The mineralogy and geochemistry of Neoarchaean late-granite suites along the southern extent of the Zimbabwe Craton

Godfrey S. Chagondah[1], Axel Hofmann[1], Allan H. Wilson[2] and Linda M. Iaccheri[2]

[1] Department of Geology, University of Johannesburg, South Africa
[2]School of Geosciences, University of the Witwatersrand, South Africa

UNIVERSITY OF JOHANNESBURG

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Presentation format

1. Regional geology overview

2. Motivation to study the granite suites

3. Summary of crystallization ages of granite suites and inheritance dates

4. Evidence of reworking of old crust: zircon inheritance and U-Pb-Hf isotope studies

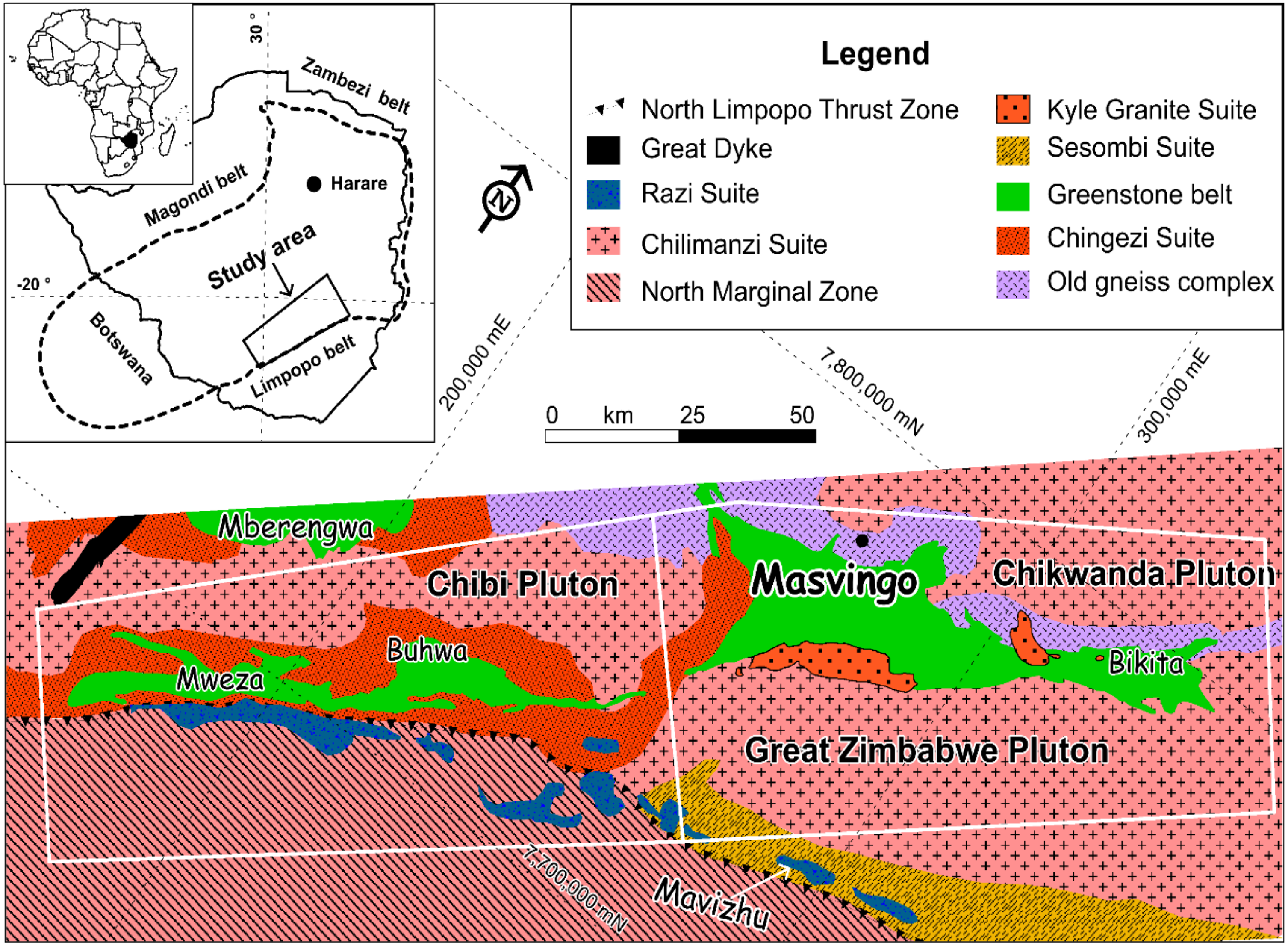
5. Representative photomicrographs of the granite suites mineralogy

6. Summary of mineralogy of representative granite rock types

7. Geochemistry of the granite suites

8. Conclusions

Geology along the southern extent of the Zimbabwe Craton (ZC)



Based on similar rock types, geochemistry & timing of events in the NMZ & ZC

(Rollinson, 2023)
Neoarchaean X-section of the ZC
Upper crust: Chilimanzi granites? and greenstone belts

Middle crust: granitoids

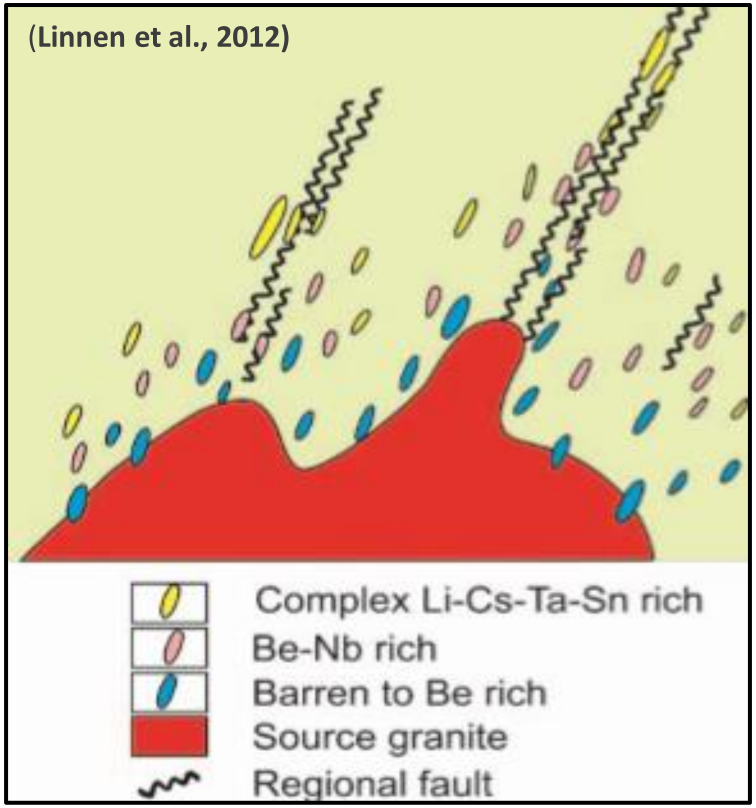
*Lower crust: NMZ (*quartzo-feldspathic gneisses (enderbites & charnockites: *granulite terrain*)

(Chagondah et al., 2023)

Motivation to study the granite suites: finger-point source plutons for the pegmatite-forming magma

1. Knowledge gap in terms of granite geochemistry and there was also need to increase geographical coverage of geochronological data.

2. Lithium demand: need to test & advance genesis models using world-class (Bikita & Sandawana) deposits.



Li-Cs-Ta pegmatites (Černý & Ercit, 2005)

- *Fractional crystallization of* syn- to late-post orogenic granites.
- Peraluminous to subaluminous S- or I-type granites.

Regional zonation of rare-element pegmatites in the Mavis Lake pegmatite group peripheral to the Ghost Lake batholith, Canada is recognized (e.g., Selway et al., 2005).

Sometimes parental granite is not known
Parent is assumed to be hidden:
Tanco pegmatite (Canada) & Greenbushes (WA).

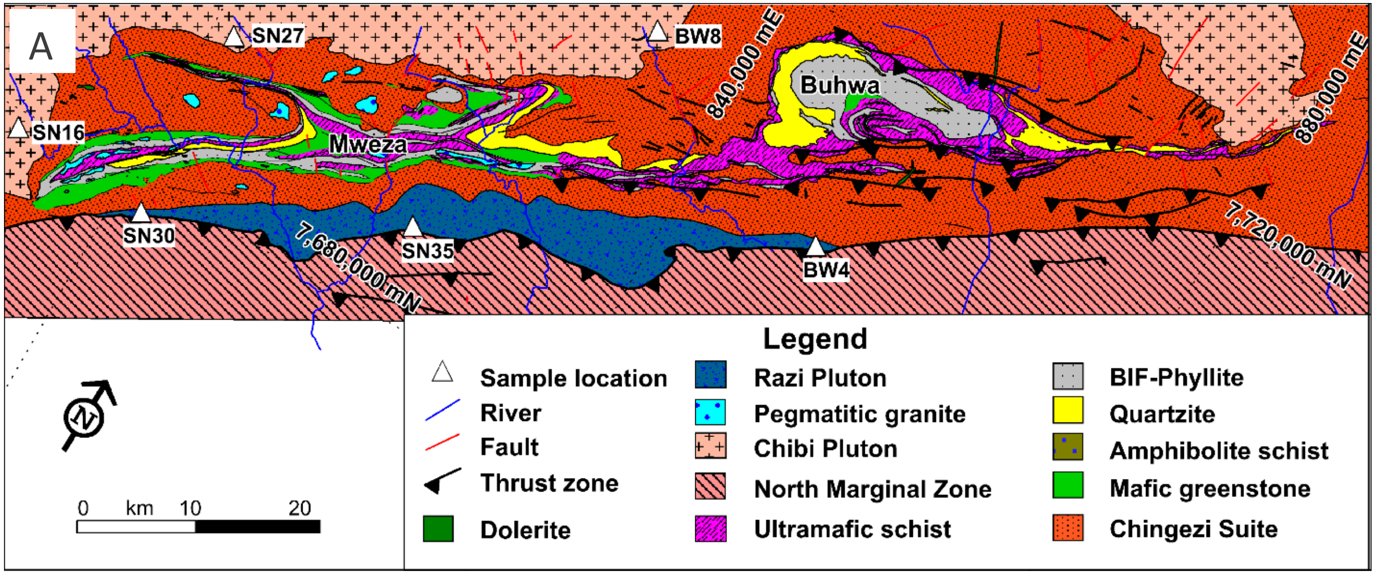
What we know….crystallization ages of granite suites and inheritance dates

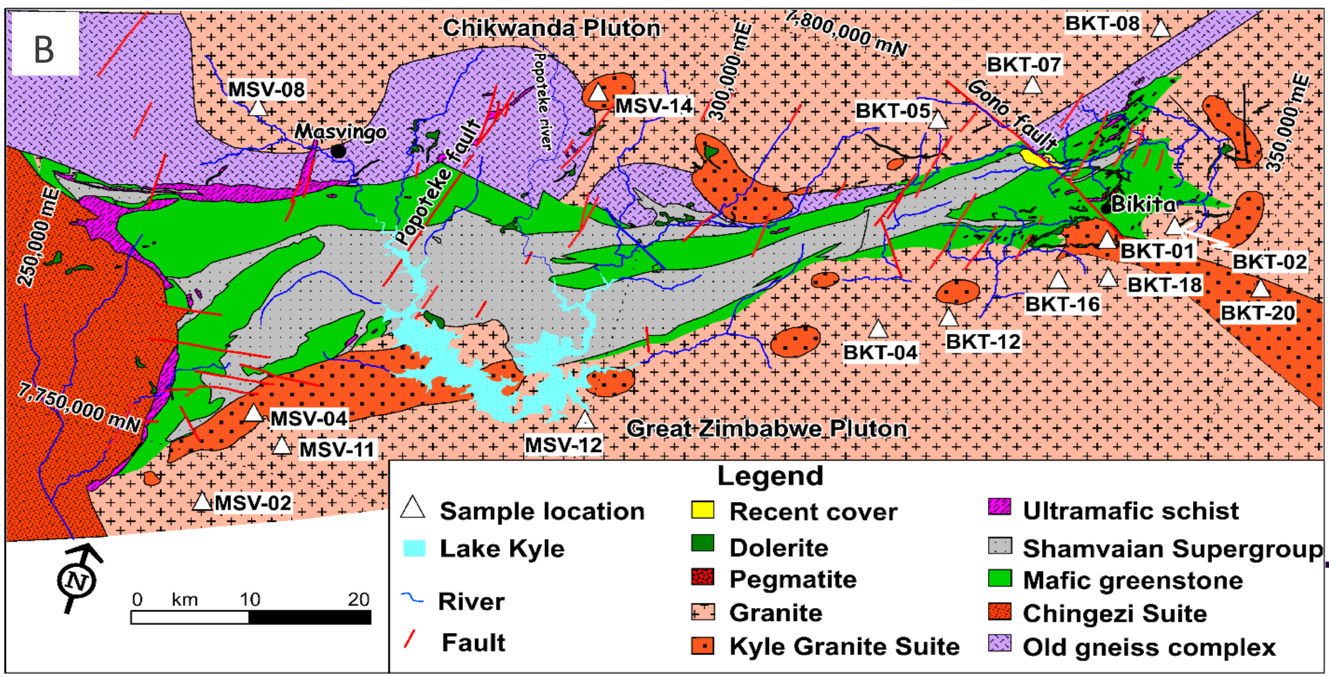
(Chagondah et al., 2023)

Suite	Pluton name	Sample	Mineral & technique	Inheritance ages (Ma)	Crystallization age (Ma)		Reference
					This study	Published	
Chilimanzi	Chibi	SN27	Zircon, U-Pb	2848±8 - 2643±4	2632±4		
	Chikwanda/ Chilimanzi		WR, Rb-Sr			2604±70	Hickman, (1976)
		MSV-08	Zircon, U-Pb			2634±17	Horstwood et al., (1999)
				3206±15 - 2644±2	2633±4		
	Great Zimbabwe	BKT-16	Zircon, U-Pb	2643±3	2625±3		
		MSV-11	Zircon, U-Pb	2640±5	2627±79		
			WR, Rb-Sr			2630±15	Hickman, (1978)
	Mangondo	BKT-01	Zircon, U-Pb	2665±4 - 2648±3	2635±5		
	Rezhura		Zircon, U-Pb			2540±38	Frei et al., (1999)
Razi	Romorehoto W		Zircon, U-Pb			2590±7	Frei et al., (1999)
	Romorehoto E					2589±11	Frei et al., (1999)
	Mataga					2627±7	Mkweli et al., (1995)
	Matibi					2604±22	Frei et al., (1999)
	Mavizhu					2517±55	Frei et al., (1999)
	Razi microgranite	BW4		2862±3 - 2650±2	2626±29		

2604 -2530 Ma: metamorphic (reset) dates, corroborated by hornblende and muscovite Ar ages (regional studies) (Tsunogae & Belyanin, 2020; Chagondah et al., under peer review).

What we know…close look at granite rock types surrounding the Mweza and Masvingo greenstone belts



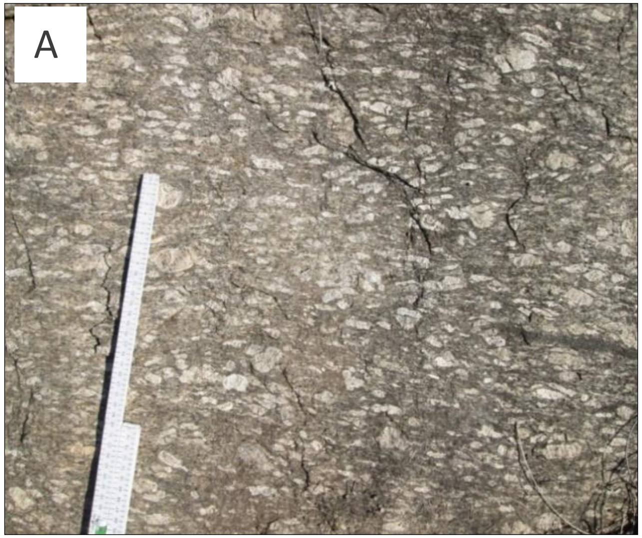


Representative field photographs of studied late-granite suites

Razi Suite

Kyle Granite Suite

Chilimanzi Suite



The Razi Pluton showing aligned K-feldspar megacrysts up to 30 mm *perpendicular to the clinorule*

2626±29 Ma

Massive Mangondo Pluton

2635±5 Ma

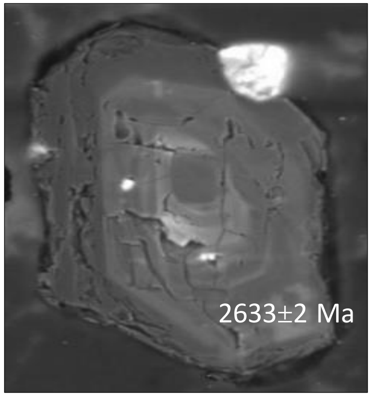
Foliation fabric at the margins of the Chibi Pluton truncated by a quartz vein

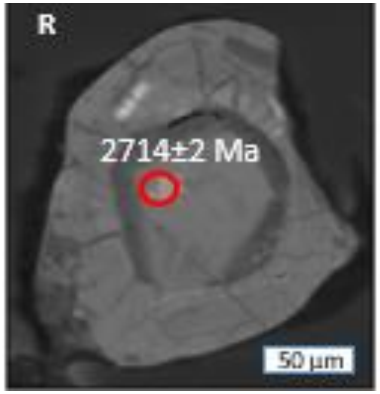
2632±4 Ma

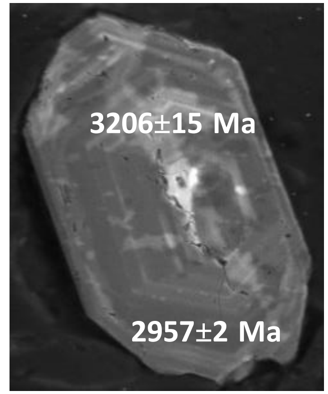
Razi Pluton looking NE

Razi Suite exploited the North Limpopo Thrust Zone:
product of thrusting of the NMZ onto the ZC.

What we know…evidence of reworking of pre-existing crust: zircon U-Pb dates

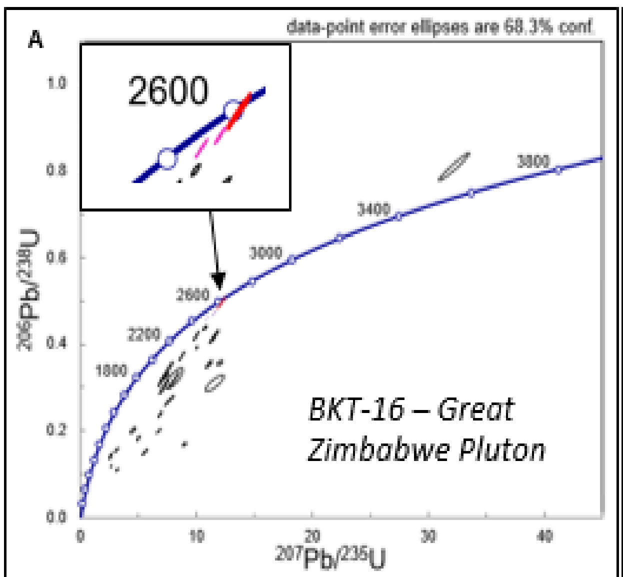


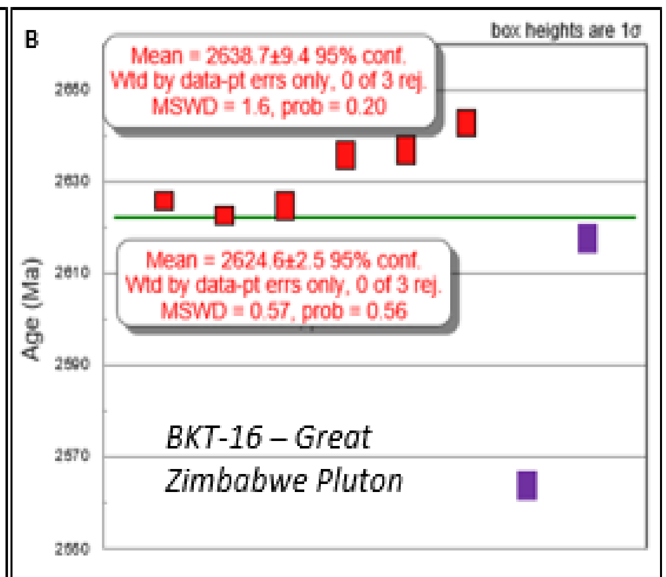




Inheritance relationships

All the studied samples contain inherited zircons, interpreted as remnants of the protoliths: assimilation of older material, emplacement and/or derivation by partial melting of older crust.

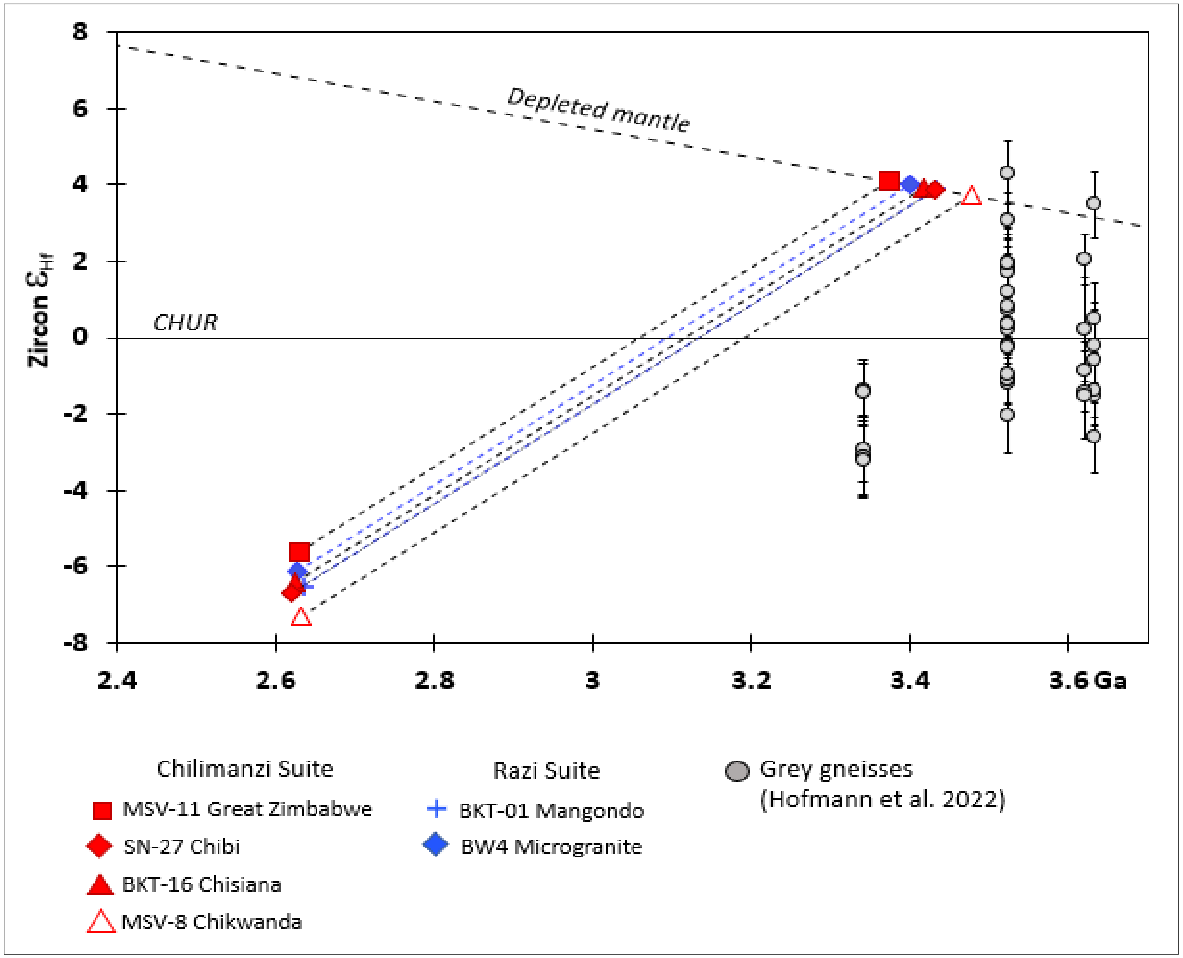




U-Pb Concordia plot of $^{207}Pb/^{206}Pb$ ages of the Great Zimbabwe granite

Typically many discordant grains: metamictization due to high content of heat producing elements (K, Th, U, Rb) in the ZC (Kramers et al., 2001)

Temporal variations in zircon εHf(t) values for samples from the granite suites…more evidence of reworking of old crust



The ε_{Hf} isotopic signatures of the grey gneisses of the Sebakwe proto-craton (Hofmann et al., 2022) are indicative of petrogenesis of the granitoids from a mixture of juvenile and reworked crustal components.

Each sample's results relate to the Hf model ages using a stippled line.

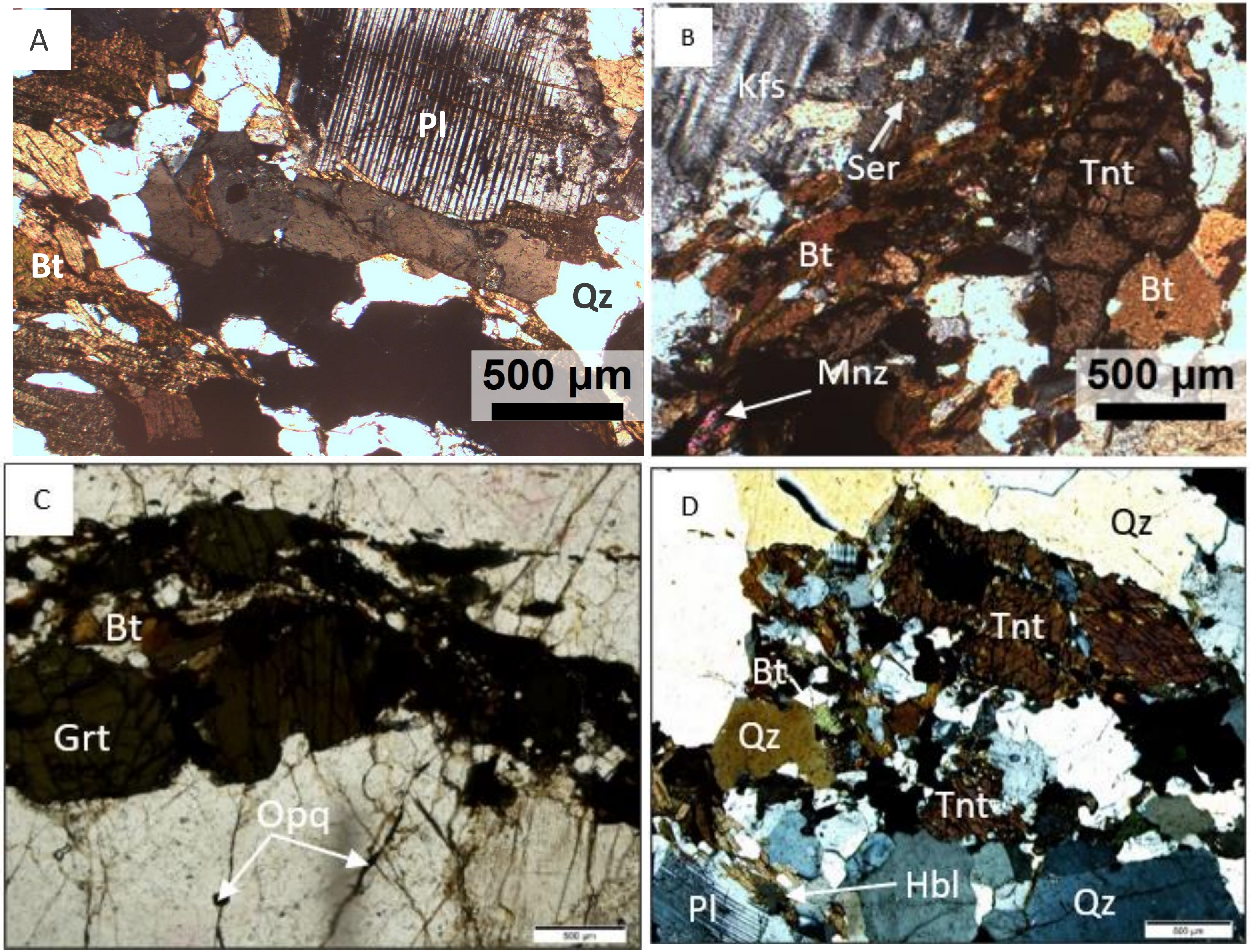
Suites have similar Hf model ages (T_{DM}) of ca. 3.4-3.5 Ga

Unradiogenic zircon Hf isotopic compositions = products of intracrustal melting, no mantle input

Further evidence of reworking: evolved isotopic systematics in the granite suites such as high initial Sr ratios of 0.704 to 0.706 (Hickman, 1978; Hawkesworth et al., 1979) and initial εNd values of about -1.6 (Horstwood et al., 1999).

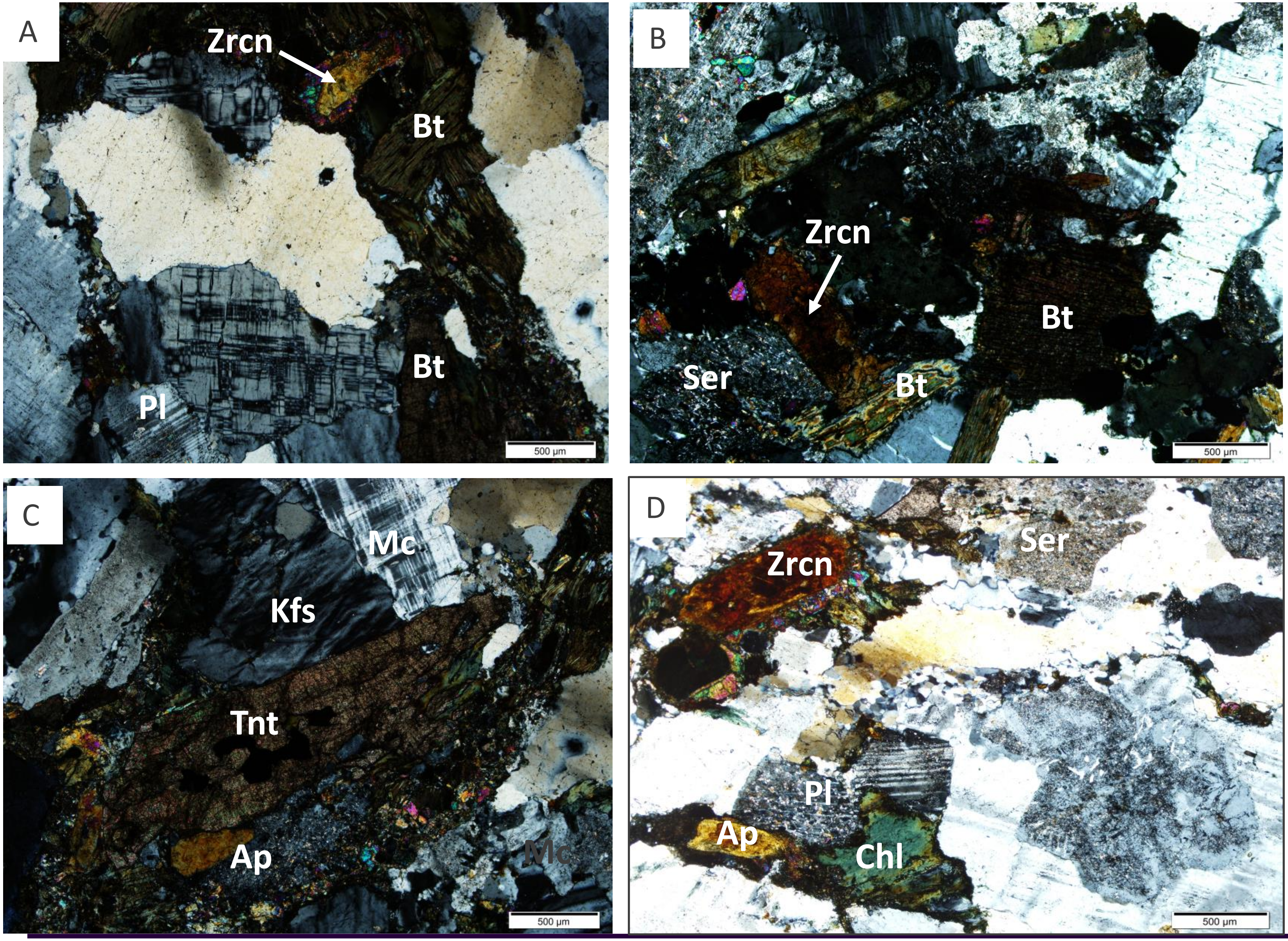
Representative photomicrographs of the Razi Suite

(Chagondah et al., 2023)



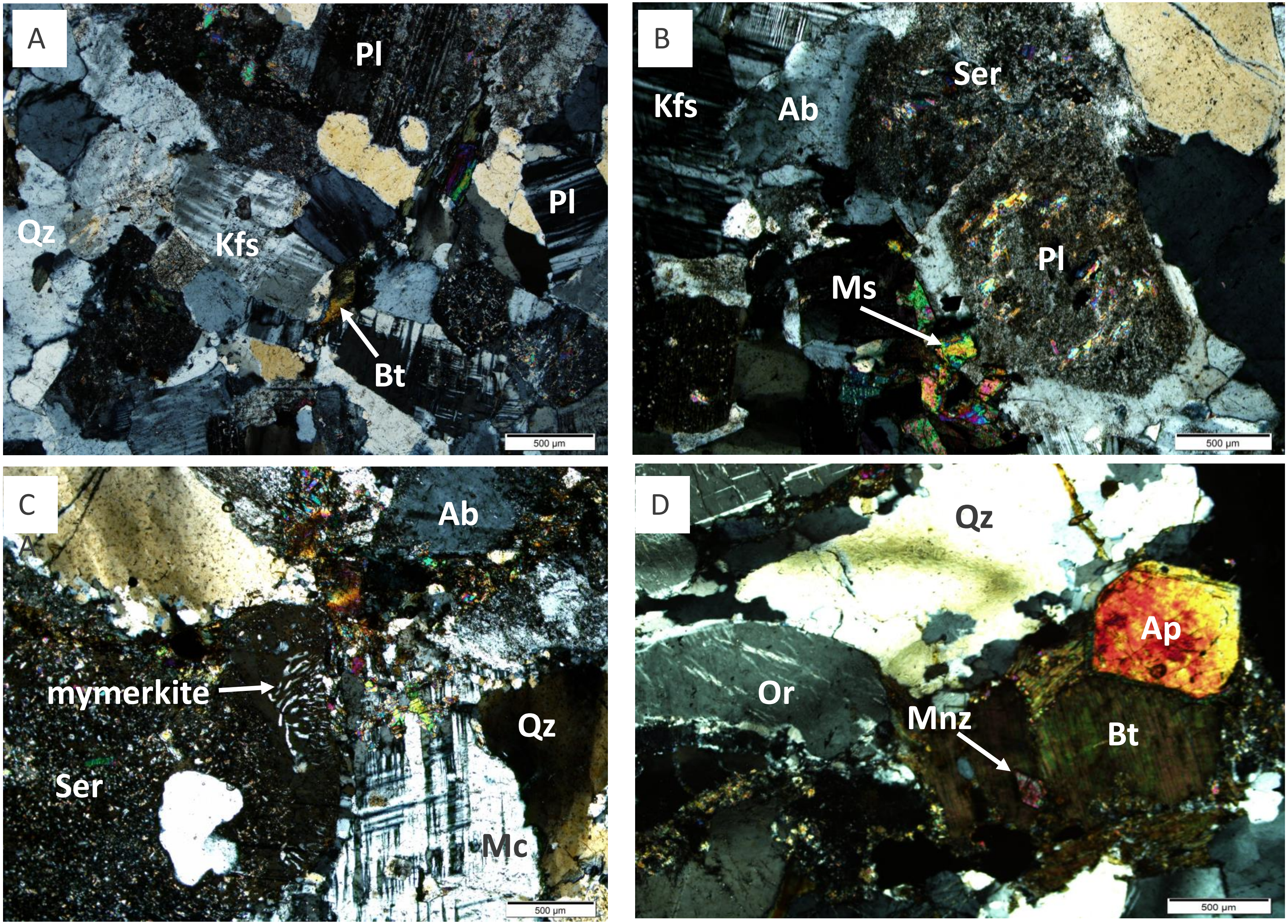
Kfs & Pl megacrysts, biotite granite; abundant mafic & accessory phases, low degree of metasomatic alteration.

Representative photomicrographs of the Kyle Granite Suite



Biotite granite; intermediate texture & composition between Razi & Chilimanzi suites.

Representative photomicrographs of the Chilimanzi Suite



High modal proportion of felsic minerals; abundant exsolution and mymerkite textures; higher degree of subsolidus metasomatic alteration relative to Razi Suite.

Summary of mineralogy of representative granite rock types

Granite suite	Representative plutons/members	Description	Major minerals (Modal Vol %)	Accessory minerals
Razi	Razi	Porphyritic to coarse-grained (megacrysts) brown-green Bt.	Kfs (30), Pl (24), Qz (22), & Bt (18). **Absence of Ms**	Opaque phases, Ttn, Grt, Zrcn, Ap, Aln, Ser, Hbl, Chl, Mnz, Ep & **Opx**.
Kyle Granite	Mangondo, Rezhura Domboranunji	Coarse-grained to porphyritic; green-brown Bt; abundant opaque minerals.	Kfs (29), Pl (26), Qz (25), & Bt (14). **Rare to absent Ms**	Opaque phases, Zrcn, Ttn, Grt, Aln, Ser, Ap, Chl, Mnz & Ep.
Chilimanzi	Chikwanda/Chilimanzi, Chibi & Great Zimbabwe	Equigranular, coarse- to medium-grained. Primary Ms is intimately associated with greenish-brown Bt.	Kfs (36), Pl (20), Qz (28), **Ms** (8), & Bt (5) ± Grt,	Opaque phases, Zrcn, Ttn, Ser, Chl, Mnz, Aln, Ap ± Ep.

Abbreviations: *Ab = albite, Or = orthoclase, Bt = biotite, Chl = chlorite, Opq = opaque phase, Pl = plagioclase, Qz = quartz, Ms = muscovite, Mc = microcline, Kfs = K-feldspar, Ep = epidote, Hbl = hornblende, Tnt = titanite, Ser = sericite, Zrcn = zircon, Ap = apatite, Mnz = monazite, Aln = allanite, and Grt = Garnet.*

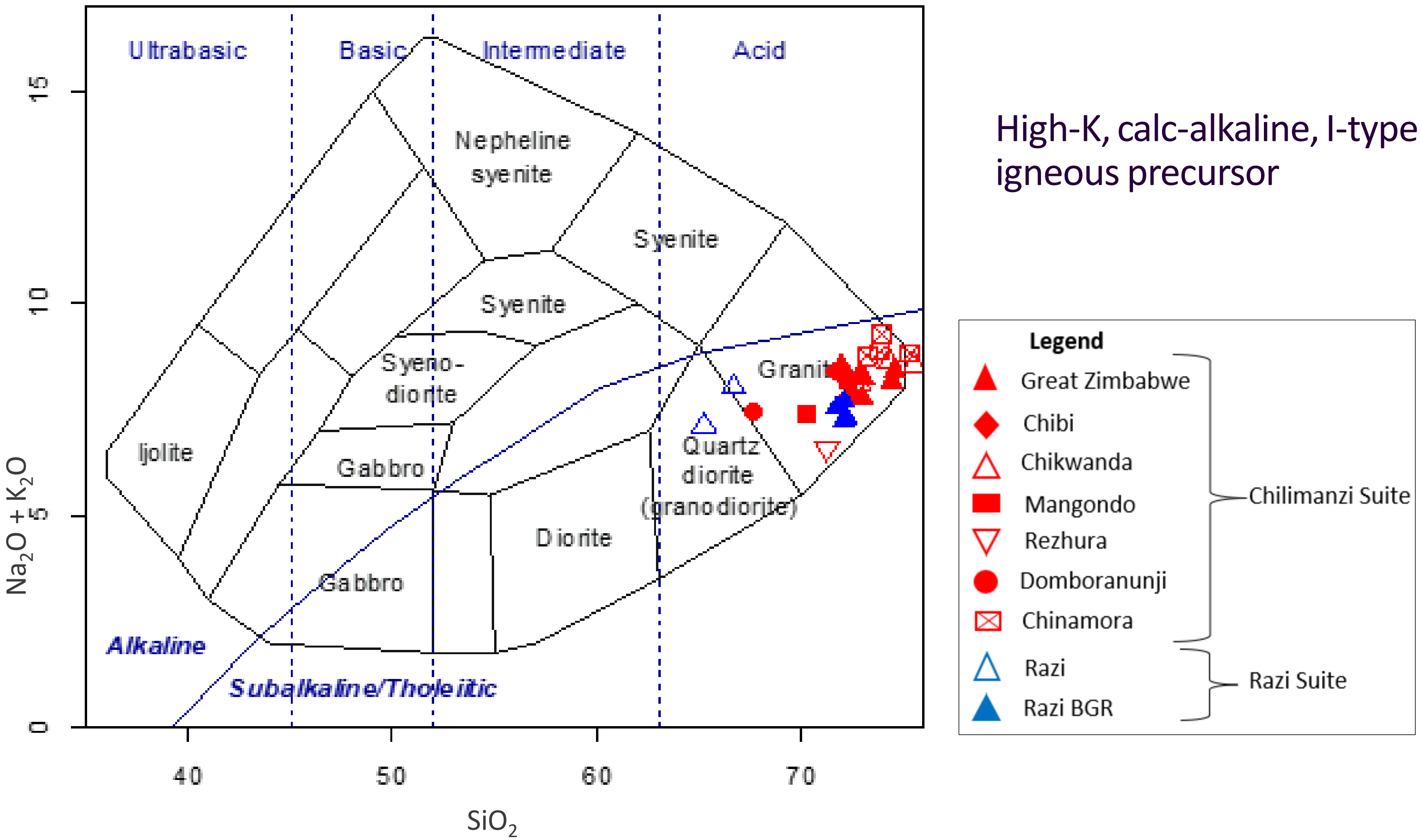
Razi Suite: anhydrous melting (absence of Ms & presence of Opx)

The granite suites have similar petrography & largely similar mineralogy

Note: Accessory minerals are main carriers of REEs (Bea, 1996; Rollinson & Peace, 2021)

Classification of the Chilimanzi and Razi granite suites

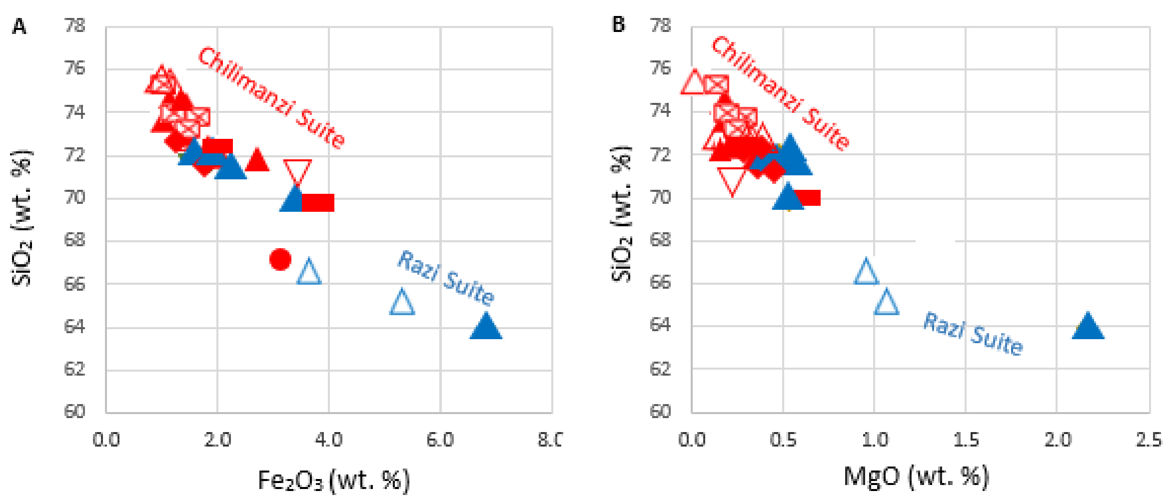
(Chagondah et al., 2023)



High-K, calc-alkaline, I-type granites with igneous precursor

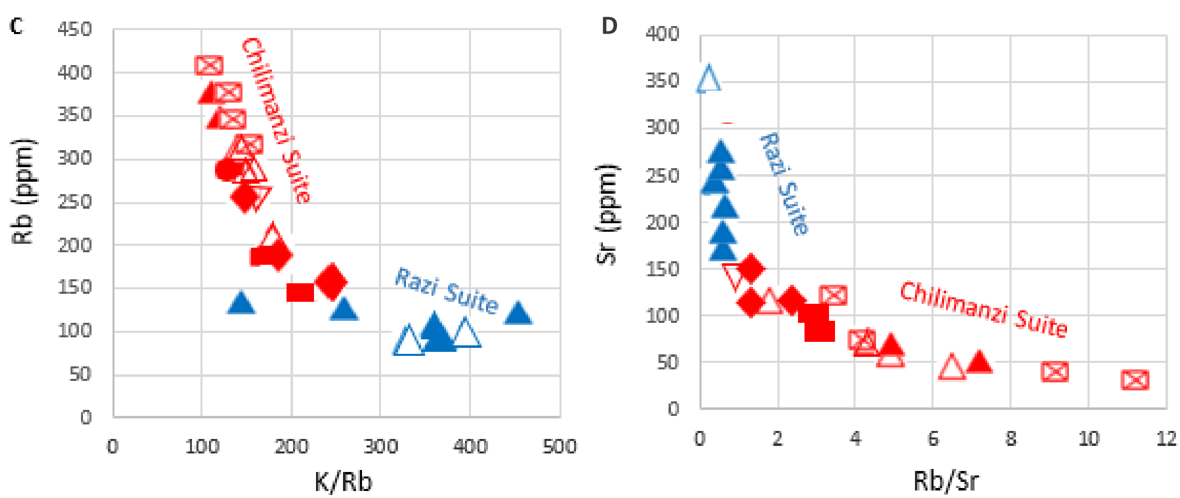
(fields after Cox et al., 1979)

Major element Harker variation & magmatic differentiation diagrams (Chagondah et al., 2023)



A & B: Decreases in the conc. of Fe & Mg oxides with increase in silica content reflects fractional crystallisation of Bt, Hbl & magnetite.

C: Low K/Rb ratios in the Chilimanzi Suite relative to the Razi Suite is consistent with fractionation of K-bearing phases e.g., Kfs & Ms & simultaneous increase in the conc. of Rb in the residual melts.



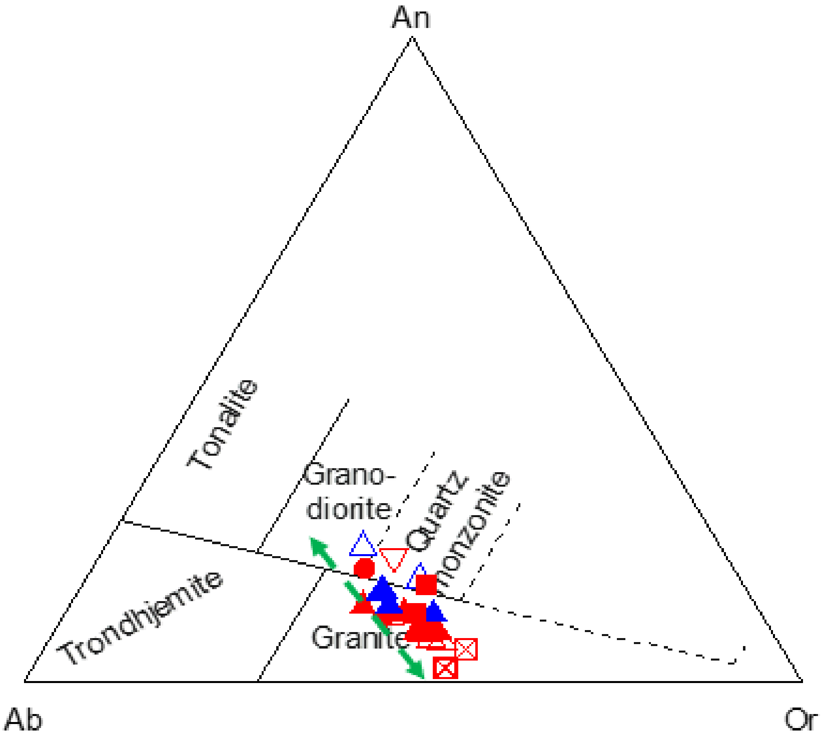
D: High Rb/Sr index in the Chilimanzi Suite: compared to the Razi reflects depletion in Sr through Pl fractionation & simultaneous increase in the content of incompatibly behaving Rb in the residual melts.

Harker & magmatic fractionation indices reveal a common evolutionary trend indicative of similar patterns of geochemical fractionations.

Emplacement of the Razi Suite magma occurred close to the source of partial melting, whereas Chilimanzi Suite magmas were emplaced at higher crustal level (Berger et al., 1995; Chagondah et al., 2023).

An-Ab-Or classification diagram for the Chilimanzi and Razi Suite samples

(fields after O'Connor, 1965)

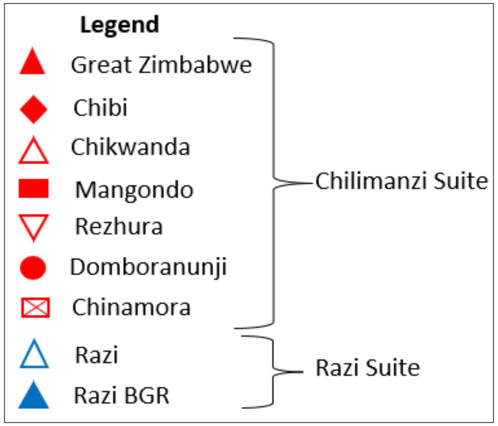


(Chagondah et al., 2023)

Broken double green arrow represents plagioclase fractionation control line.

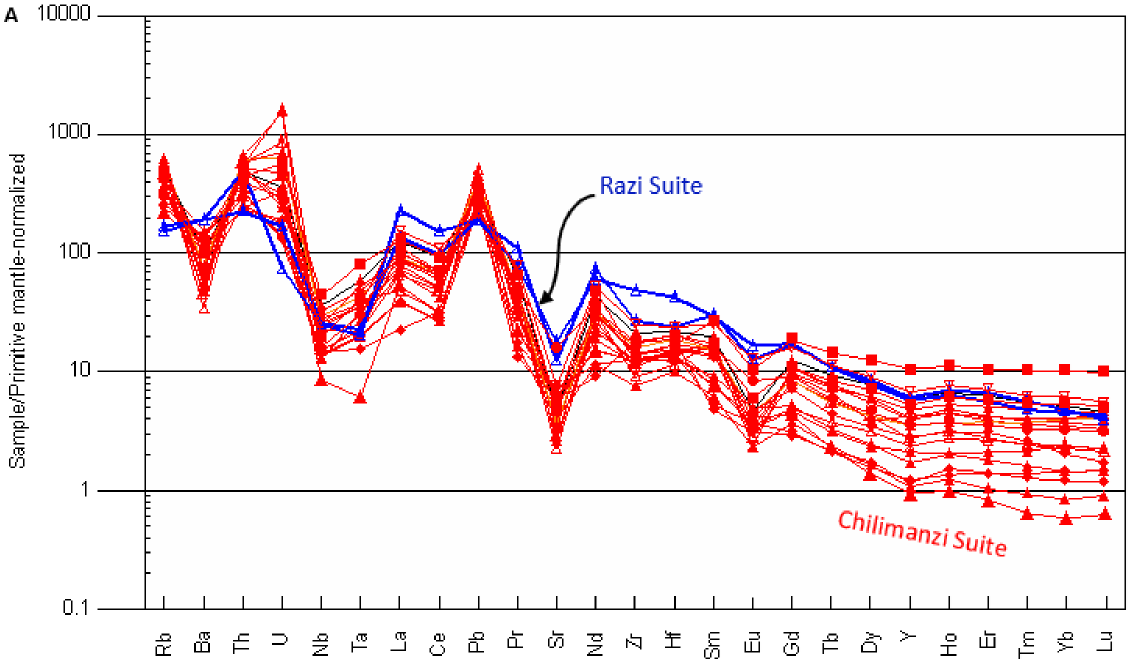
Plagioclase fractionation is one of the major determinant in the small difference in geochemistry of the Razi and Chilimanzi suites.

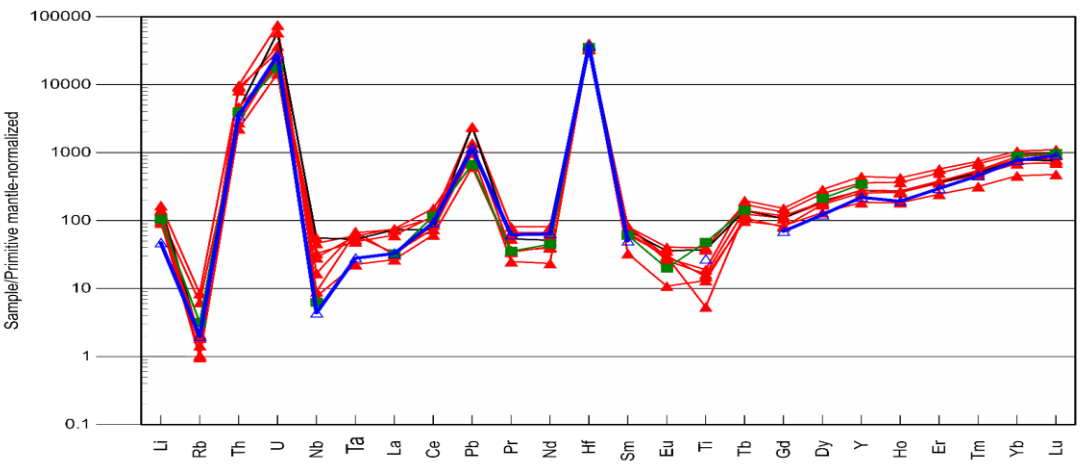
Similar trends of plagioclase fractionation are shown in the evolution of Neoarchaean granitoids from the NMZ and the ZC (Rollinson, 2021).



Primitive mantle-normalized multi-element geochemistry

(normalization data after McDonough and Sun, 1995) *(Chagondah et al., 2023)*





Whole-rock geochemistry

Overlap in chemical comp. of the suites.

Elevated conc. of Rb, Th, U, Pb & negative Nb, Ta, Sr, Ba, & Eu anomalies are attributed to fractionation processes.

Negative Sr and Eu anomalies are controlled by fractionation of Pl, whereas Y is controlled by fractionation of Hbl, with Nb and Ta controlled by crystallisation of Tnt.

Thus pronounced anomalies in the Chilimanzi = consistent with removal of Pl and Hbl in the residual magmas during ascent.

Zircon geochemistry

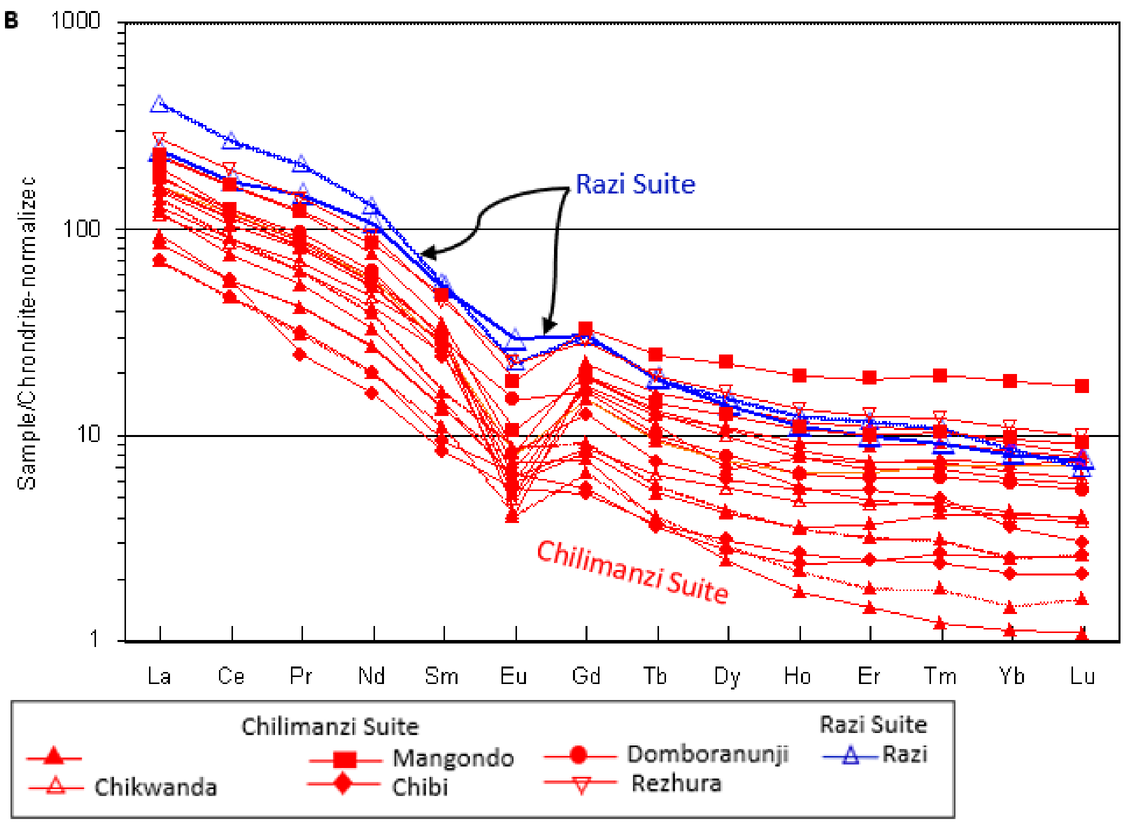
Chagondah et al., (under peer review)

The ionic radii of the REE decreases from La^{3+} to Lu^{3+}, allows enrichment of HREE into the zircon structure due to higher atomic number which match Zr^4 (Grimes et al., 2007).

The Razi Suite shares features with charnoenderbites of the NMZ (Berger et al., 1995; Berger and Rollinson, 1997), e.g., dry, granulite facies mineralogy (Opx & paucity of primary Ms) and similar REE patterns.

Chondrite-normalized REE patterns

(normalization data from Taylor and McLennan, 1985)



Mineralogy: the Razi Suite is dominated by higher modal proportions of REE reservoir minerals e.g., Zrcn, Ap, Mnz & Aln relative to the Chilimanzi Suite.

Thus, higher REEs in the least fractionated Razi Suite relative to the more fractionated Chilimanzi Suite is due to a combination of partial melting of an REEs enriched TTG source and preservation of the melts in the lower crust.

Mineral	Formula
Allanite	$(Ce,Ca,Y,La)_2(Al,Fe^{+3})_3(SiO_4)_3(OH)$
Apatite	$(Ca_5[PO_4]_3(OH,F,Cl)$
Euxenite	$(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)2O_6$
Titanite	$CaTiSiO_5$
Monazite	$(Ce,La,Nd,Th)(PO_4,SiO_4)$
Zircon	$(Zr,Hf,HREE,Th,U)(Si,P)O_4$

(Chagondah et al., 2023)

Conclusions

- Similar geochemical signatures & inheritance zircon data suggests common source for the granite suites.
- Mineralogical & geochemical data together with geochronological & Hf systematics data supports the view that the granite suites are products of partial melting of underlying mid- to lower crustal TTG protoliths.
- The Rb/Sr and K/Rb indices depicted across the granite suites is mainly controlled by fractionation processes and thus shows that fractional crystallisation is the main evolutionary process.
- The difference between the Razi and Chilimanzi suites reflects different degrees of intra-crustal fractionation as the melts evolve to higher crustal levels.
- It is probable that the Razi Suite, which is deeper and less silicic, is dominated by cumulus mineralogy, whereas the more potassic Chilimanzi Suite are the residual melts preserved at high crustal levels.
- The Kyle Granite Suite, likely represent floor rocks to shallow level intrusions of the Chilimanzi suite.
- Our study affirms the proposition by Robertson (1973b) who hinted that the Chilimanzi Suite could be related to the Razi Suite, with the former being a more evolved equivalent of the latter.

On-going work & pending publications

Neoarchaean and Palaeoproterozoic tectono-metamorphic events along the southern margin of the Zimbabwe Craton: Insights from muscovite $^{40}Ar/^{39}Ar$ record on rare-metal pegmatites

Godfrey S. Chagondah[1], Jan D. Kramers[1], Axel Hofmann[1], and Hugh Rollinson[2]

[1] *Department of Geology, University of Johannesburg, Auckland Park, 2006, Johannesburg, South Africa*
[2] *School of Built and Natural Environment, University of Derby, Kedleston Road, Derby DE22 1GB, UK*

The late Archaean granite paradox

Hugh Rollinson[1], Godfrey Chagondah[2] and Axel Hofmann[2]

[1] School of Built and Natural Environment, University of Derby, UK.
[2] Department of Geology, University of Johannesburg, South Africa

Zircon trace and rare earth elements geochemistry of the Neoarchaean late-granite suites along the southern margin of the Zimbabwe Craton: Implications to petrogenesis

Godfrey S. Chagondah[1], Axel Hofmann[1], Marlina A. Elburg[1], Henriette Uckermann[1], Clarisa Voster[1] and Hugh Rollinson[2]

[1] *Department of Geology, University of Johannesburg, Auckland Park, 2006, Johannesburg, South Africa* [2] *School of Built and Natural Environment, University of Derby, Kedleston Road, Derby DE22 1GB, UK*

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Godfrey S. Chagondah[1], Axel Hofmann[1] and Marlina A. Elburg[1]

[1] *Department of Geology, University of Johannesburg, Auckland Park, 2006, Johannesburg, South Africa*

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