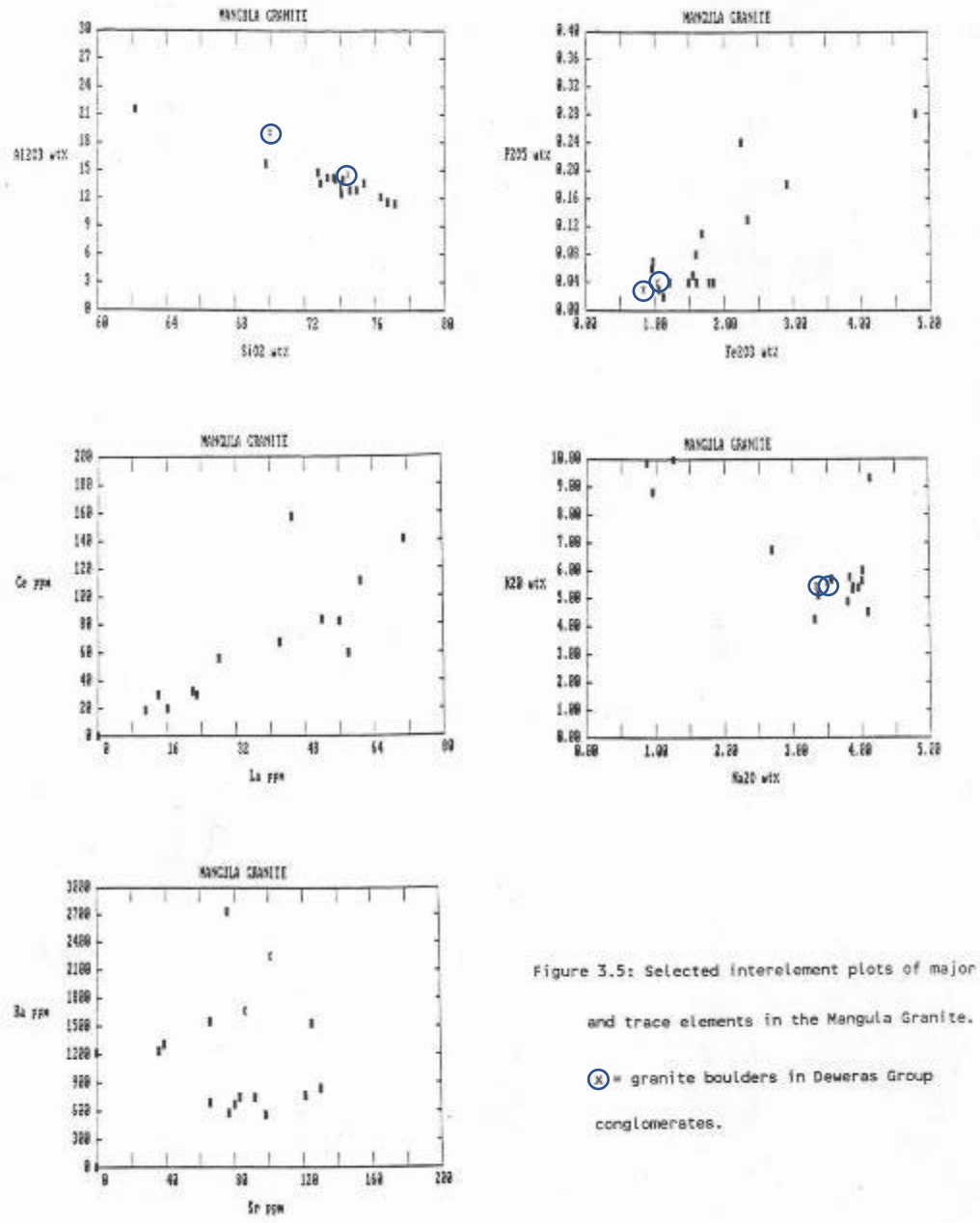
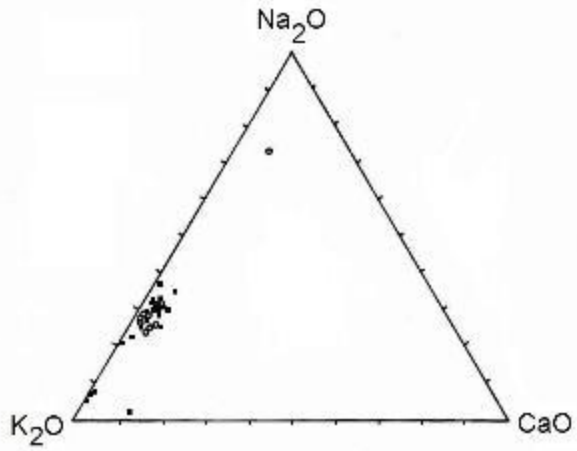
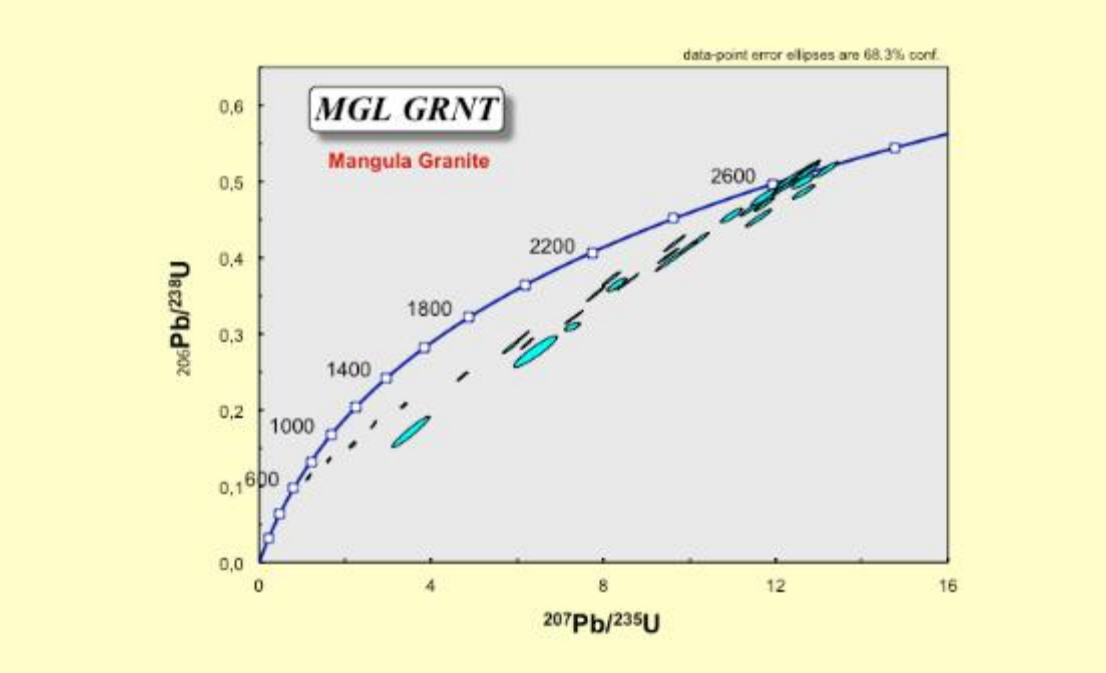
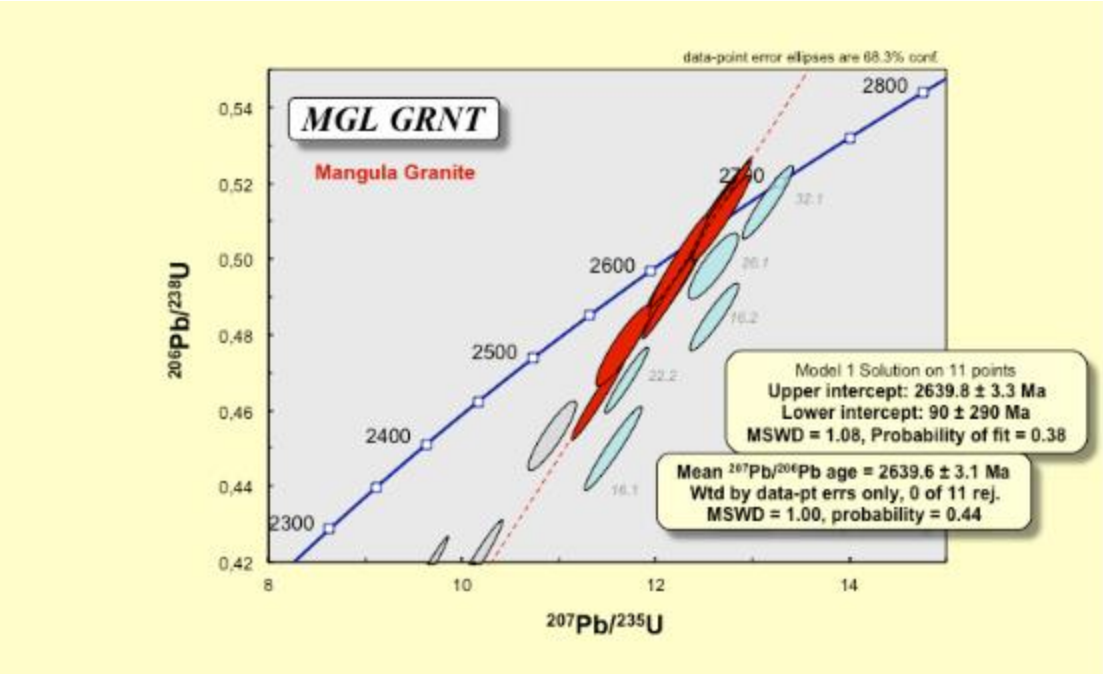


Figure 3.5: Selected interelement plots of major and trace elements in the Mangula Granite. ⊗ = granite boulders in Deweras Group conglomerates.



Mangula Granite ∘ and granite boulders ▪ in Deweras Group conglomerates are part of the same geochemical population. The boulders are derived from the Mangula Granite





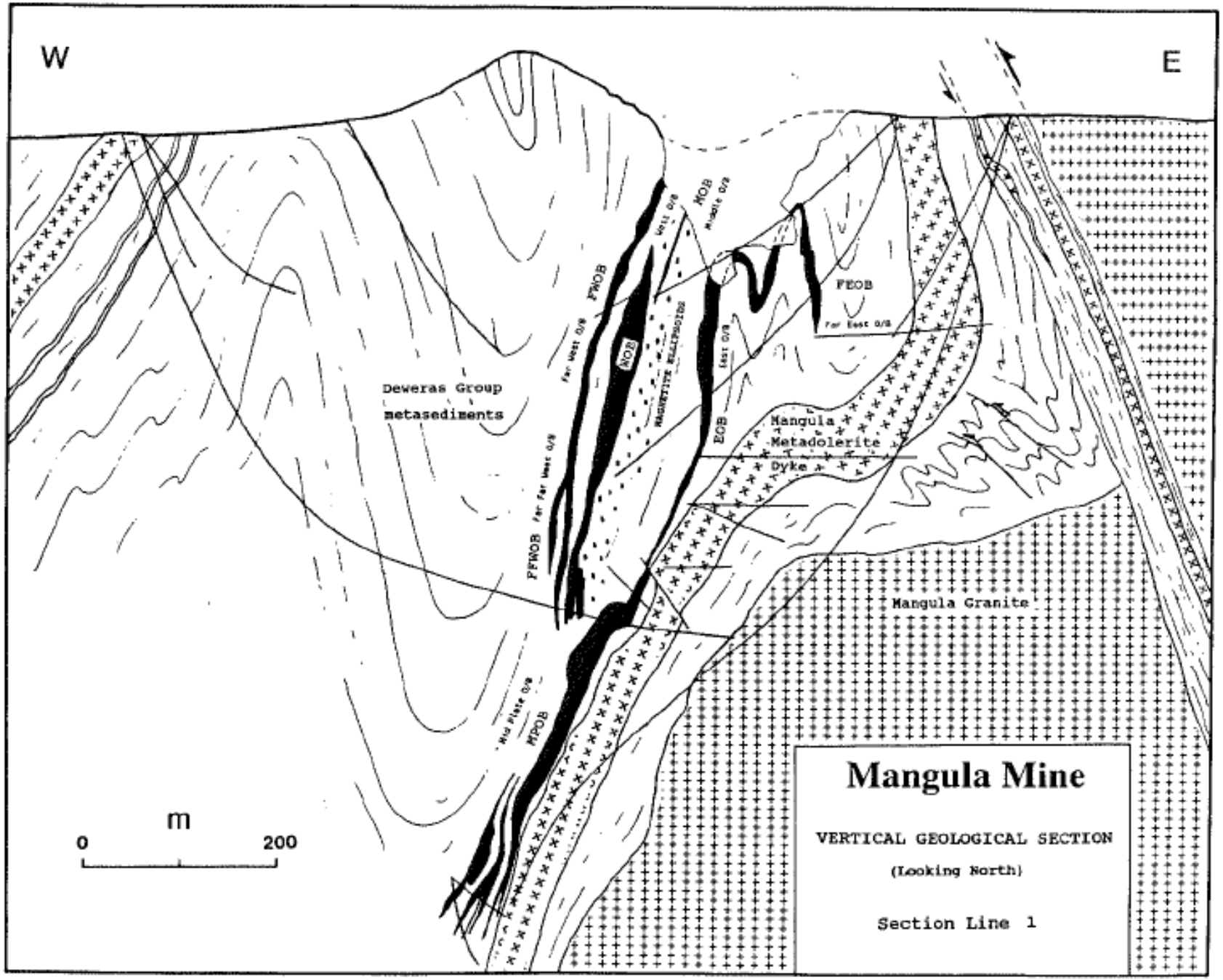
Mangula Granite: SHRIMP U-Pb zircon age: 2639.6 +/- 3.1 Ma

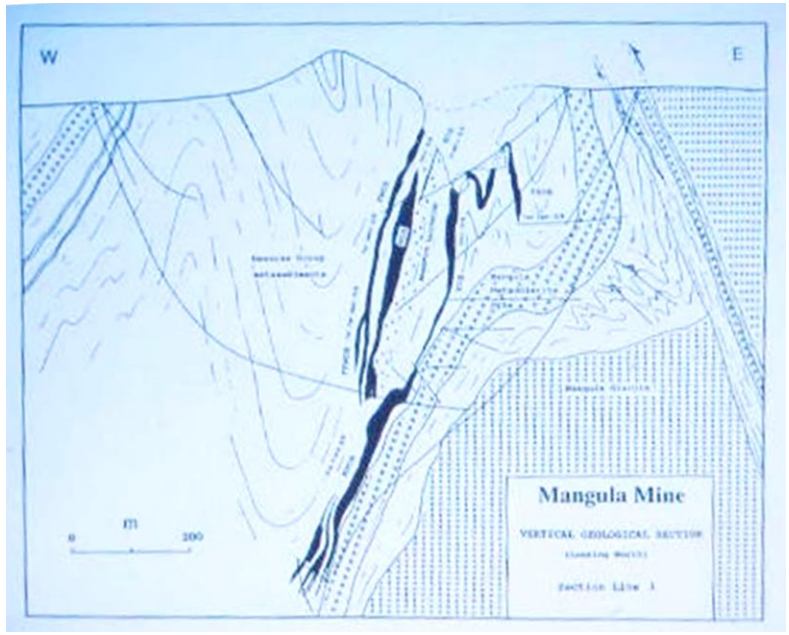
The Mangula Granite belongs to the older Archaean basement below the Deweras Group, and is NOT intrusive into it.

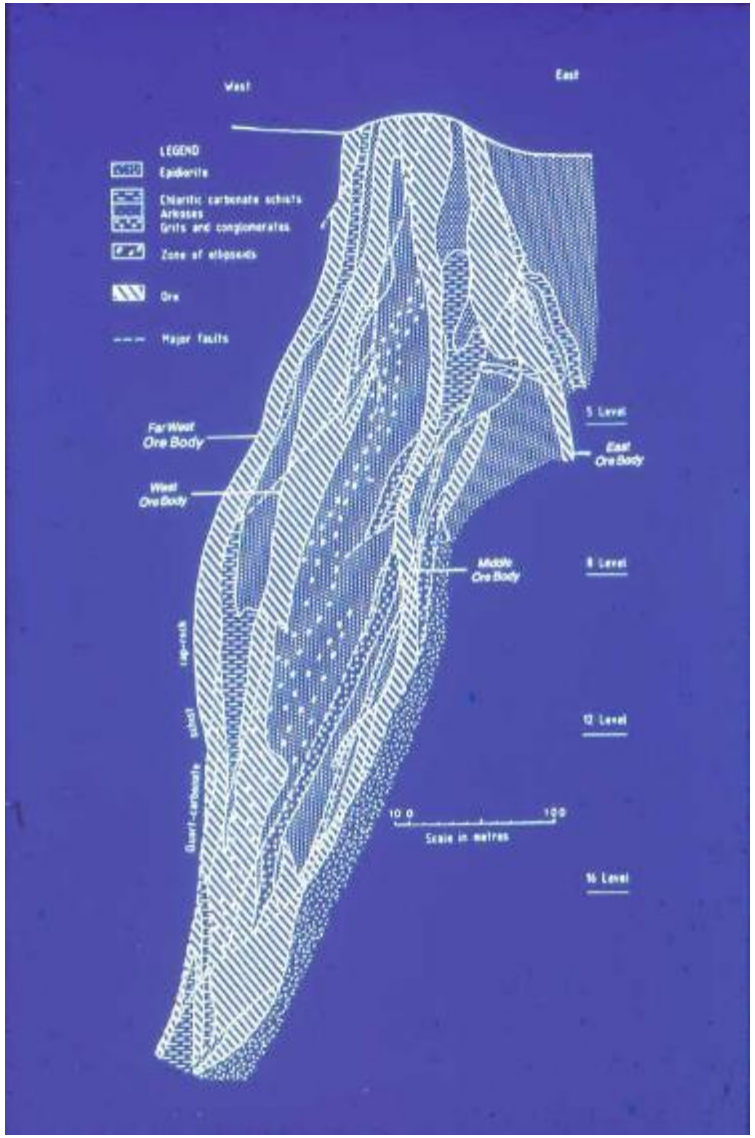
Macgregor (1931) was right, and Stagman (1959), J.B.E., Jacobsen (1962) and W.B.G. Jacobsen (1964) were wrong!

Figure 6.2: Mid Plate Orebody in borehole E12/1865 at Mangula Mine

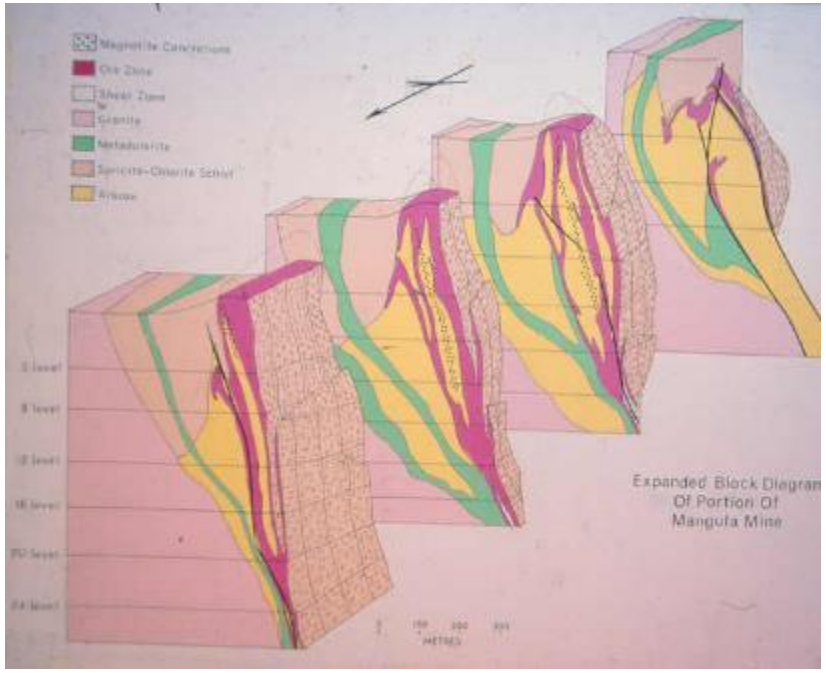
Figure 6.1: Borehole E16/558 showing the West Orebody at the top of the second upward-fining cyclothem at Mangula. Note the sulphide mineral zonation. bn = bornite, cp = chalcopyrite, MoS_2 = molybdenite.

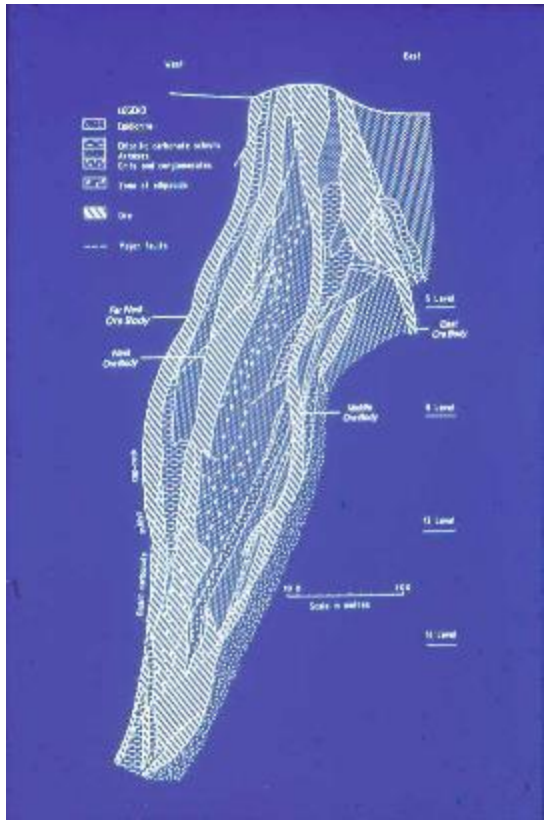

W
E
Deweras Group
metasediments
PFWOB
FWOB
NOB
MOB
EOB
FEOB
Mangula
Metadolerite
Dyke
Mangula Granite
MFOB
m
0
200
Mangula Mine
VERTICAL GEOLOGICAL SECTION
(Looking North)
Section Line 1

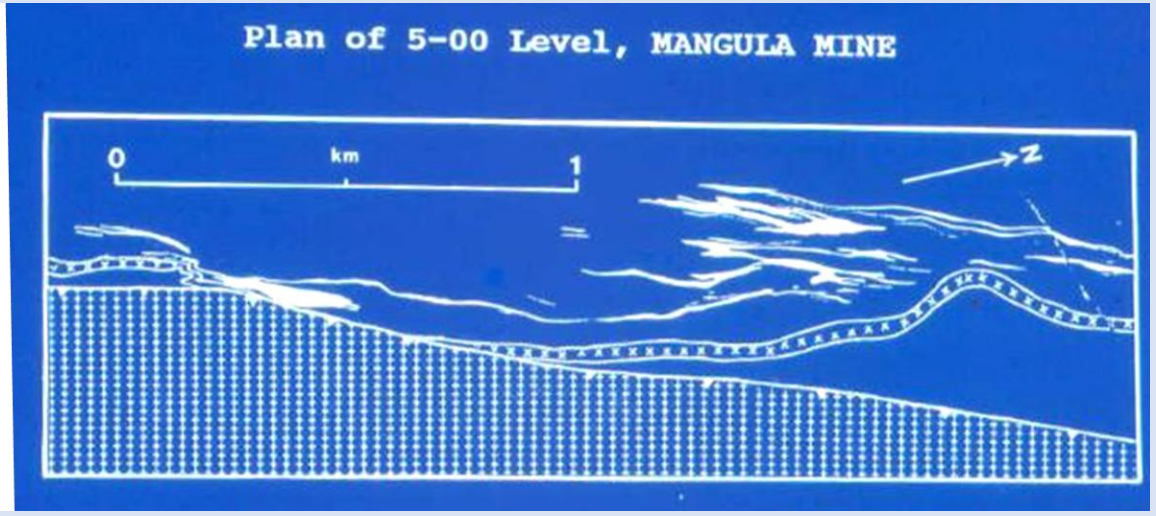




Mangula Mine

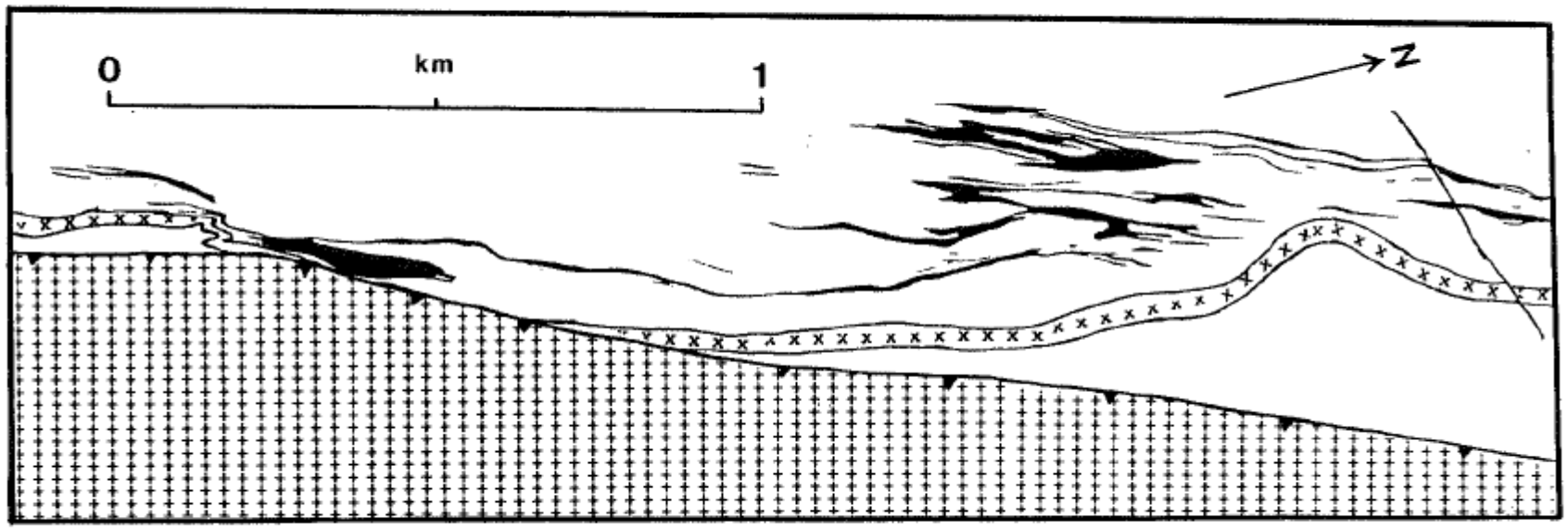






Mangula Mine

Plan of 5-00 Level, MANGULA MINE



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

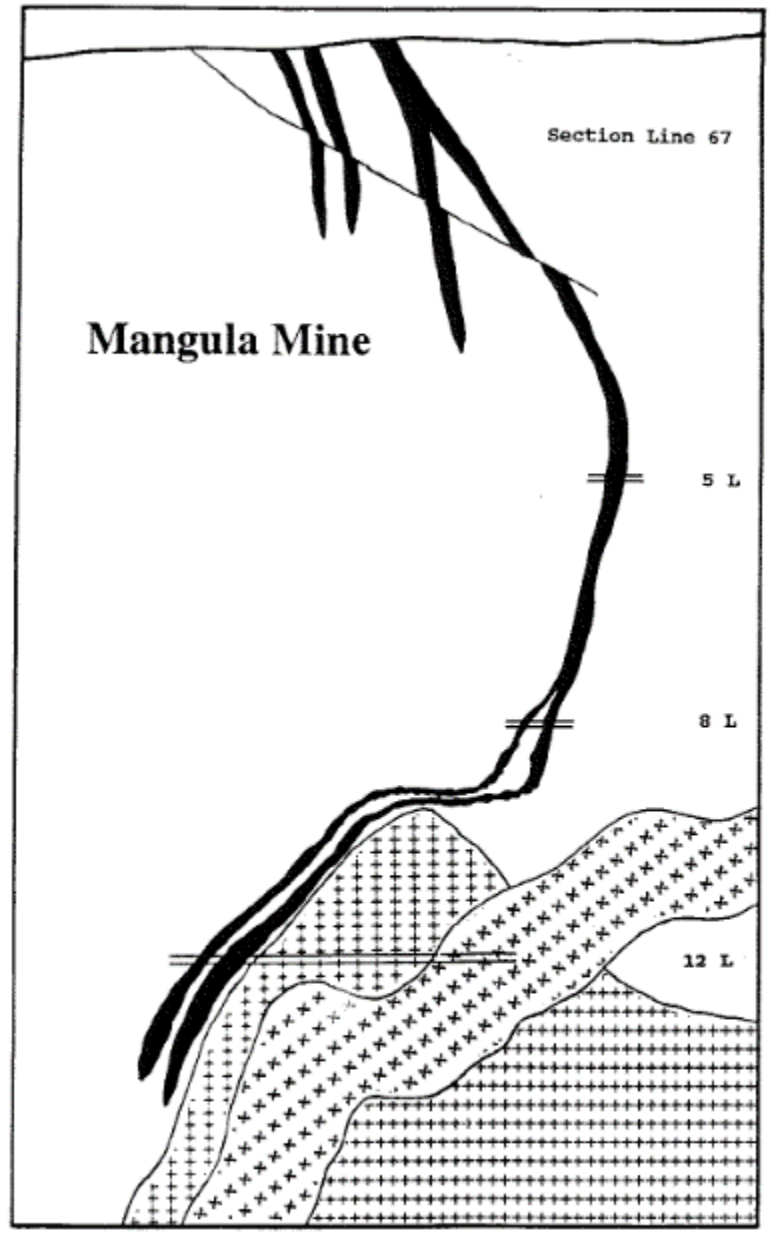
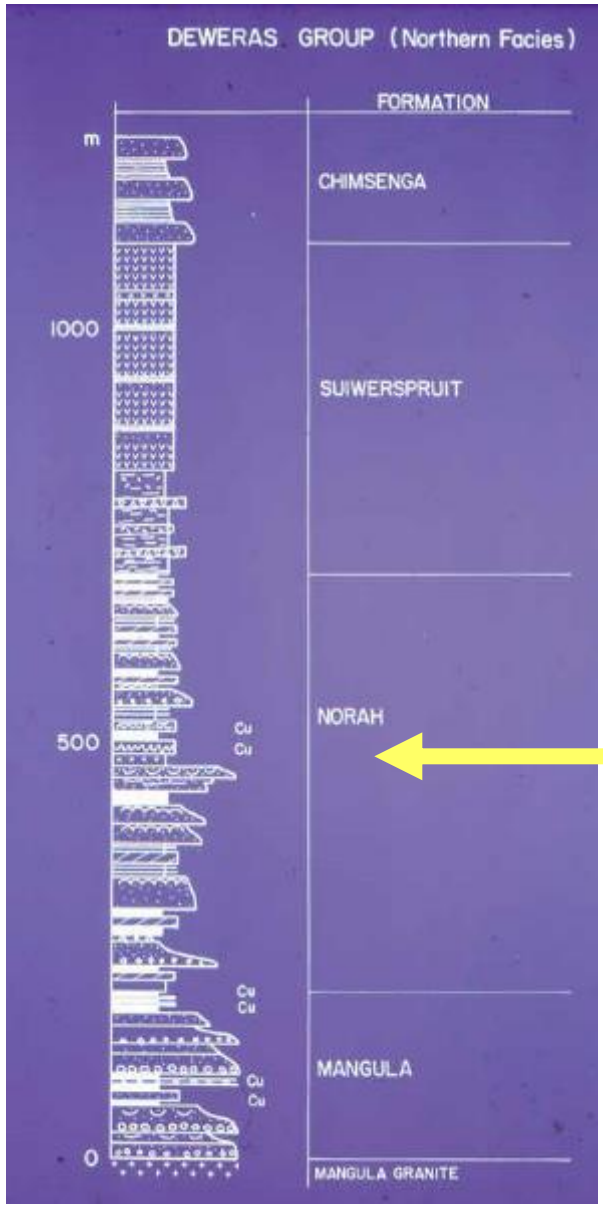
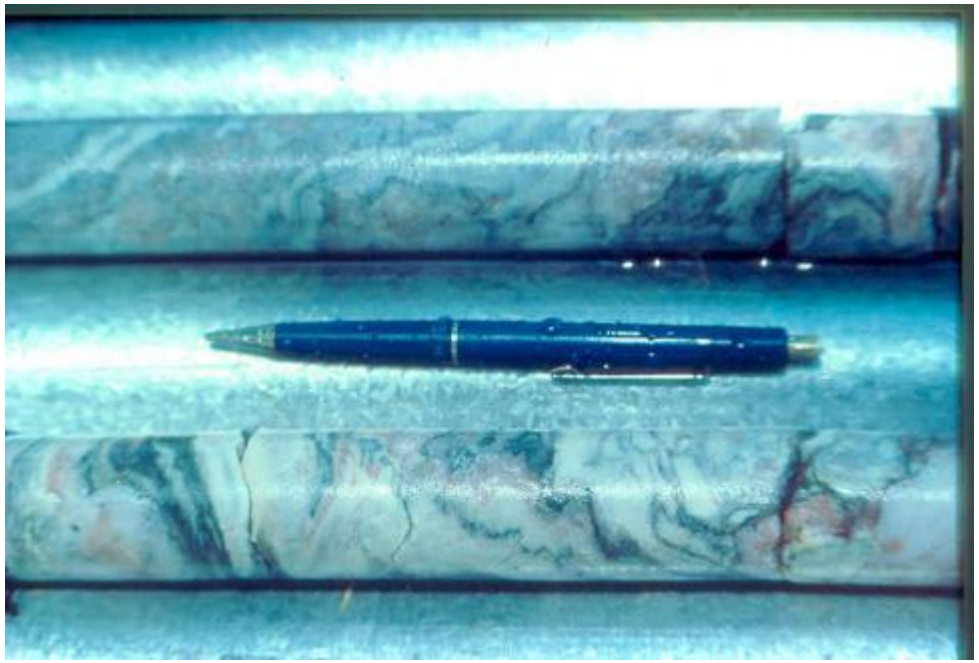
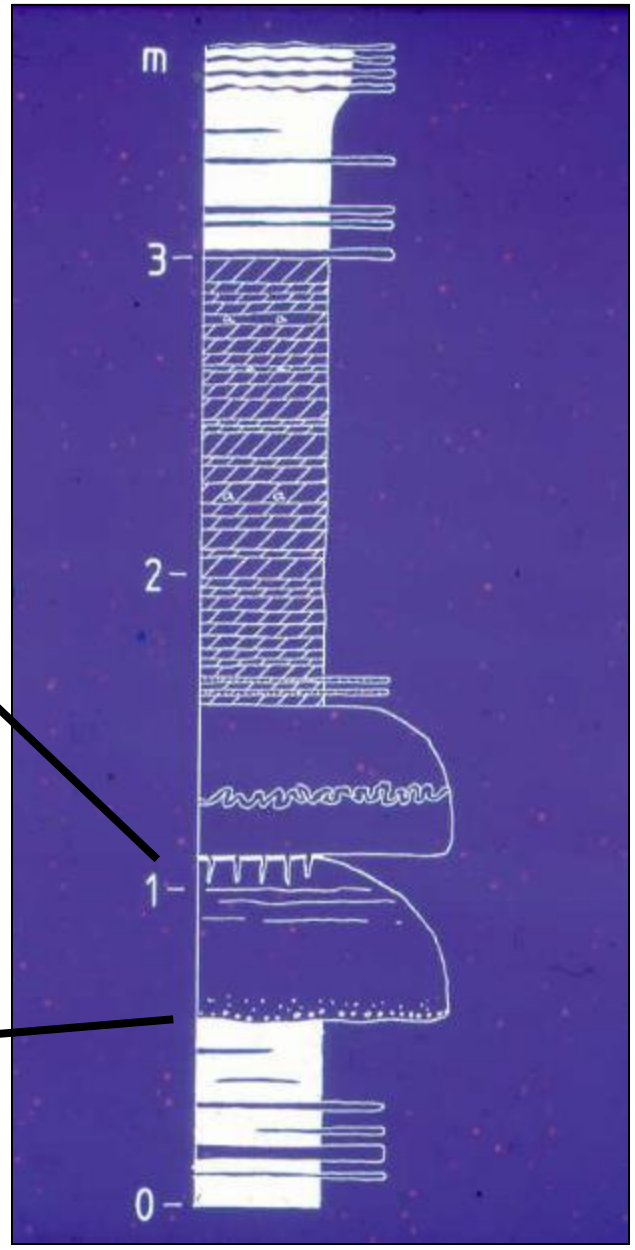


Figure 6.6: Vertical geological section, looking North, Line 67, Mangula Mine

Norah Cu-Ag Mine

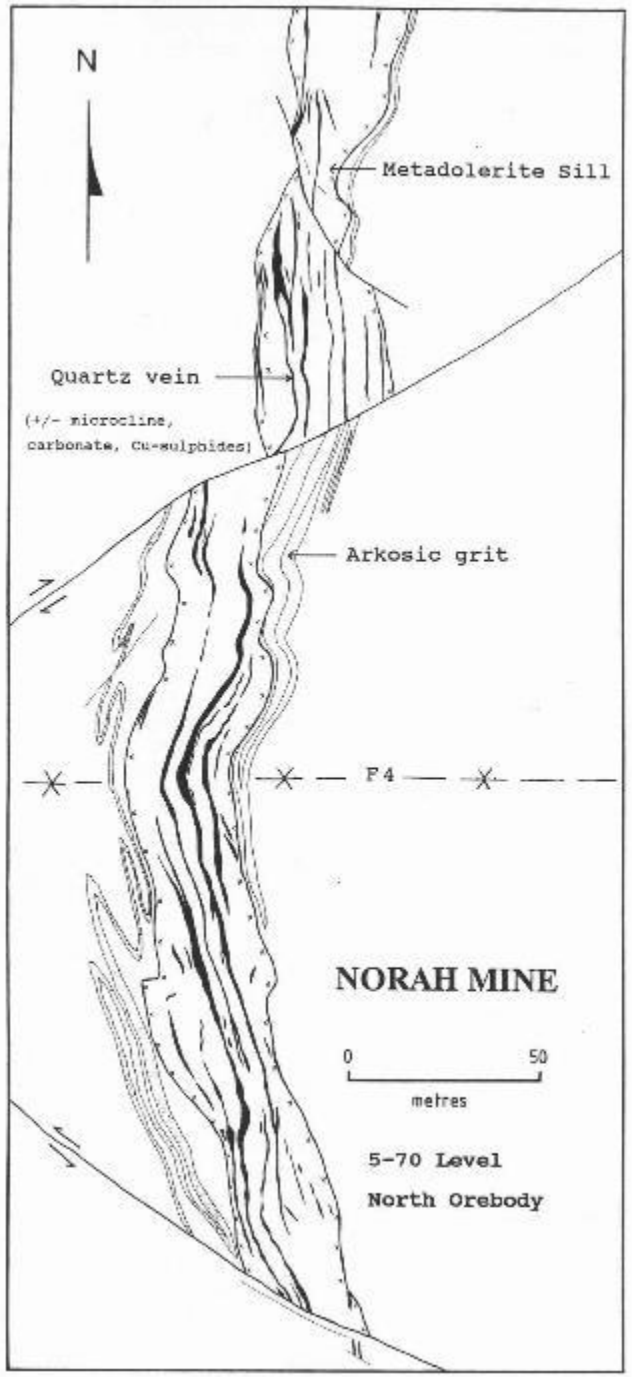

DEWERAS GROUP (Northern Facies)
FORMATION
m
1000
500
0
CHIMSENGA
SUIWERSPRUIT
NORAH
MANGULA
MANGULA GRANITE
Cu
Cu
Cu
Cu
Cu
Cu

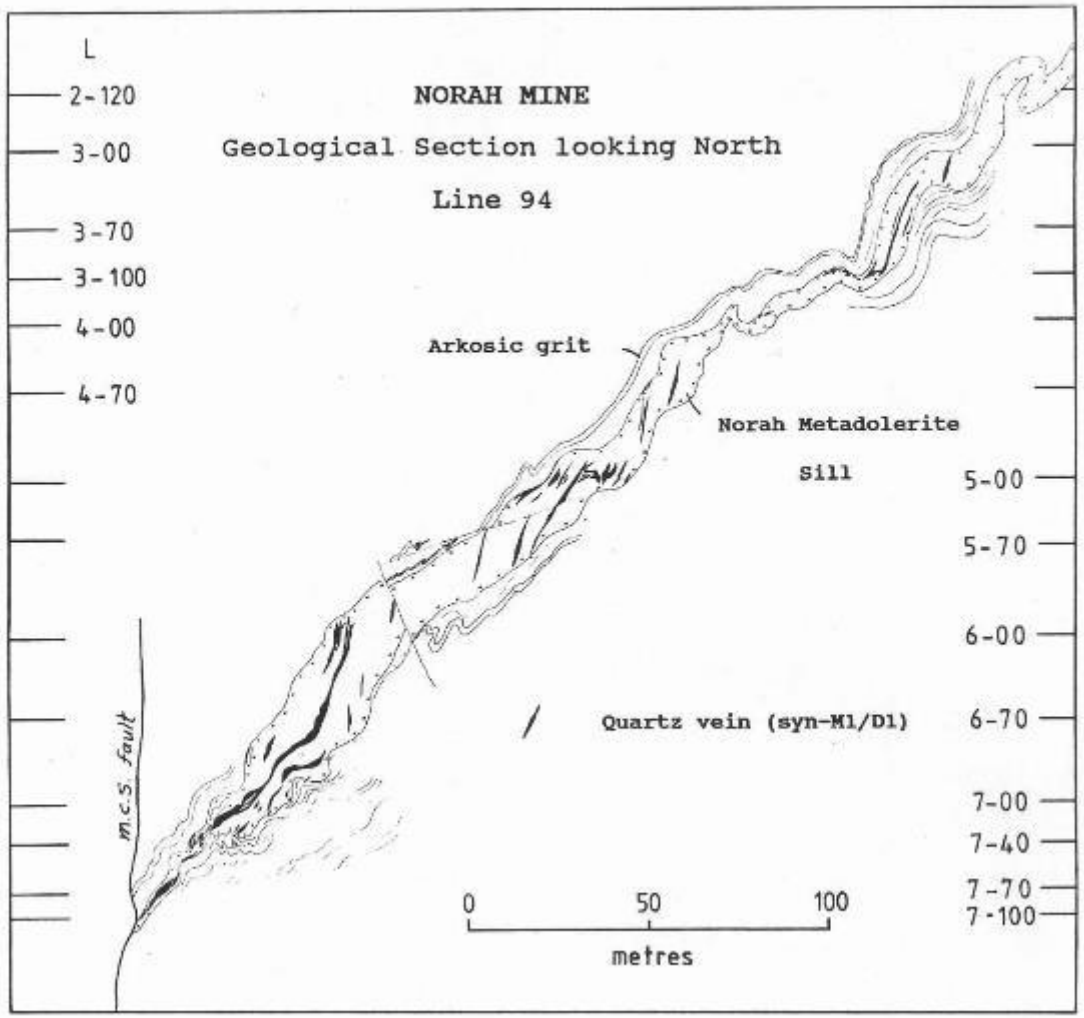


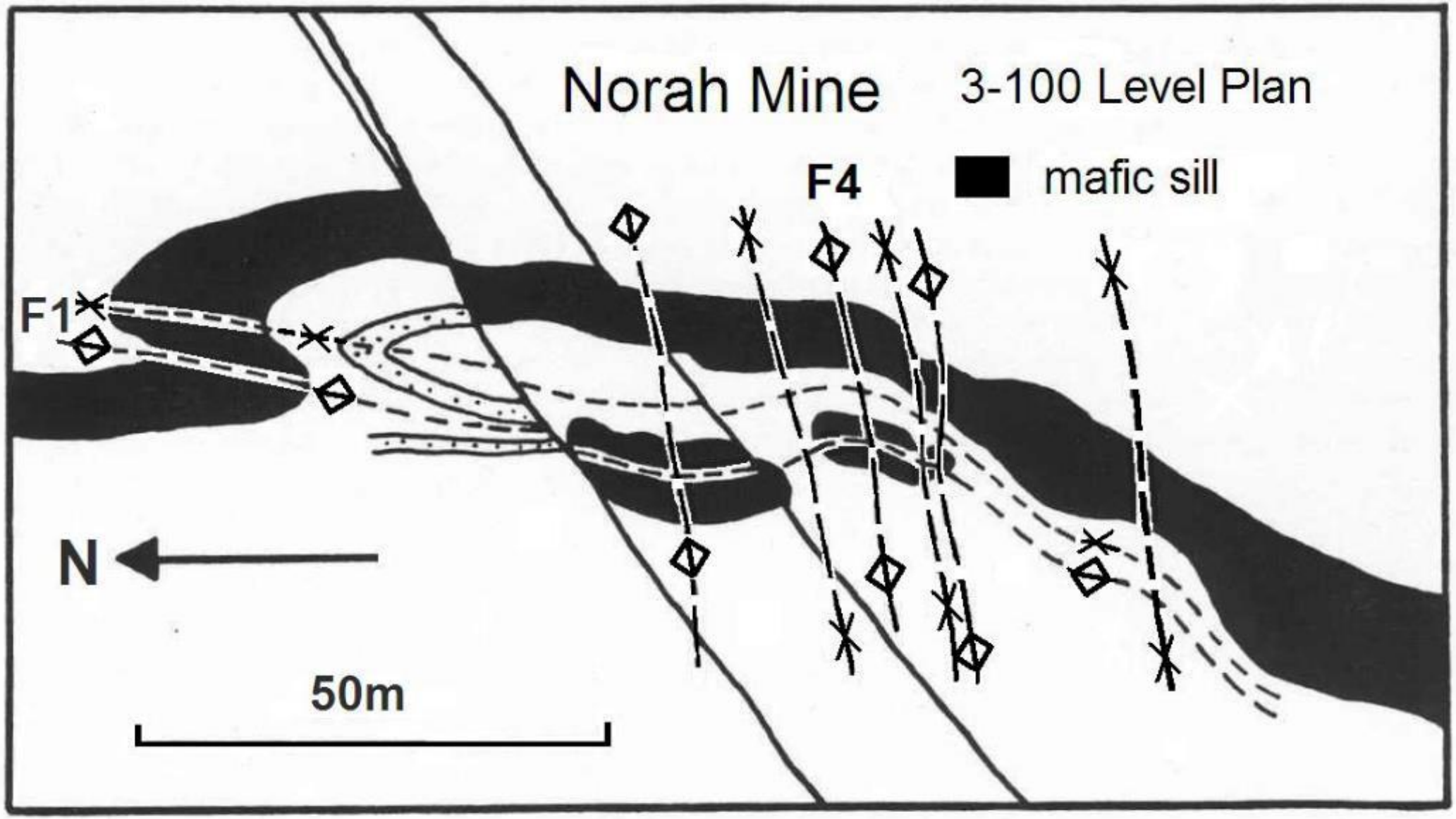

m
3
2
1
0

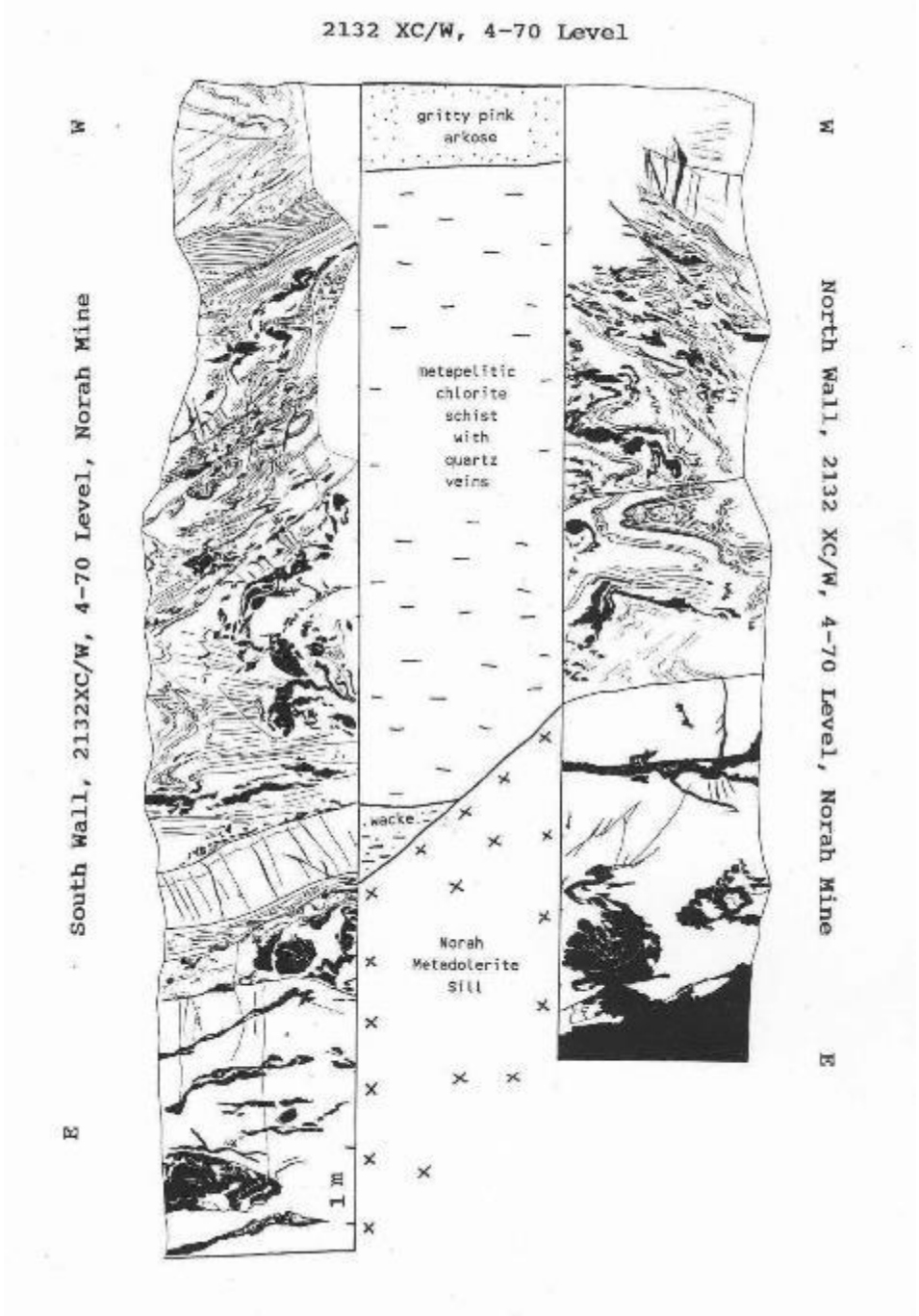
Ripple marks

Norah Mine plan and section






Norah Mine
3-100 Level Plan
mafic sill
F4
F1
N
50m



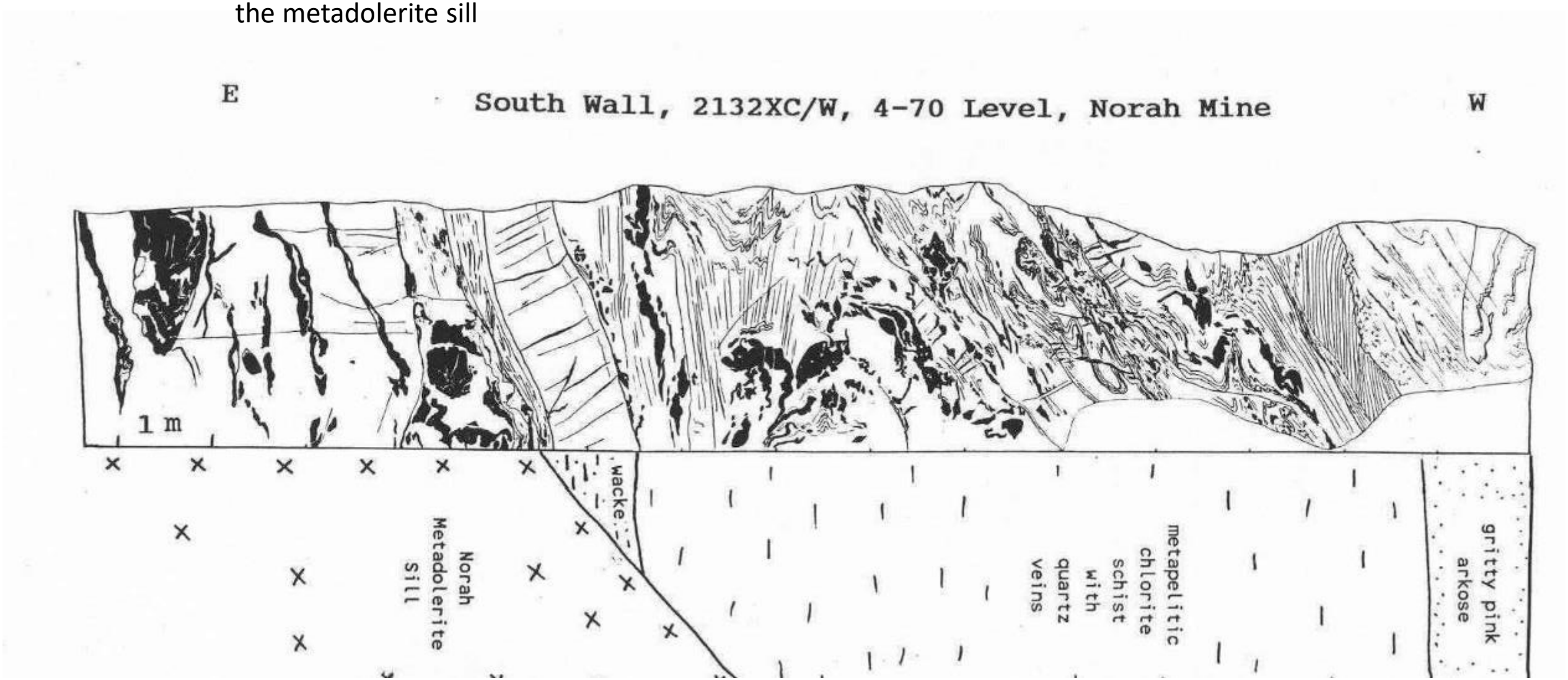
Norah Mine

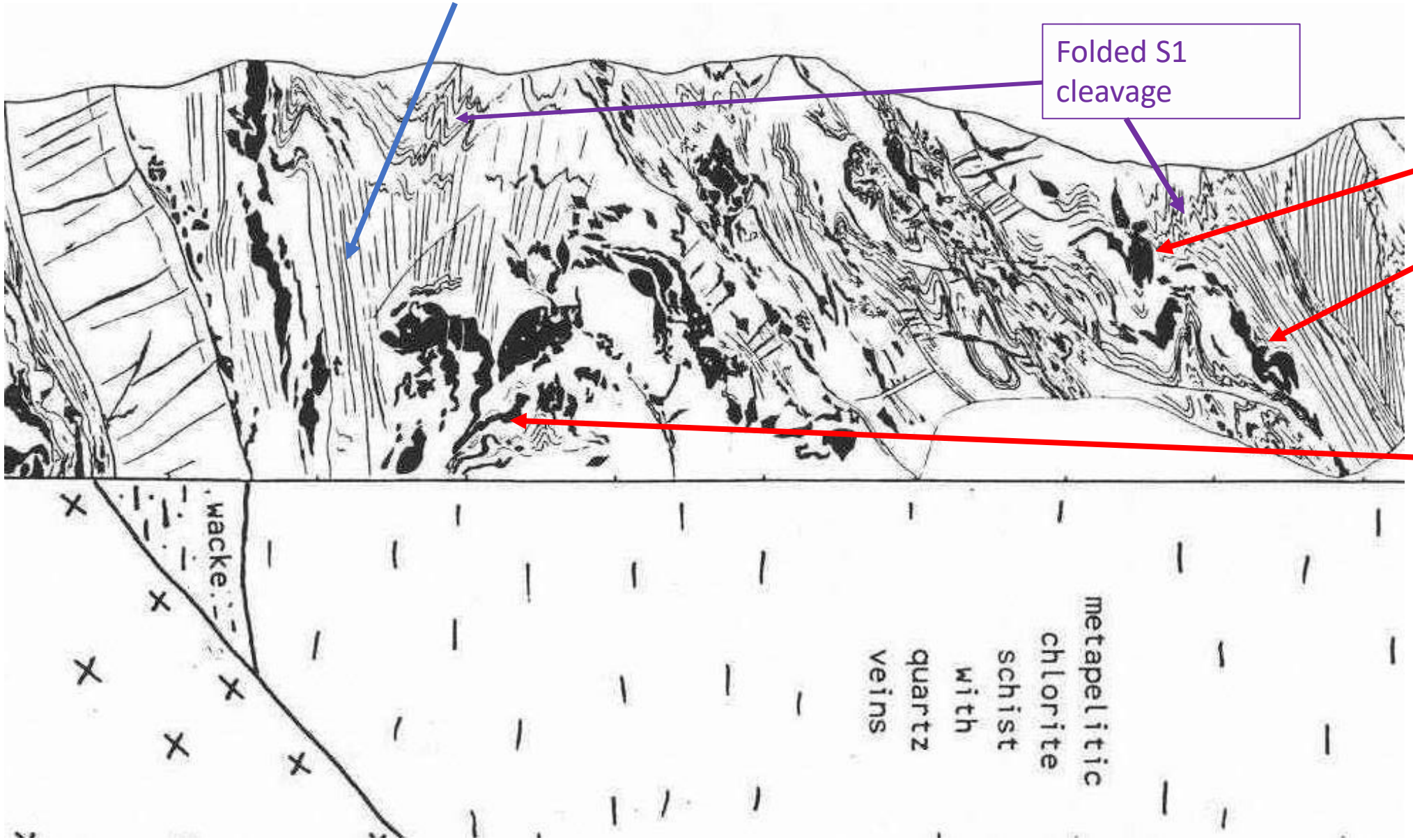
Detailed (1:20 scale) mapping

Master 1991, PhD thesis

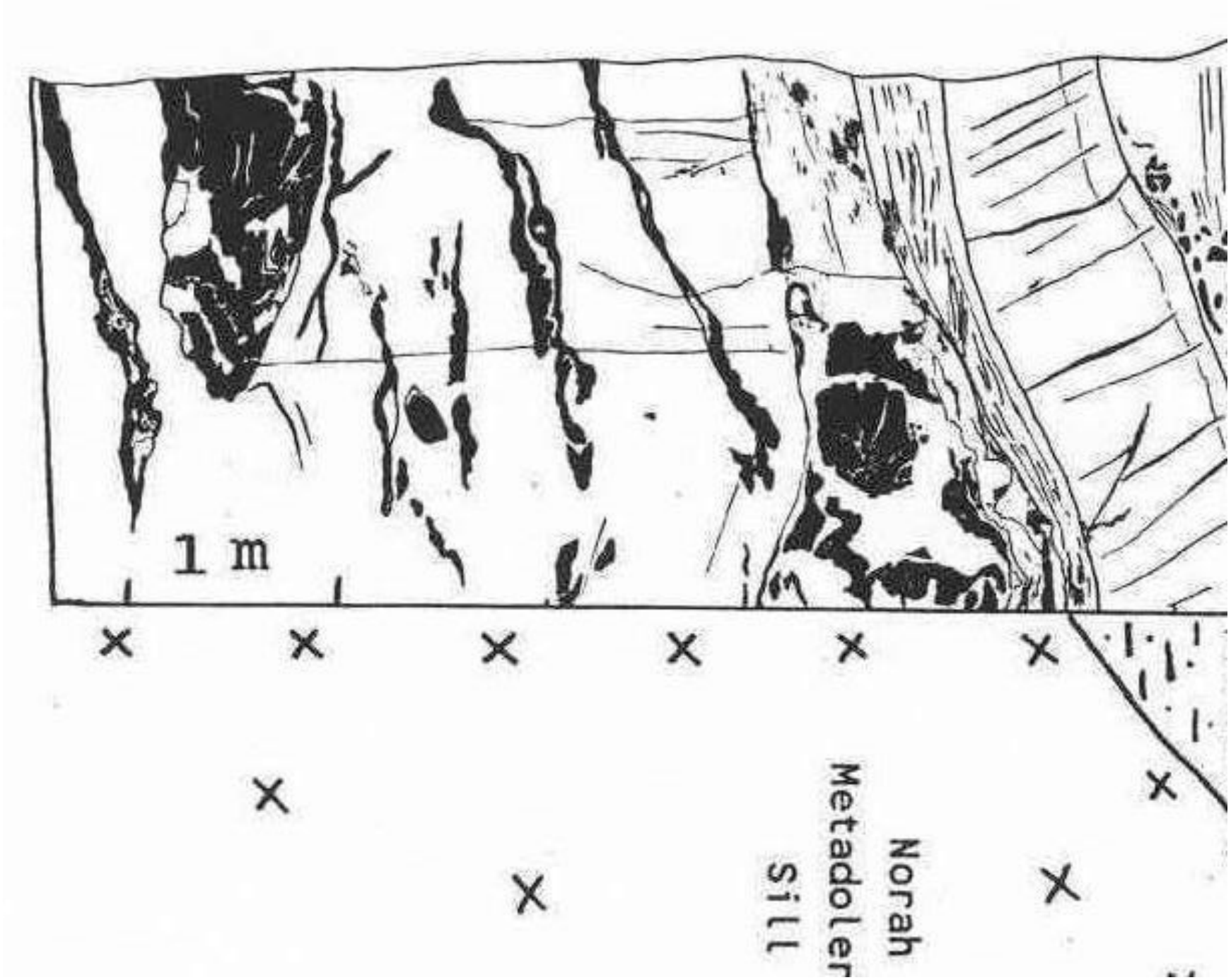
Norah Mine, Magondi Copperbelt, Zimbabwe

Detailed (1:20 scale) mapping shows the origin of quartz-sulphide veins to be related to cleavage formation and pressure solution during D1 deformation, and injection of veins into the metadolerite sill



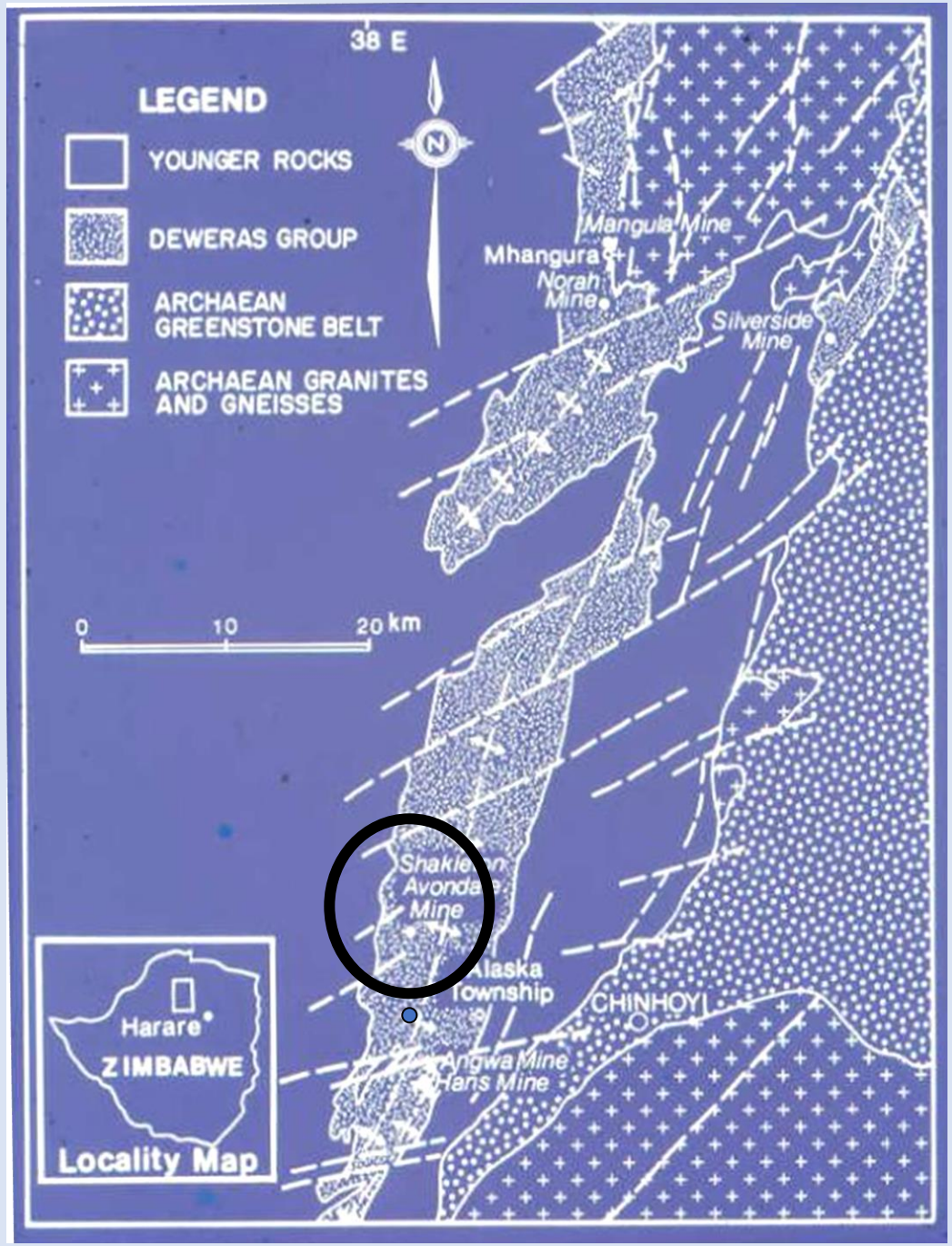


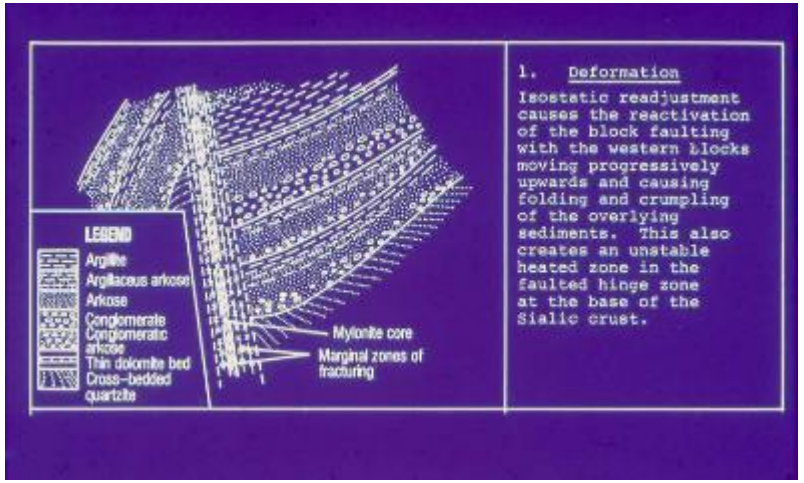
Mineralized copper-sulphide bearing quartz-carbonate veins formed by pressure solution parallel to S1 cleavage, and subsequently folded during D2 deformation

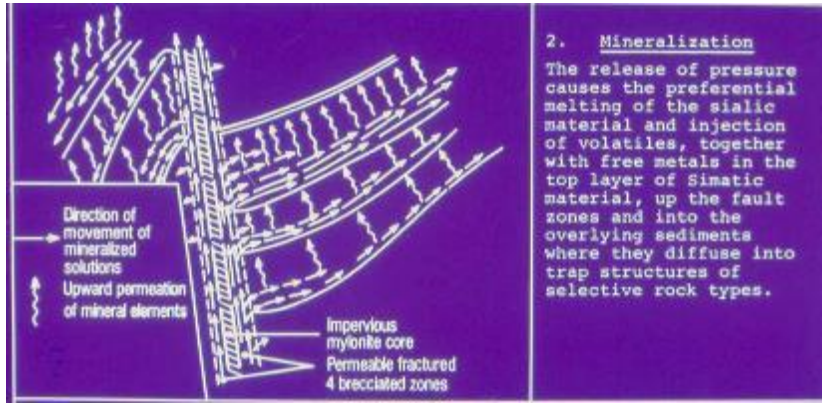


Mineralized quartz-carbonate veins with copper suphides cutting the Norah Metadolerite Sill are derived from the wallrocks by pressure solution during deformation, and injected onto vertical fractures into the sills, and subsequently folded in later deformation episodes

Master (1991)
PhD thesis


38 E
LEGEND
YOUNGER ROCKS
DEWERAS GROUP
ARCHAEAN GREENSTONE BELT
ARCHAEAN GRANITES AND GNEISSES
N
Mangula Mine
Mhangura
Norah Mine
Silverside Mine
0
10
20 km
Shakleton
Avonda
Mine
Alaska
Township
CHINHOYI
Angwa Mine
Hans Mine
Harare
ZIMBABWE
Locality Map





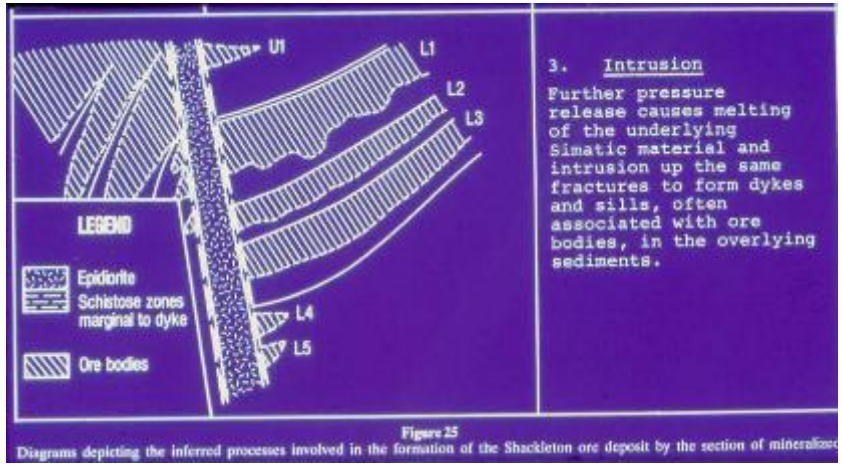


Figure 25
Diagrams depicting the inferred processes involved in the formation of the Shackleton ore deposit by the section of mineralisec

Ore genesis model, Shackleton Mine

(Newham, 1986)

Avonshack

Disseminated copper sulphide mineralization (chalcocite) in arkose between argillites

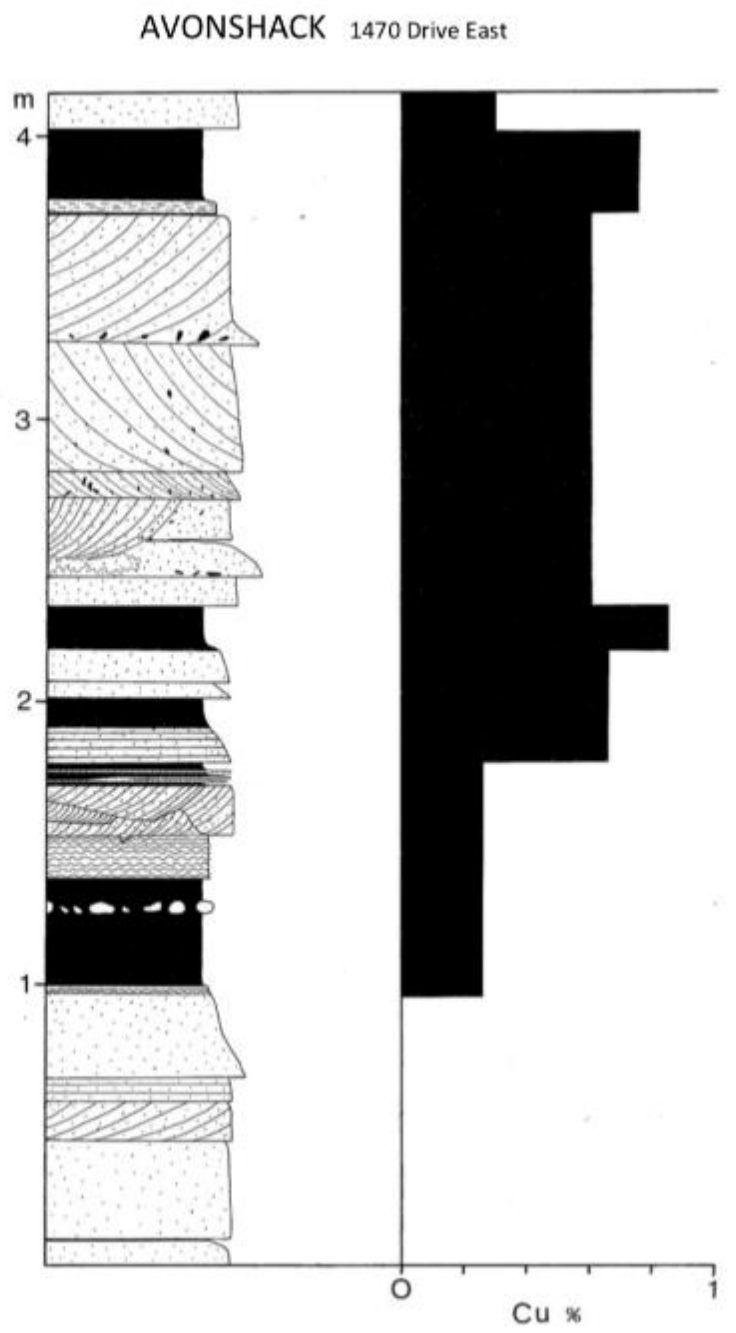


Figure 2: Stratigraphic section of the mineralized horizons of the Avonshack orebody,

Angwa Cu-Ag Mine

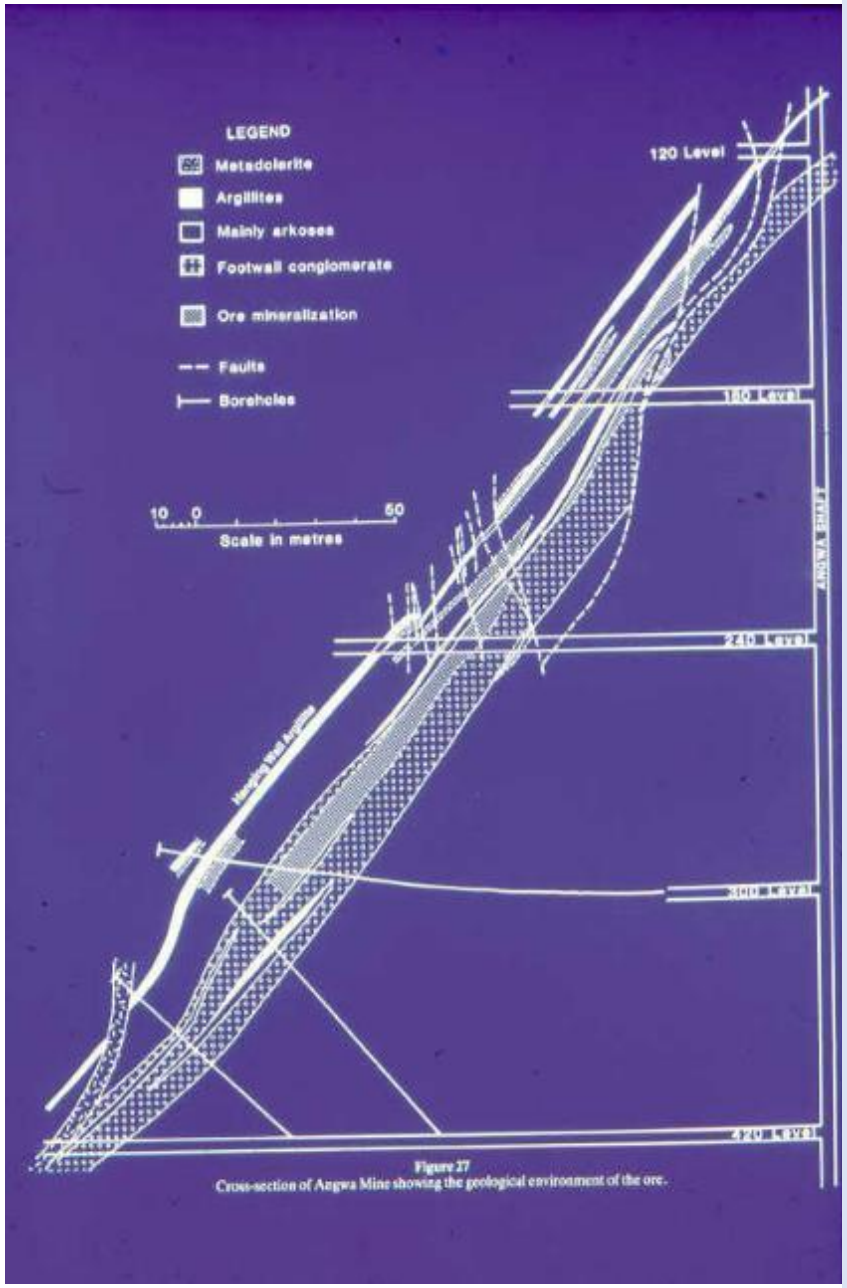
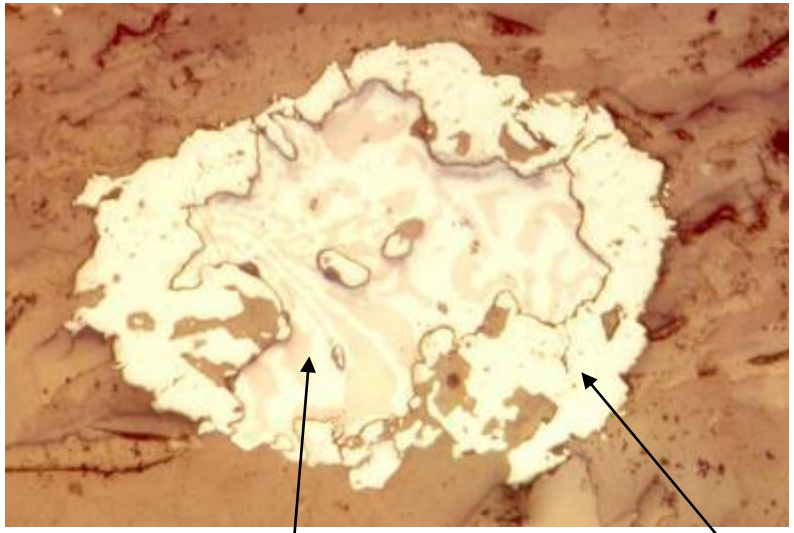
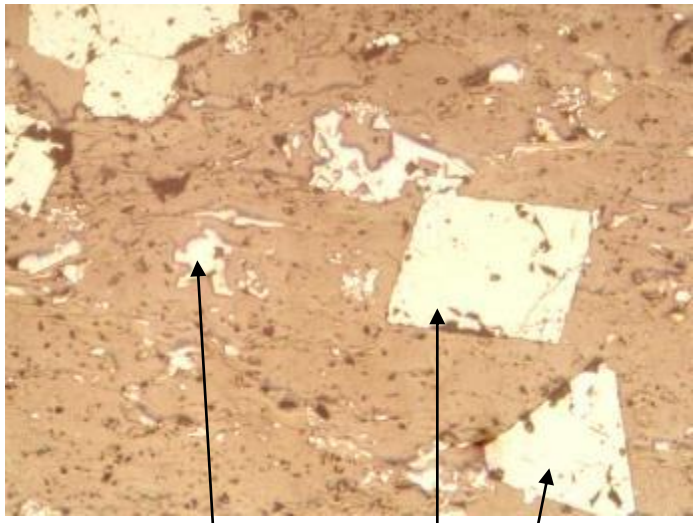


Figure 27
Cross-section of Angwa Mine showing the geological environment of the ore.

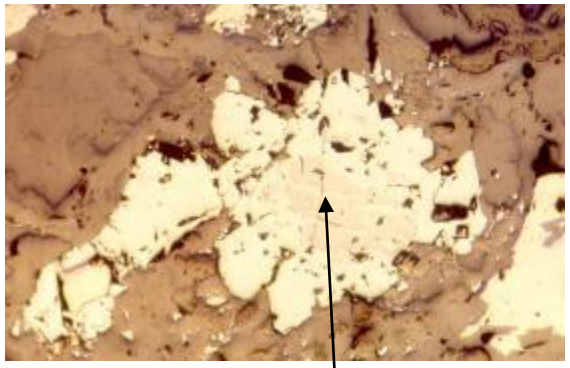


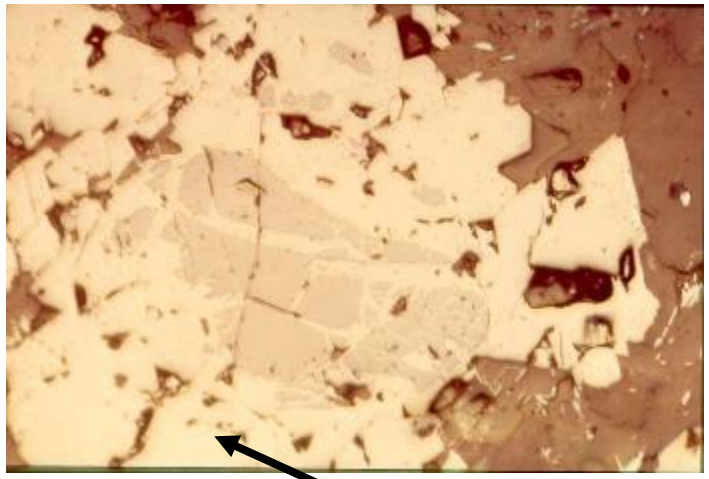
Cc-Bn myrmekite rimmed by Hm



Chalcocite magnetite

Angwa Mine ore textures





Detrital chromite replaced by magnetite