Contrasting rare-element mineralization in the Bikita & Mweza pegmatite fields, Zimbabwe

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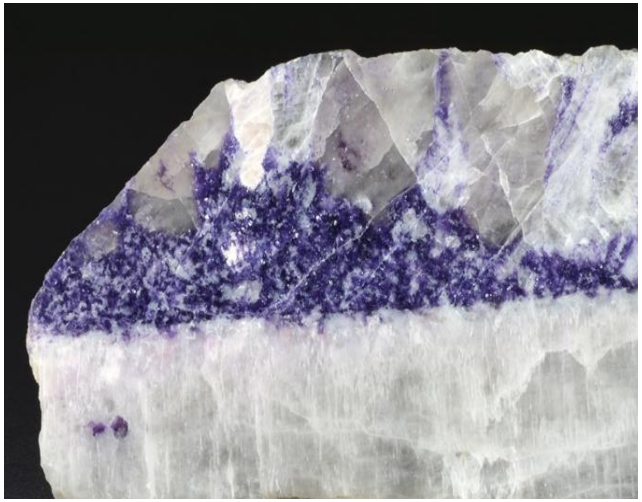
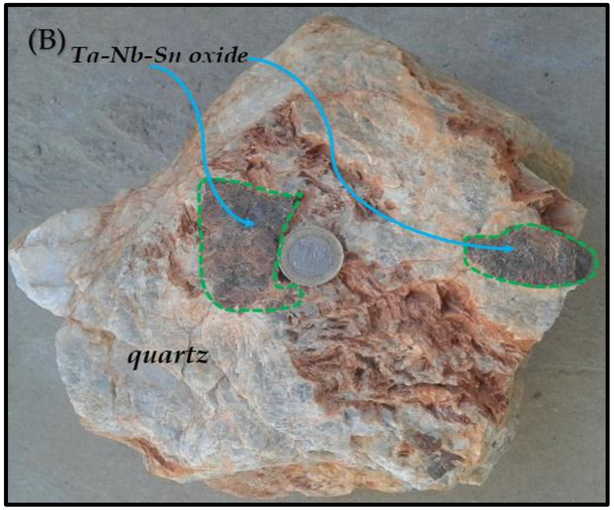
Why interest in Lithium-Cesium-Tantalum pegmatites?

Ore minerals for rare elements: Li, Rb, Cs, Be, Sn, Ga, Nb> Ta plus (fluxes= Li, B, P, F)



Li: lepidolite & petalite

Cs: pollucite



Ta-Nb-Sn: columbite-tantalite

(Linen et al. 2012): "strategic elements" or "critical elements"

- High-technology applications
- Lithium-ion batteries, electric cars revolution, capacitor in electronics, cesium clocks for cell phones & GPS receivers, special alloys.

On today's docket

(1) Classification of rare-element granitic pegmatites & formation hypothesis.

(2) Geology appraisal of southern margin of the Zim craton.

(3) Geochronology on pegmatites & spatially associated granite suites.

(4) Whole-rock trace elements chemistry on granite suites vs UCC (fertility test).

(5) Muscovite chemistry on the Bikita & Mweza pegmatites: petrogenetic implications.

Overview on classification of rare-element pegmatites

The family system of petrogenetic classification of granitic pegmatites (Černý & Ercit, 2005); widely accepted

Family	Pegmatite subclass	Geochemical signature	Pegmatite bulk composition	Associated granites	Granites composition
LCT	REL-Li MI-Li	Li, Rb, Cs, Be, Sn, Ga, Nb>Ta (B, P, F)	peraluminous to subaluminous	synorogenic to late-orogenic (to anorogenic); largely heterogenous	peraluminous, S, I or mixed S+I types
NYF	REL-REE MI-REE	Nb>Ta, Ti, Y, Sc, REE, Zr, U, Th, F	subaluminous to metaluminous (to subalkaline)	Syn-, late, post-to mainly anorogenic; quasi-homogeneous	peraluminous to Subaluminous & metaluminous; A and I types
Mixed	Cross-bred; LCT & NYF	mixed	metaluminous to moderately peraluminous	post-orogenic to anorogenic; heterogenous	subaluminous to slighly peraluminous

Where does the pegmatite-forming magma come from?

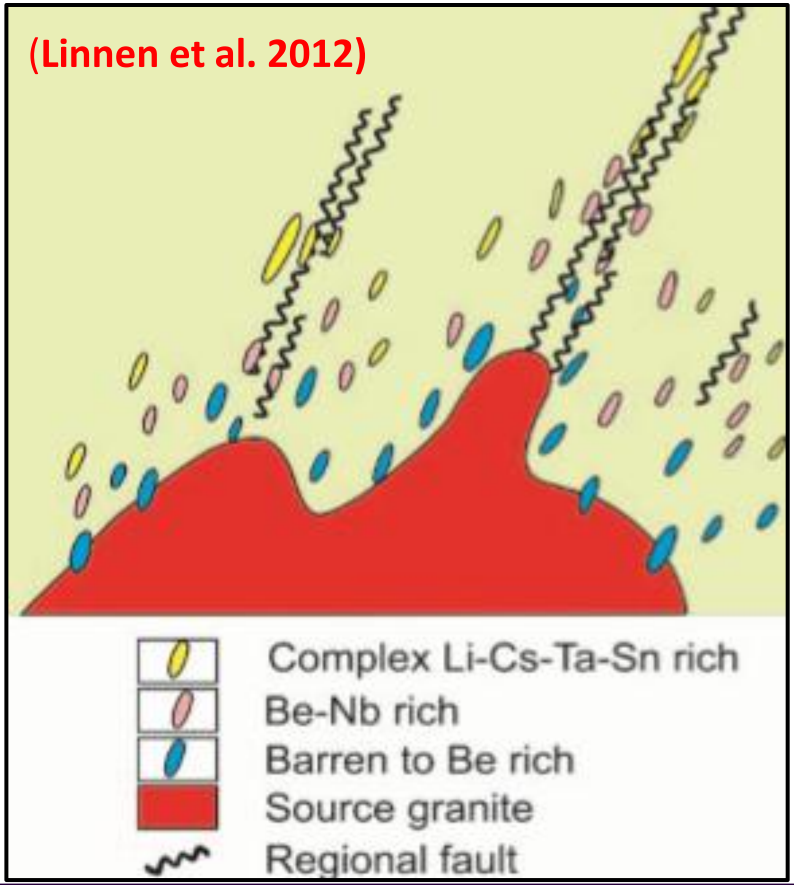
LCT pegmatites (Černý & Ercit, 2005)

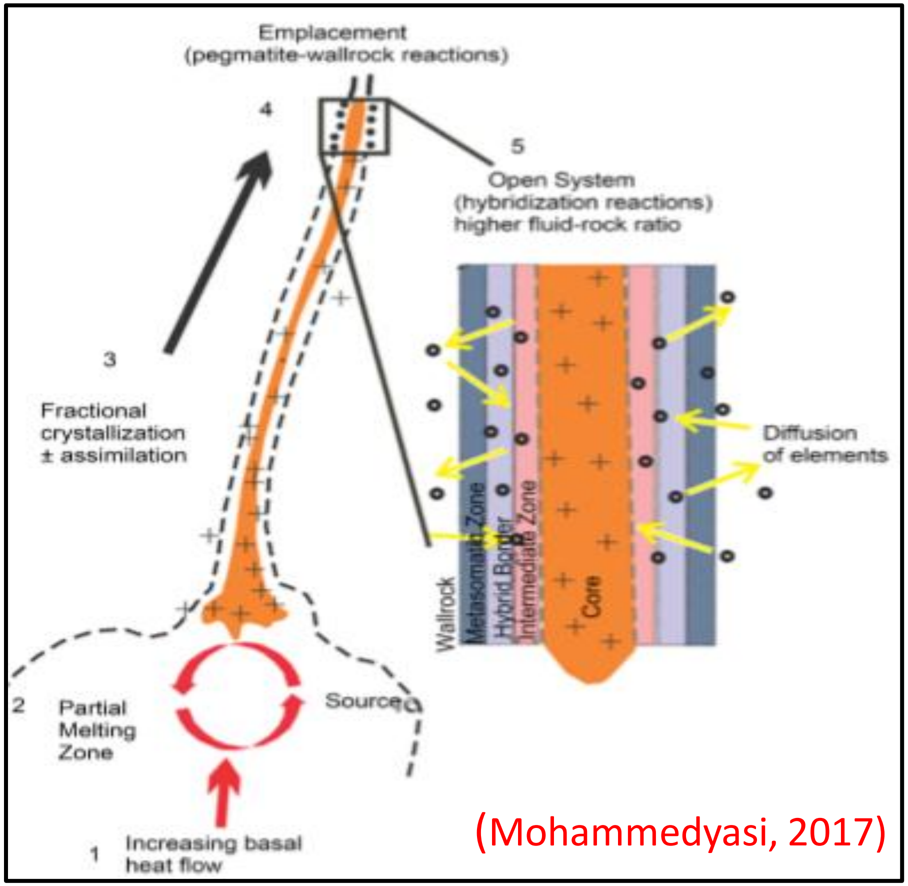
unusual magmas: fluxed

- **Peraluminous to subaluminous S- or I-type granites.**

(a) fractional crystallization of parental granite

(b) "anatectic" model (low degree melting of local crust)

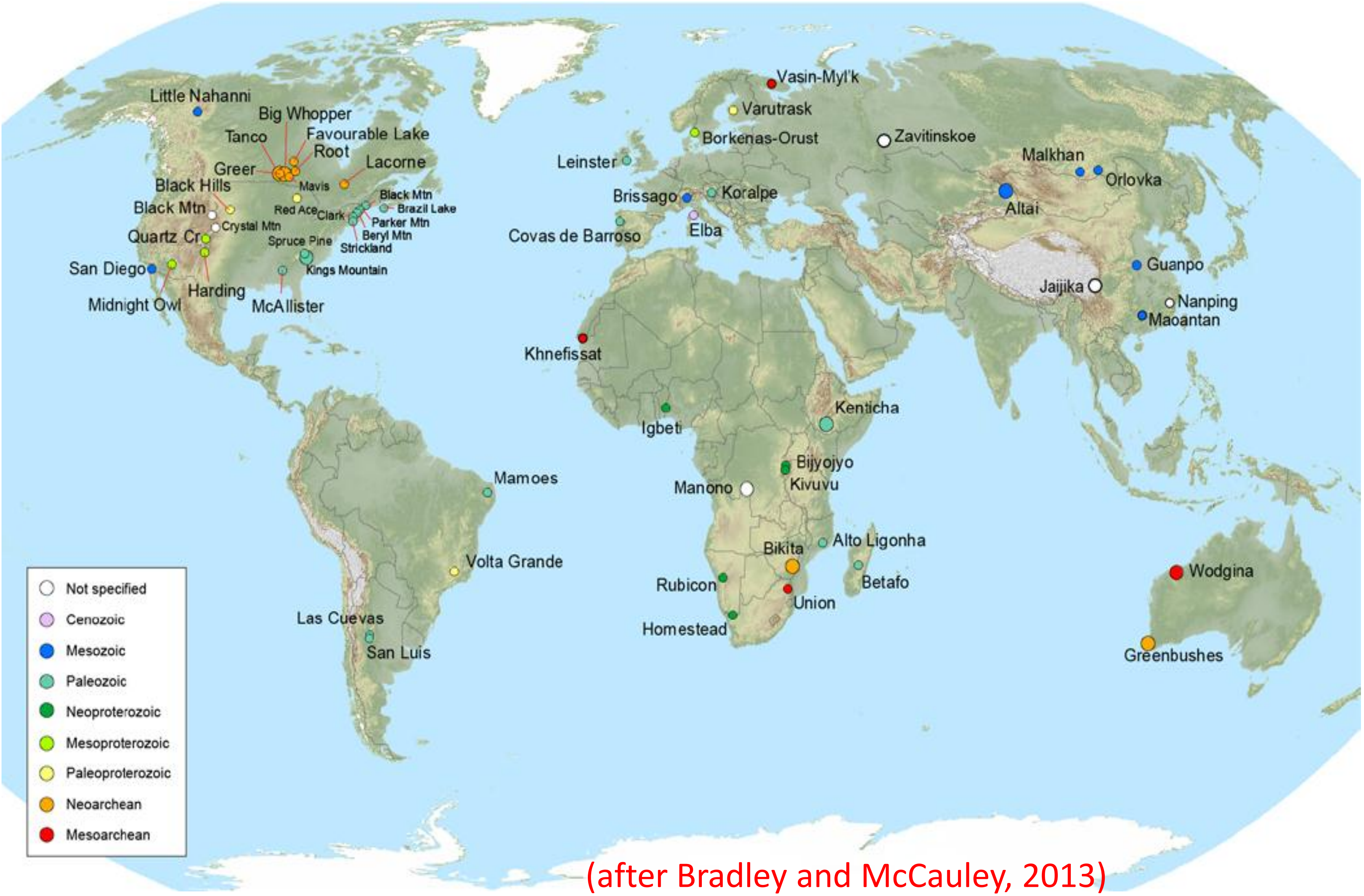




Associated granite: syn- to late-post orogenic

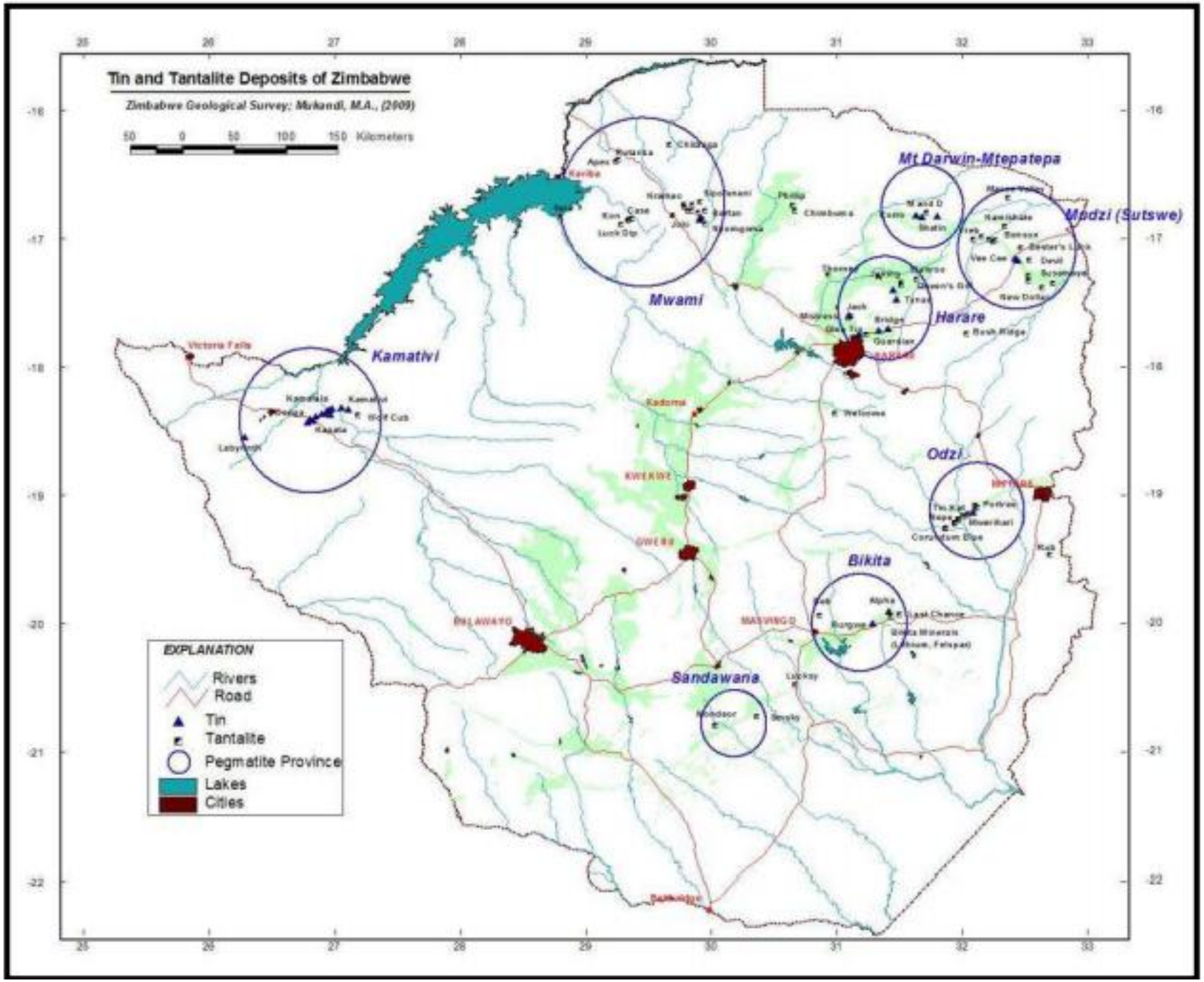
- ***parent is assumed to be hidden: Tanco (Canada) & Greenbushes (WA***

Global distribution of LCT pegmatites



(after Bradley and McCauley, 2013)

Distribution of rare-element pegmatites in Zim



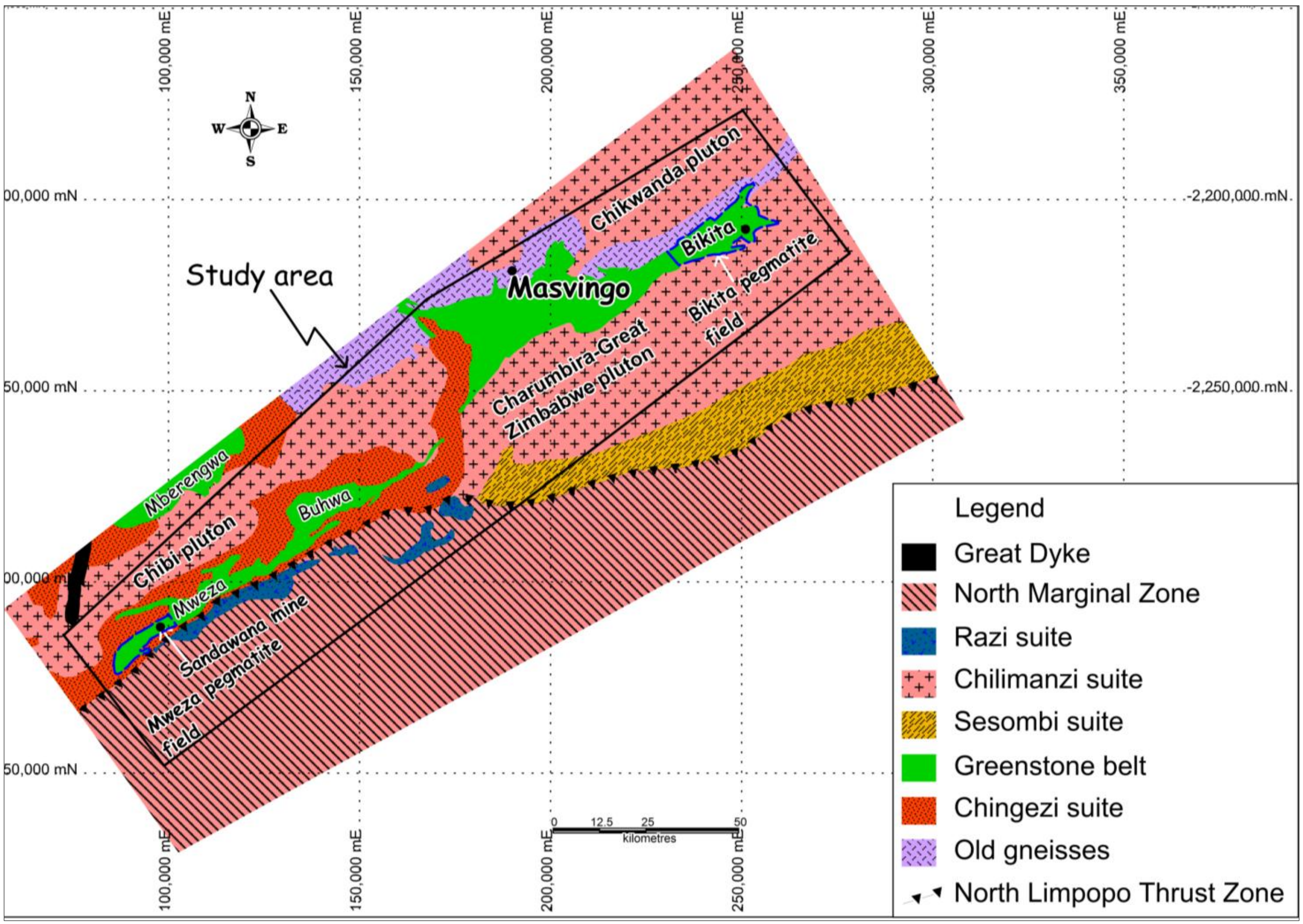
Granite genesis:
Re-working of older crust

cratonization:
2.63-2.52 potassic granites.

(Mukandi,2009: ZGS)

Geology of SM of Zim craton: Mweza & Bikita pegmatite fields

Paleo-Mesoarchean granite-gneisses BS.



(extract from Hofmann & Chagondah, 2018)

Regional fabric: NMZ thrusting over the Zim craton

Syn- to post-tectonic granites & granodiorites

I-type granites: metaluminous to low peraluminous affinity

εHf = -ve signals & inherited zircon ages.

Orogenic signatures: Syn-COLG & VAG

Host rocks: Mweza field = shear zones, Bikita= fracture network: upper greenschist-amphibolite grade

Previous workers: younger granites of the SM of the Zim craton

Viewing (1968): SM granites are more potassic relative to craton interior.

Robertson (1973): K-rich younger granites at Zim craton boundary = partial melts of pre-existing Limpopo belt gneisses during the Limpopo main event.

Moorbath et al. (1977): Craton interior granites: low initial $^{87}Sr/^{86}Sr$ ratio = 0.701

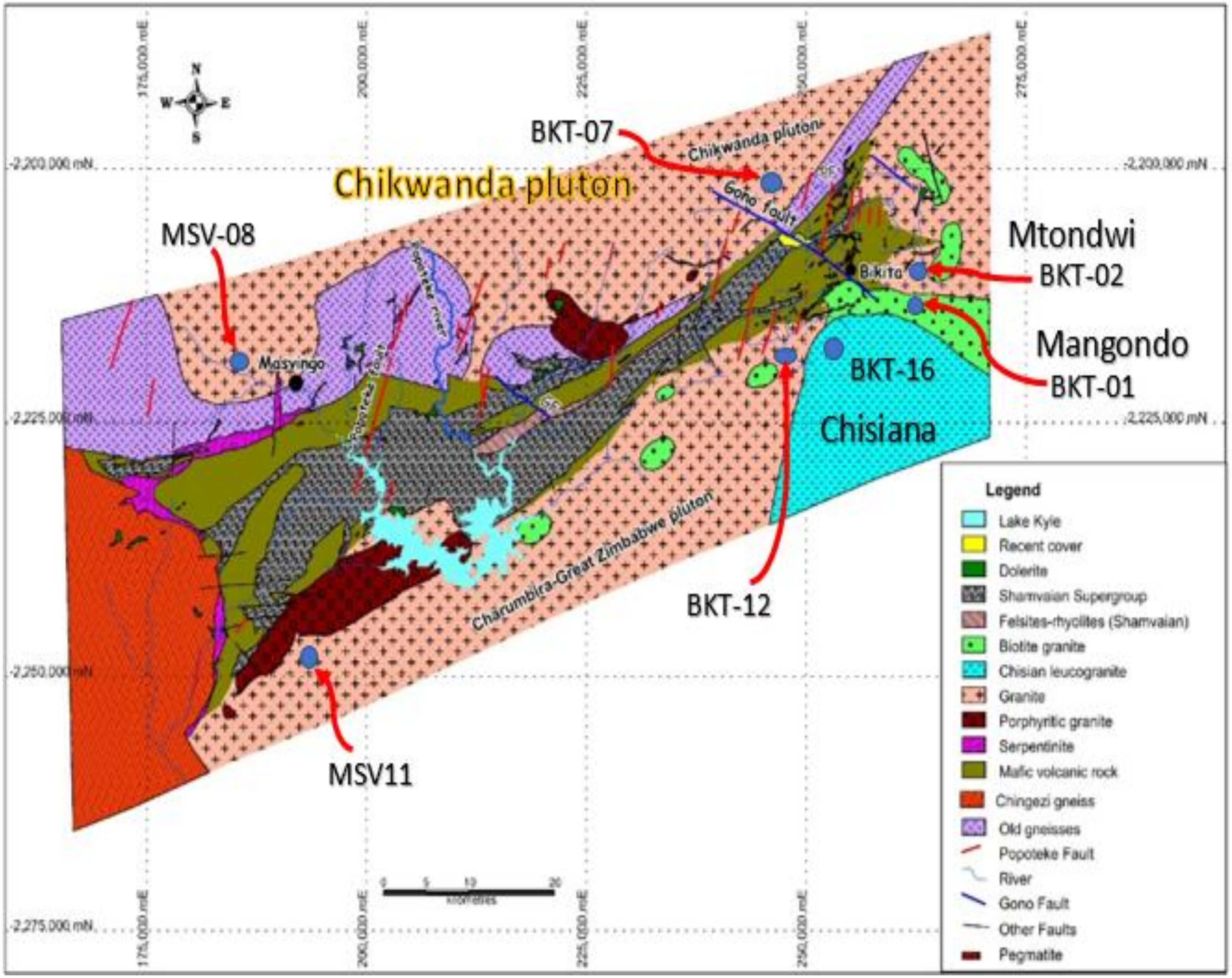
Hickman (1978): Younger granites: high initial $^{87}Sr/^{86}Sr$ = 0.7040 (indicative of input from re-working of a significantly radiogenic source, not 3.5-3.6 Ga gneisses, but the source could be the 2930 Ma Bangala Gneisses (Limpopo terrane)).

Hawkesworth et al. 1975; Moorbath et al. (1977): the geographic extent of re-worked crust is unknown = restricted to the craton margin?

Hawkesworth et al. (1979): high initial $^{87}Sr/^{86}Sr$ ratios are rare in Archean rocks. Younger granites melted from a pre-dominantly 2.9 Ga material (in deeper parts of the crust).

Berger et al. (1995); Kramers et al. (2001): NMZ and SM of Zim craton granites are enriched in radiogenic elements: K, Rb, Th & U by a factor of 2 relative to UCC

Geochronology- Bikita field



Wilson, 1964

Bikita: 2630-2616 (Ditrich,2017; Melcher et al. 2014)

2636-2633 Ma: (Chagondah et al. *in prep*

Pegs: 5-15 Ma younger: associated plutons

Plausible: late-stage differentiates of the Chikwanda, Chisiana & Mangondo plutons

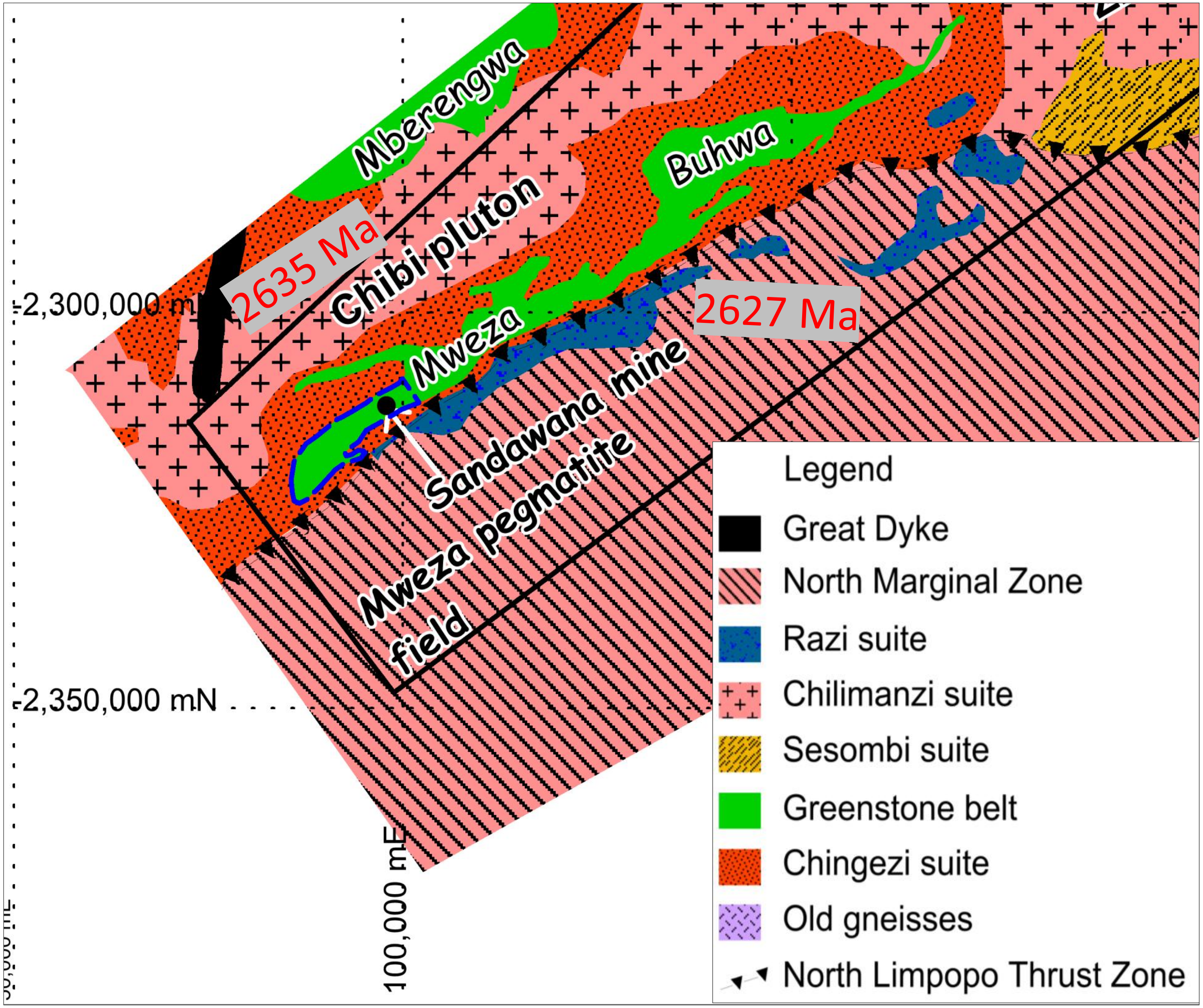
Conundrum?

(a) Mtondwi vs MBP? c.40 Ma

(b) MBP > Great Zim

Acknowledge: Profs Marlina & Kramers; Henriette (UJ) for geochronology interpretations

Geochronology: Mweza field



Pluton ages 2635-2627 Ma: (Chagondah et al. *in prep*

- **No direct age available for the pegs.**
- **Minimun age of trusting: 2627 Ma (Mkweli et al. 1995)**
- Pre-2627 Ma
- **Mother & daughter cannot be of similar age!!**

✓ **Chibi pluton**

Back to early workers: significance of high K-granites

If we agree on fractional crystallization model: Pegs origin

- Major K-bearing minerals in granites = biotite, muscovite & K-feldspar.
- Muscovite & K-feldspar are the main carriers of rare-elements in the Bikita & Mweza field pegmatites.

Note: biotite is not stable in evolved, mineralized pegmatites (Hulsbosch et al. 2014).

Plagioclase structure is impoverished in RE due to small ionic radius (Na^+) (Černý, 1994).

- Chibi granite has minor amounts of muscovite (Hawkesworth et al. 1979).

We failed to isolate Ms in Chibi & Razi plutons in this study for EPMA analyses…

- K-feldspar: metasomatic alteration & "rare element precipitation (e.g., during magmatic-hydrothermal transition: Bolloaurd et al. 2016; 2020).

- It appears Mweza field is enveloped by Ms-poor plutons; "Poor two-mica granites": low prospectivity

Whole-rock magmatic fractionation ratios in granite suites vs UCC

Element	UCC[1]	Literature	Chilimanzi suite				Razi suite		Wedza suite	Old Gneisses
			Chikwanda	GTZ	Chisiana	Chibi	Razi	Mangondo	Mtondwi	TTG
Li (ppm)	21.0		48.0	43.1	70.4	30.0	9.7	62.1	135.7	34.0
Sr	320.0		72.9	98.6	61.8	125.8	301.4	166.4	96.3	370.8
Cs	4.9		6.2	3.2	5.9	2.0	0.3	4.4	14.6	4.1
Ba	624.0		389.3	513.8	444.5	792.1	1267.3	724.2	1018.1	727.9
U	2.7		15.5	11.2	13.7	3.1	2.5	8.4	3.0	2.6
Ratios										
K/Ba	37.2	>61.8[5]	128.7	82.7	94.2	46.9	27.6	53.0	37.1	33.8
Rb/Sr	0.3	>2.3[4]	4.4	2.7	5.9	1.6	0.3	1.8	2.3	0.3
Mg/Li	712.2	<30[5]	21.2	42.2	18.0	78.7	643.7	78.4	9.1	377.8

Chagondah et al. *in prep*

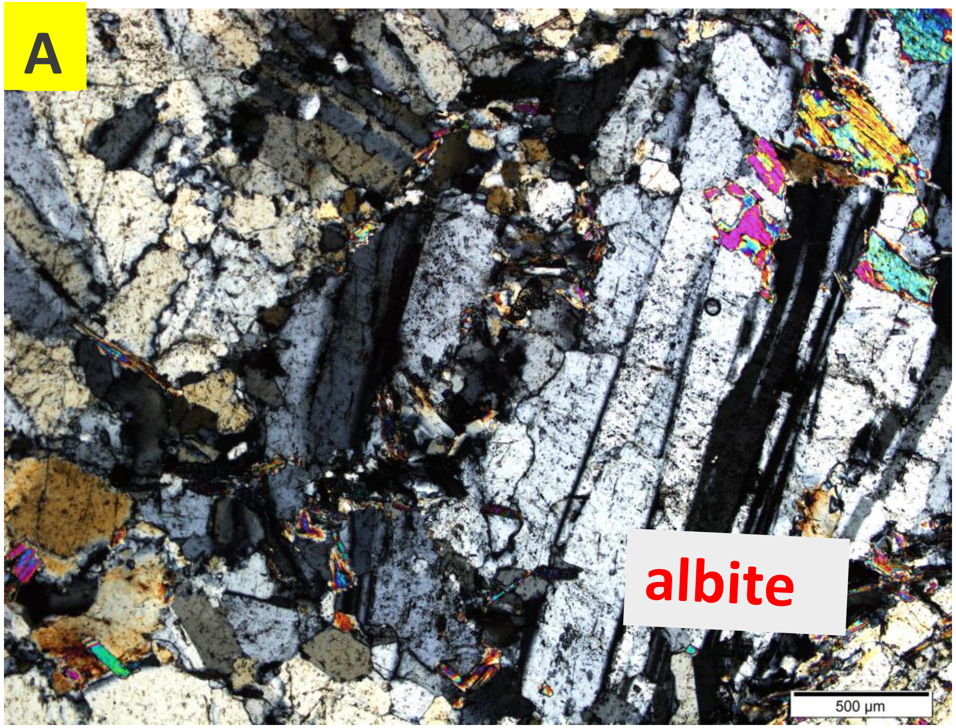
Upper Continental Crust (UUC[1]) values= Rudnick & Gao (2014)

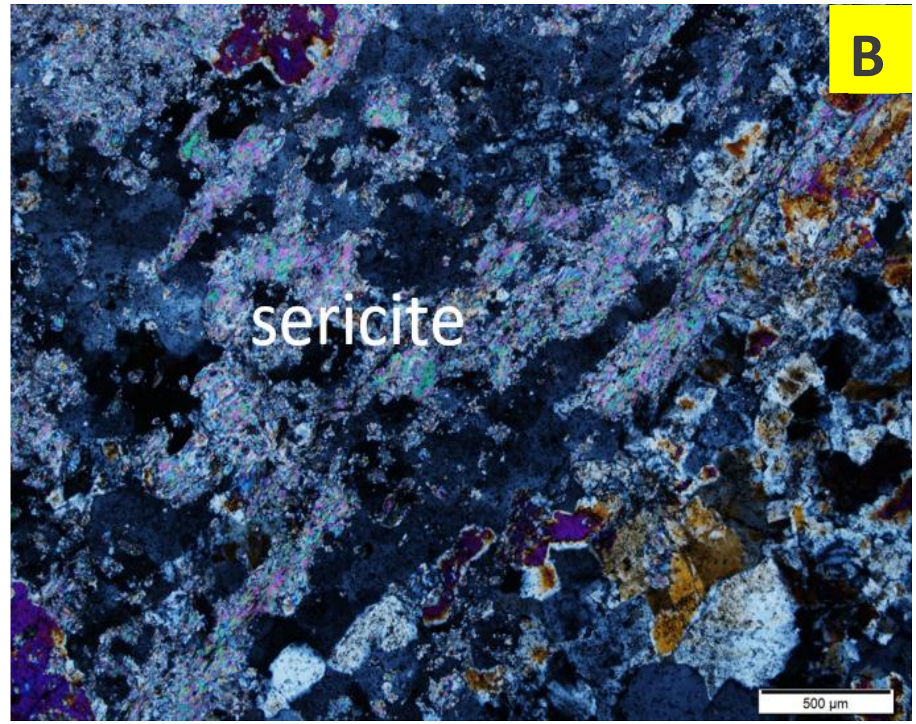
Prospective fertile plutons: enriched in trace elements but depleted in Sr & Ba relative to UCC.

- Razi pluton, low T. element budget & is weakly fractionated to spawn pegmatites?

Rare element concentration processes = magmatic differentiation & fractional crystallization

Petrography: Mweza & Bikita pegmatites & environs





Mweza pegmatites (A): low degree of metasomatic alteration relative to the Bikita field (B)

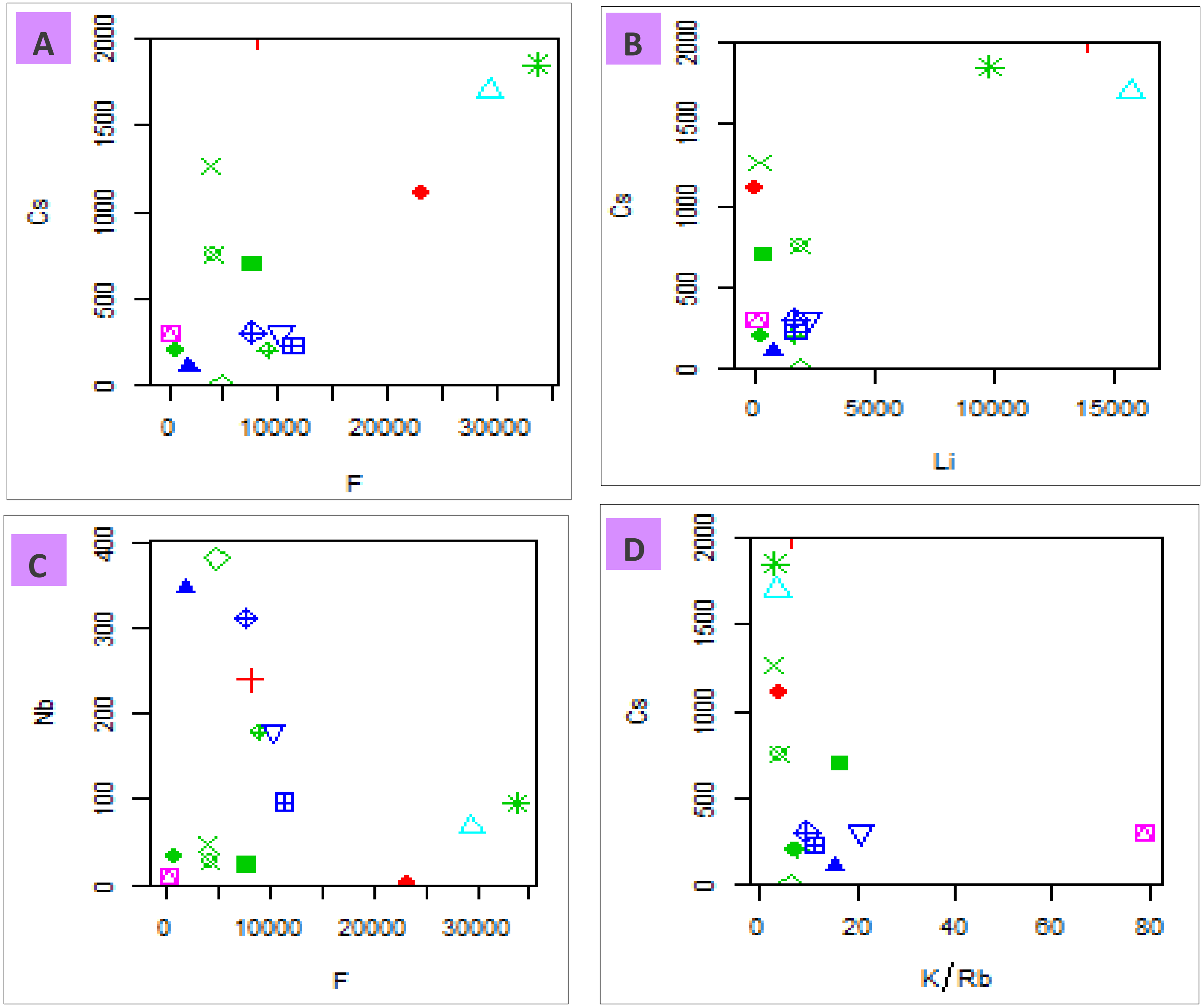
Mweza environs = Chibi & Razi plutons: less altered (albitization & sericitization by residual magmatic fluids during magma evolution)

Bikita environs = granite suites more altered

Suite of rare-element ore minerals: Bikita vs Mweza field pegmatites

Bikita field	**Mweza field**
lepidolite $K(Li,Al)_3(Al,Si,Rb)_4O_{10}(F,OH)$	localized lepidolite
petalite ($LiAlSi_4O_{10}$)	?
spodumene ($LiAl(SiO_3)_2$	localized spodumene
amblygonite $(Li, Na)AlPO_4(F,OH)$	
eucryptite ($LiAlSiO_4$),	
bikitaite ($LiAlSi_2O_6.H_2O$)	
beryl ($Be_3Al_2SiO_6$)	beryl (emeralds)
columbite ($(Fe, Mn, Mg) (Nb, Ta)_2O_6$)	columbite
tantalite ($(Fe,Mn)(Ta,Nb)_2O_6$)	tantalite
cassiterite (SnO_2)	localized cassiterite
scheelite ($CaWO_4$)	localized scheelite
pollucite $(Cs, Na)_2Al_2Si_4O_{12}.2H_2O$)	

Pegmatite muscovite chemistry



Fluxing agents: F, Li,B, P & H2O

Refs: Dingwell et al. 1988; Nabelek et al. 2010; Roda-Robles 2012; 2018; Marchal et al. 2014

D = Contrasting efficiencies in magmatic differentiation & fractional crystallization

From source pluton to Peg

Blue = Mweza field pegs; other colours = Bikita field pegs

Take Aways

(a) Bikita field pegmatites derive from more fractionated source rocks: geochronology: Chilimanzi suite (Chisiana, Chikwanda, Mangondo- higher level intrusions)- are conceivable parental granites.

(b) Mweza field: Razi pluton unlikely over more fractionated Chibi pluton.

- Chibi pluton is less fractionated (Fe-rich) relative to other Chilimanzi suite plutons. Razi pluton: lower intrusion level.

(c) Fluxing agents (F, Li, P, B & H_2O): more enriched in the Bikita field.

(d) Thus, fractional crystallization: more efficient in the Bikita relative to Mweza field.

(e) Pegmatites across both fields appear to be late-stage differentiates of fractionated I-type granites, with orogenic signatures.
Evidence for re-working of older crust: evolved isotopic systematics, εHf = -ve signatures & inherited zircons in younger granite suites.

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Acknowledgements

Thank You