How the Magondi Belt lost its length:

Chemostratigraphic test for correlation in Central African Precambrian metamorphic belts

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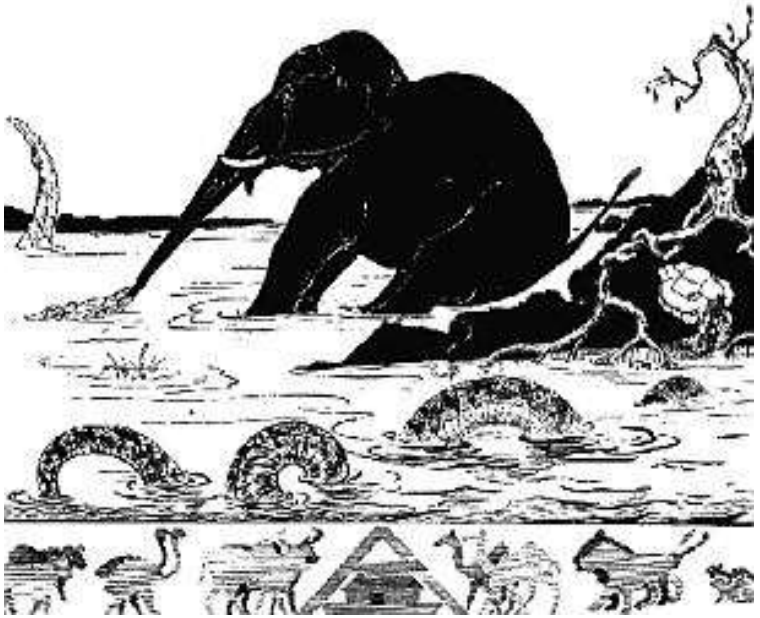
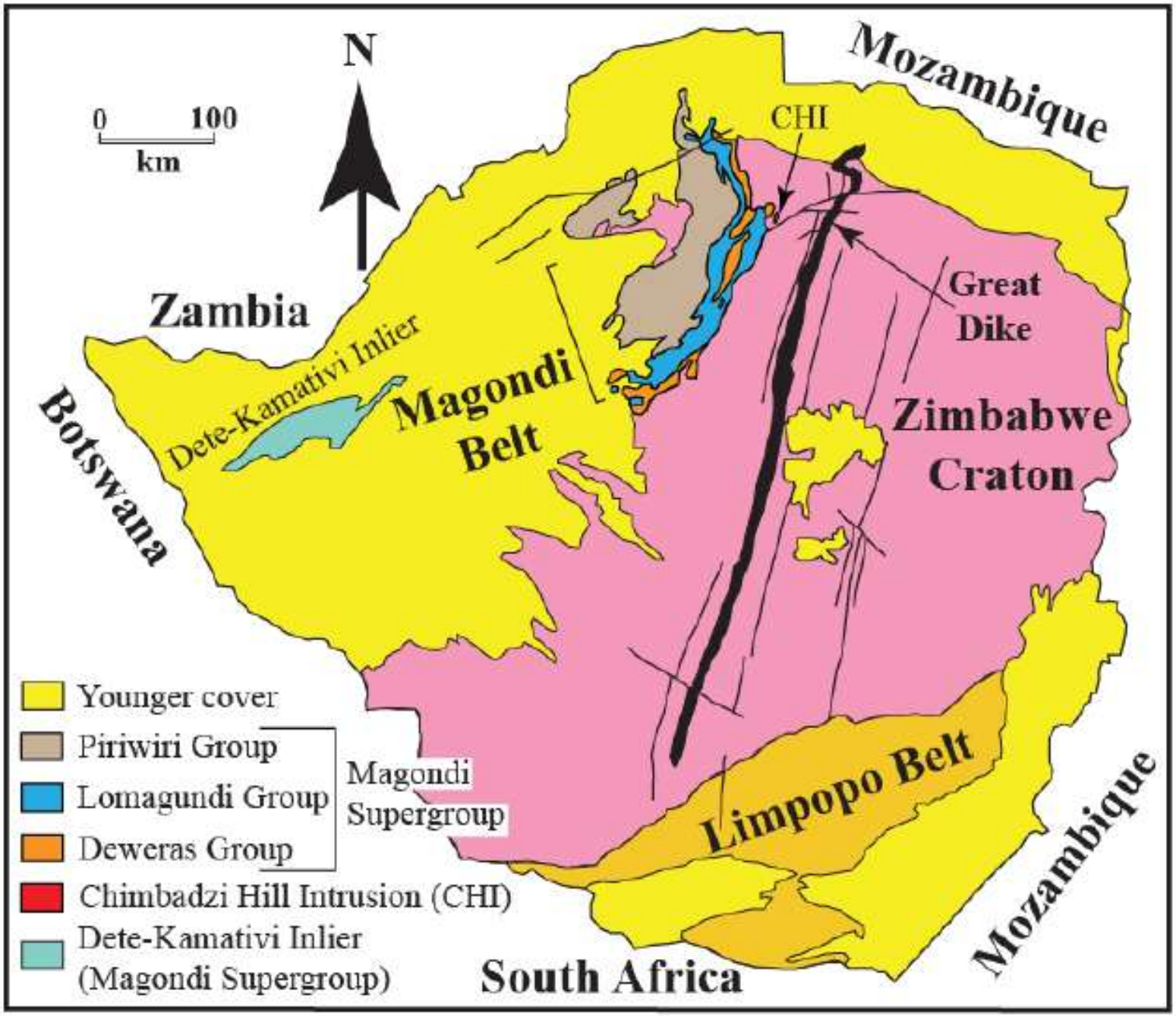
With apologies to Rudyard Kipling's Just So Stories

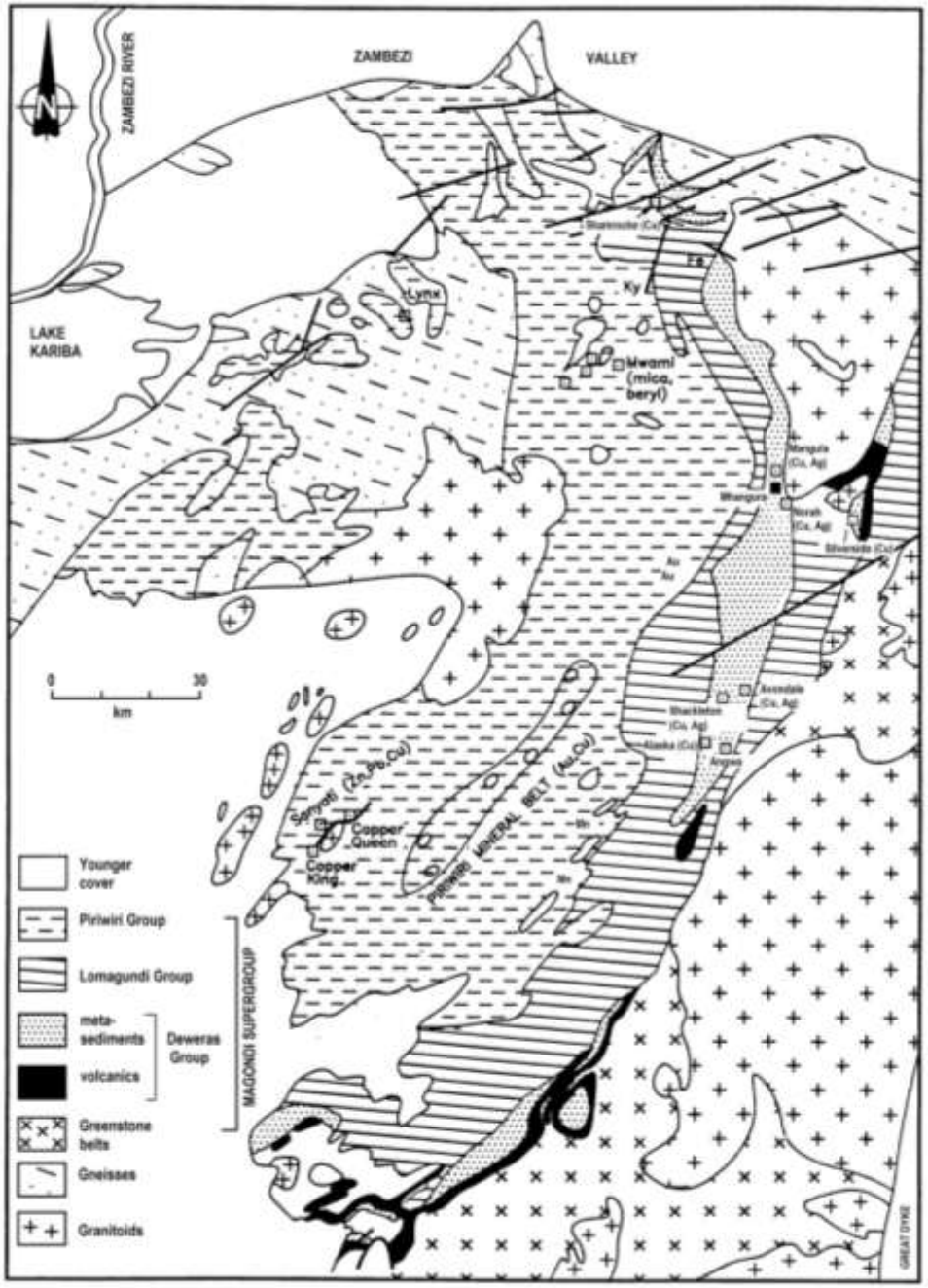
How the Elephant got his trunk



Part 1. How the Magondi Belt got its length

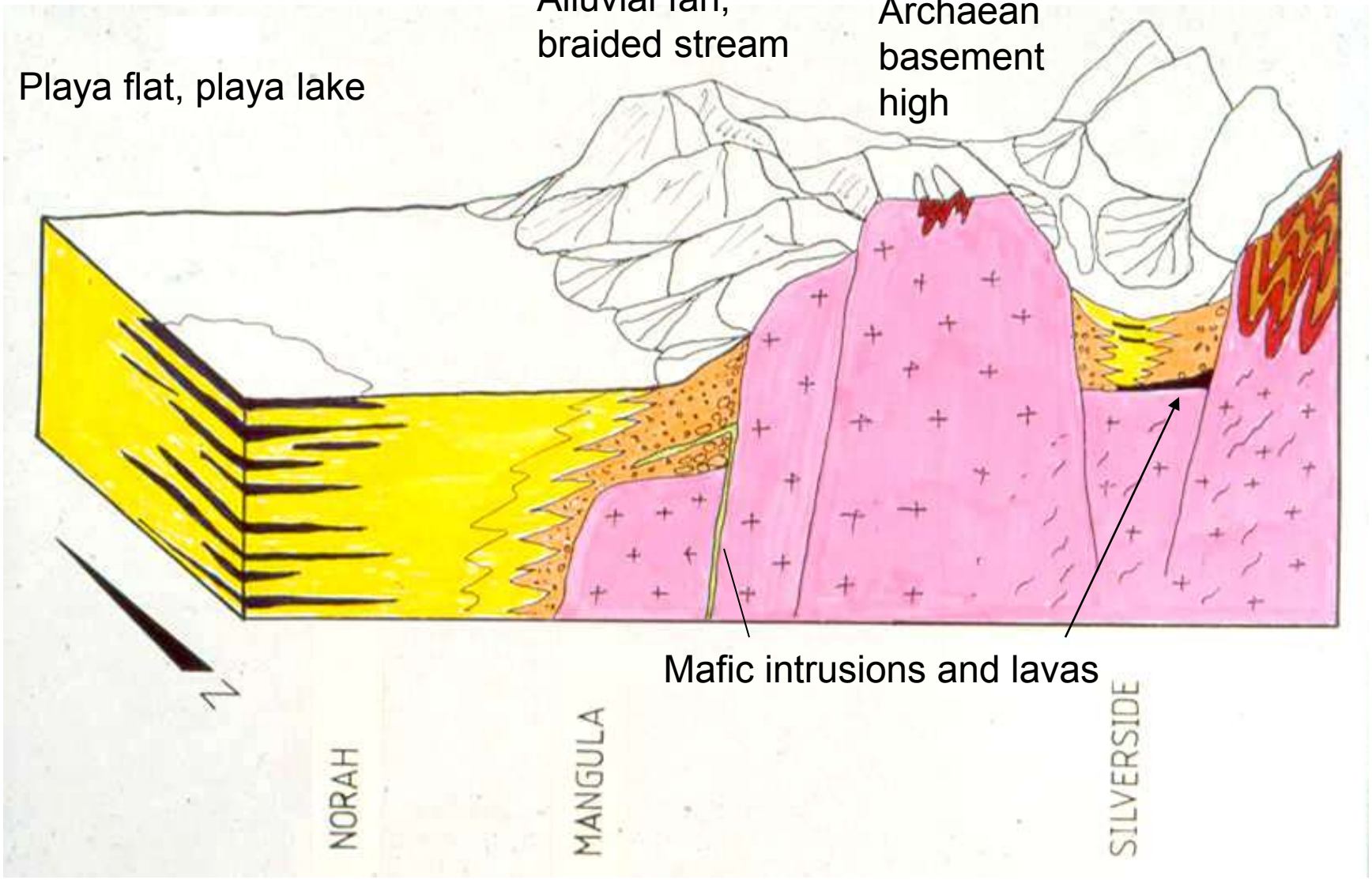
The Palaeoproterozoic Magondi Supergroup, ZImbabwe


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

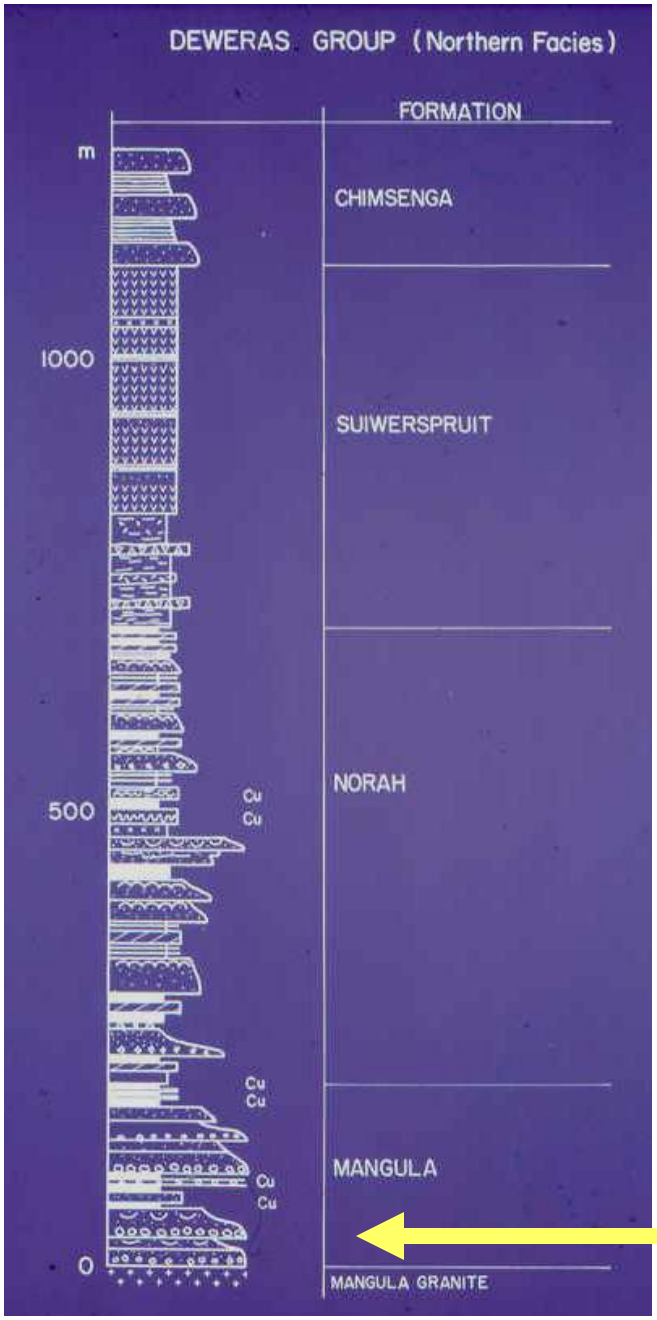

ZAMBEZI RIVER
ZAMBEZI VALLEY
LAKE KARIBA
Lynx
Ky
Mwami (mica, beryl)
Mangula (Cu, Ag)
Bwangura
Silverside (Cu)
Shackleton (Cu, Ag)
Alaska (Cu)
Angwa
Sipolilo (Au,Pb,Cu)
Copper Queen
Copper King
PIRIWIRI MINERAL BELT (Au,Cu)
GREAT DYKE
0
30
km
Younger cover
Piriwiri Group
Lomagundi Group
meta-sediments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

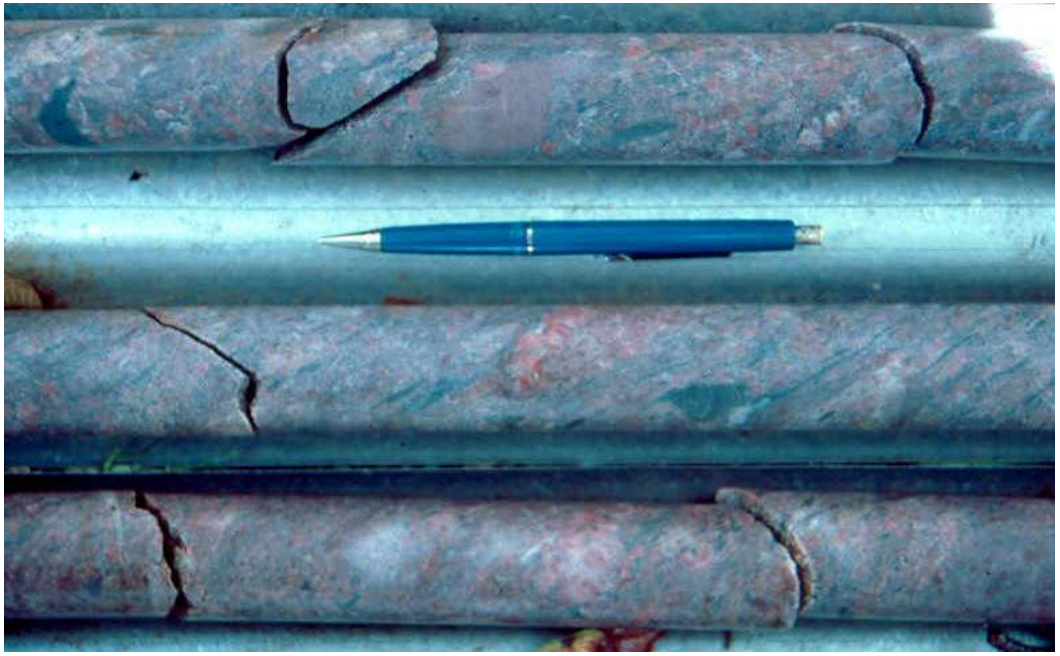
Generalised stratigraphy, lithology and environments of the Magondi Supergroup.

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)	



Palaeoenvironments, Deweras Group





Conglomerates in the Mangula Formation, Deweras Group

Master et al., 2010, Precambrian Research

Arkoses in Deweras Group with abundant detrital magnetites on trough-crossbed foresets (fluvial environment).

Anhydrite-bearing dolomites, Deweras Group

Master et al., 2010, Precambrian Research

Lomagundi Group- post-rift sag basin carbonate platform

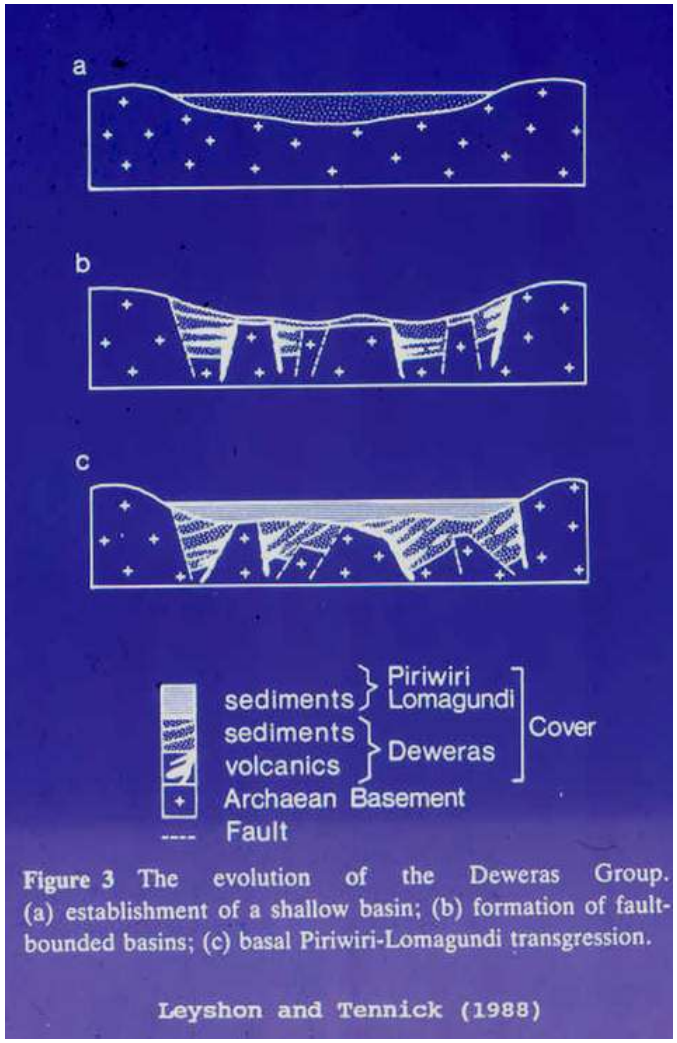
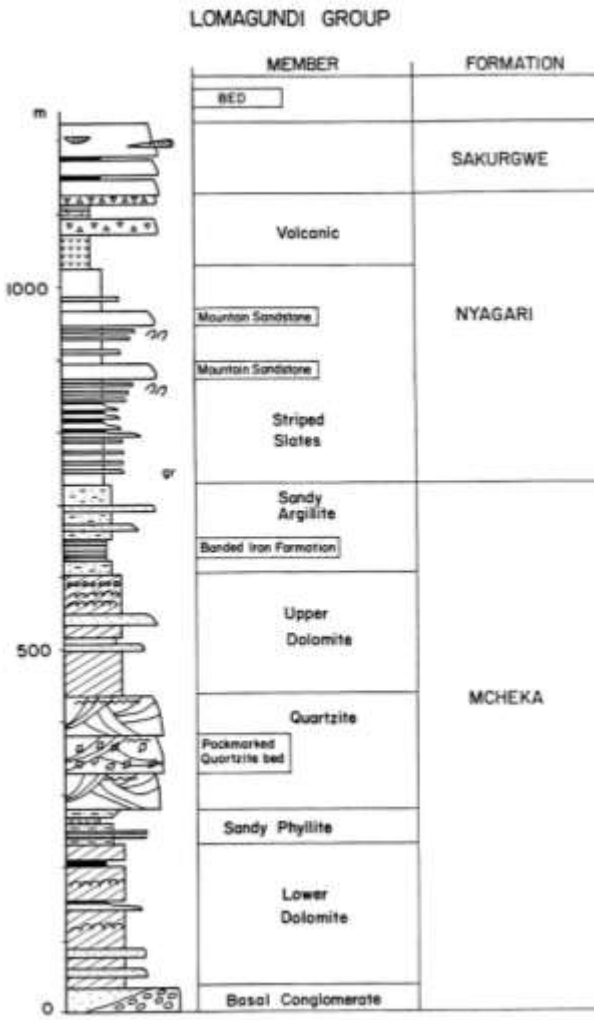


Figure 3 The evolution of the Deweras Group. (a) establishment of a shallow basin; (b) formation of fault-bounded basins; (c) basal Piriwiri-Lomagundi transgression.

Leyshon and Tennick (1988)

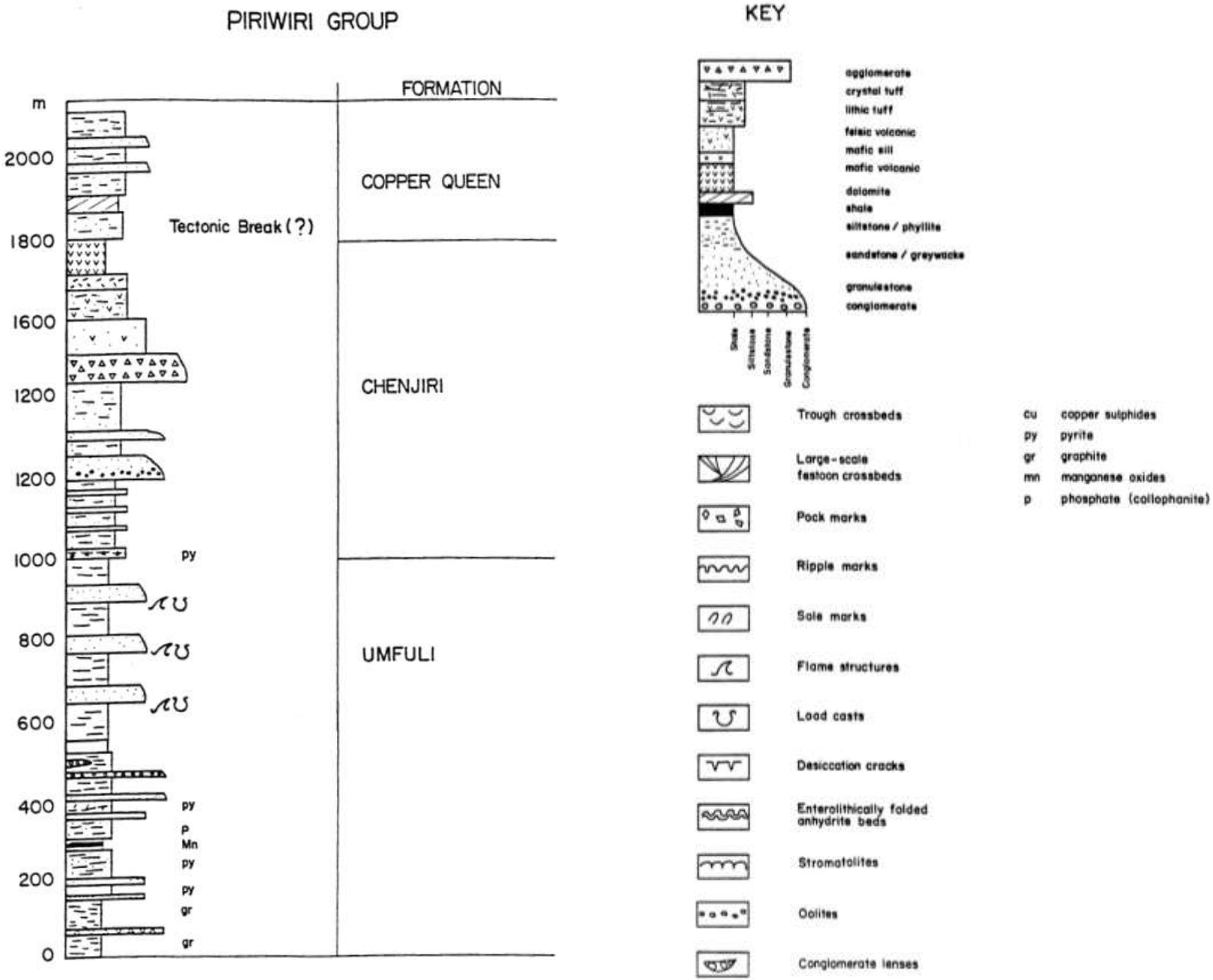


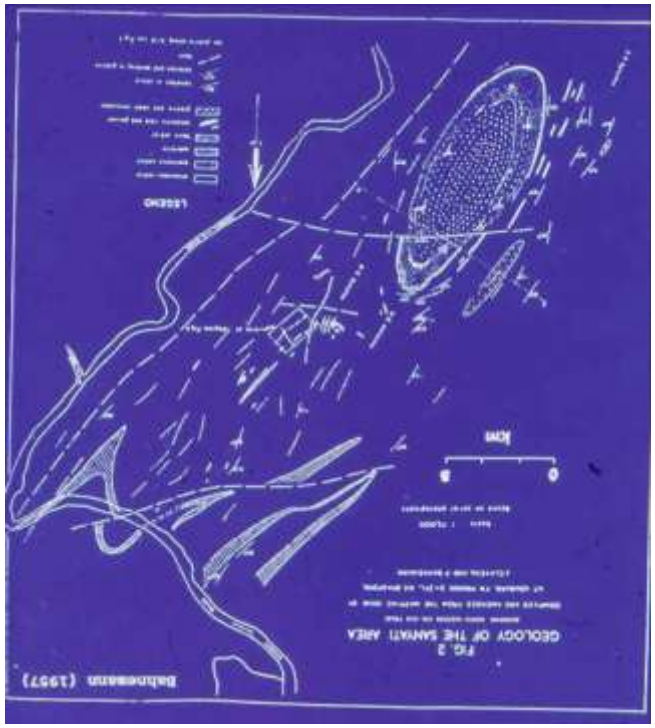
Lower Dolomite, Mcheka Formation, Lomagundi Group

Lower Dolomite, Mcheka Formation, Lomagundi Group

Upper Dolomite, Mcheka Formation, Lomagundi Group

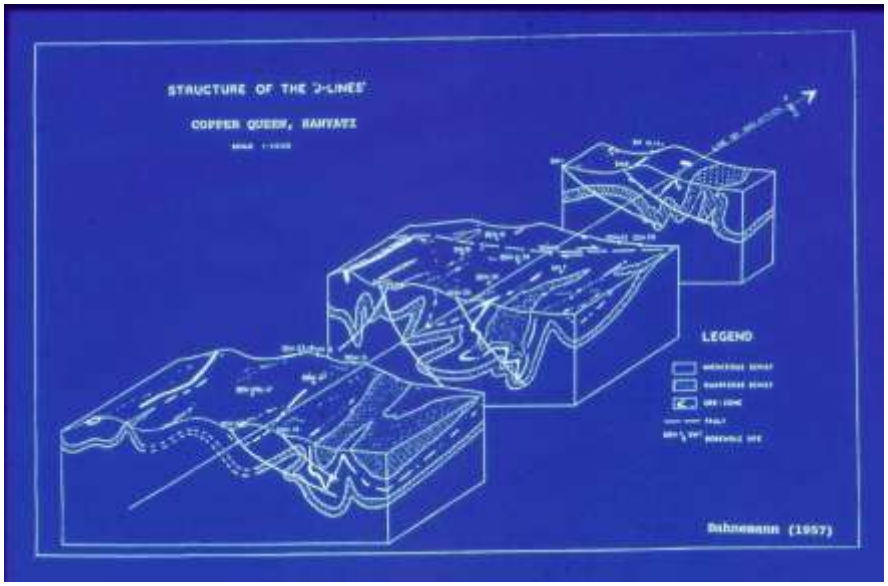
Plan view of deformed domical stromatolites, Lower Dolomite, Lomagundi Group

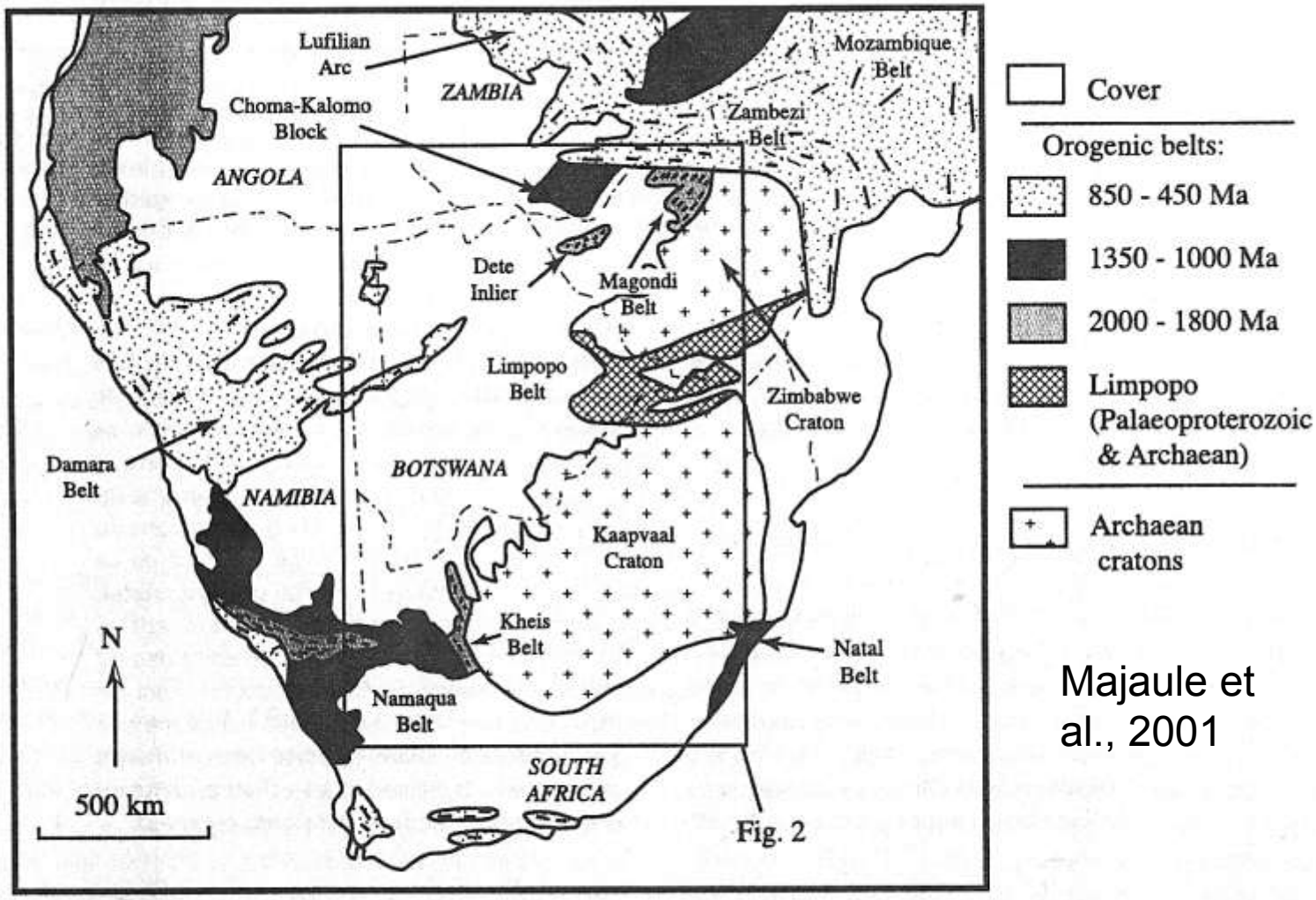

PIRIWIRI GROUP
FORMATION
m
2000
1800
1600
1200
1200
1000
800
600
400
200
0
COPPER QUEEN
CHENJIRI
UMFULI
Tectonic Break (?)
py
py
p
Mn
py
py
gr
gr
KEY
agglomerate
crystal tuff
lithic tuff
felsic volcanic
mafic sill
mafic volcanic
dolomite
shale
siltstone / phyllite
sandstone / greywacke
granulestone
conglomerate
Shale
Siltstone
Sandstone
Granulestone
Conglomerate
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)



Copper Queen Cu-Zn-(Pb)-(Ag) SHMS deposit, Piriwiri Group

Deeper water facies equivalent of Lomagundi Group. Massive sulphides overlain by high $\delta^{13}C$ carbonates





Majaule et al., 2001

***Figure 1**. Simplified map of the Precambrian tectonic framework of southern Africa, showing exposed parts of Proterozoic orogenic belts and Archæan cratons. The Limpopo Belt includes both Archæan and Palæoproterozoic components. Location of Fig. 2 is indicated.*

Majaule et al., 2001

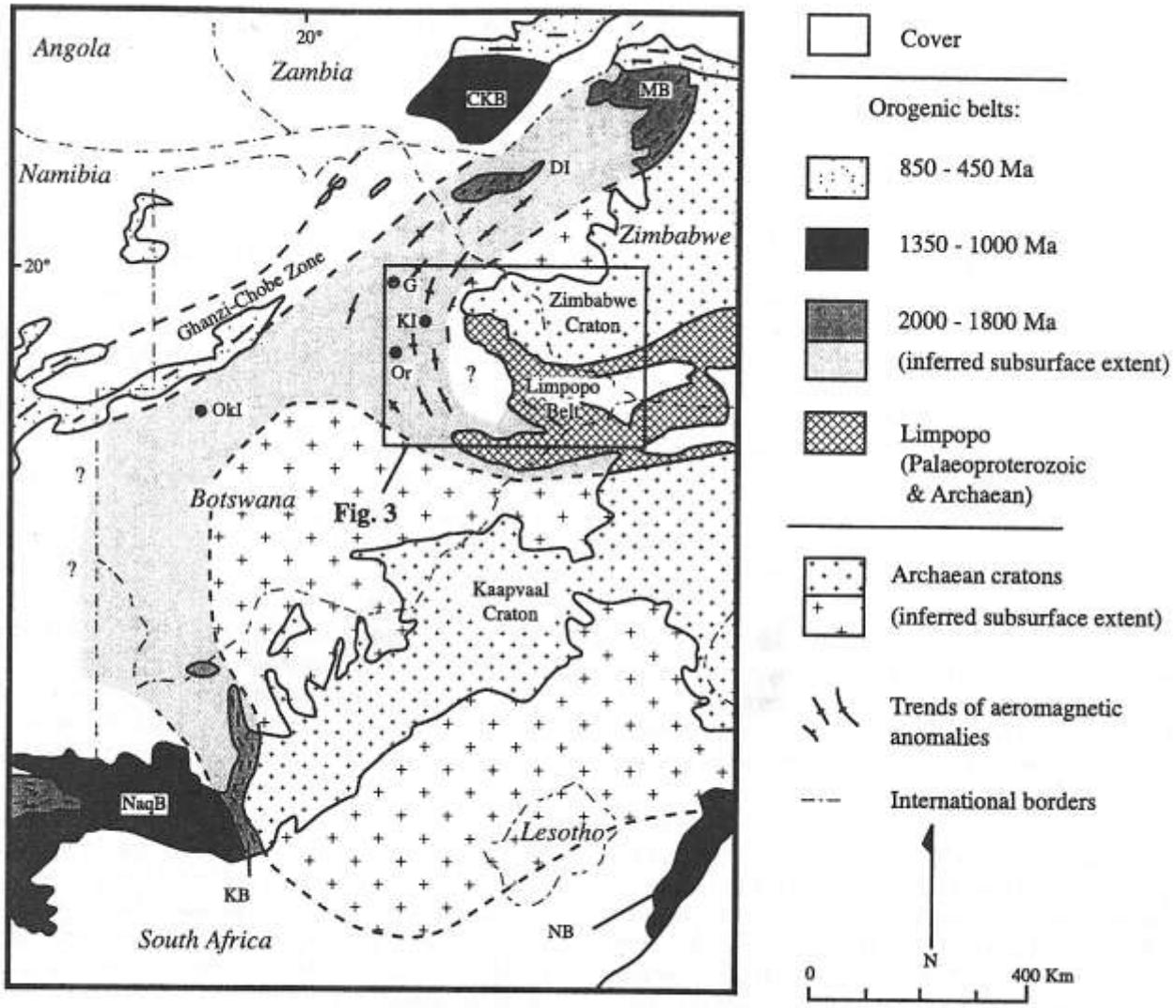


Figure 2. *Regional Precambrian tectonic framework of Botswana and adjacent areas (modified primarily from Carney* et al., *1994; Thomas* et al., *1994). CKB: Choma-Kalomo Block; MB: Magondi Belt; DI: Dete Inlier; G: Gweta; KI: Kubu Island; Or: Orapa diamond mine; Okl: Okwa Inlier; NaqB: Namaqua Belt; KB: Kheis Belt; NB: Natal Belt. Location of Fig. 3 is indicated.*

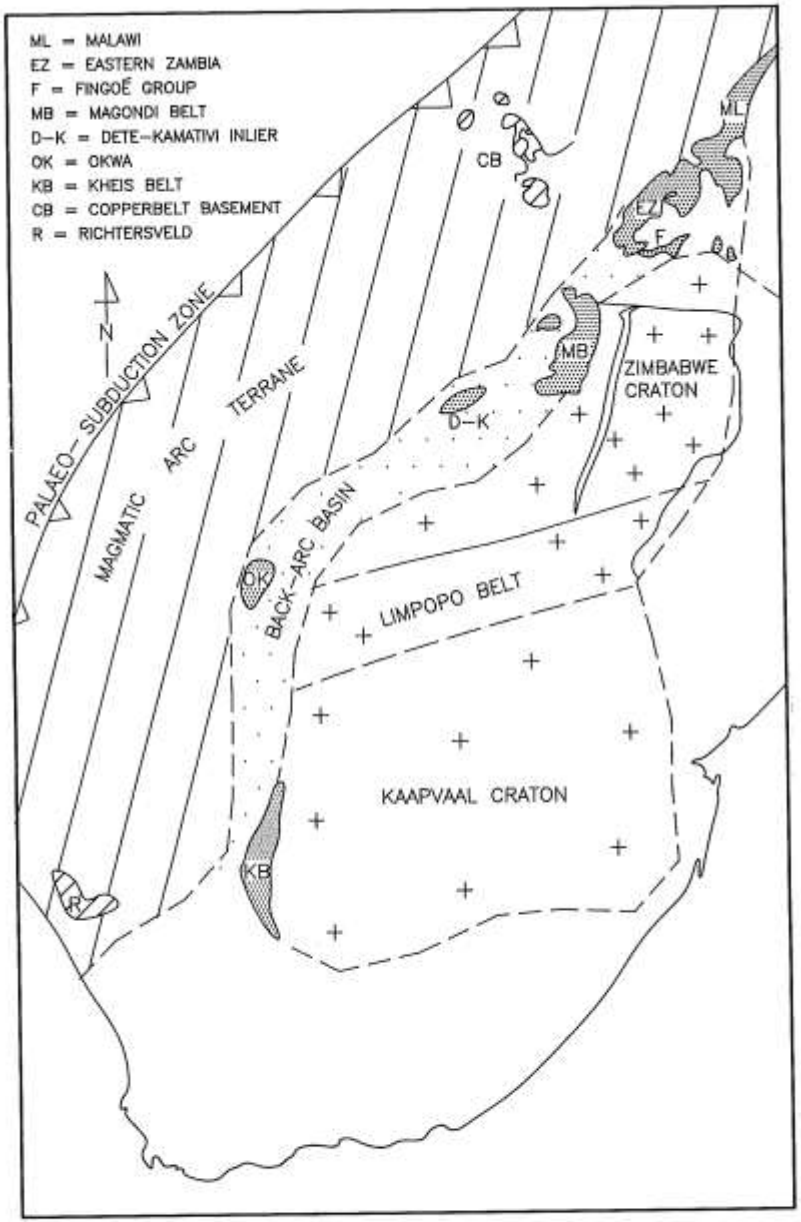
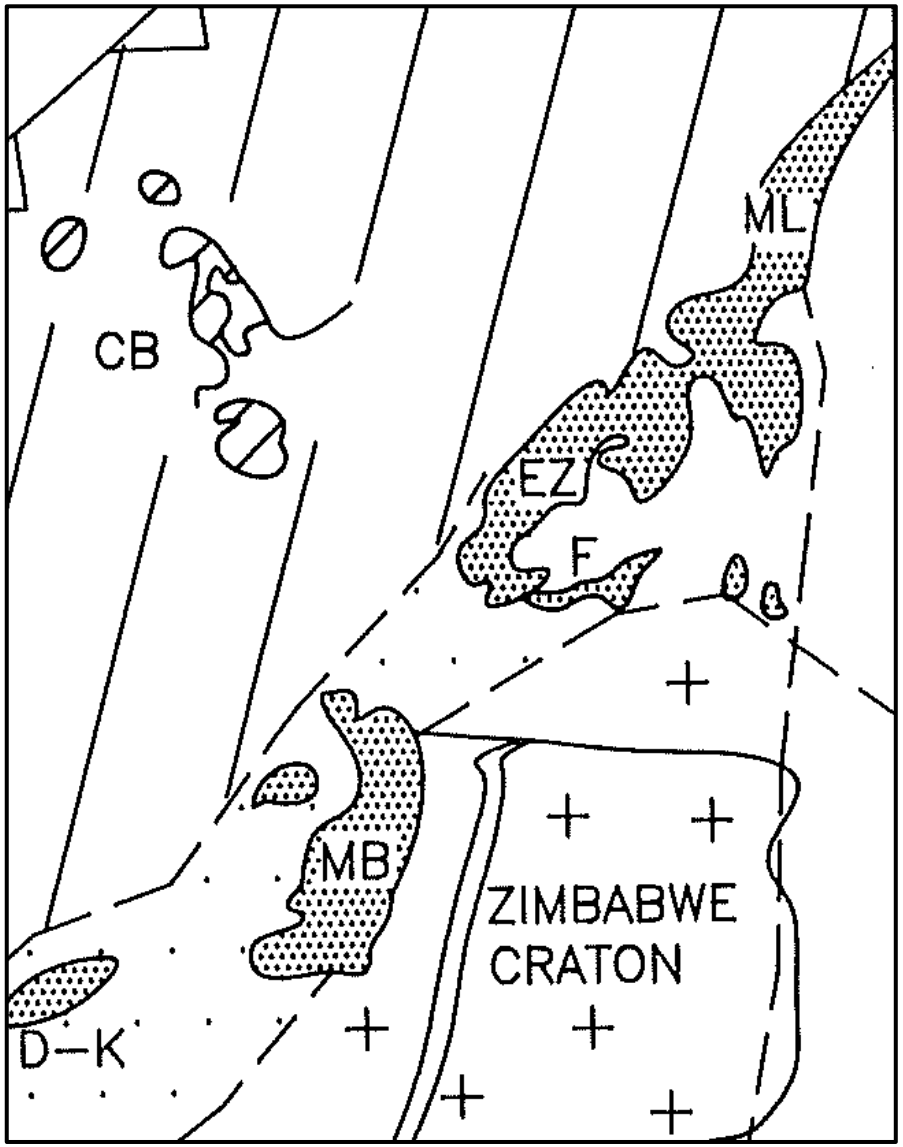
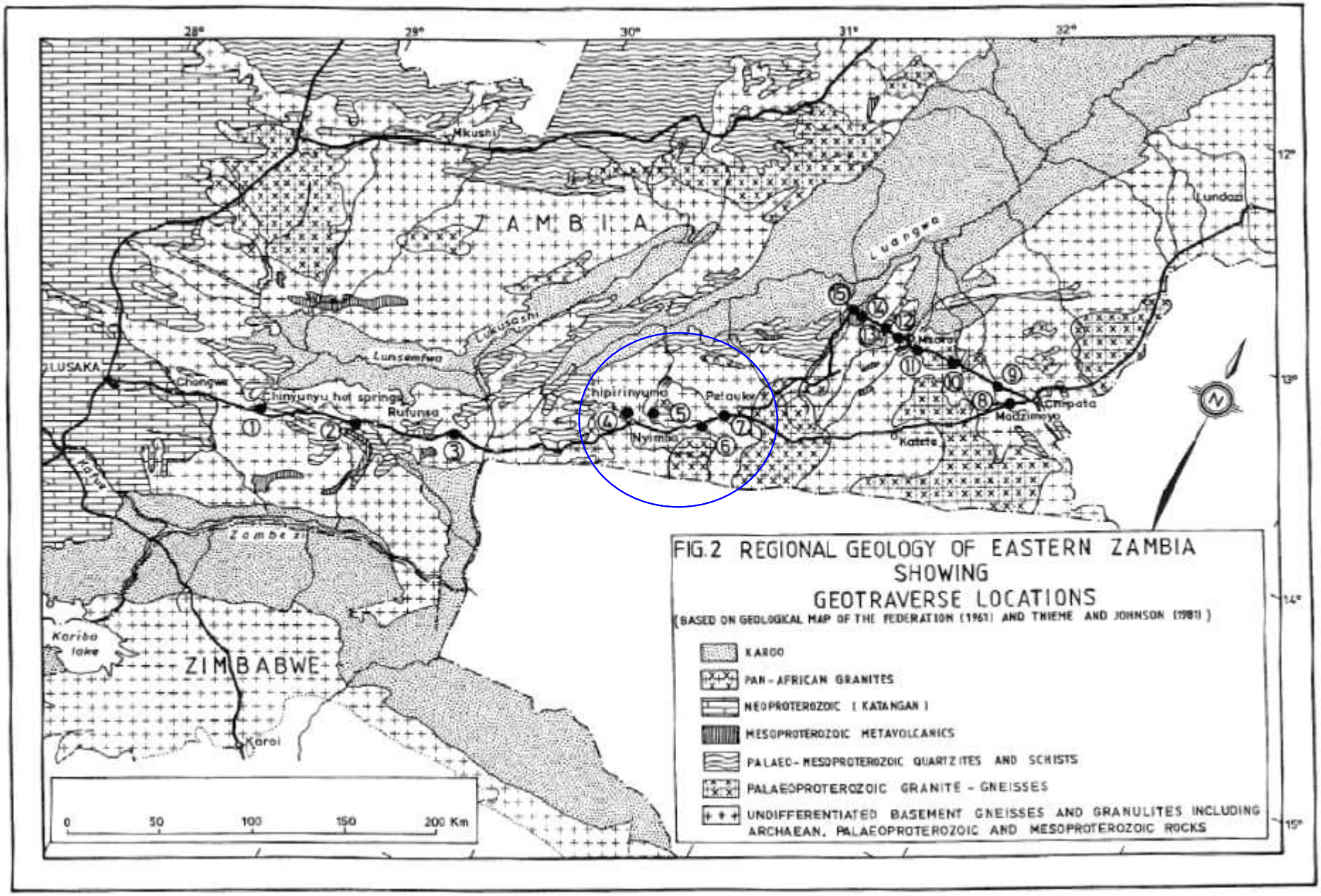


Figure 9: Schematic plan showing position of Magondi Supergroup and correlative sequences in a continental back-arc basin, with respect to the postulated magmatic arc terrane, palaeo-subduction zone, and the combined Zimbabwe-Limpopo-Kaapvaal continent (after Master, 1990d, 1991).



Master (1991a,b, 1994)



Kamona, Tembo, Sikazwe, Siegfried, Master, 1996. IGCP 363 Excursion Guidebook

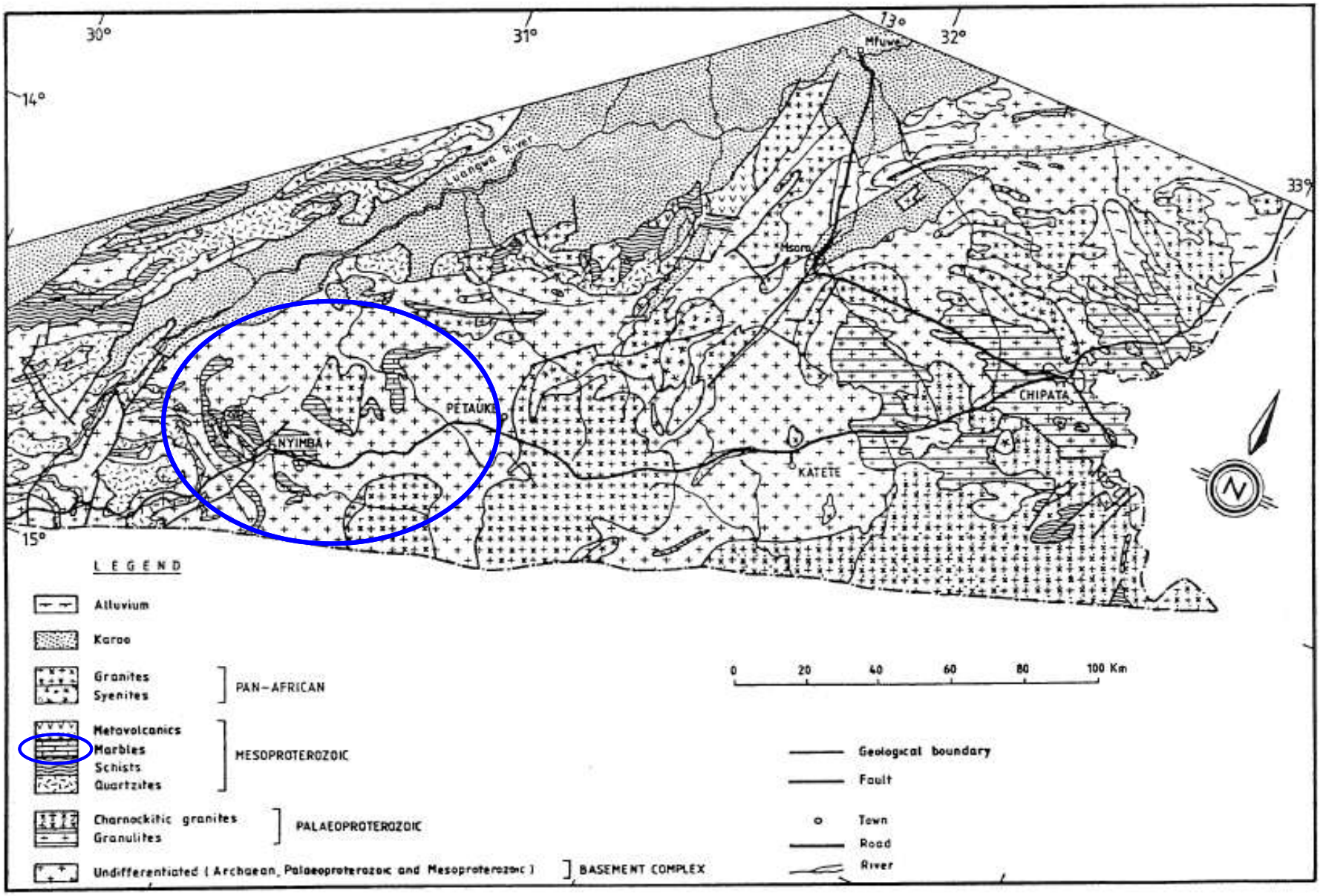


FIG. 3 GEOLOGICAL MAP OF NYIMBA — CHIPATA AREA (BASED ON THIEME AND JOHNSON, 1981)

Kamona, Tembo, Sikazwe, Siegfried, Master, 1996. IGCP 363 Excursion Guidebook

Northern continuation of Magondi Belt? (Master, 1991a,d; 1994)

Magondi Belt, NW Zimbabwe

- Deweras Group
  - Arkose, pelite, carbonates, mafic volcanics
- Lomagundi, Piriwiri Groups
  - quartzite, dolostones, black shales, graphitic schists, Cu-Pb-Zn massive sulphides
  - *Greenschist –amphibolite facies metamorphism*

Sinda, Lusandwa and Mvuvye terranes, Eastern Zambia

- Sinda, Lusandwa Groups

  -quartzo-feldspathic gneisses, schists, marbles, amphibolites
- Mvuvye Group
  - quartzite, marbles, graphite schists; Cu-Pb-Zn massive sulphides
  - *Amphibolite- granulite facies metamorphism*

- The Magondi basin developed from continental rift to passive margin (and later to a foreland basin), and in the marine successions there are represented both proximal shallow water and distal deep water facies, and in all facies there are ^{13}C-enriched carbonate rocks.

2. Carbon isotope anomalies and use of high $\delta^{13}C$ carbonate rocks in chemostratigraphic correlation

Precambrian Research, 2 (1975) 2 (1975) 1—69

PRECAMBRIAN SEDIMENTARY CARBONATES: CARBON AND OXYGEN ISOTOPE GEOCHEMISTRY AND IMPLICATIONS FOR THE TERRESTRIAL OXYGEN BUDGET*

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(Received March 20, 1974; accepted July 1, 1974)

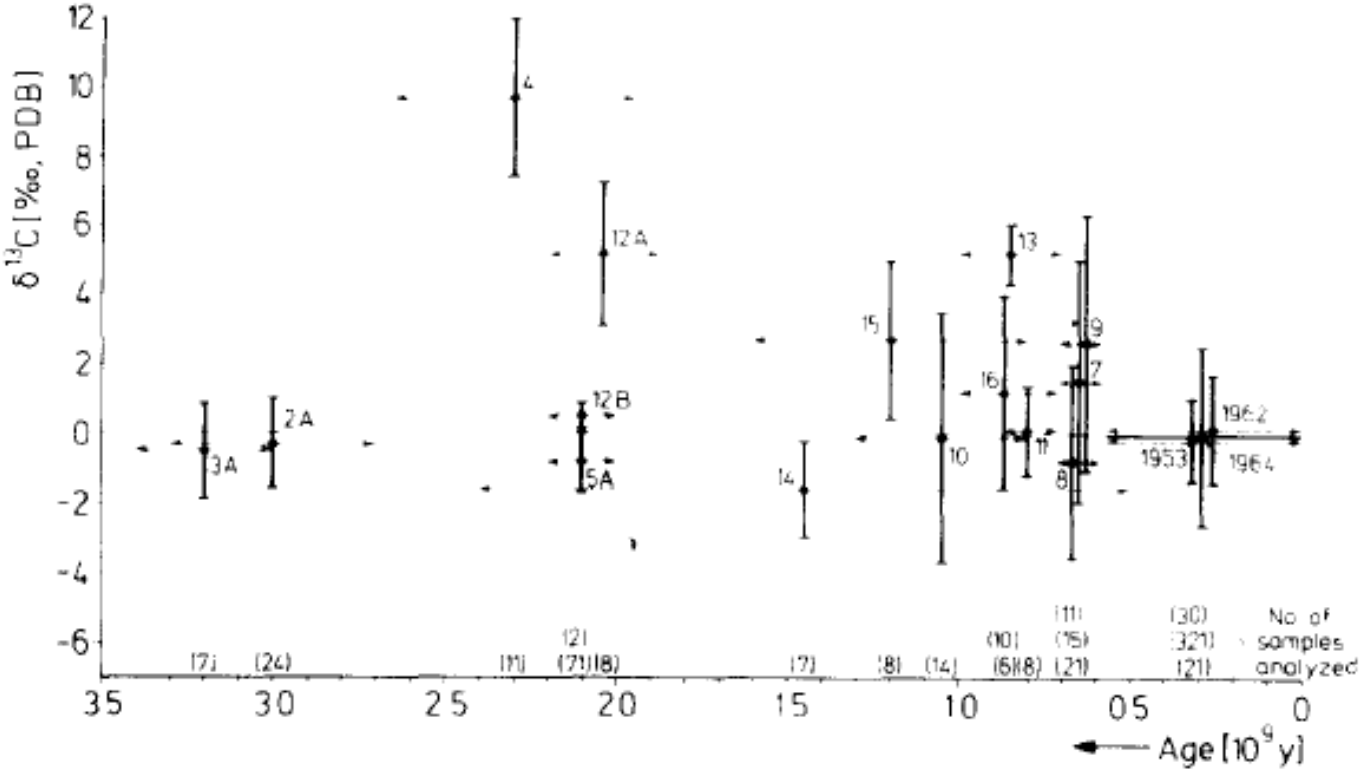
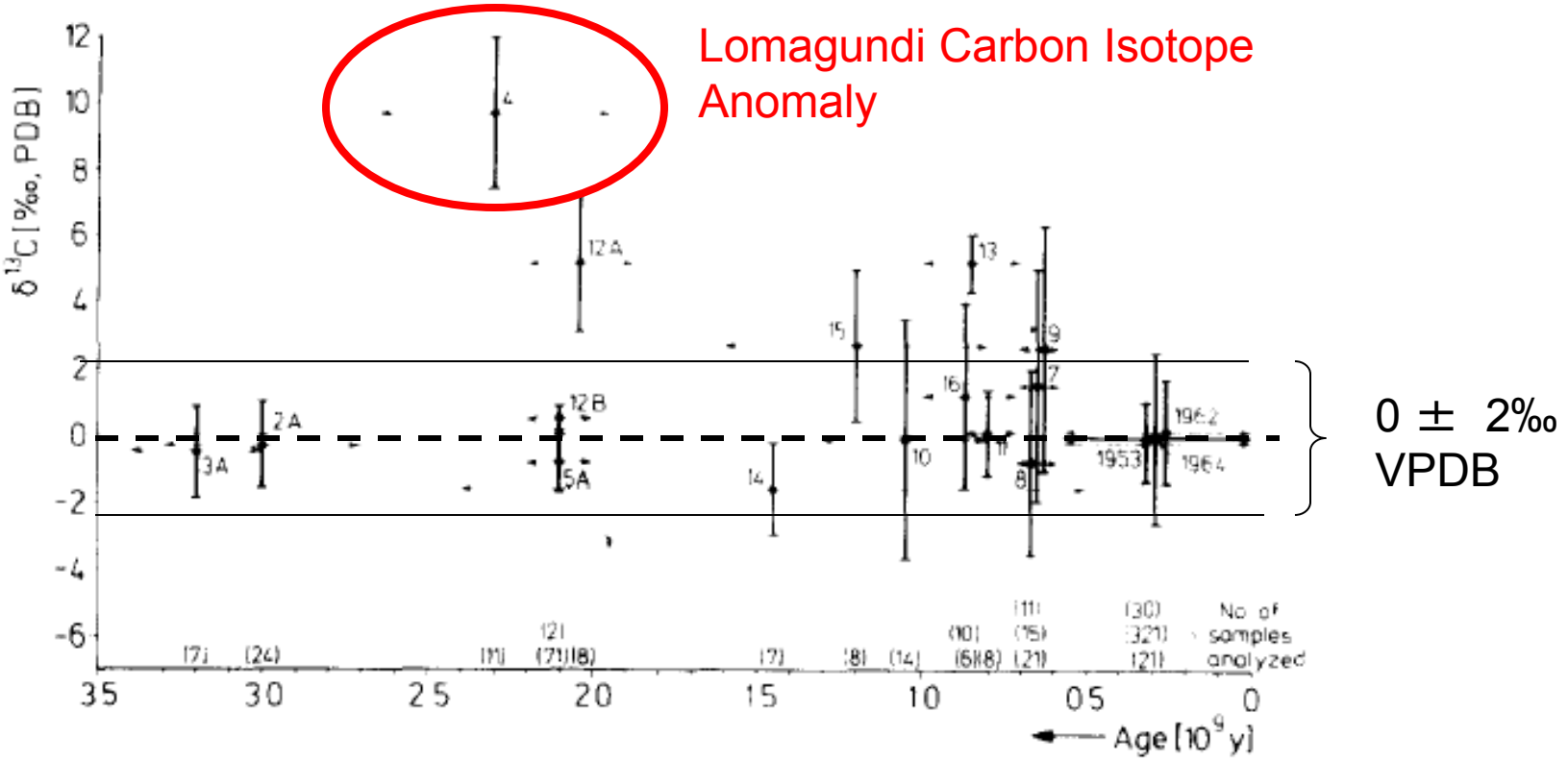


Fig. 11. Carbon isotope composition of substantially unaltered sedimentary carbonates as a function of geologic time. Mean $\delta^{13}C$ values of carbonate groups investigated are indicated by circles, the vertical bars representing the standard deviation; horizontal arrows show possible geological time range. Numbers refer to Tables IIA—XVI listing the values yielded by individual samples of each group or locality. (Values for Phanerozoic carbonates (< 0.57 10^9y) according to Craig, 1953; Degens and Epstein, 1962; Keith and Weber, 1964.)

Schidlowski, Eichmann & Junge, 1975



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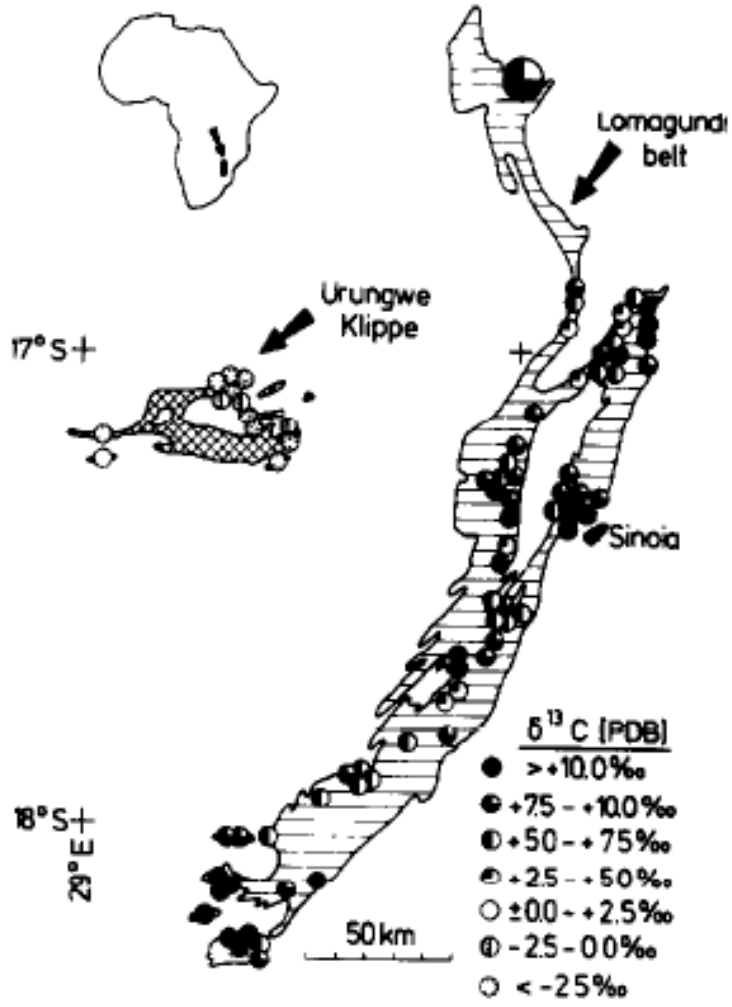


Fig. 2. Outcrops of Lomagundi sediments (hatched, Lomagundi belt) or rocks of assumed Lomagundi association (crosshatched, Urungwe klippe) with regional distribution pattern of $\delta^{13}C$ values yielded by the intercalated carbonates. Major circle near northern tip of Lomagundi belt shows average for Shamrocke Mine area (R. H. Thole, personal communication, 1974). For situation of the area cf. key map in upper left corner.

Schidlowski, Eichmann & Junge, 1976

In a reconnaissance isotopic study of global Precambrian carbonates, by Schidlowski et al. (1975), the carbonate rocks of the Lomagundi Group were found to be the most isotopically anomalous regional carbonate province in the world, being **very enriched in ^{13}C**, with an average $\delta^{13}C$ value of +8.2‰ VPDB.

Subsequent work in the Magondi Basin has shown that high $\delta^{13}C$ carbonates are also present in the continental rocks of the underlying Deweras Group.

This isotopic anomaly has now been recognized globally in carbonate rocks deposited in the time span 2.24-2.06 Ga.

It is known as the Lomagundi Carbon Isotope Excursion

Schidlowski et al. 1975

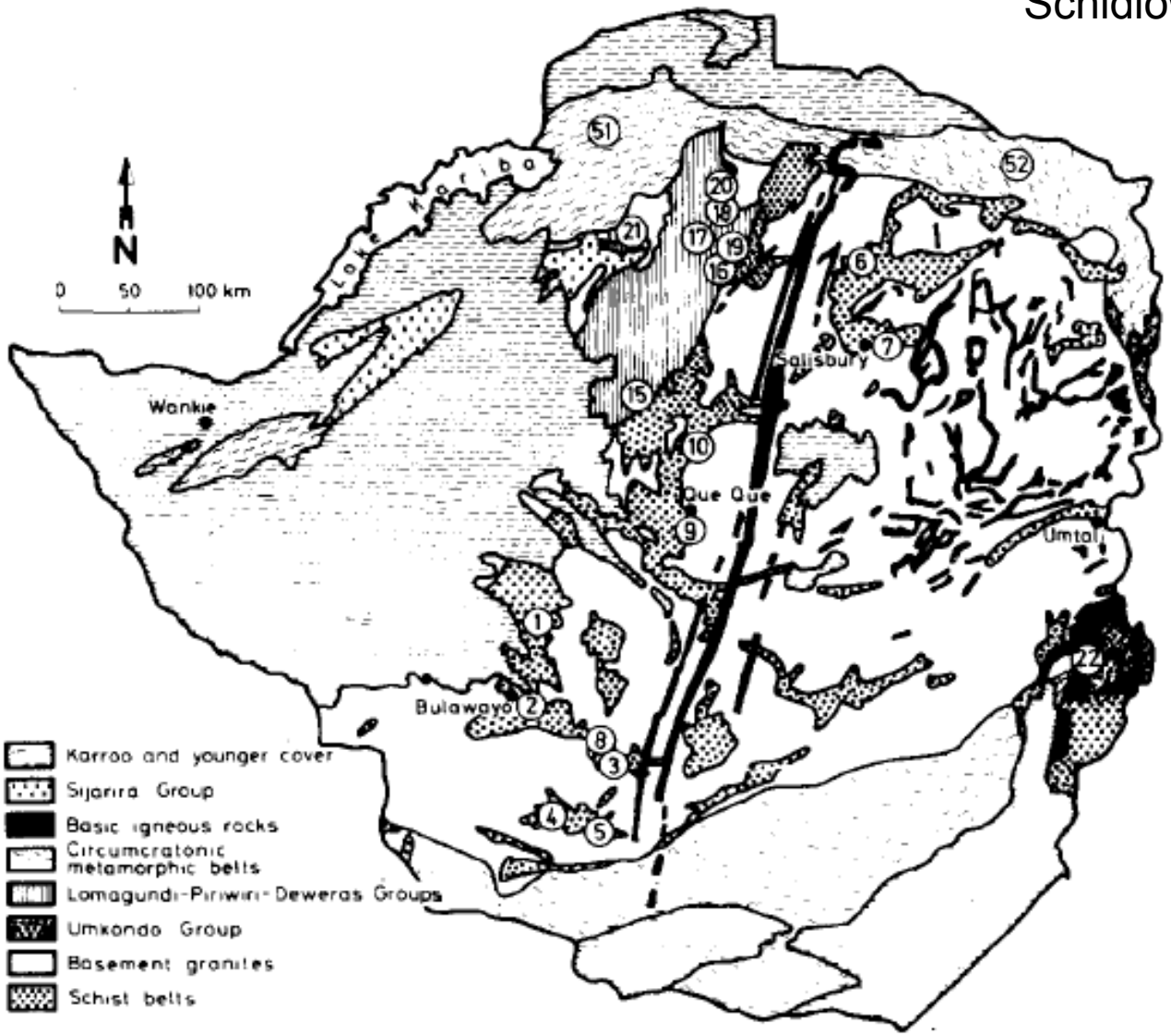
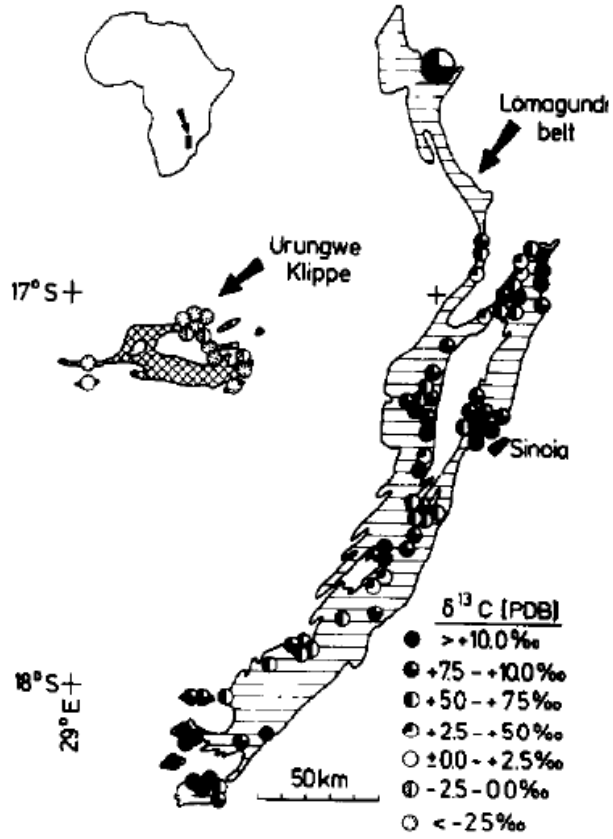


Fig.3. Geological sketch map of Rhodesia showing the localities (encircled numbers) within the ancient 'schist belts' (dotted areas) from where the carbonate samples listed in Table II have been collected. Other sampling localities refer to carbonates from the Lomagundi and Umkondo Groups (see Table IV) and from the circumcratonic belts (Table VI).



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Geochimica et Cosmochimica Acta, 1976, Vol. 40, pp. 449 to 455. Pergamon Press. Printed in Great Britain

Carbon isotope geochemistry of the Precambrian Lomagundi carbonate province, Rhodesia

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(*Received* 18 *March* 1975; *accepted in revised form* 14 *October* 1975)

Abstract—Carbon isotope measurements carried out on 67 dolomite samples from the Middle Precambrian Lomagundi Group (Rhodesia) have yielded a $\delta^{13}C$ mean of $+8{\cdot}2 \pm 2{\cdot}6$‰ vs PDB. With the outcrop of these dolomites extending over a distance of almost 300 km, the Lomagundi dolomite facies is likely to represent the largest isotopically anomalous sedimentary carbonate province ever recorded. It is concluded that the anomalous carbonates formed in a closed basin whose $\delta^{13}C$ level had been substantially increased as a result of a preferential removal (within sedimentary organics) of the light carbon isotope.

Schidlowski et al. 1976

TABLE 1. CARBON ISOTOPE COMPOSITIONS OF CARBONATE AND SEDIMENTARY ORGANIC MATTER

	Stratigraphic unit*	$\delta^{13}C_{carb}$ (‰, PDB)	n	$\delta^{13}C_{org}$ (‰, PDB)	n	Age (Ga)	Source of data†	Reference to age†
1.	Wittenoom/Carawine Dolomite	-0.3 ± 1.5	103	-27.5 ± 9.2	17	2.603 ± 0.007	22, 25	8, 24, 10
2.	Malmani/Campbellrand Subgroup	-0.7 ± 0.8	186	-31.6 ± 7.2	64	2.55 ± 0.01	22, 26	2, 11
3.	Mt Sylvia and Mt McRae formations	-12.9 ± 3.9	29	-32.0 ± 6.5	7	2.54 ± 0.07	22	8, 24
4.	Madetkoski Formation	-1.7	1			2.53 ± 0.05	12	12
5.	Brockman Iron Formation	-9.6 ± 1.7	51			2.47 ± 0.07	22	24
6.	Asbesheuwels and Koegas subgroups			-26.0 ± 6.4	4	2.43 ± 0.03	22	24
7.	Itabira Group	-0.9 ± 1.4	9	-23.2 ± 1.9	10	2.42 ± 0.02	22	1
8.	Seidorecha Formation	-2.7 ± 0.8	3			2.423 ± 0.007	12	12
9.	Huronian Supergroup	-1.3 ± 0.5	35	-28.4 ± 3.8	26	2.34 ± 0.12	22, 26	6, 13
10.	Sericite Schist Formation, Kuusamo	8.1 ± 0.1	2			2.25 ± 0.05	12	12
11.	Sompujärvi Formation	7.3 ± 1.2	3			2.25 ± 0.04	12§	12
12.	Misi dolomite	12.6 ± 0.4	5			2.23 ± 0.07	12	12
13.	Pretoria Group	0.8 ± 0.6	3	-23.2 ± 3.4	3	2.22 ± 0.02	22	28
14.	Hotazel Formation	-10.0 ± 2.1	3			2.22 ± 0.02	22	28
15.	Lower Viistola Formation	10.0 ± 0.7	5			2.113 ± 0.004	12	12
16.	Piracicaba Group			-23.8 ± 5.5	15	2.10 ± 0.04	22	14, 1
17.	Jouttiaapa Formation	8.4 ± 1.6	10			2.09 ± 0.07	12	12
18.	Lomagundi Group	8.4 ± 2.7	79	-23.9 ± 0.3	2	2.07 ± 0.10	22	23
19.	Francevillian Series	4.3 ± 1.6	4	-31.7 ± 7.7	40	2.07 ± 0.05	7	4
20.	Upper Petonen Formation	2.0 ± 1.4	2			2.062 ± 0.002	12	12
21.	Belcher and Nastapoka groups	-1.3 ± 0.9	5	-23.4 ± 2.8	8	1.99 ± 0.04	22	5
22.	Earaheedy Group	-0.7 ± 1.2	8	-22.1 ± 6.5	22	1.98 ± 0.03	22	20
23.	Svecofennian group	0.8 ± 1.1	52			1.92 ± 0.03	12	12
24.	Coronation Supergroup	0.6 ± 1.6	33	-20.5 ± 6.0	19	1.91 ± 0.02	22, 27	27
25.	Great Slave Supergroup	0.8 ± 1.1	6	-27.3 ± 8.2	4	1.90 ± 0.03	22	3
26.	Amisk Group			-26.4 ± 2.8	40	1.89 ± 0.01	22	21
27.	Koolpin Formation			-30.8 ± 0.3	2	1.885 ± 0.002	22	16, 18
28.	Grythyttan Slate			-28.6 ± 1.5	3	1.88 ± 0.02	22	29
29.	Spartan Group			-29.9 ± 0.6	3	1.86 ± 0.02	22	15
30.	Upper Wyloo Group	0.2 ± 1.2	32	-23.1 ± 2.9	13	1.843 ± 0.002	22, 27	19
31.	Whitewater Group			-30.5 ± 5.0	5	1.75 ± 0.10	22	13
32.	Urquhart Shale			-24.2 ± 2.1	33	1.653 ± 0.007	22	17, 18
33.	McArthur Group	-1.1 ± 0.8	120	-29.7 ± 2.8	44	1.640 ± 0.007	22, 27	17, 18
34.	Paradise Creek Formation			-28.9 ± 0.3	4	1.640 ± 0.007	22	17, 18
35.	Changcheng group			-30.1 ± 2.0	19	1.62 ± 0.01	22	9

Note: Isotope data represent average $\delta^{13}C$ values ±1 standard deviation; PDB-Peedee belemnite standard.

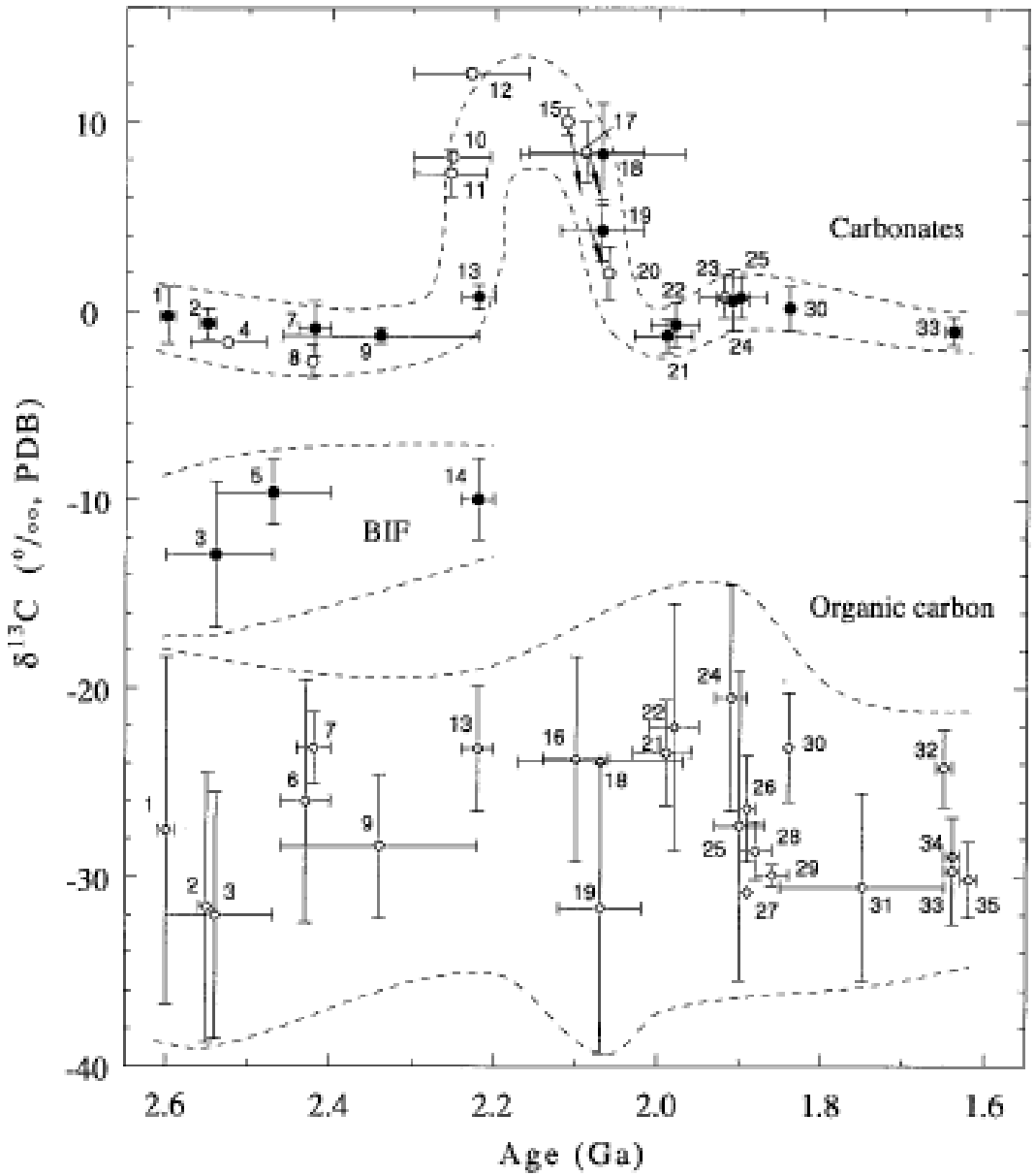
*Numbers refer to Figure 1 and to the text.

†References: 1-Babinski et al., 1995, 2-Barton et al., 1994, 3-Bowring et al., 1984, 4-Bros et al., 1992, 5-Chandler and Parrish, 1989, 6-Corfu and Andrews, 1986, 7-Gauthier-Lafaye and Weber, 1989, 8-Hassler, 1993, 9-Jahn and Cuvellier, 1994, 10-Jahn and Simonson, 1995, 11-Jahn et al., 1990, 12-Karhu, 1993, 13-Krogh et al., 1984, 14-Machado et al., 1992, 15-Machado et al., 1993, 16-Needham et al., 1988, 17-Page et al., 1994, 18-Page, 1988, 19-Pidgeon and Horwitz, 1991, 20-Russell et al., 1994, 21-Stern et al., 1993, 22-Strauss et al., 1992, 23-Treloar, 1988, 24-Trendall et al., 1990, 25-Veizer et al., 1990, 26-Veizer et al., 1992a, 27-Veizer et al., 1992b, 28-Walraven et al., 1990, 29-Welin, 1987.

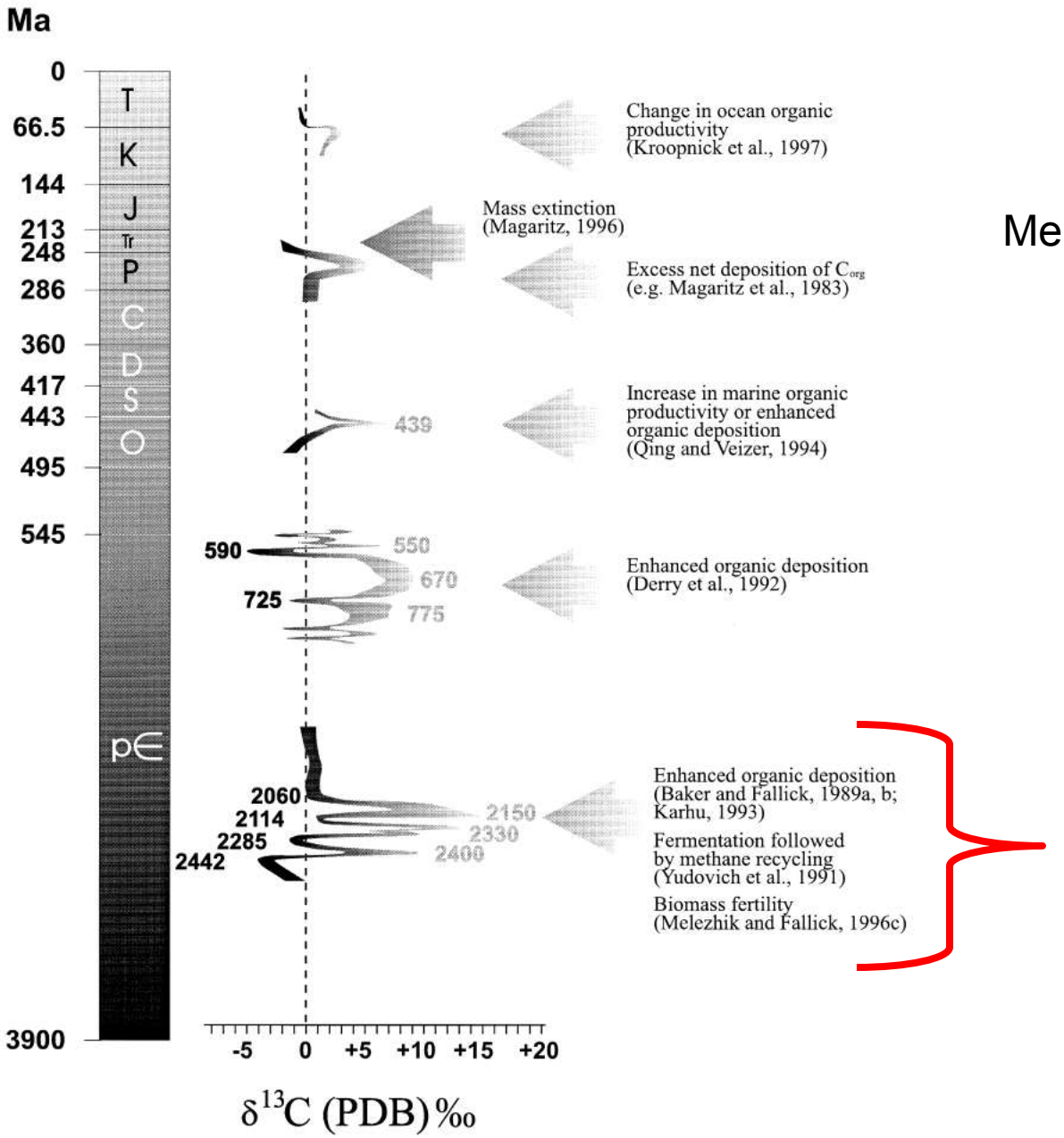
§Two new analyses ($\delta^{13}C$ = 7.22‰, 6.11‰) from the same location have been included.

Karhu & Holland 1996

Figure 1. Variation in isotopic composition of carbon in sedimentary carbonates and organic matter during Paleoproterozoic time. Sources of isotopic and age data are given in Table 1. Mean $\delta^{13}C$ values of carbonates from Fennoscandian Shield from Karhu (1993) are indicated by open circles; data for all other carbonate units listed in Table 1 are indicated by closed circles. Vertical bars represent ±1 standard deviation of $\delta^{13}C$ values, and horizontal bars indicate uncertainty in age of each stratigraphic unit. Arrows combine dated formations that are either preceded or followed by major $\delta^{13}C$ shift. BIF denotes field for iron and manganese formations. Note that uncertainties given for ages do not necessarily cover uncertainties in entire depositional periods of sample groups. PDB—Peedee belemnite.



Karhu & Holland 1996



Melezhik et al. 1999

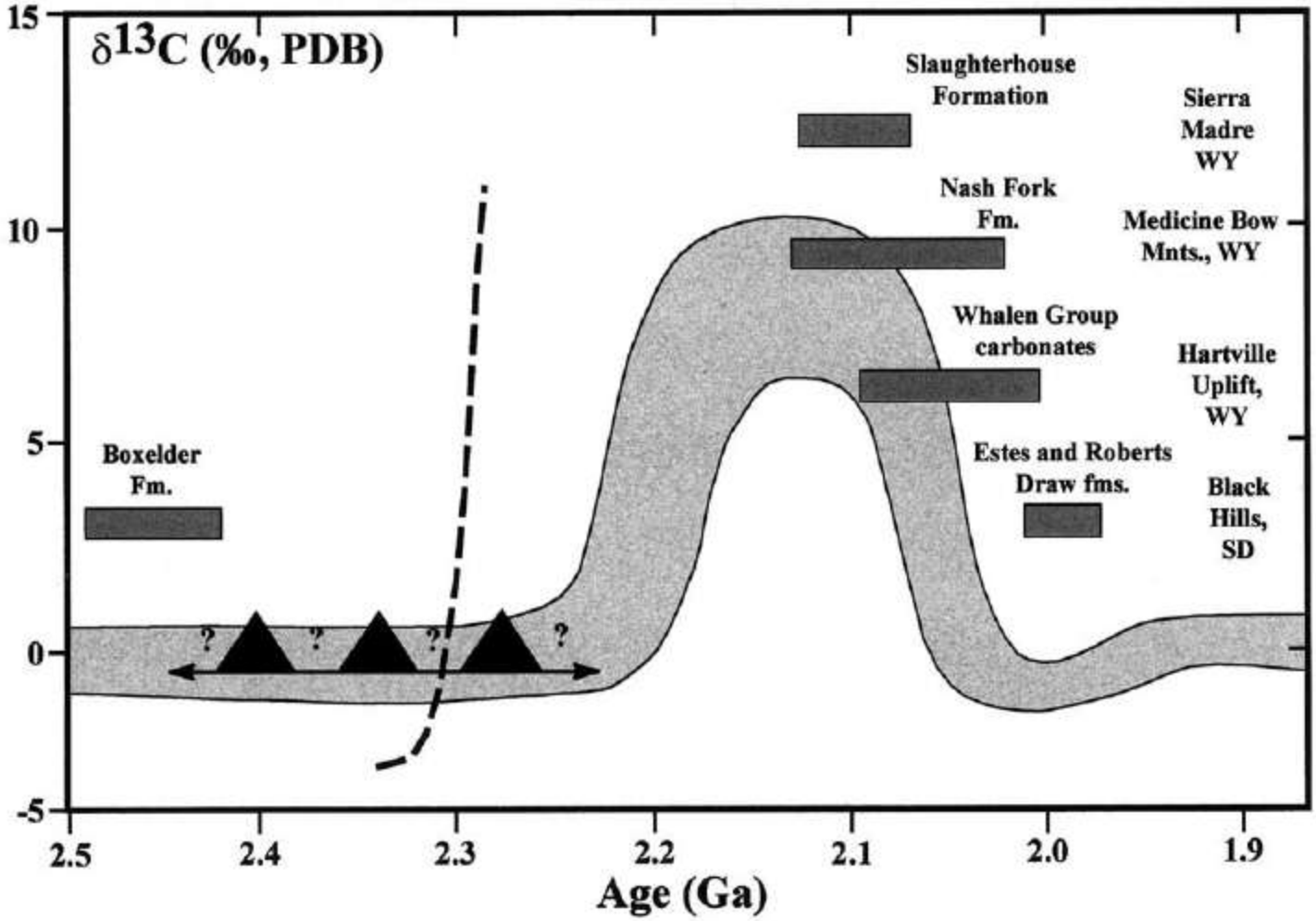


Fig. 10. Schematic representation of Paleoproterozoic secular carbon isotope variations after Karhu and Holland (1996) with additional information from Bekker et al. (2001a) shown by dashed line. Black triangles and question marks between them represent three Paleoproterozoic glacial events in North America and their age uncertainties. Studied units are arranged along the horizontal axis according to their geochronologic, lithostratigraphic, and chemostratigraphic age constraints (see text for discussion).

Bekker et al. 2003

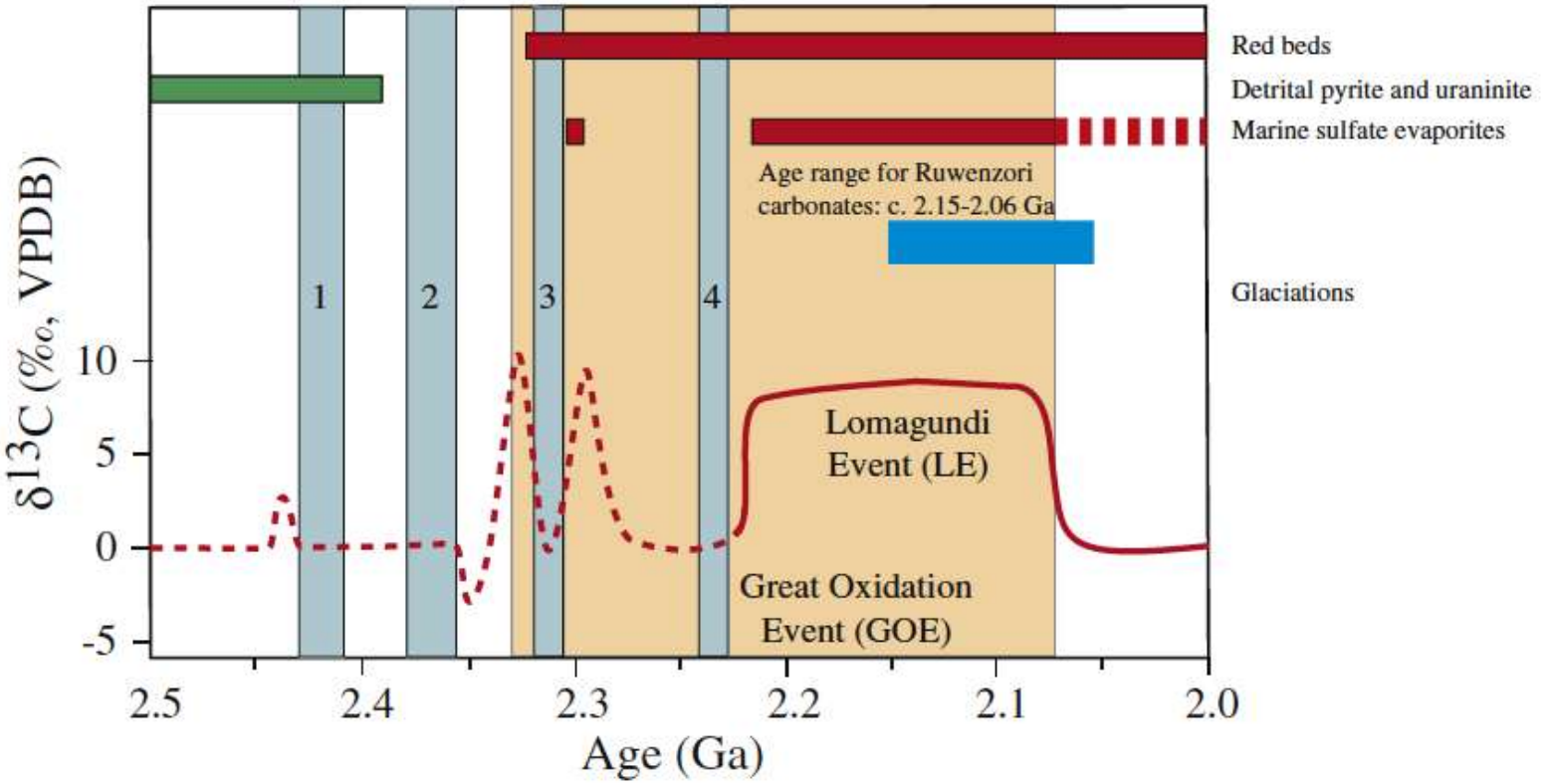
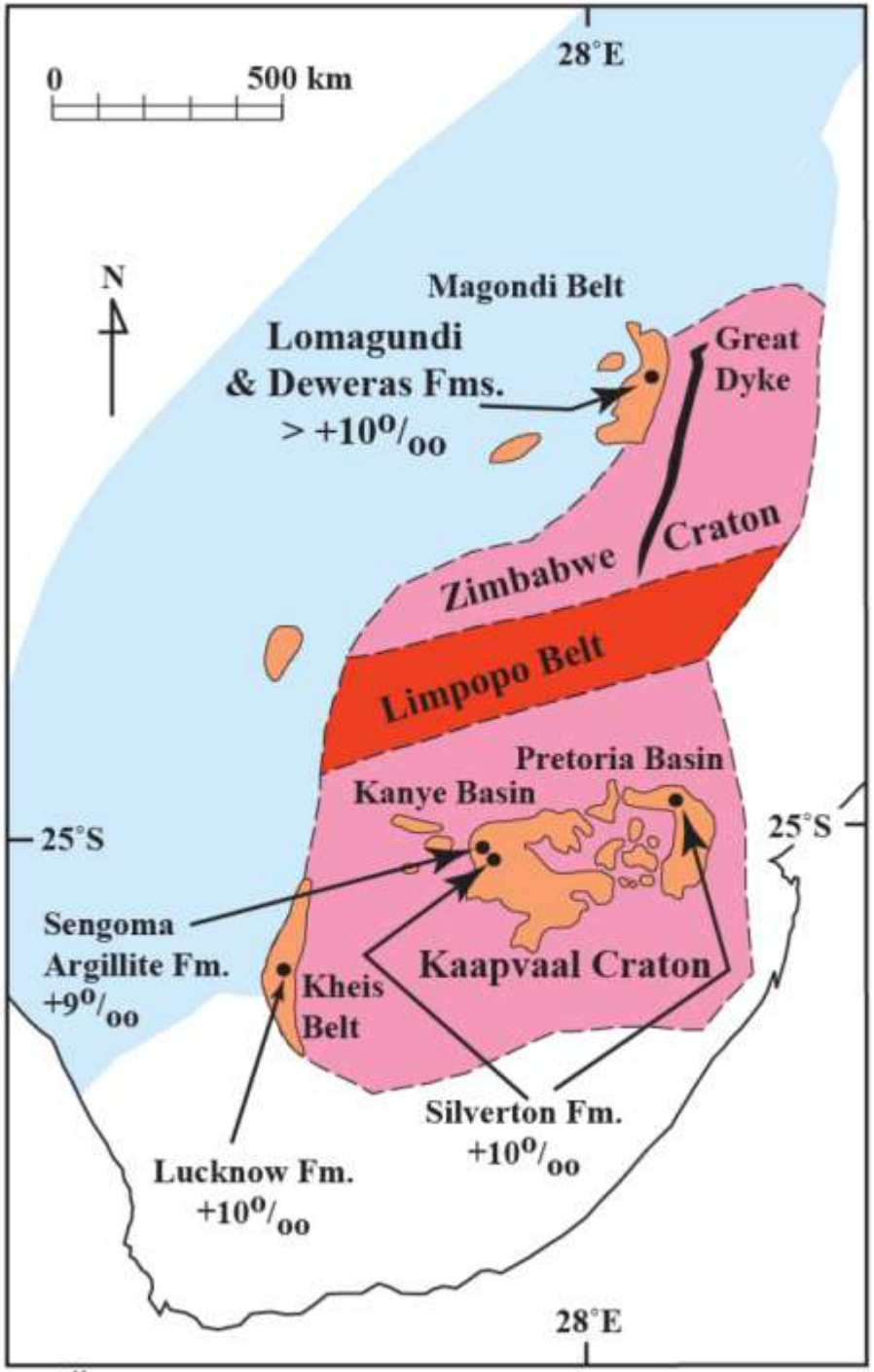


Fig. 4. Plot of $\delta^{13}C_{carb}$ values in ‰ VPDB vs. age (in Ma) for Paleoproterozoic sedimentary carbonates (after Bekker and Holland, 2012) showing data age range for Ruwenzori carbonates. Relevant redox indicators for the oxidation state of the atmosphere–ocean system and four blue vertical lines marking Paleoproterozoic glacial events are also shown (modified from Bekker and Holland, 2012). The dashed secular carbon isotope curve between 2.5 and 2.22 Ga emphasizes the uncertainty in this part of the curve, and the dashed bar for marine sulfate evaporites after c. 2.07 06 Ga indicates that sulfate evaporites again became scarce in the Paleoproterozoic and Mesoproterozoic records after that time.

Master , Bekker & Karhu, 2013, Chemical Geology

Use of high $\delta^{13}C$ carbonate rocks in chronostratigraphic correlation

3. How the Magondi Belt lost its length


28°E
0
500 km
N
Magondi Belt
Lomagundi
& Deweras Fms.
> +10‰
Great
Dyke
Zimbabwe
Craton
Limpopo Belt
Pretoria Basin
Kanye Basin
25°S
25°S
Sengoma
Argillite Fm.
+9‰
Kheis
Belt
Kaapvaal Craton
Silverton Fm.
+10‰
Lucknow Fm.
+10‰
28°E

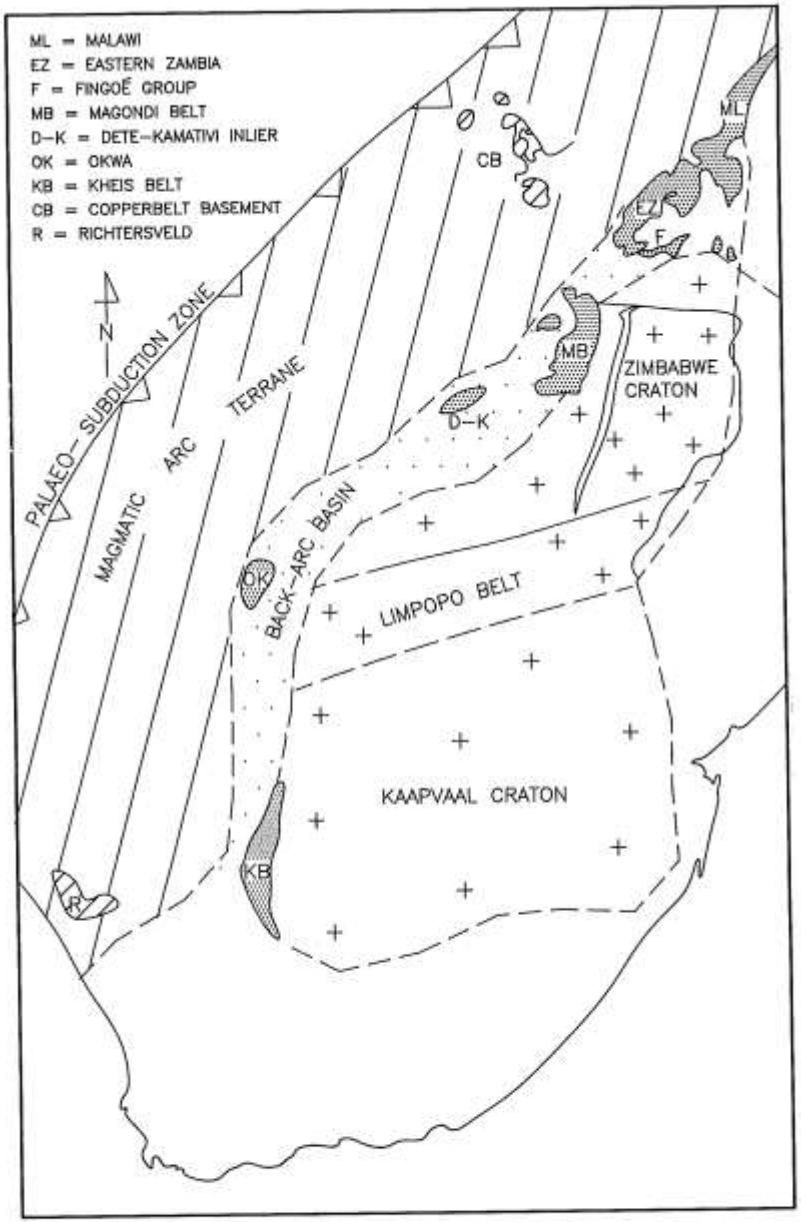
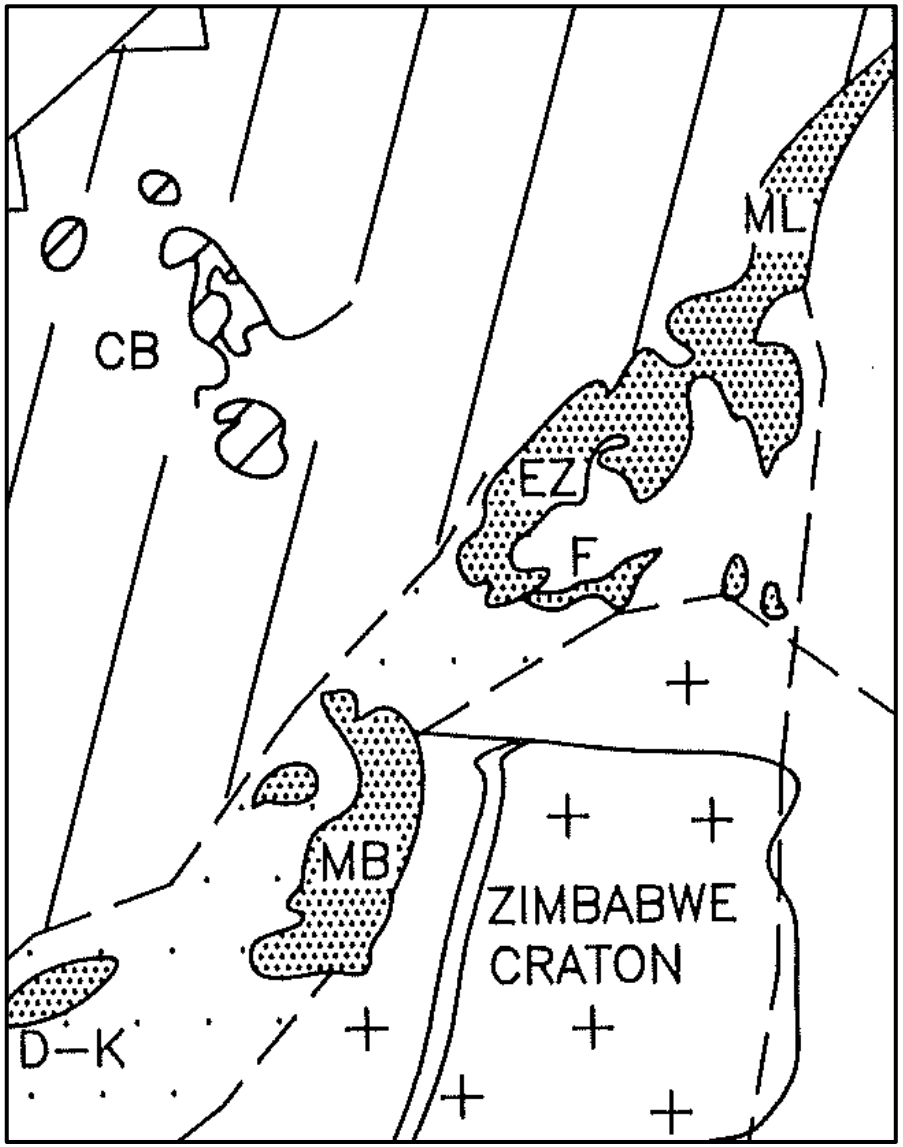


Figure 9: Schematic plan showing position of Magondi Supergroup and correlative sequences in a continental back-arc basin, with respect to the postulated magmatic arc terrane, palaeo-subduction zone, and the combined Zimbabwe-Limpopo-Kaapvaal continent (after Master, 1990d, 1991).



Master (1991a,b, 1994)

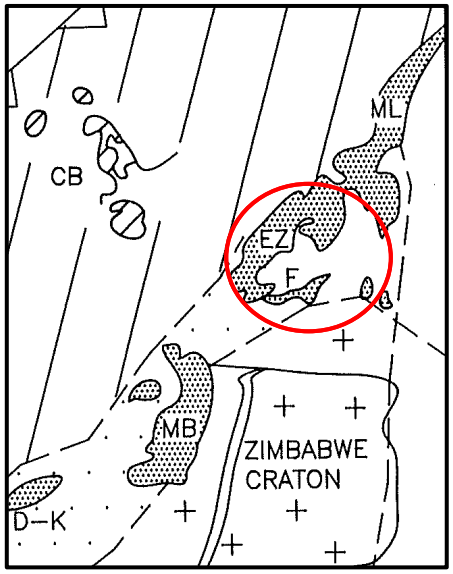
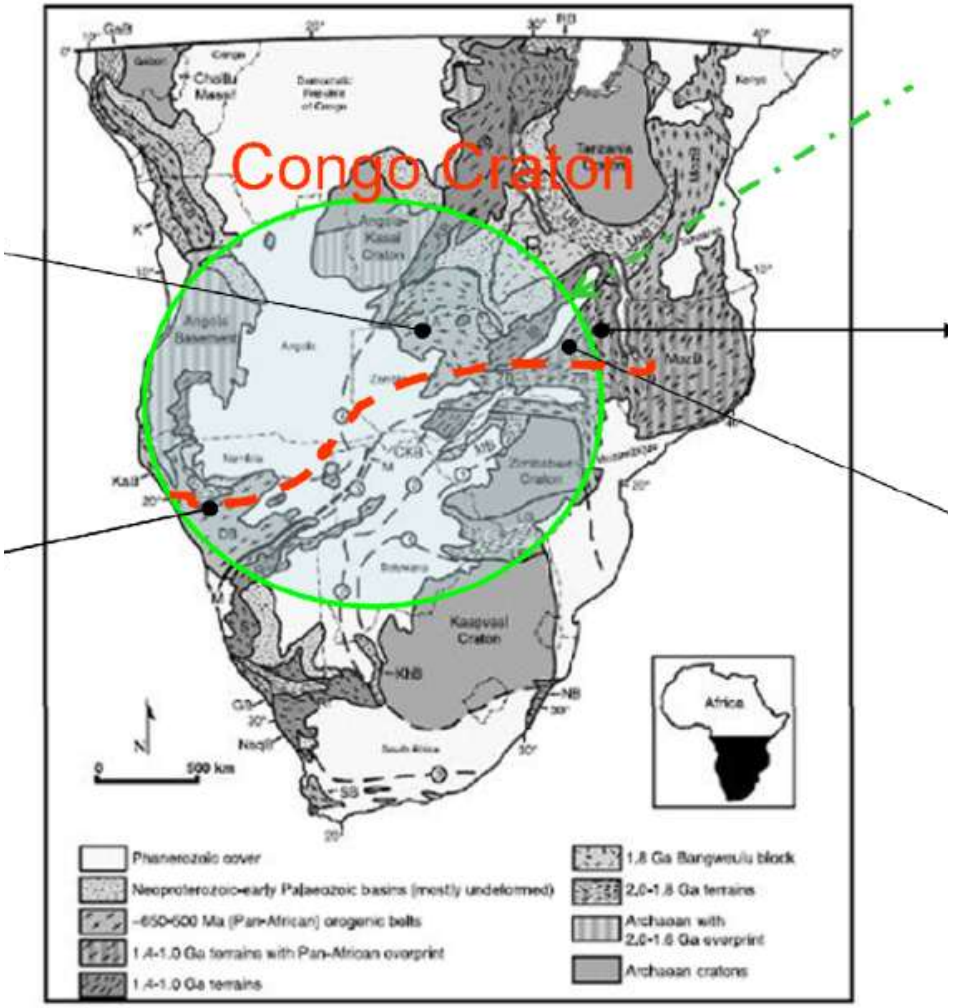


Table 1: Carbon and oxygen isotope geochemistry of marbles from the Mvuvye and SInda

Mvuvye Gp	$\delta^{13}C$ ‰V-PDB	$\delta^{18}O$ ‰V-PDB
V-2	0.30	- 8.80
MV-3	-0.28	-10.53
MV-5	0.47	- 9.27
Sinda Gp		
CD-1	-1.30	-12.50
CD-3	-1.30	-12.70
CD-4	1.21	-12.31

Rifting on the southern margin of the Congo Craton, c. 765-730 Ma

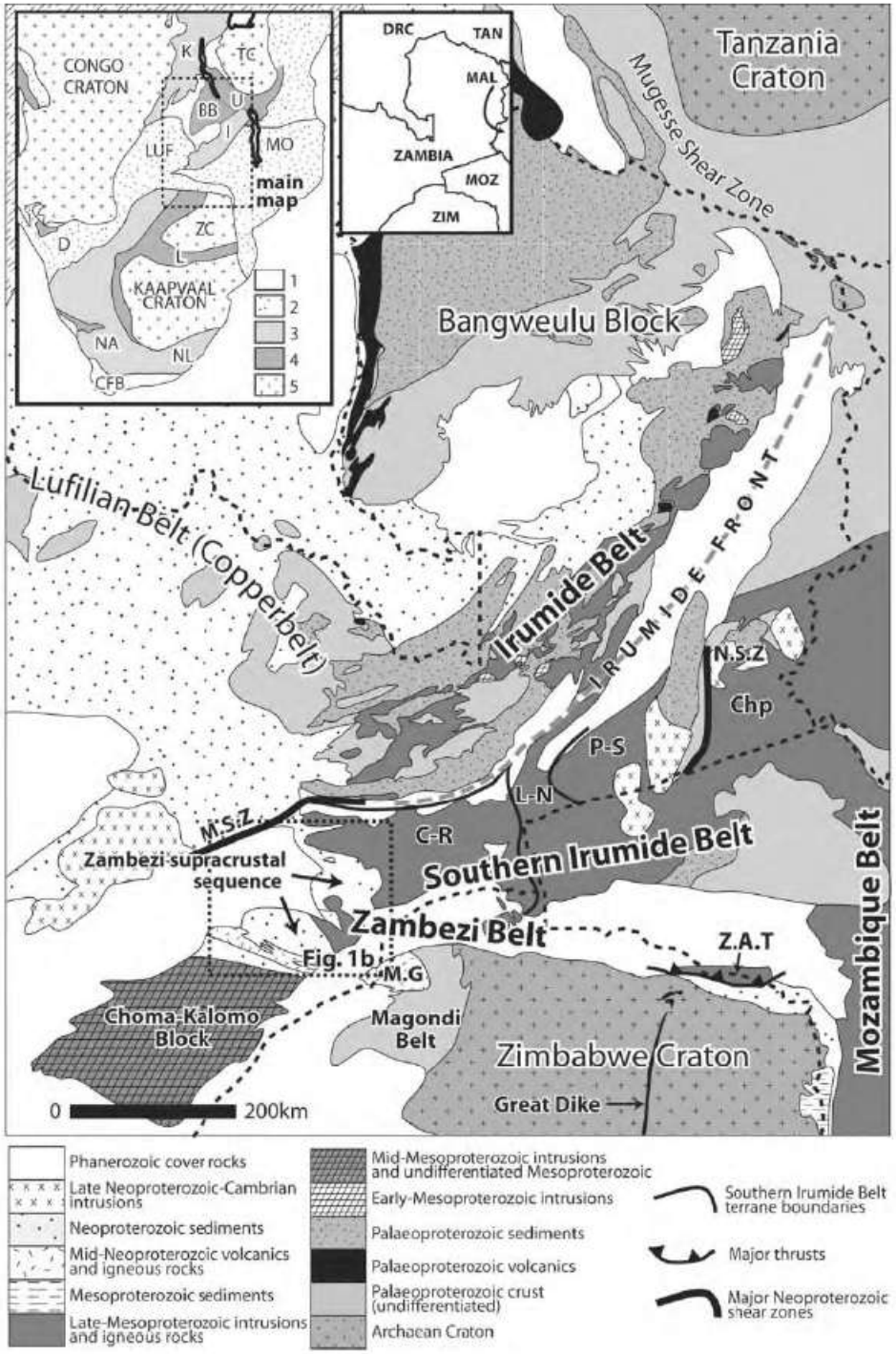


Carbonate rocks in E Zambia (Mvuvye & Chindeni marbles):

δ13C = -1.3 to +1.21 ‰ VPDB

Therefore these marbles do NOT correlate with Magondi Belt

Southern Irumide Belt, Zambezi Belt and Zimbabwe Craton



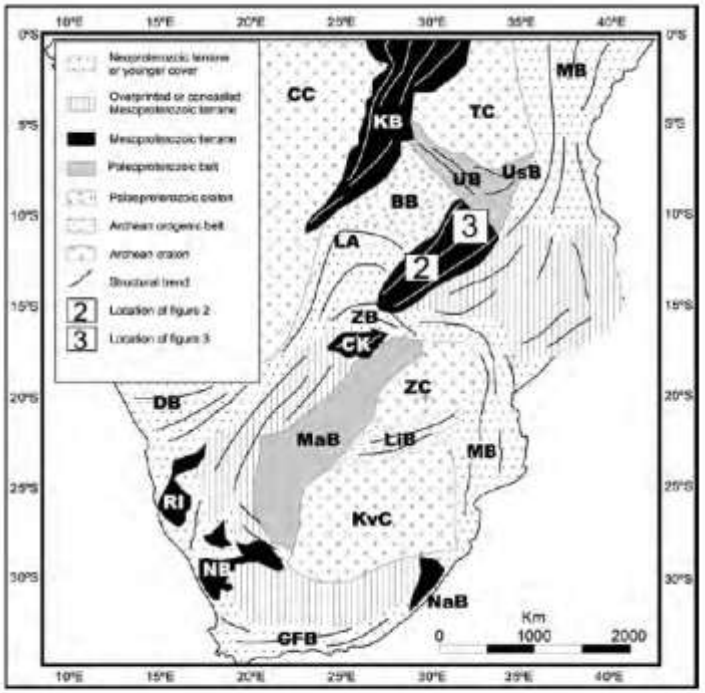


Figure 1. Tectonic provinces of central and southern Africa. Abbreviations: BB—Bangweulu block; CC—Congo craton; CFB—Cape fold belt; CK—Choma-Kalomo block; DB—Damara belt; KB—Kibaran belt; KvC—Kaapvaal craton; LA—Lufilian Arc; LIB—Limpopo belt; MaB—Magondi belt; MB—Mozambique belt; NaB—Natal belt; NB—Namaqua belt; RI—Rehoboth inlier; TC—Tanzania craton; UB—Ubendian belt; UsB—Usagaran belt; ZB—Zambezi belt; ZC—Zimbabwe craton.

De Waele et al., 2003, Geology

Johnson et al. (2007). Journal of Geology, 115, 355-374.

Zambezi Belt- a suture zone during Gondwana amalgamation

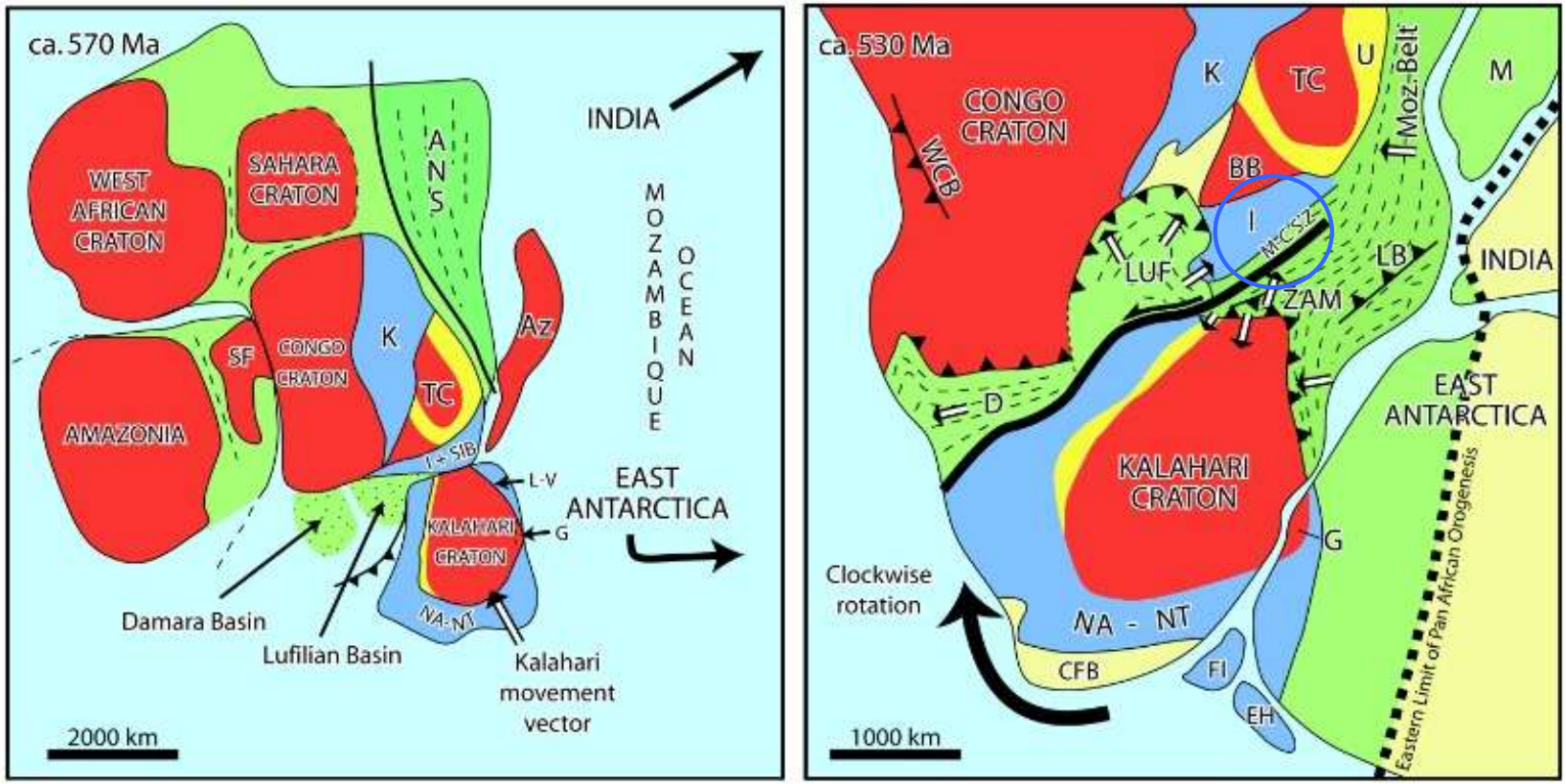


Figure 5. Cartoon showing the tectonic evolution and assembly history of the southern African cratons at a) 570 Ma and b) 530 Ma. Abbreviations as previous except: Az–Azania; EH–Ellsworth-Haag; FI–Falkland Islands; G–Grunehogna; LB–Lurio Belt; L-V–Lurio-Vijayan Peninsula; M-C SZ–Mwembeshi-Chimaliro Shear Zone; SF–Sao Fransisco; SIB–Southern Irumide Belt; WCB–West Congo Belt.

Johnson et al., 2007.

Conclusions

- Carbon isotope analyses of marbles from the Petauke and Nyimba districts of Eastern Zambia (Sinda, Lusandwa and Mvuvye Groups) do not show the enrichments in $\delta^{13}C$ which are characteristic of the Magondi Supergroup carbonate rocks.
- The Magondi Belt did not extend further north than the Zambezi valley escarpment- it is separated from Eastern Zambia ("Southern Irumide Belt") by a Neoproterozoic ("Pan-African" suture

Acknowledgments

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