Expanding our knowledge of melting and metal enrichment in the cratonic basement of Zimbabwe

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Who I am

- Lot Koopmans
- DPhil Earth Sciences at University of Oxford
- Working with Richard Palin, Nick Gardiner, Laurence Robb in UK
- Antony Mamuse, Brian Mapingere, Tony Martin in Zimbabwe

Outline

- How do we form TTGs? Lessons from other Archean cratons
- Field observations from the Zimbabwe craton
- Preliminary geochemical observations from the Zimbabwe craton
- How do we form pegmatites?
- What insight might these give us in Zimbabwe?

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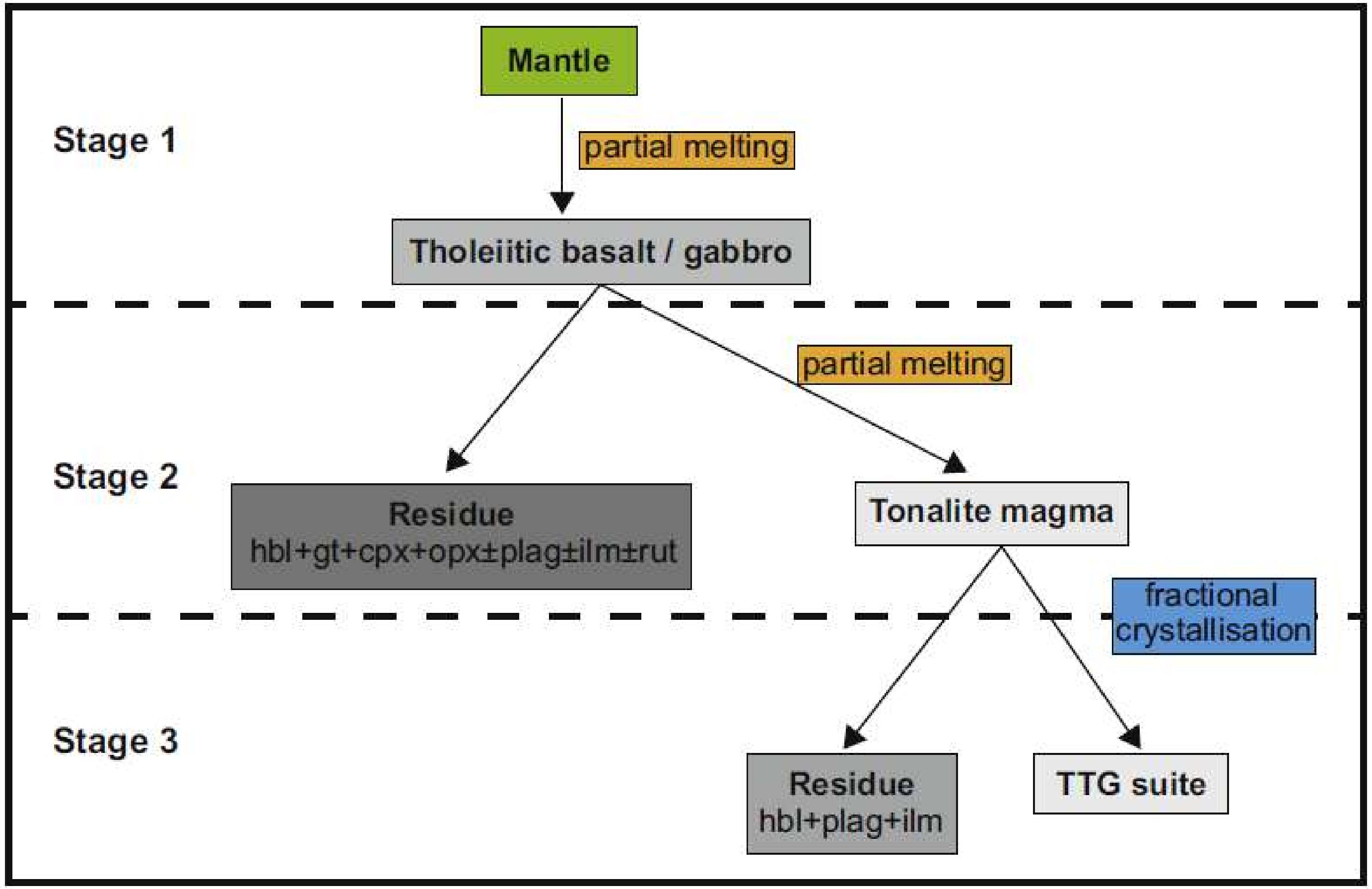
Why care about the basement?

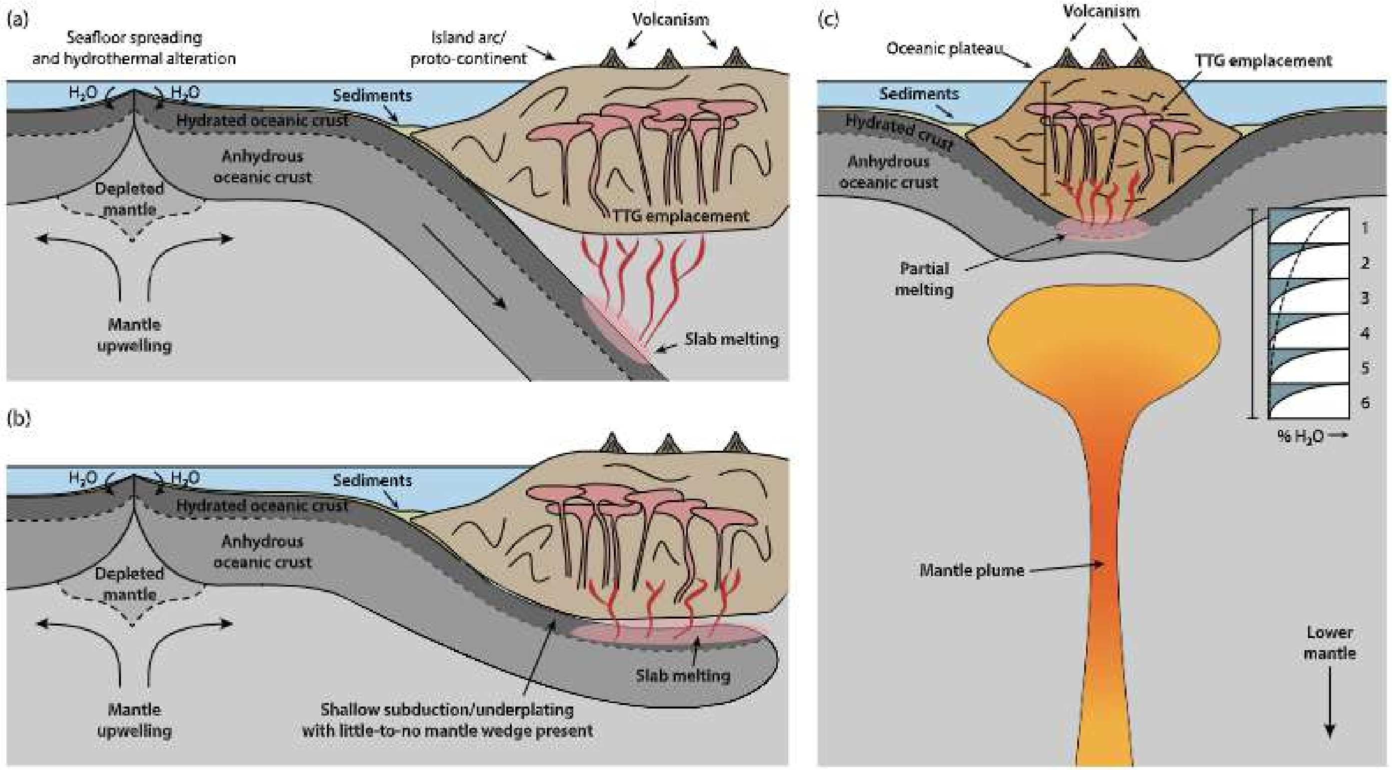
- Provides insight into formation of continental crust
- Can be a very good record of cratonic evolution
- Informs us of the nature of plate tectonics at the time
- Can record crustal recycling and enrichment

How to form a TTG



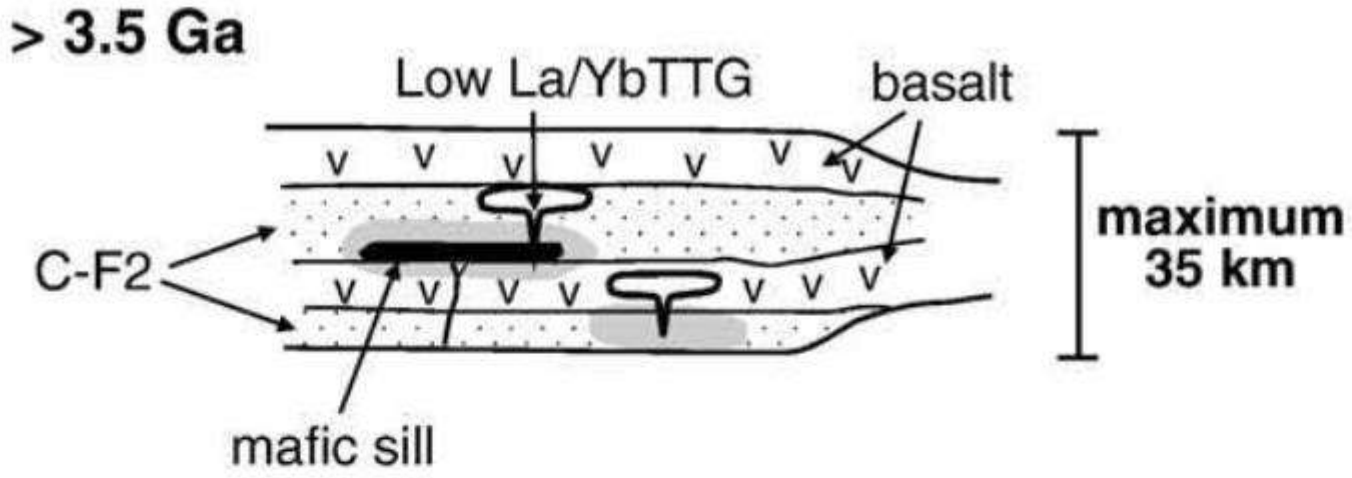
Different models for archean ttg formation

- Pilbara model
- Greenland model

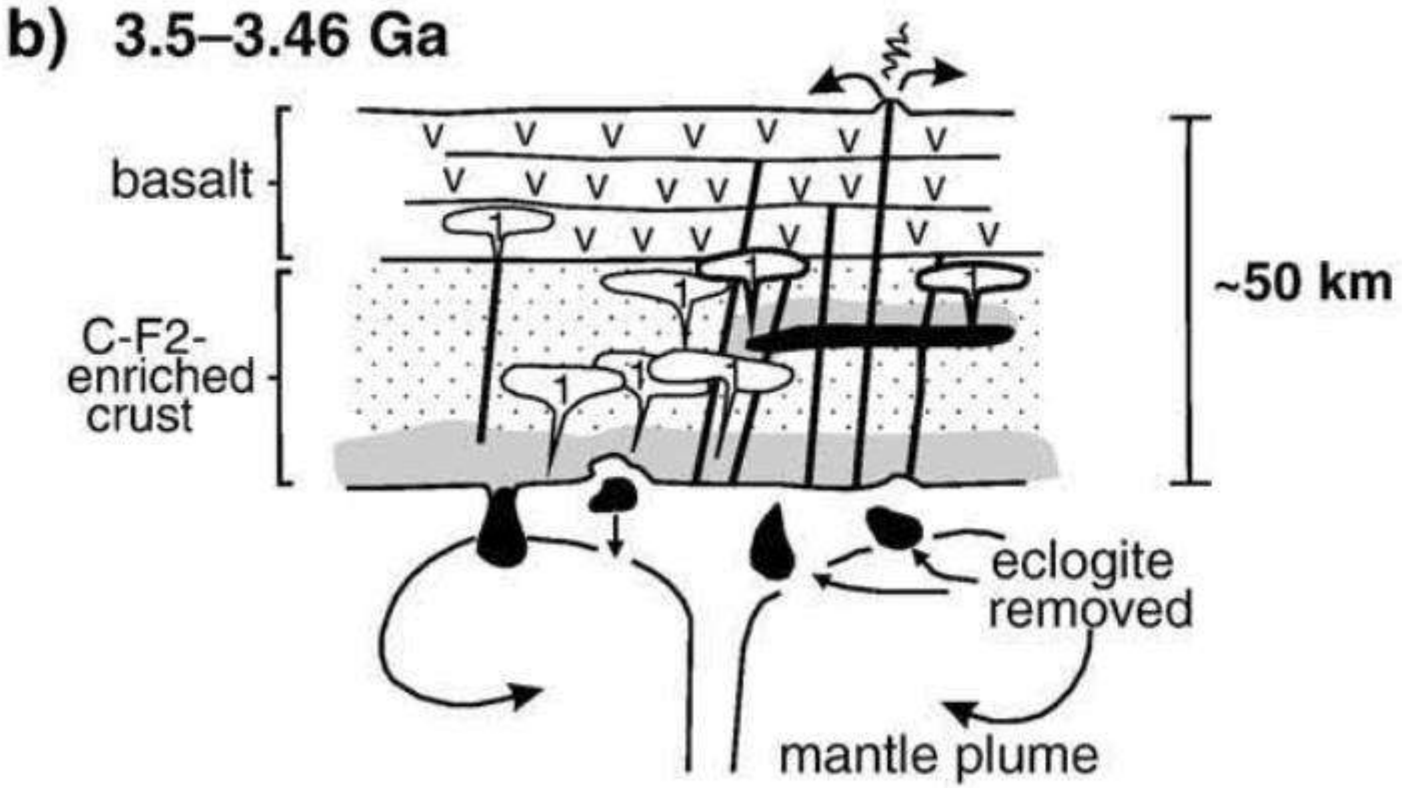


Pilbara model

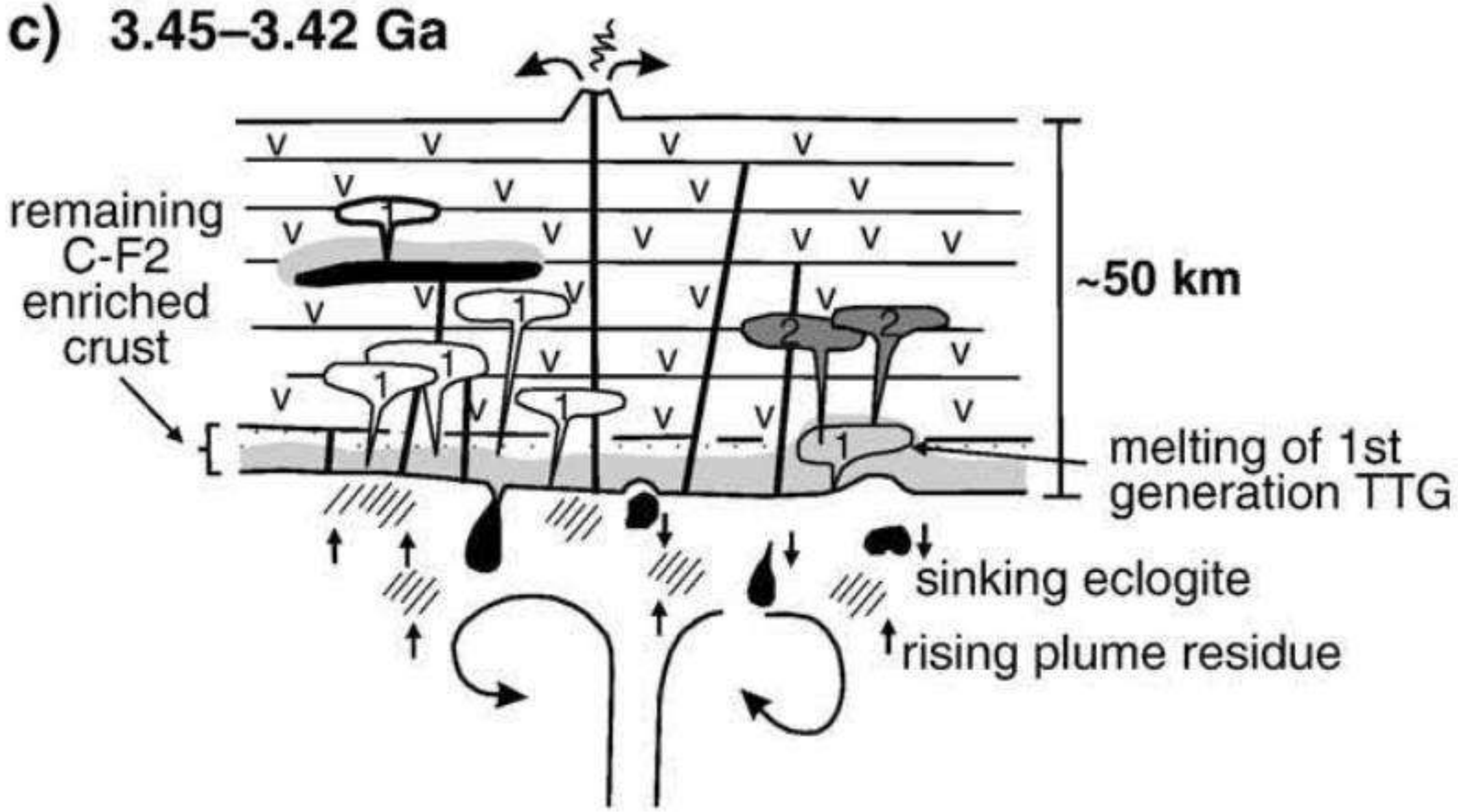
- (non-plate tectonic model)



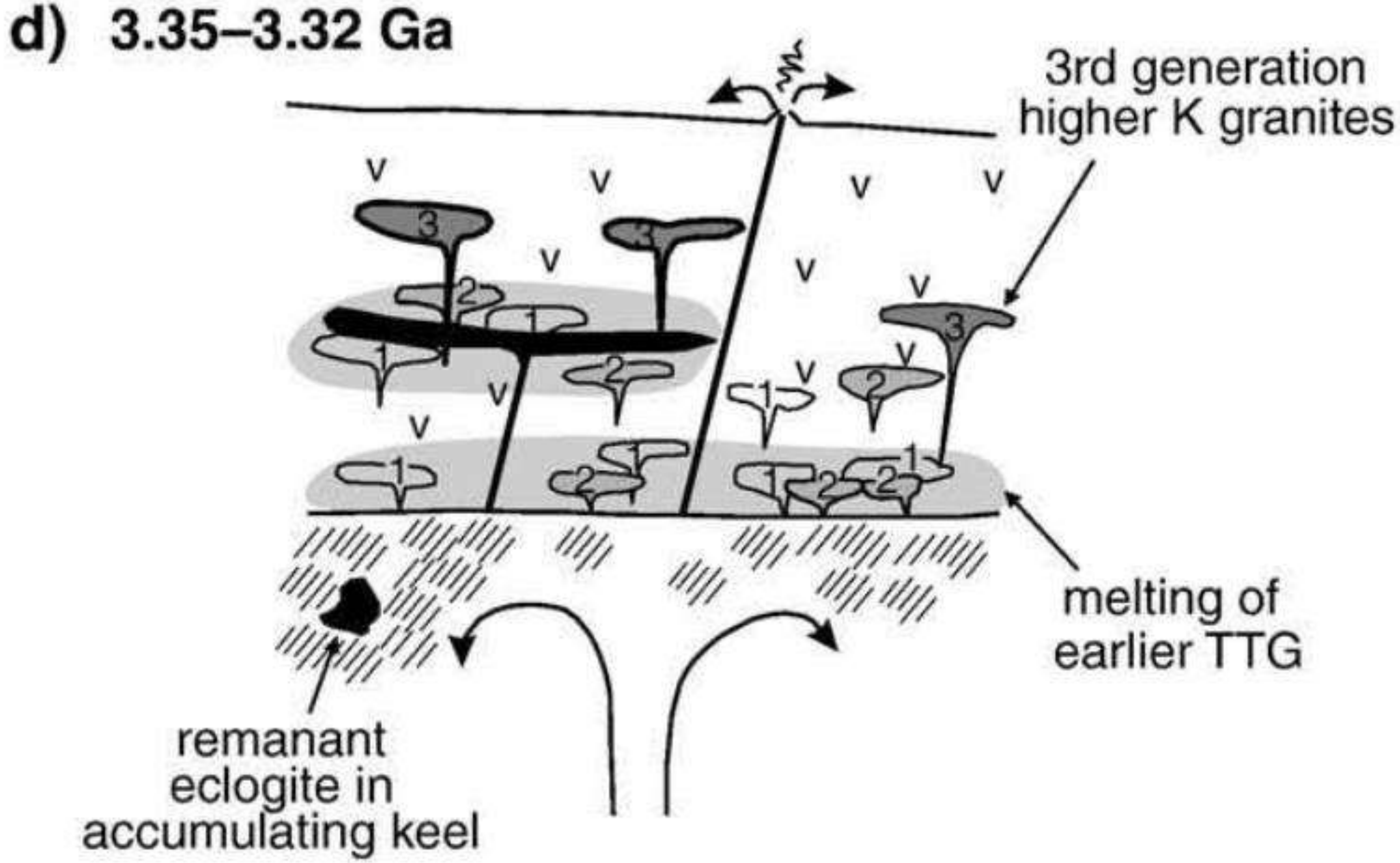
Pilbara model



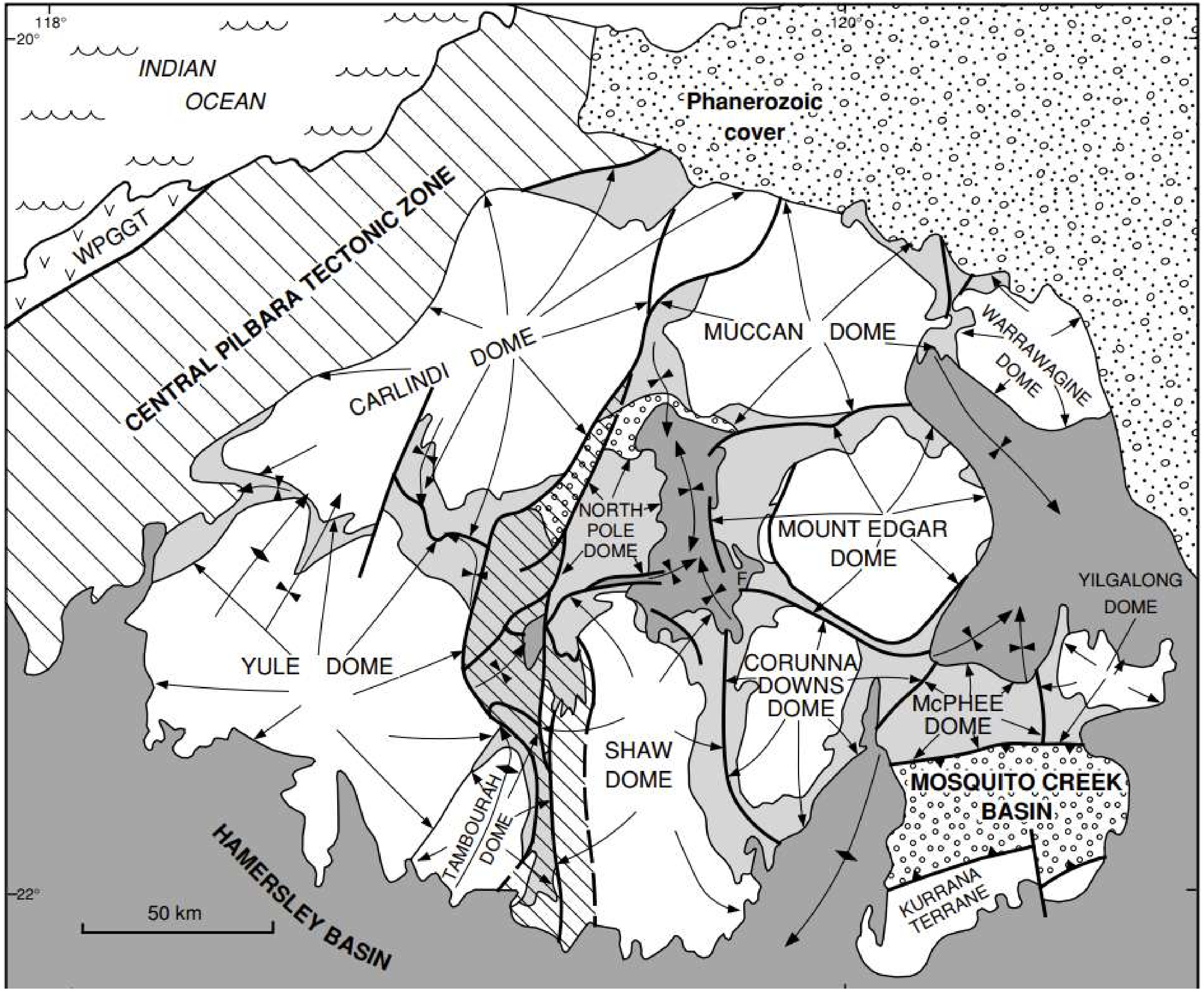
Pilbara model



Pilbara model

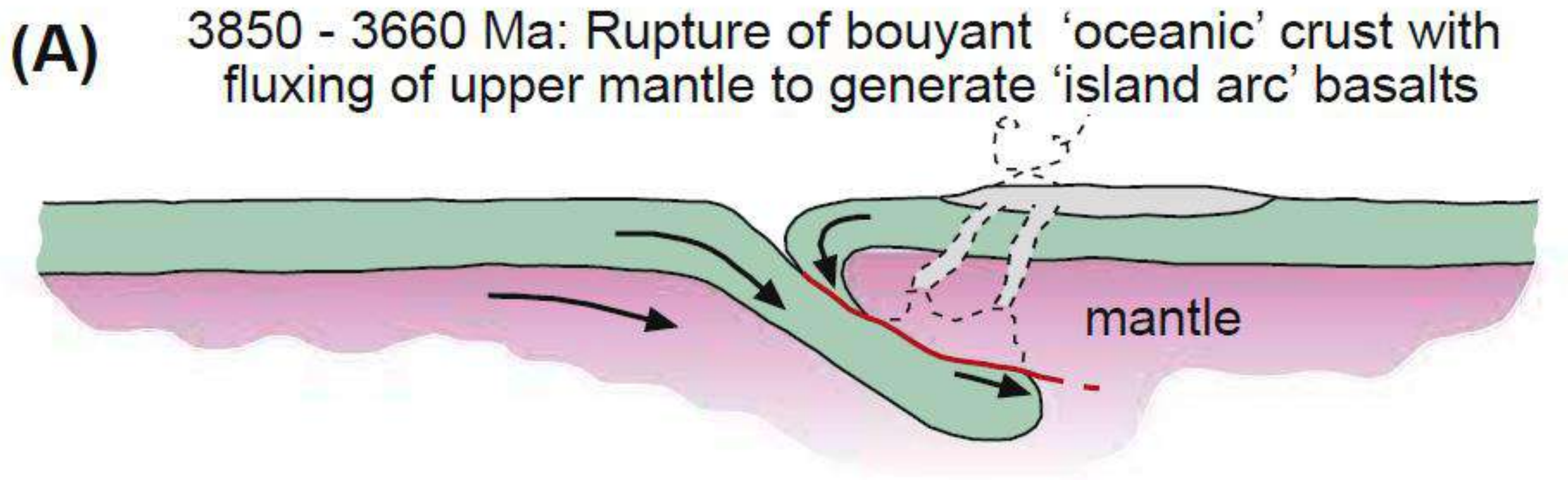


Pilbara model

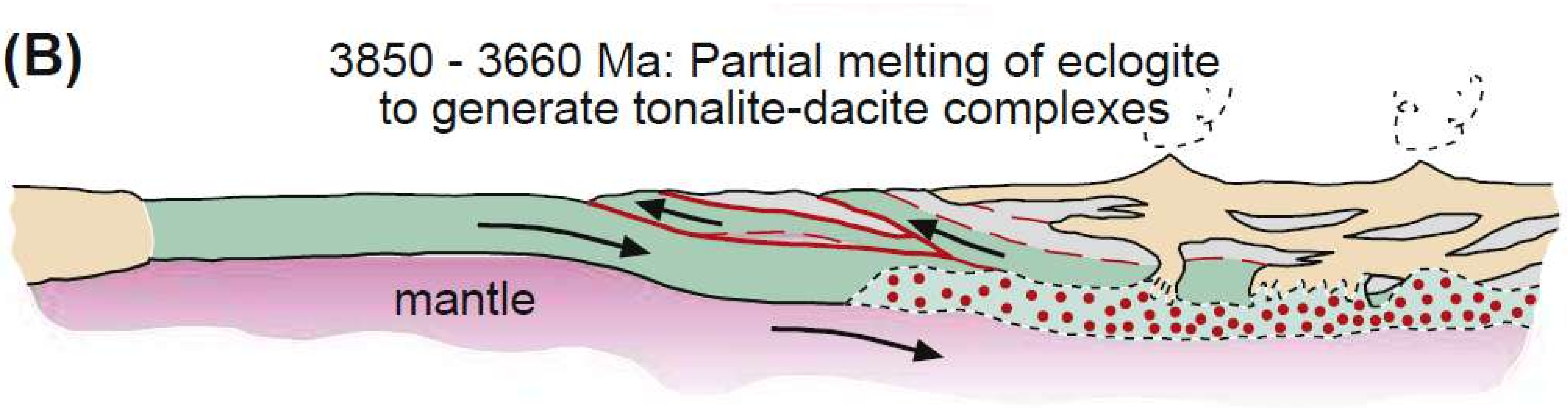


Greenland model

- (plate tectonic model)

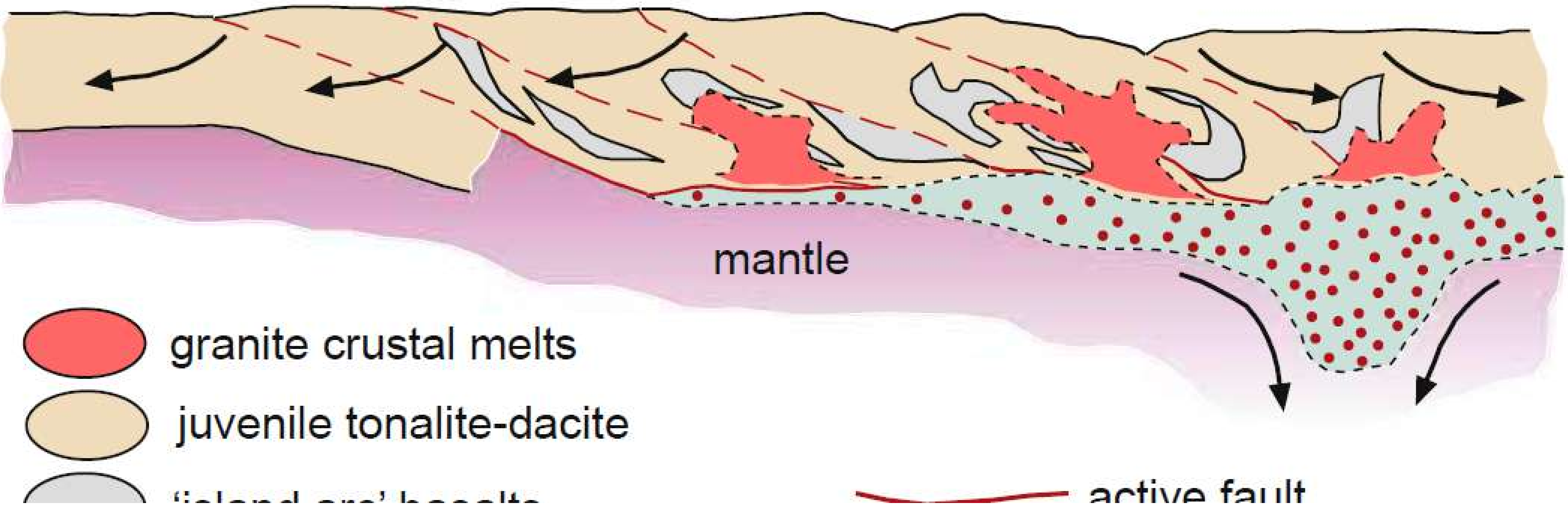


Greenland model

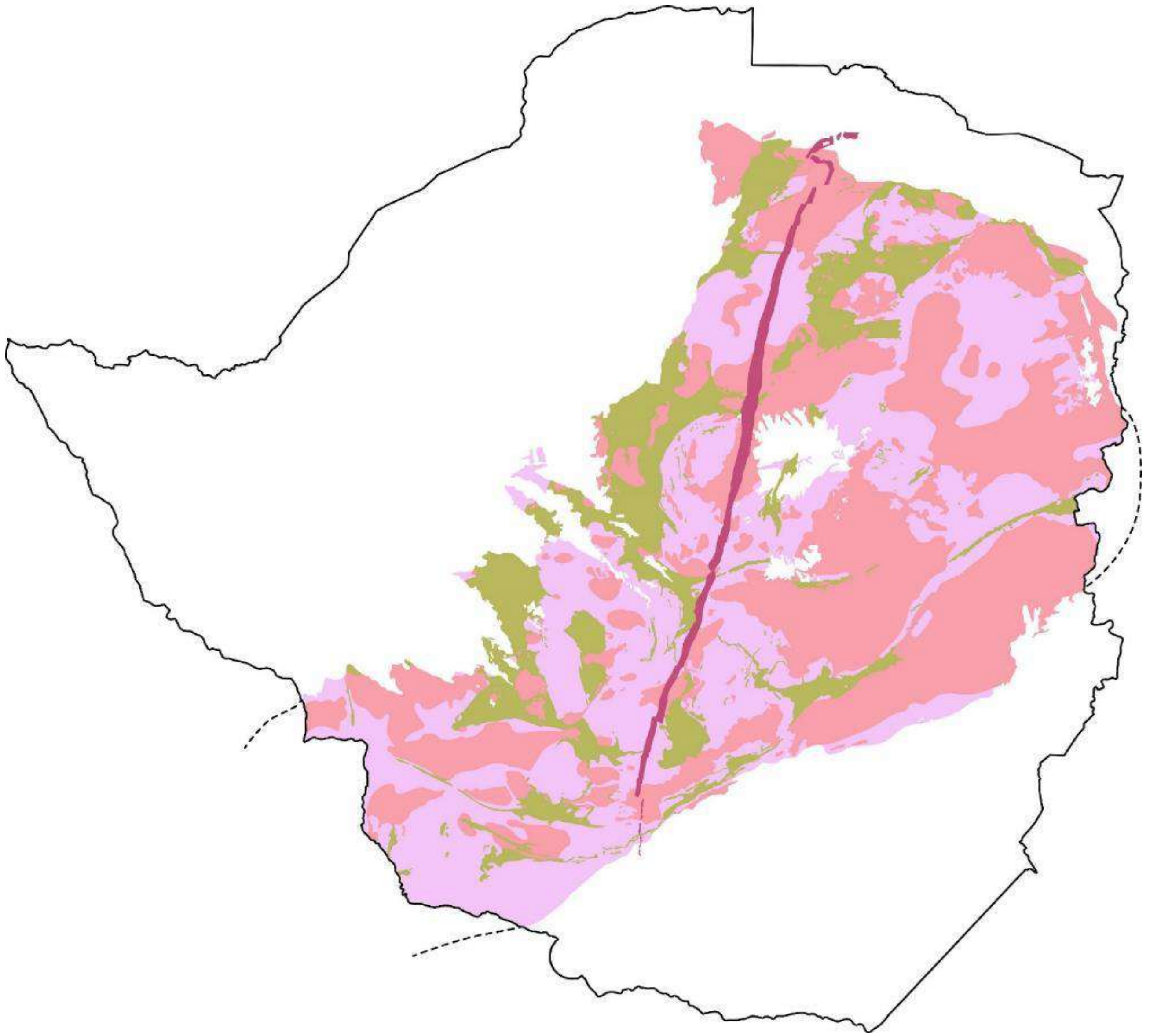


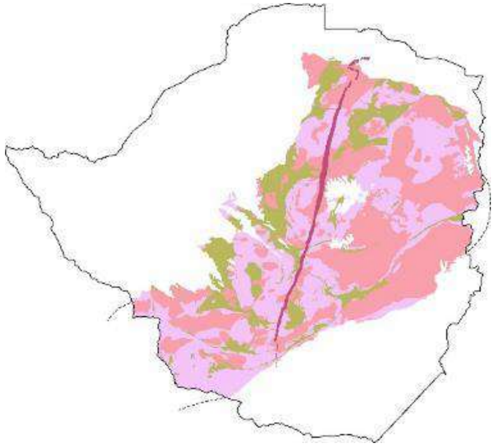
Greenland model

(C) 3660-3600 Ma (i) Isukasian collisional orogeny crustal thickening by amalgamating arcs then (ii) extensional collapse and crustal melting

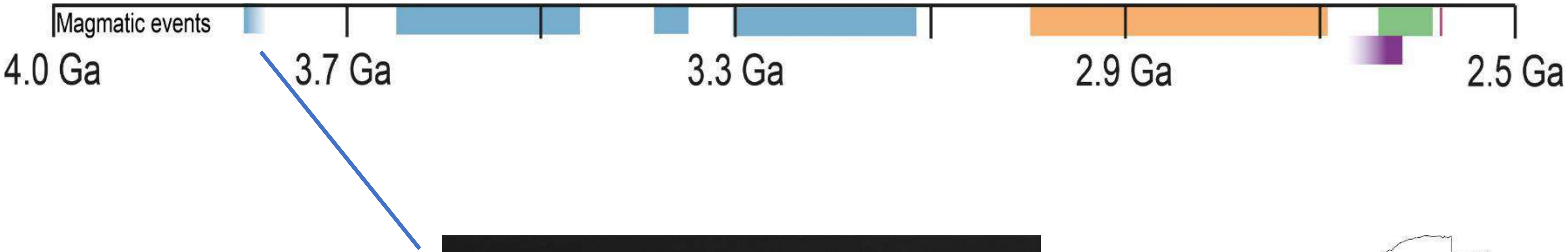


Applying this to the Zimbabwe craton






Magmatic events
4.0 Ga
3.7 Ga
3.3 Ga
2.9 Ga
2.5 Ga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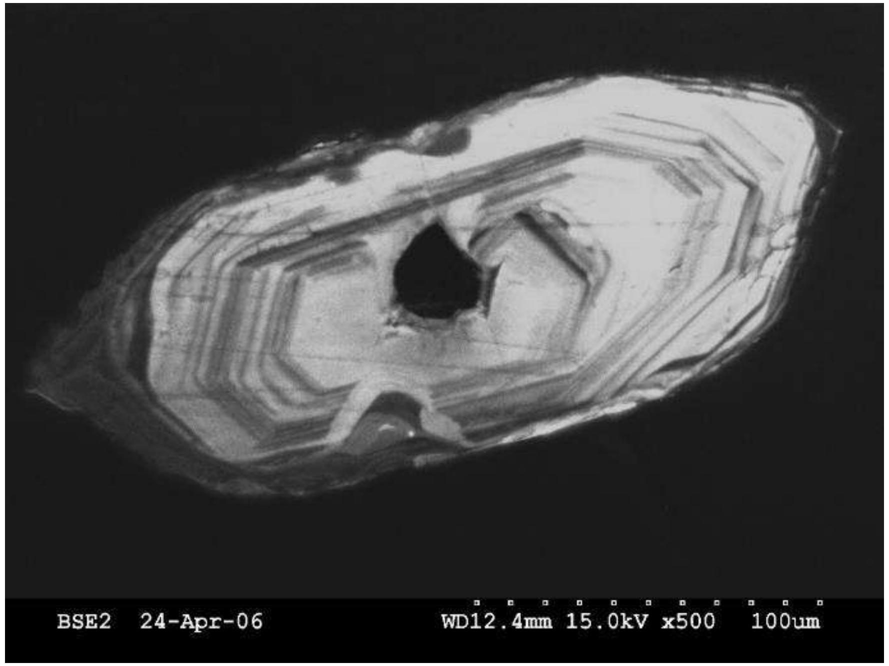
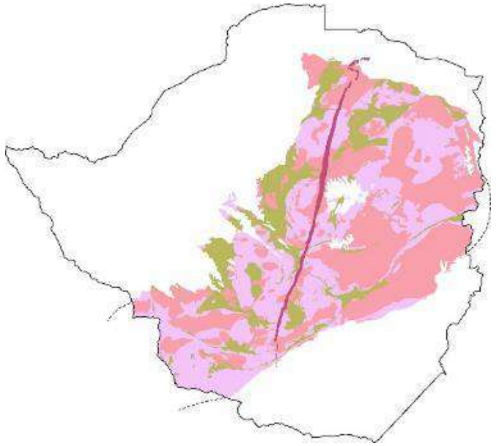

BSE2 24-Apr-06
WD12.4mm 15.0kV x500 100um




Magmatic events
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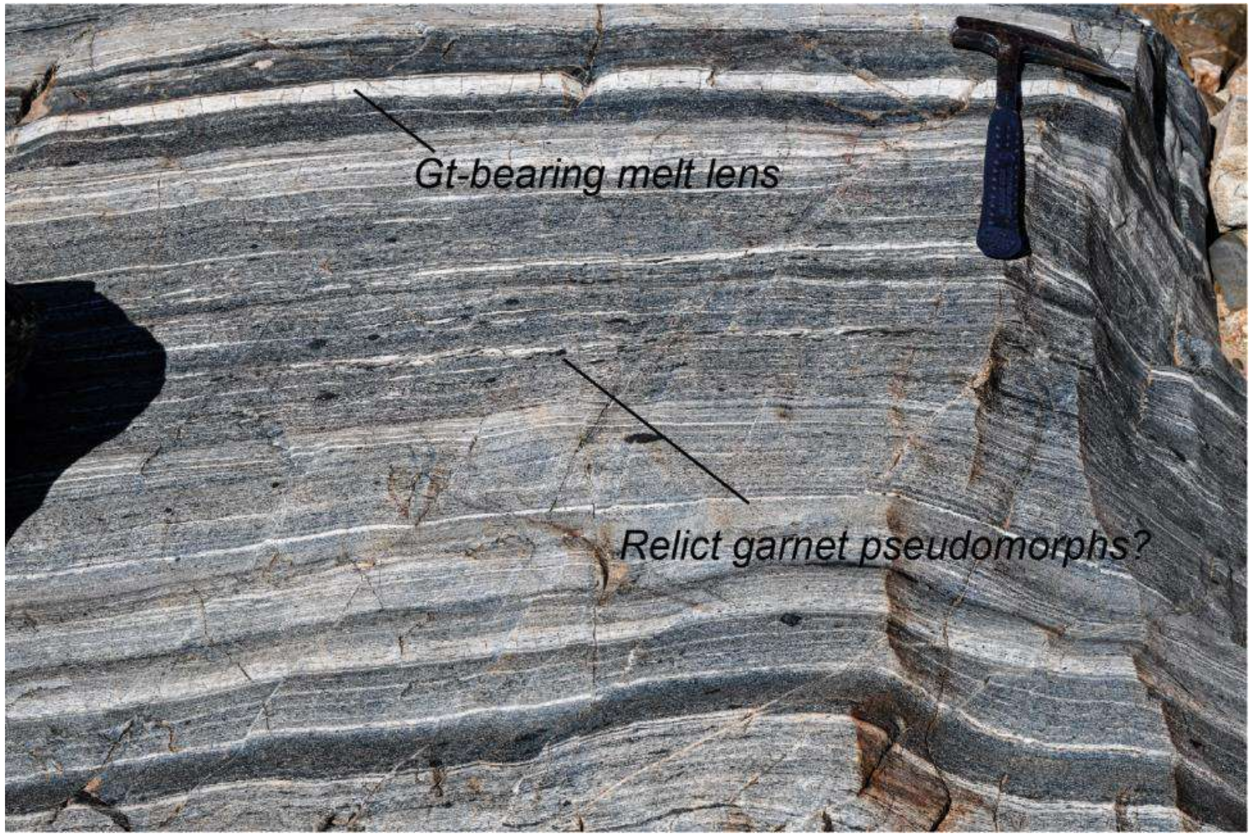
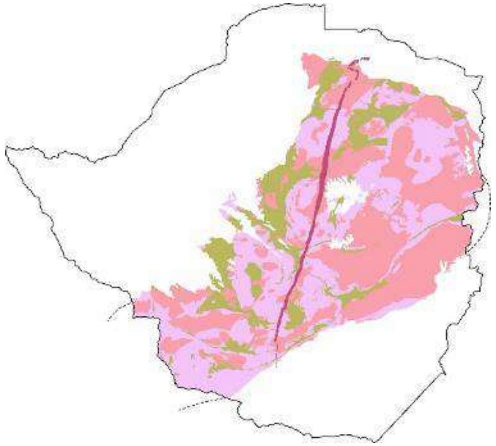
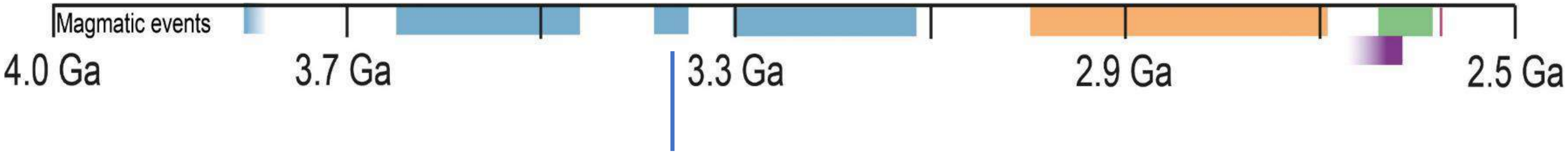

Gt-bearing melt lens
Relict garnet pseudomorphs?





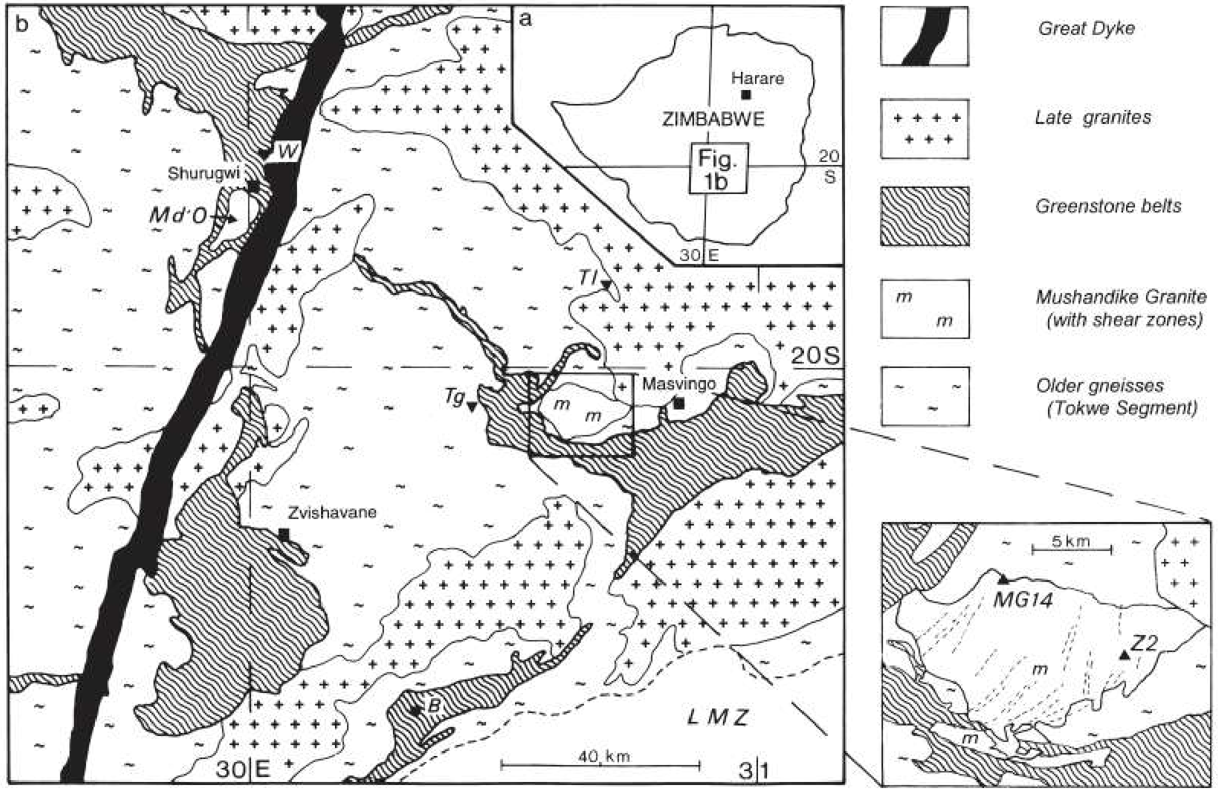
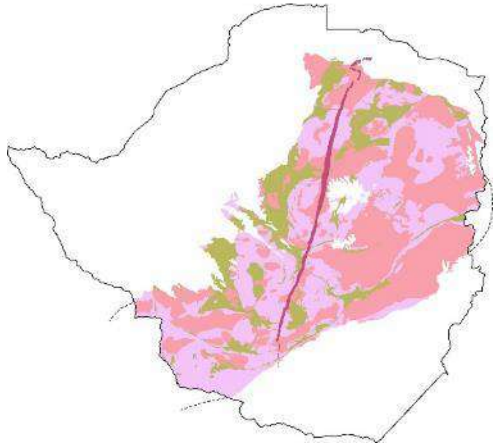
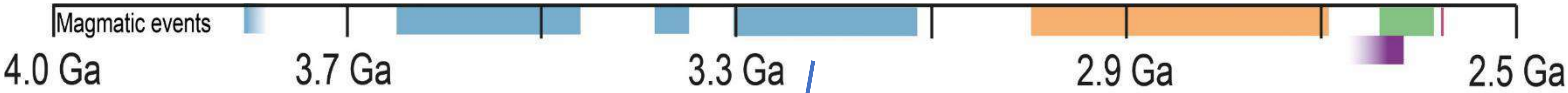


Figure 1. (a) Location of main map within Zimbabwe; (b) regional setting of Mushandike Granite (after Zimbabwe, 1985; Geological Survey, 1965). Sample locations: MG14, Z2, this paper; B – Buchwa; W – Wanderer (Dodson *et al.* 1988); Tg – Tokwe Gneiss; Tl – Tokwe leucosome (Horstwood *et al.* 1999). LMZ – Limpopo Mobile Zone. Md'O – Mont d'Or granite.




Magmatic events
4.0 Ga
3.7 Ga
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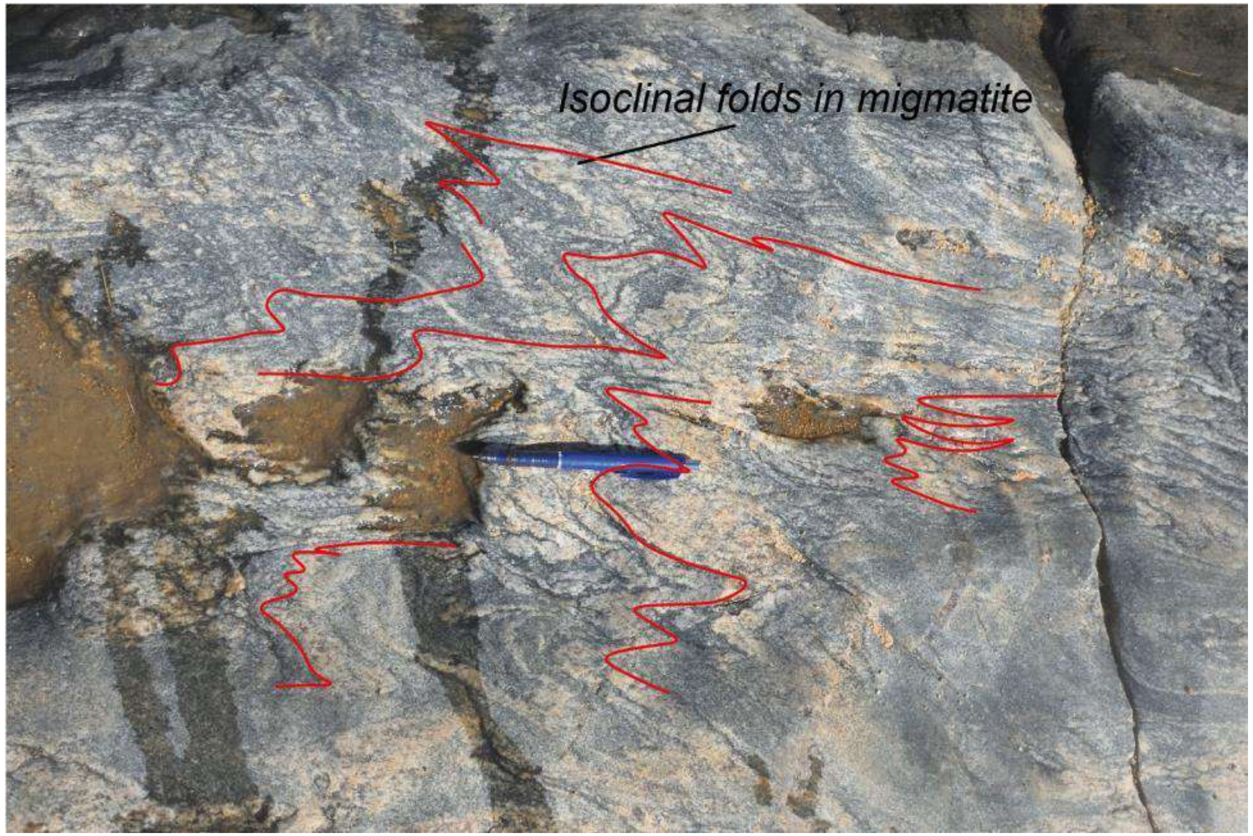
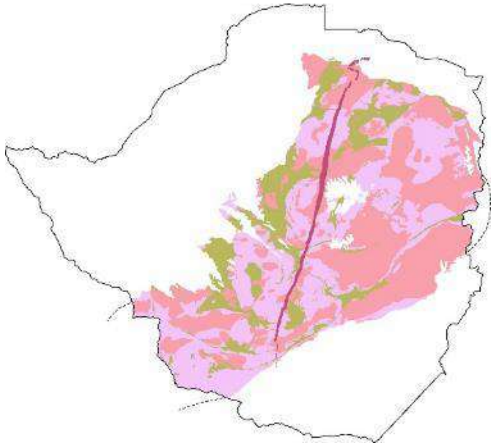
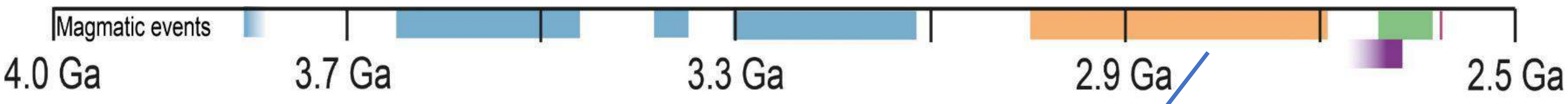
2.9 Ga
2.5 Ga


Isoclinal folds in migmatite




Magmatic events
4.0 Ga
3.7 Ga
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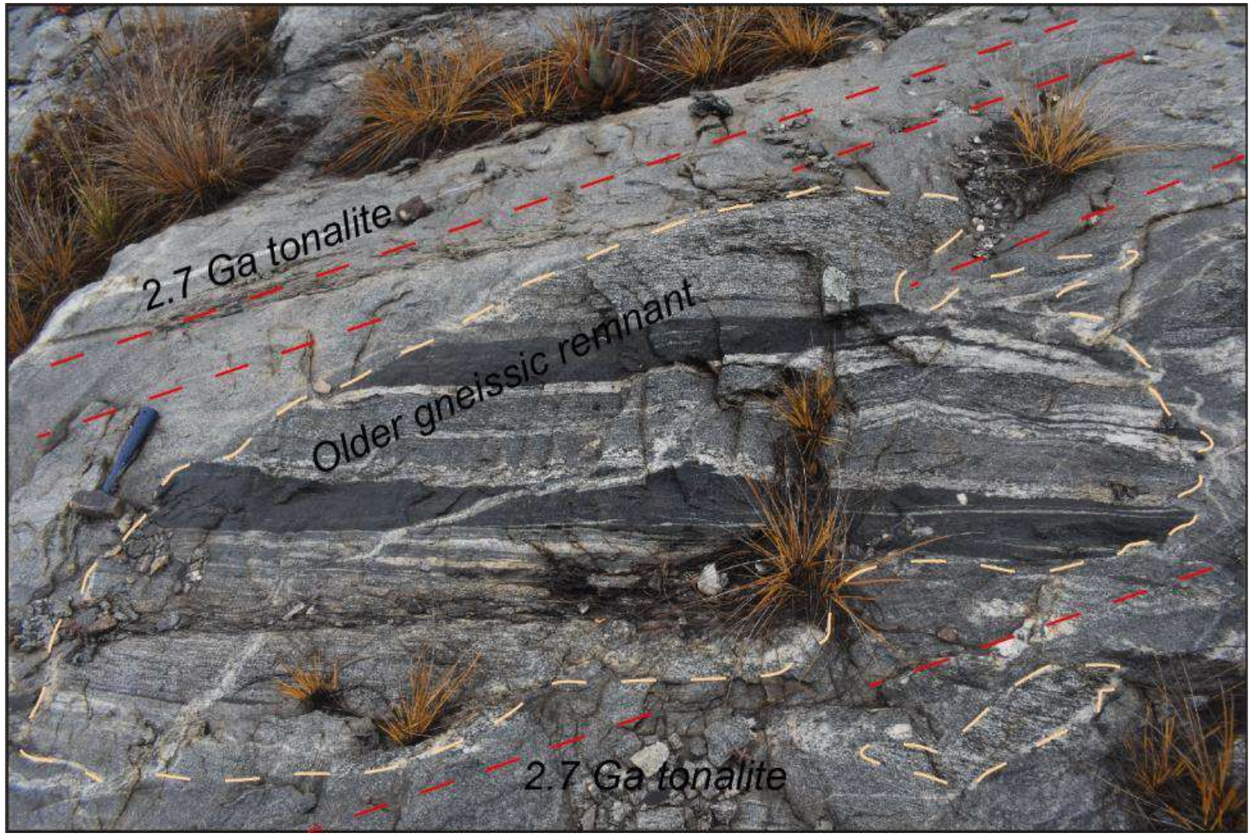
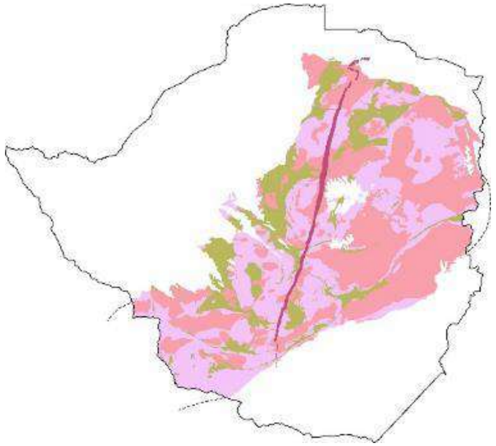
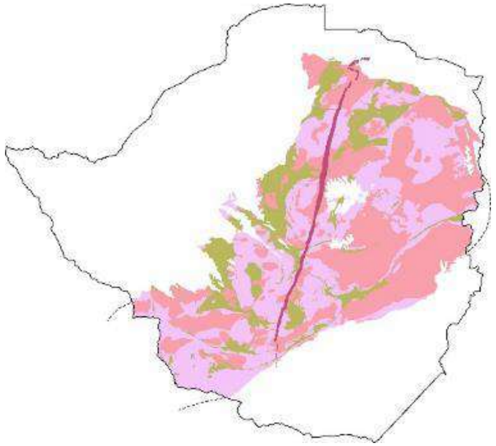
2.5 Ga


2.7 Ga tonalite
Older gneissic remnant
2.7 Ga tonalite



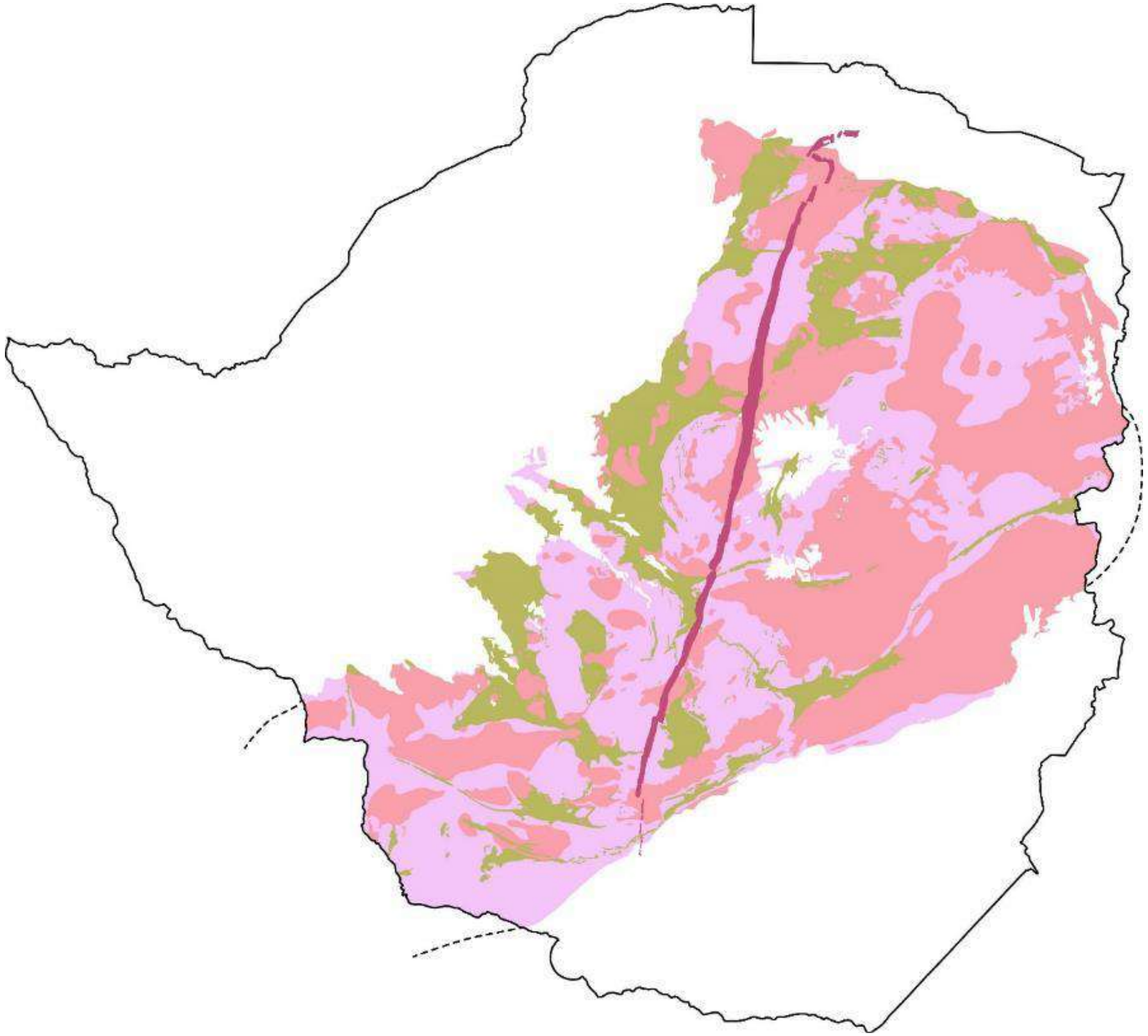

Magmatic events
4.0 Ga
3.7 Ga
3.3 Ga
2.9 Ga
2.5 Ga


Granite whalebacks

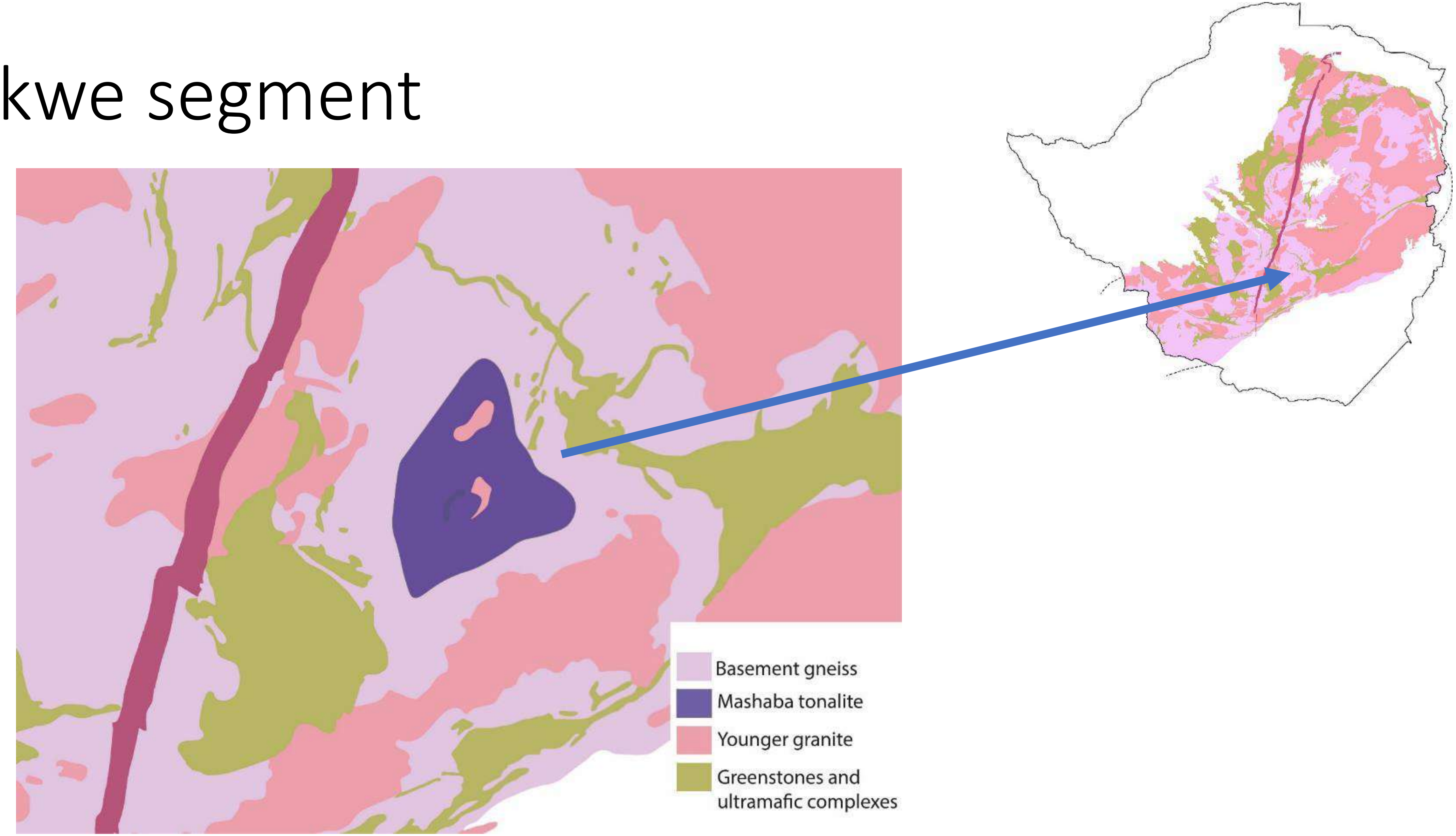


Focus on three areas today

- Tokwe Segment
- ‘Gwenoro Segment’
- ‘Fort-Rixon Segment’



Tokwe segment



3.63 Ga grey gneisses reveal the Eoarchaean history of the Zimbabwe craton

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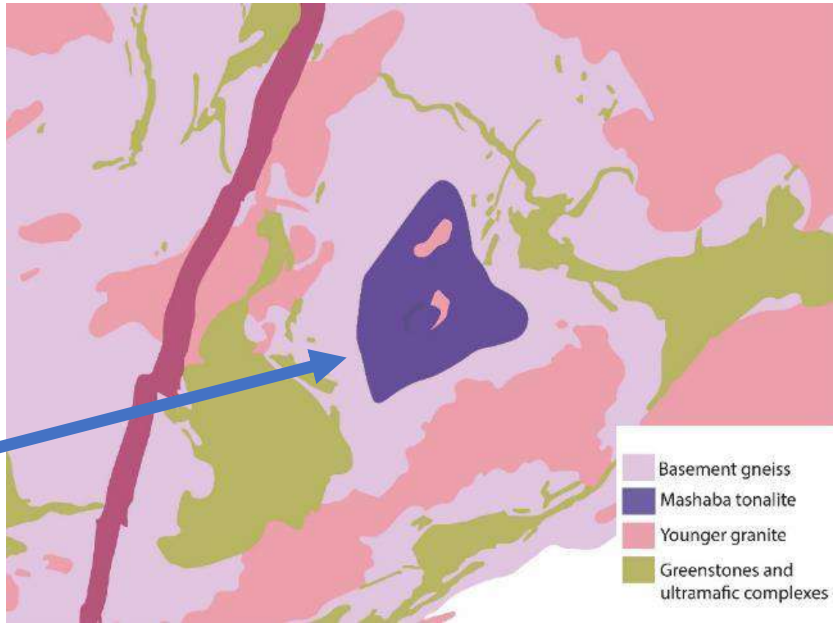
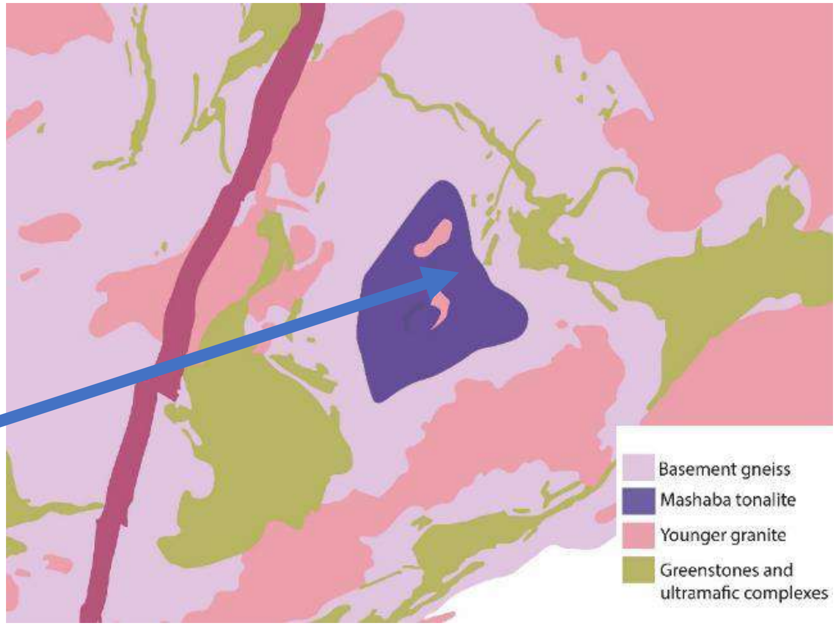
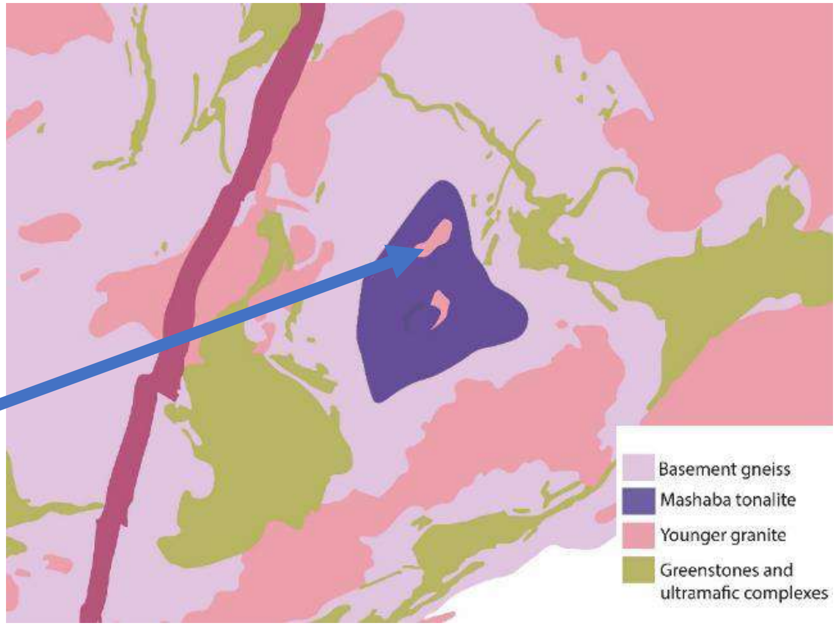
Tokwe segment



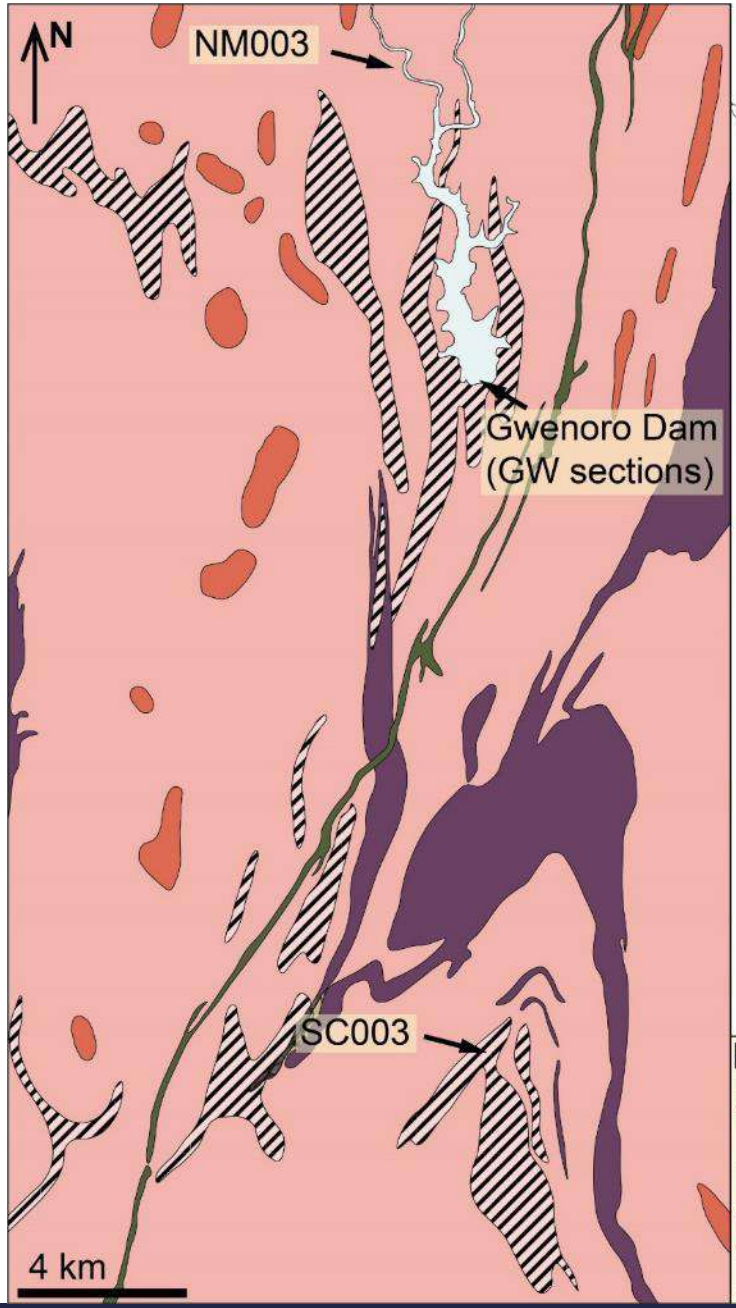
Tokwe segment

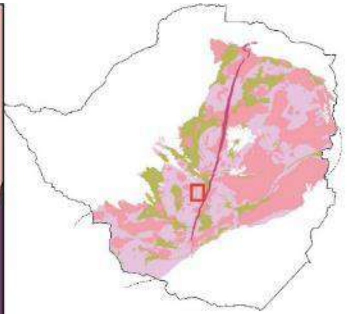


Tokwe segment

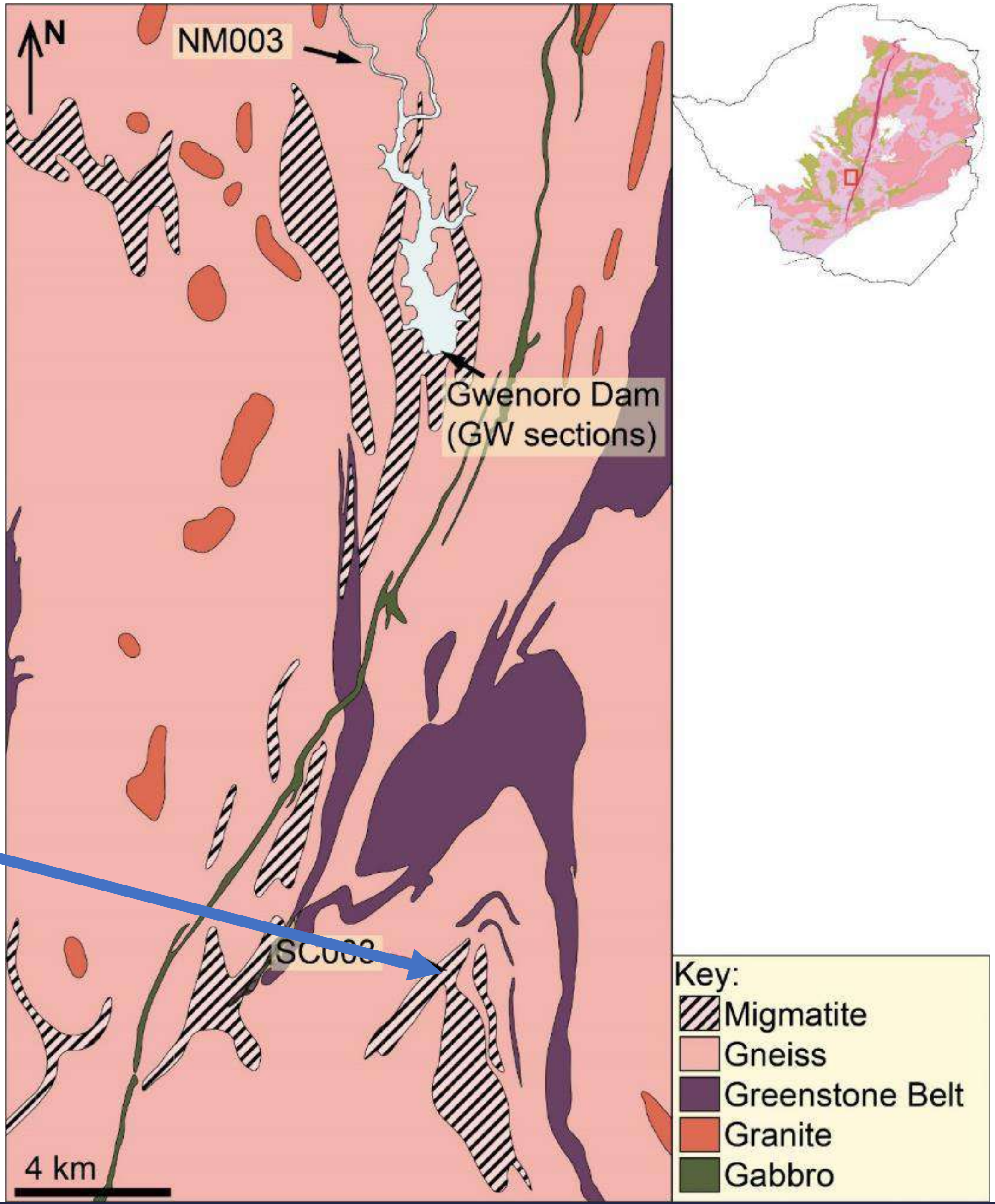


Gwenoro segment

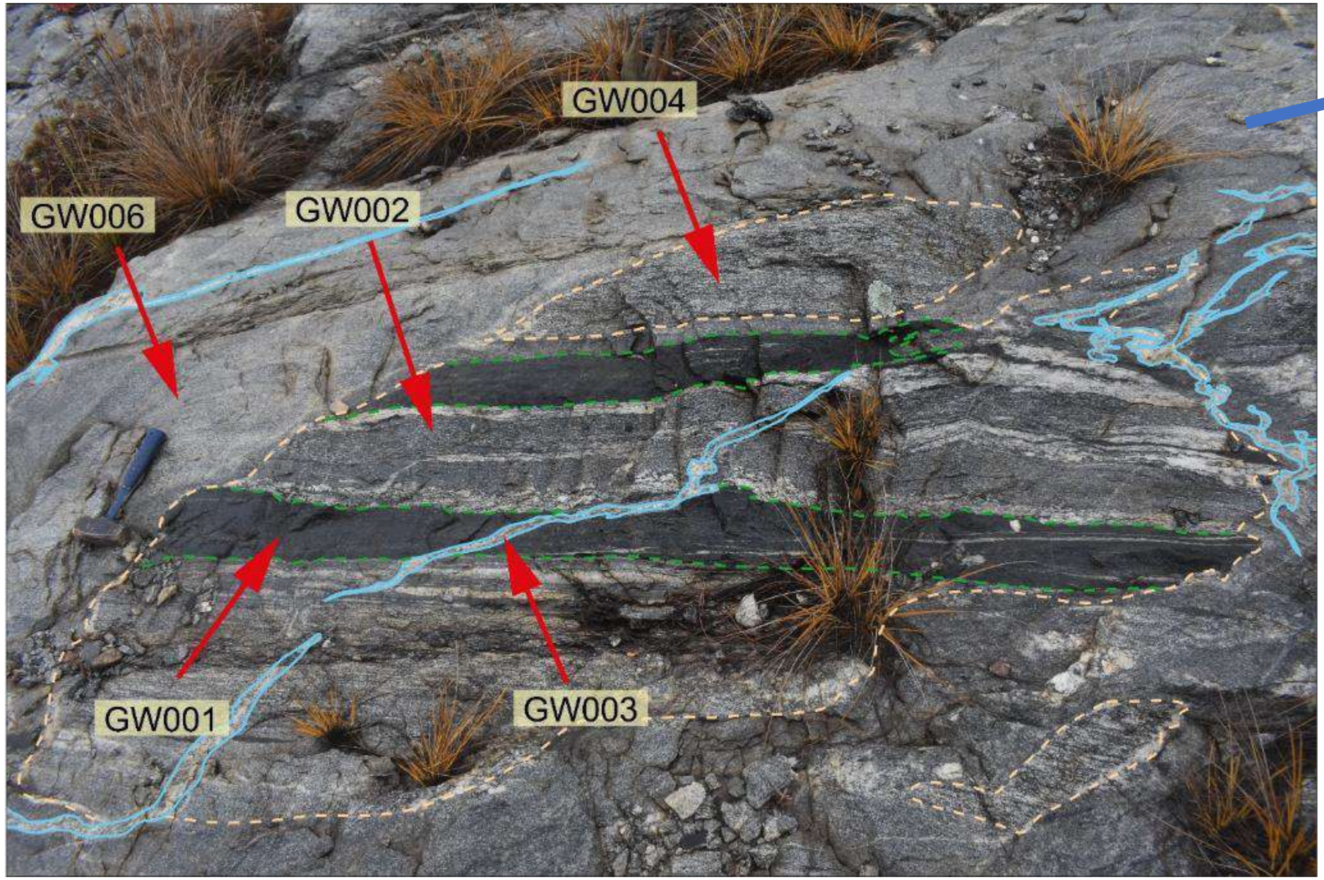


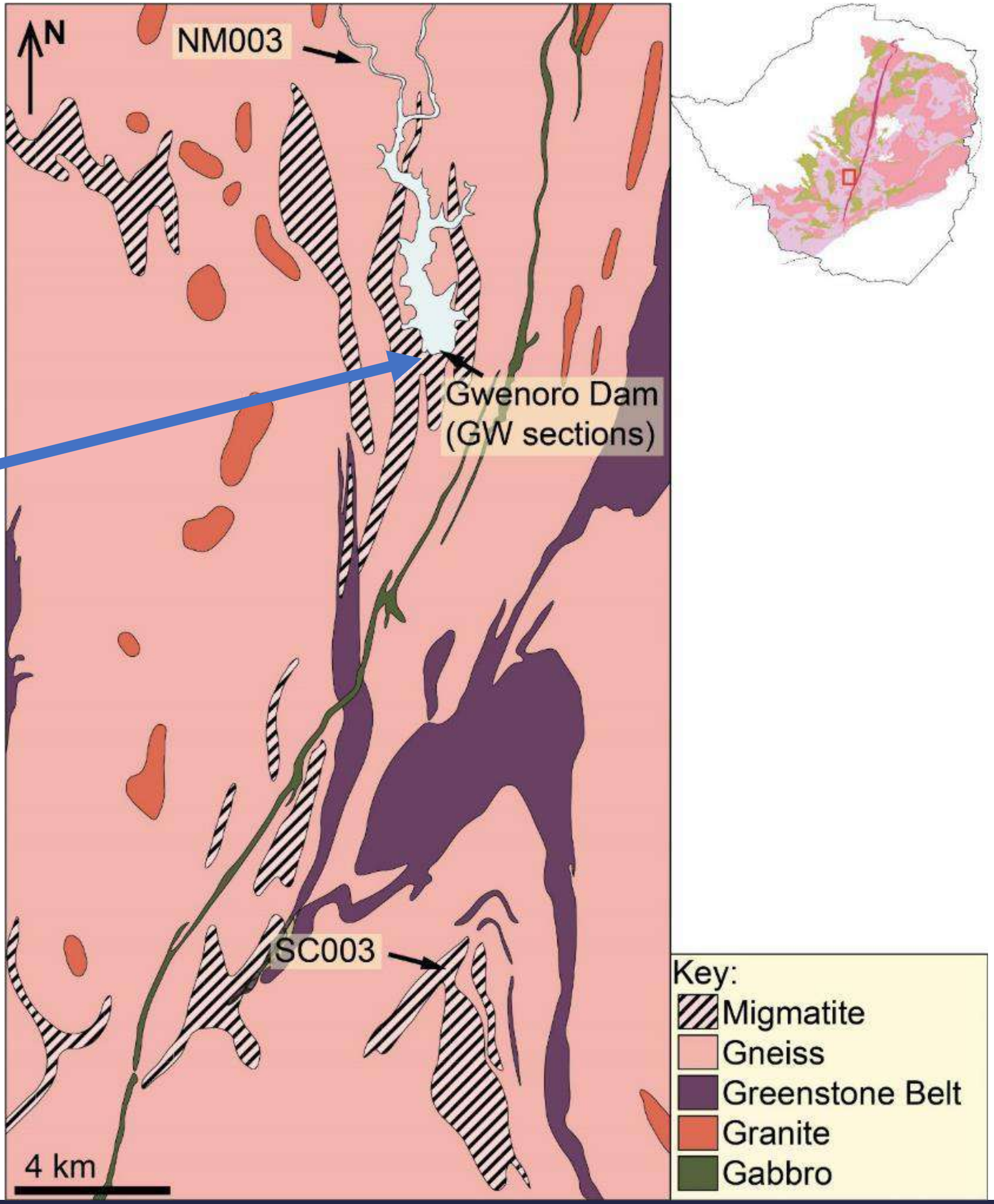


Gwenoro segment

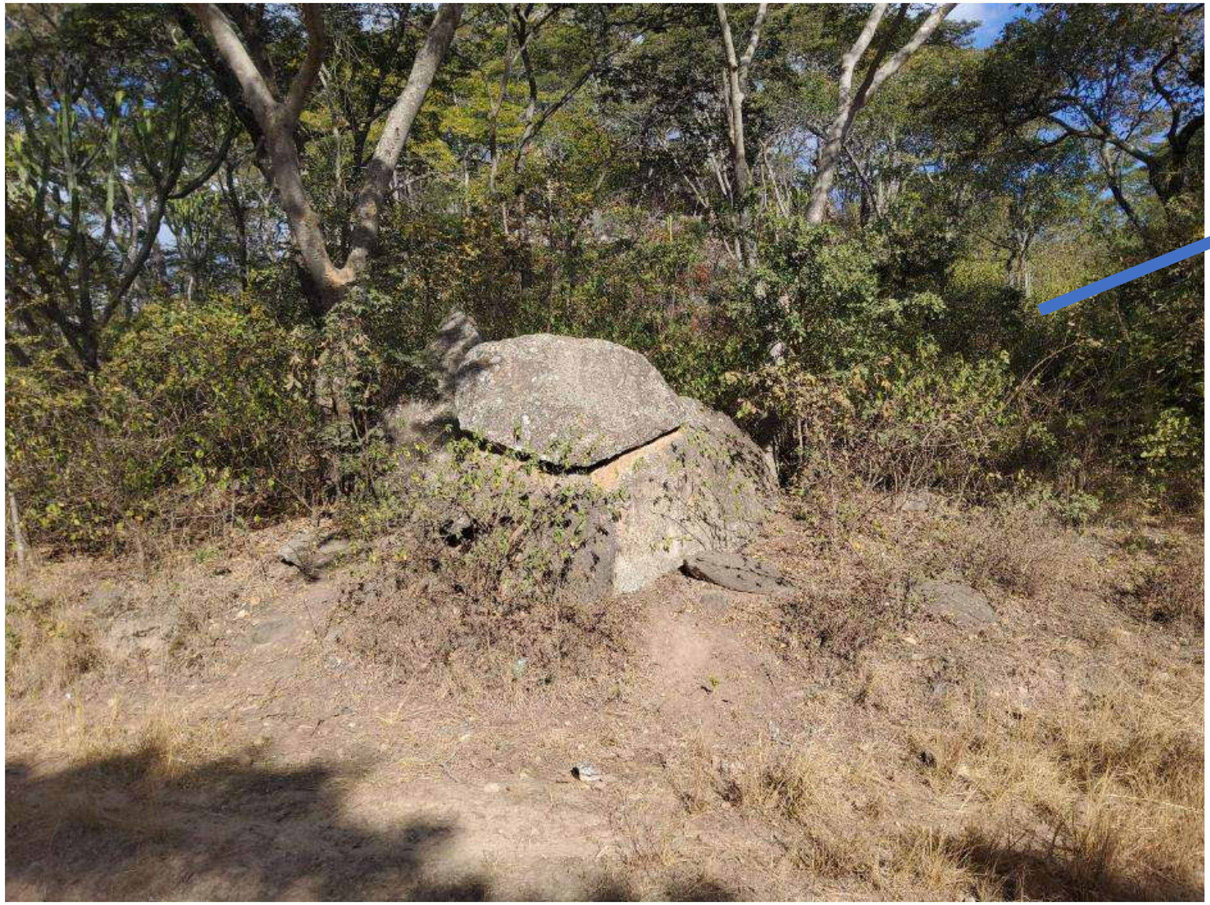


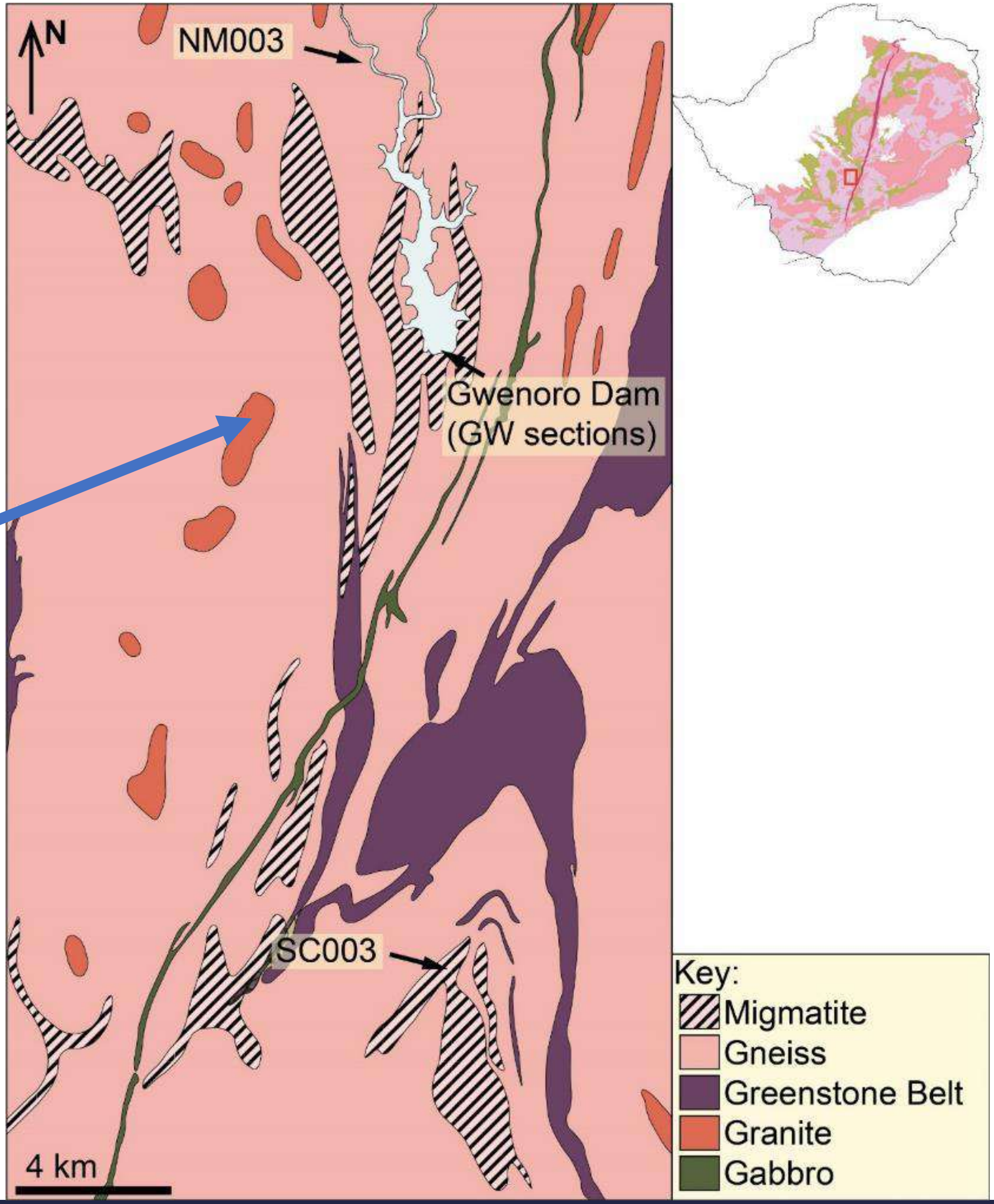
Gwenoro segment



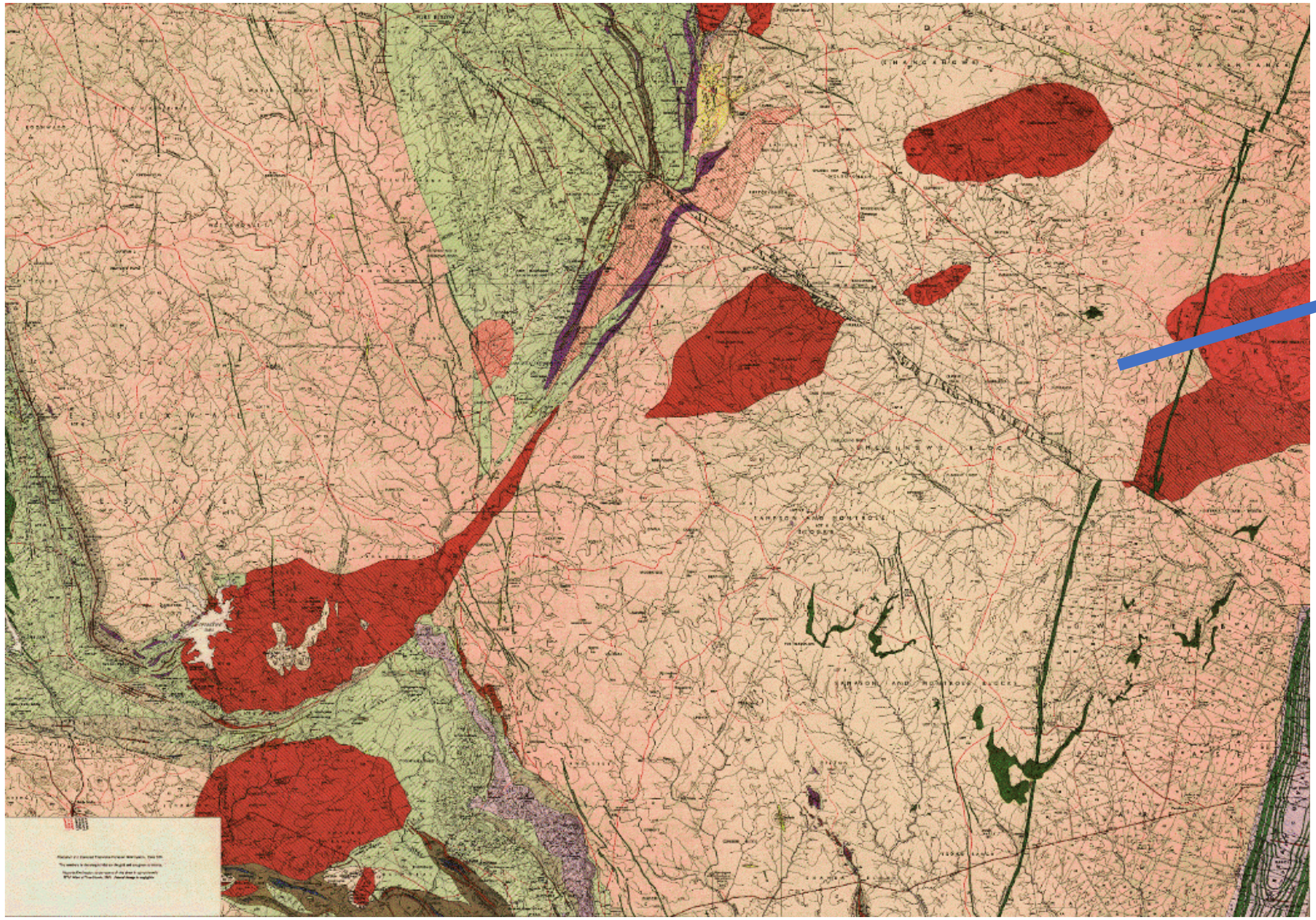


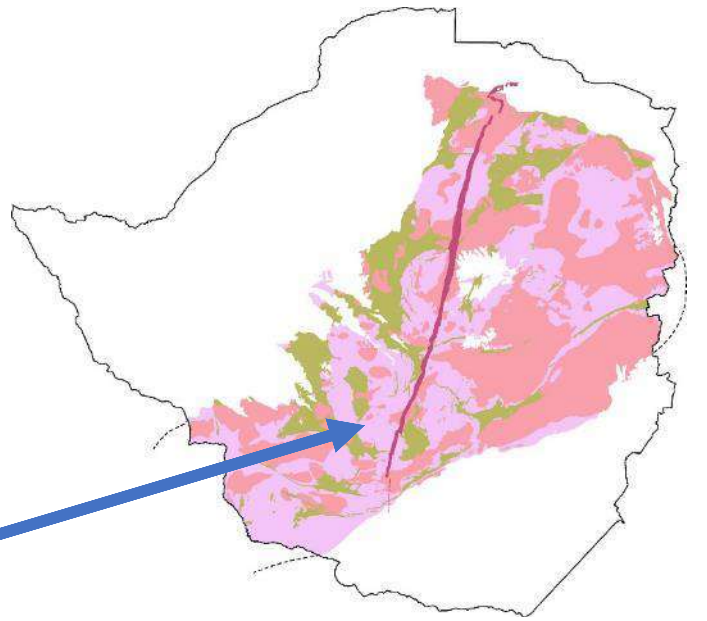
Gwenoro segment



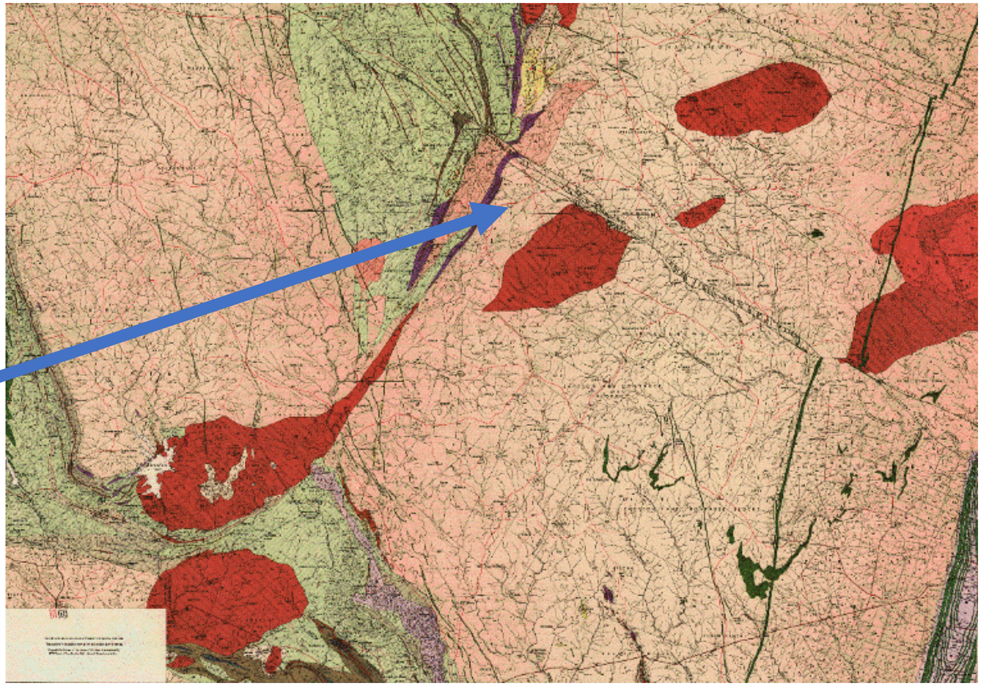


Fort Rixon segment

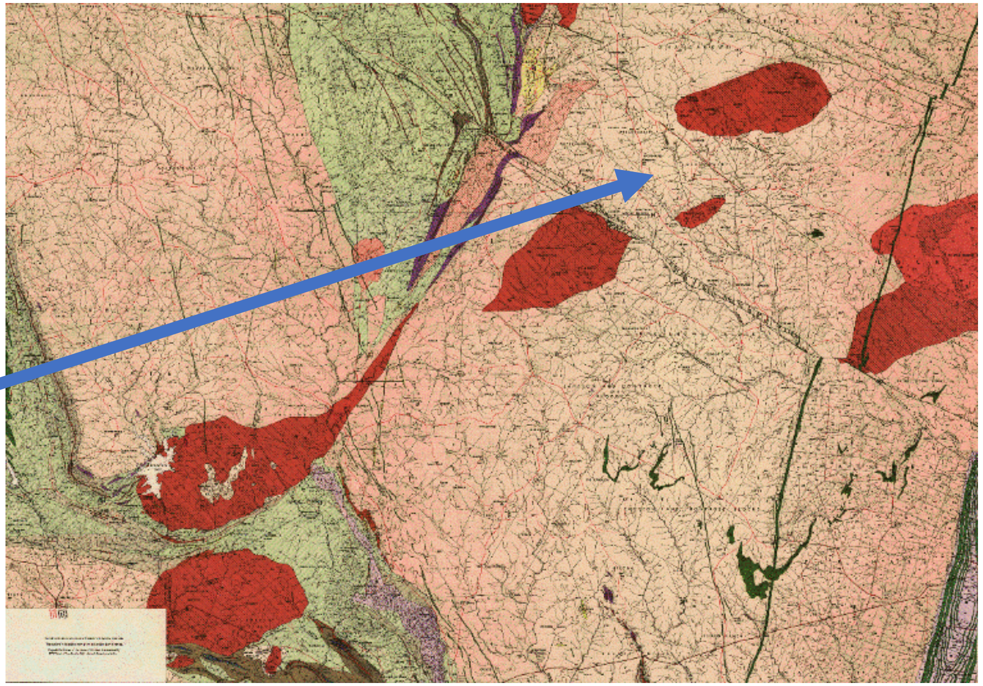




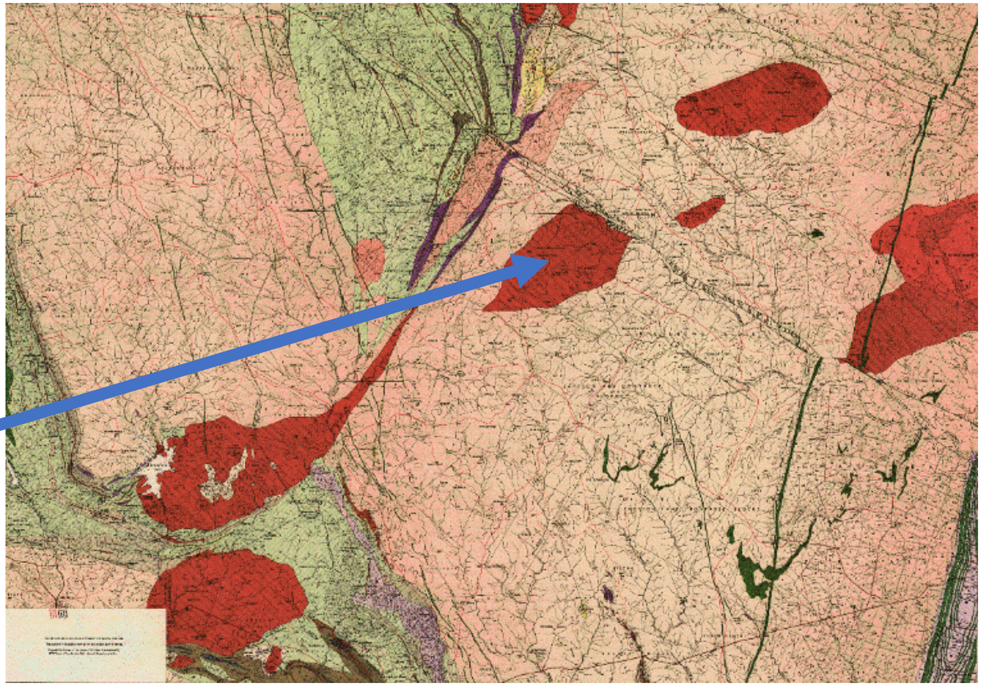
Fort Rixon segment



Fort Rixon segment



Fort Rixon segment



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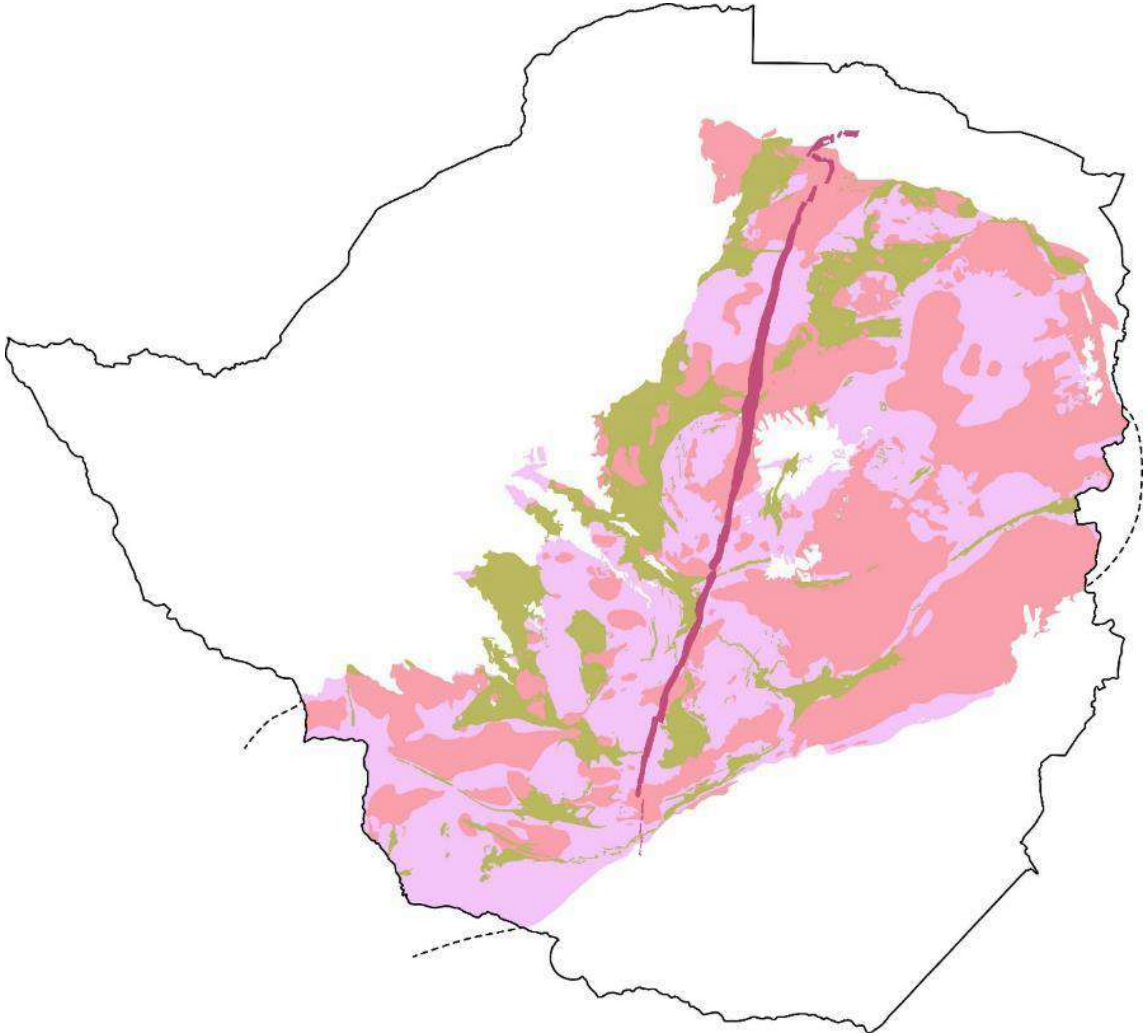
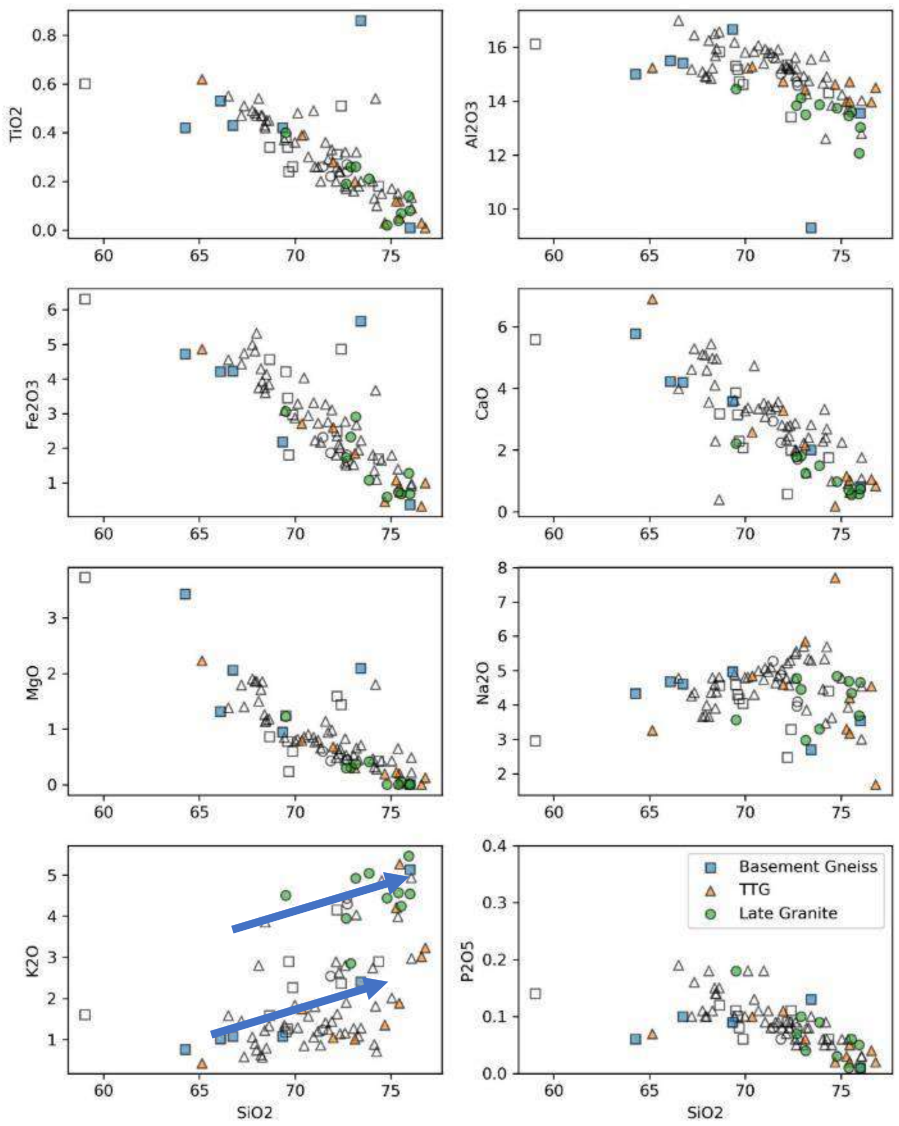
Summary

- We have what appear to be dome-like structures in the craton (Tokwe, Fort Rixon)
- However, some regions do not conform with this interpretation (Gwenoro)



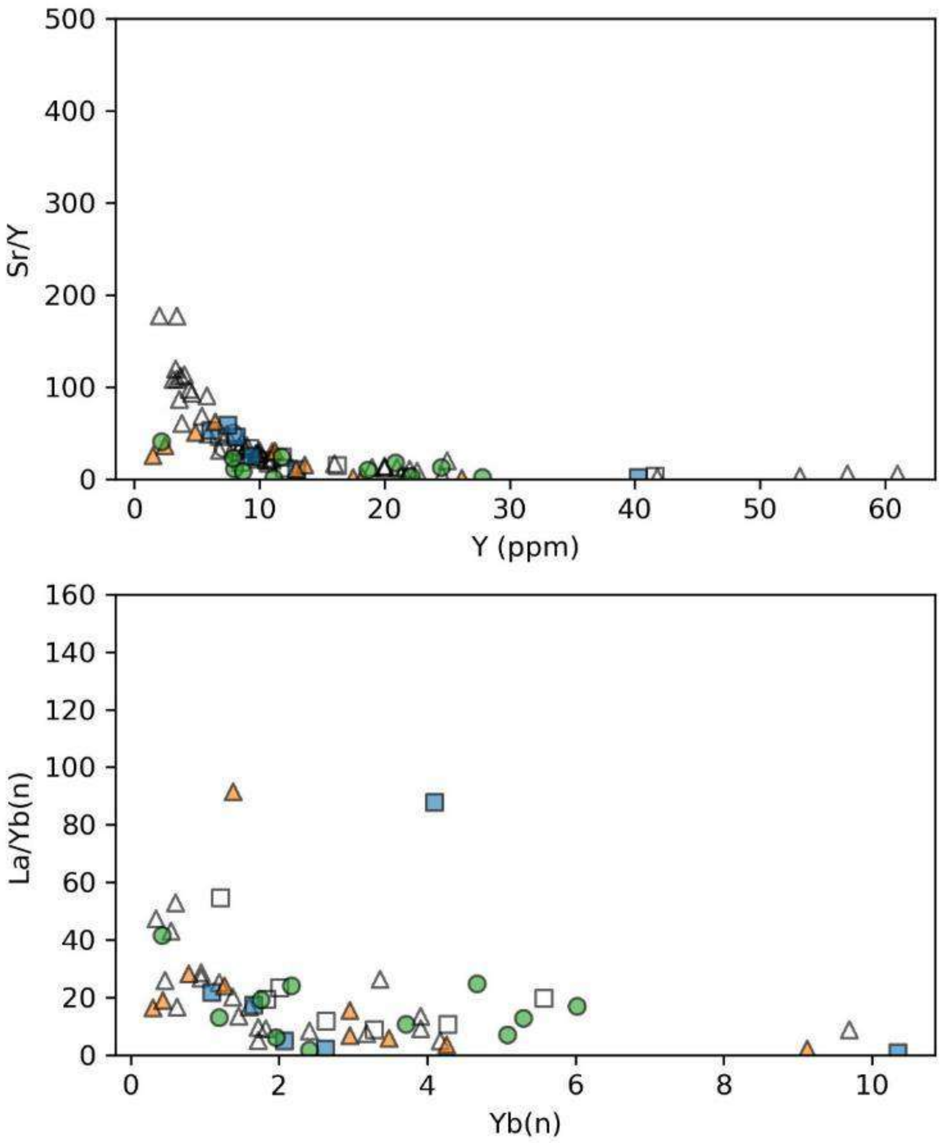
Geochemistry

- Fractionation trends can inform us of any correlations around the craton
- Can provide insight on mineralization potential



Harker plots

- Most Archean magmatism in Zimbabwe follows clear fractionation trends
- Suggests genetic relationship
- This trend does not exist clearly in potassium



Trace element diagrams

- Sr/Y and La/Yb are proxies for depth of melting
  - Presence/absence of plagioclase and garnet in residuum
- All Zimbabwe TTGs measured thus far can be classified as ‘low-pressure’ TTGs
  - Implies relatively shallow melting to produce the TTG complexes
- **Implies it is easier to incorporate surface material into melt source**

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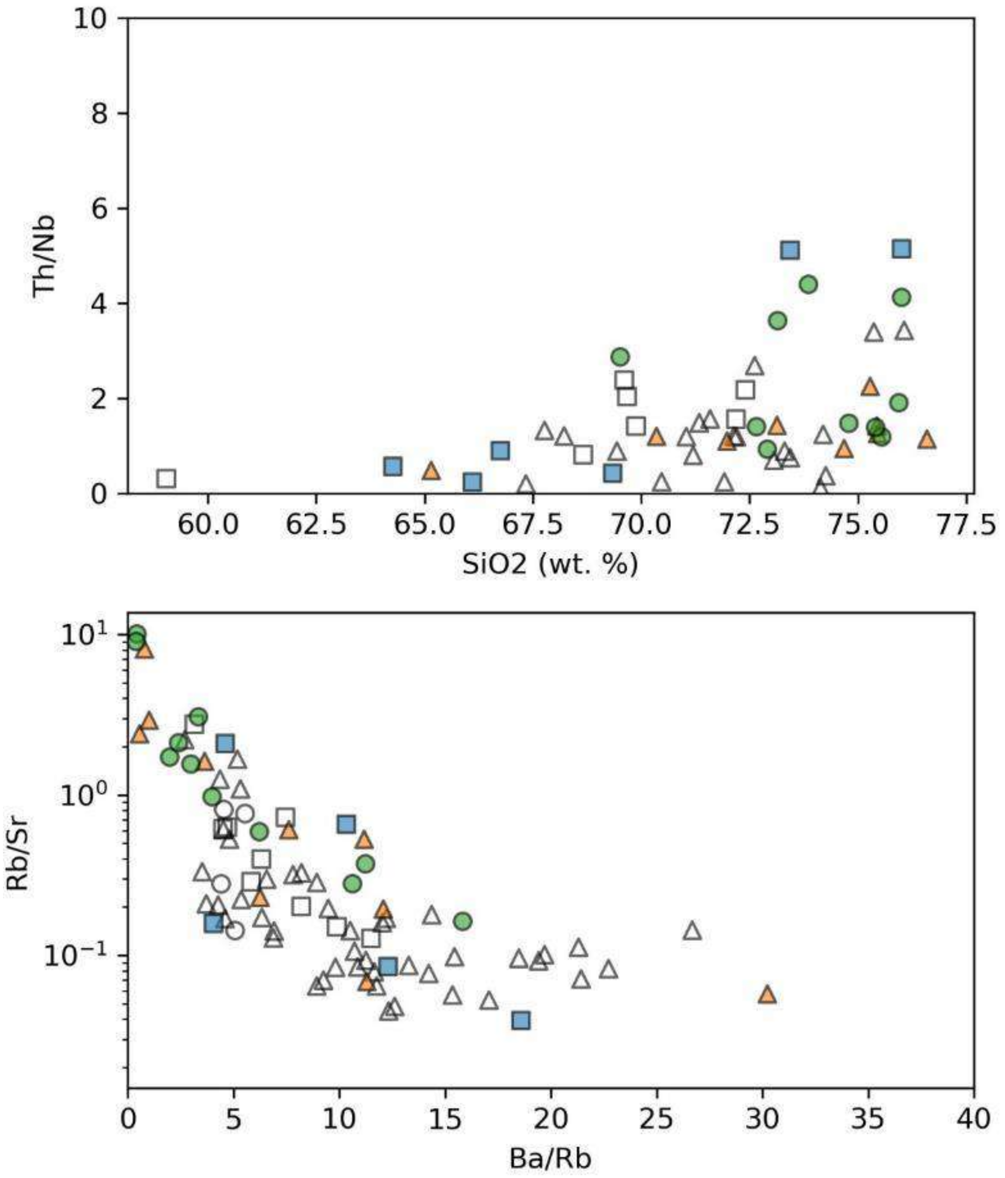
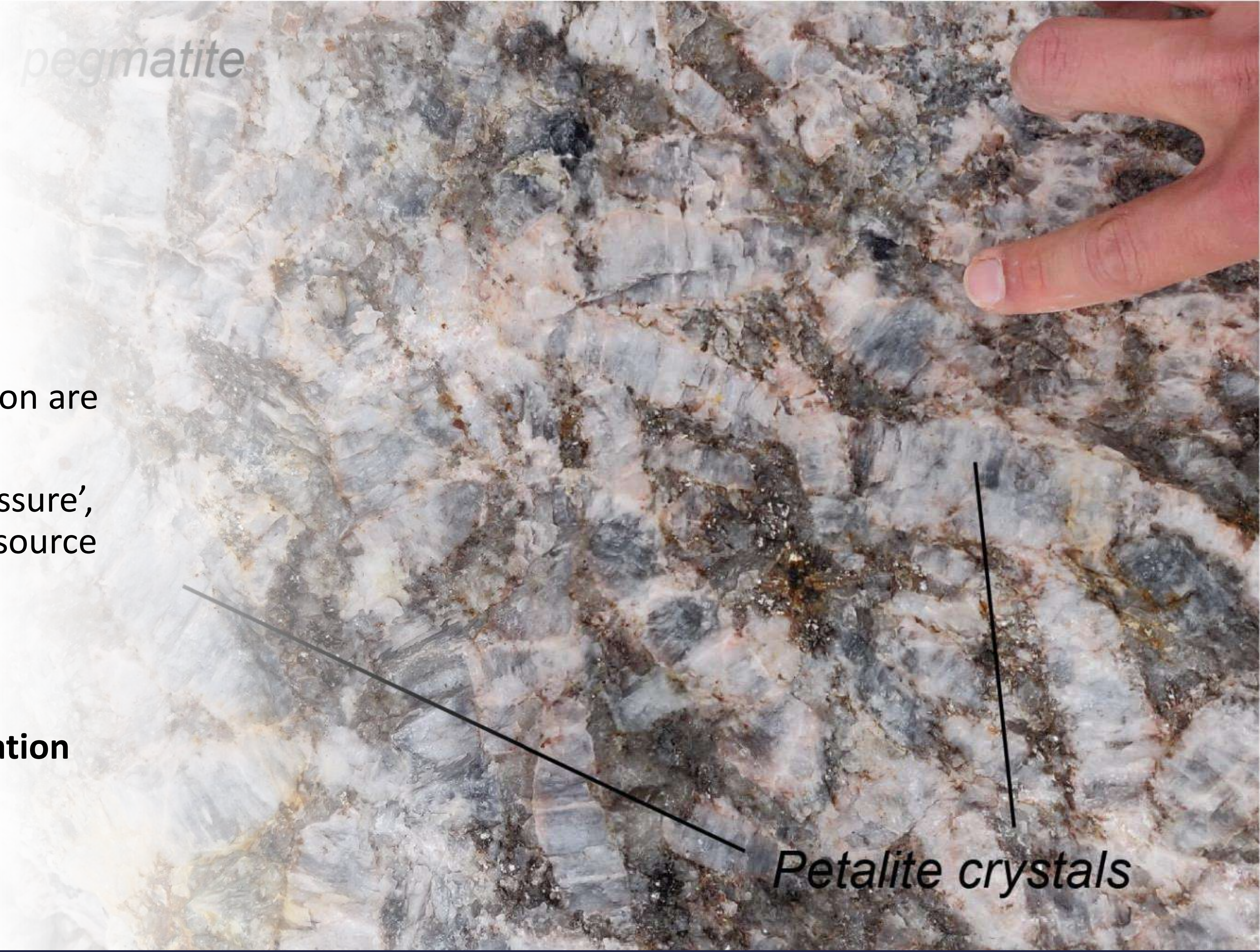


Enrichment profiles

- Th/Nb is a proxy for crustal assimilation (Th is incompatible)
  - Small positive trend with increasing SiO_2 content
  - Suggests minor input from previous crustal material
- Rb/Sr and Ba/Rb are proxies for fractionation (and therefore incompatible element enrichment)
  - Decrease in Ba/Rb corresponds with an increase in Rb/Sr
  - Some late granites have much higher enrichment
  - **Only some late granites have mineralization potential**
  - **Correlated with amount of crustal assimilation**

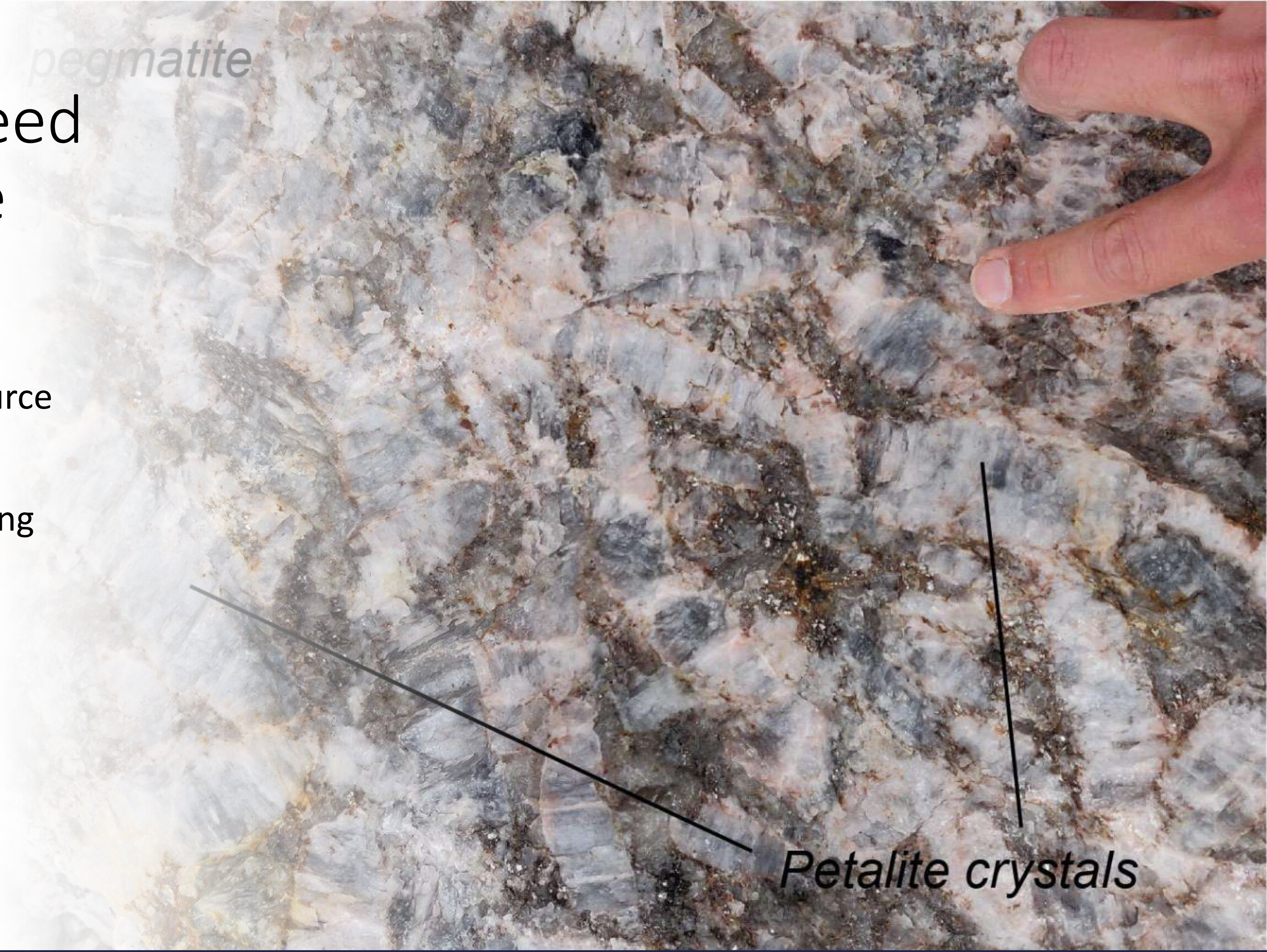
Summary

- TTGs in the Zimbabwe craton are broadly related
- TTGs are typically ‘low-pressure’, suggesting a shallow melt source
- Some late granites have geochemical signatures of crustal assimilation
- **Correlated with mineralization potential**



What do you need for Li pegmatite formation?

- Input of sediment into source
- >5000 ppm Li in melt
- High degree of undercooling (relatively cold host rocks)



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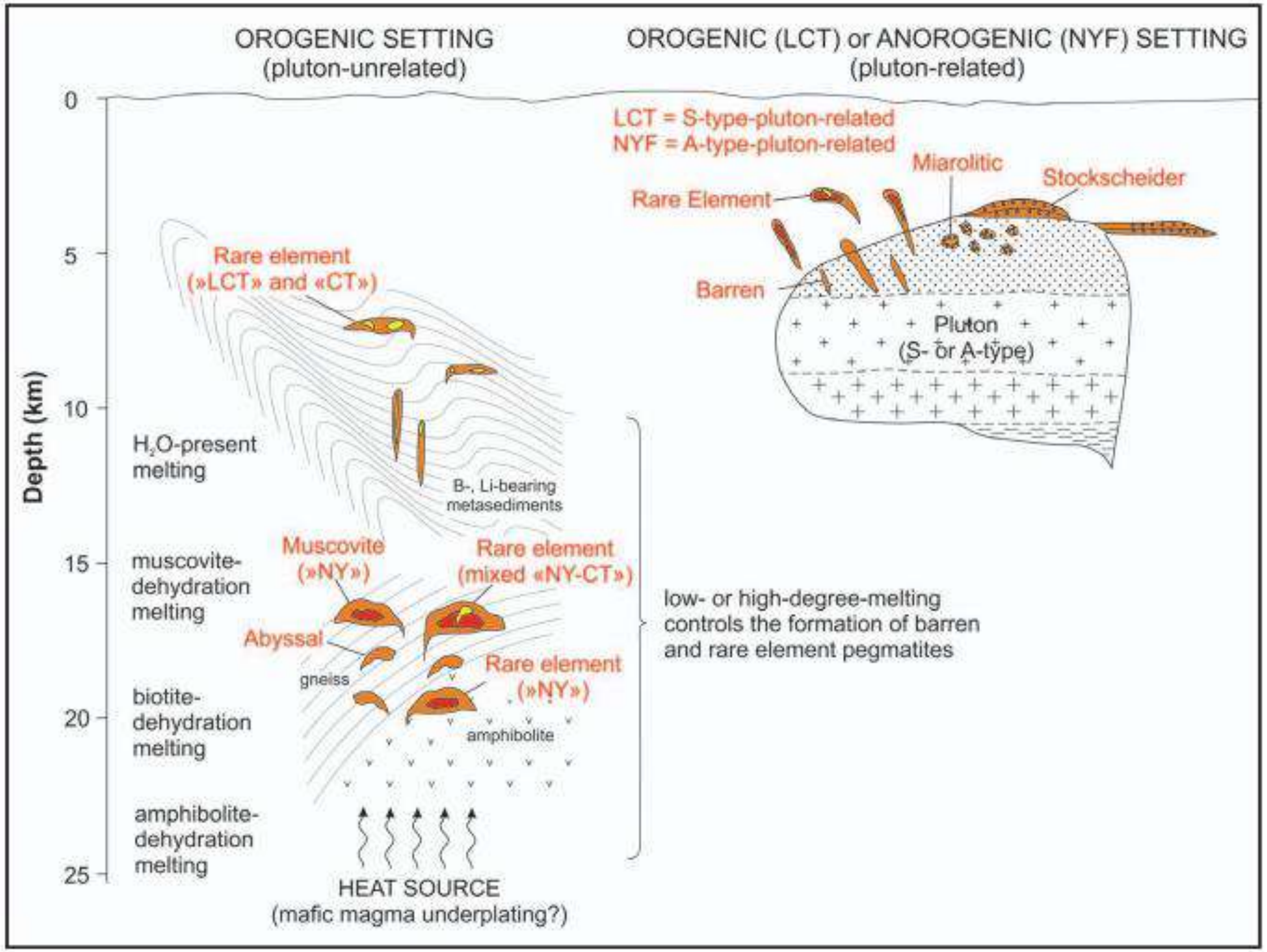
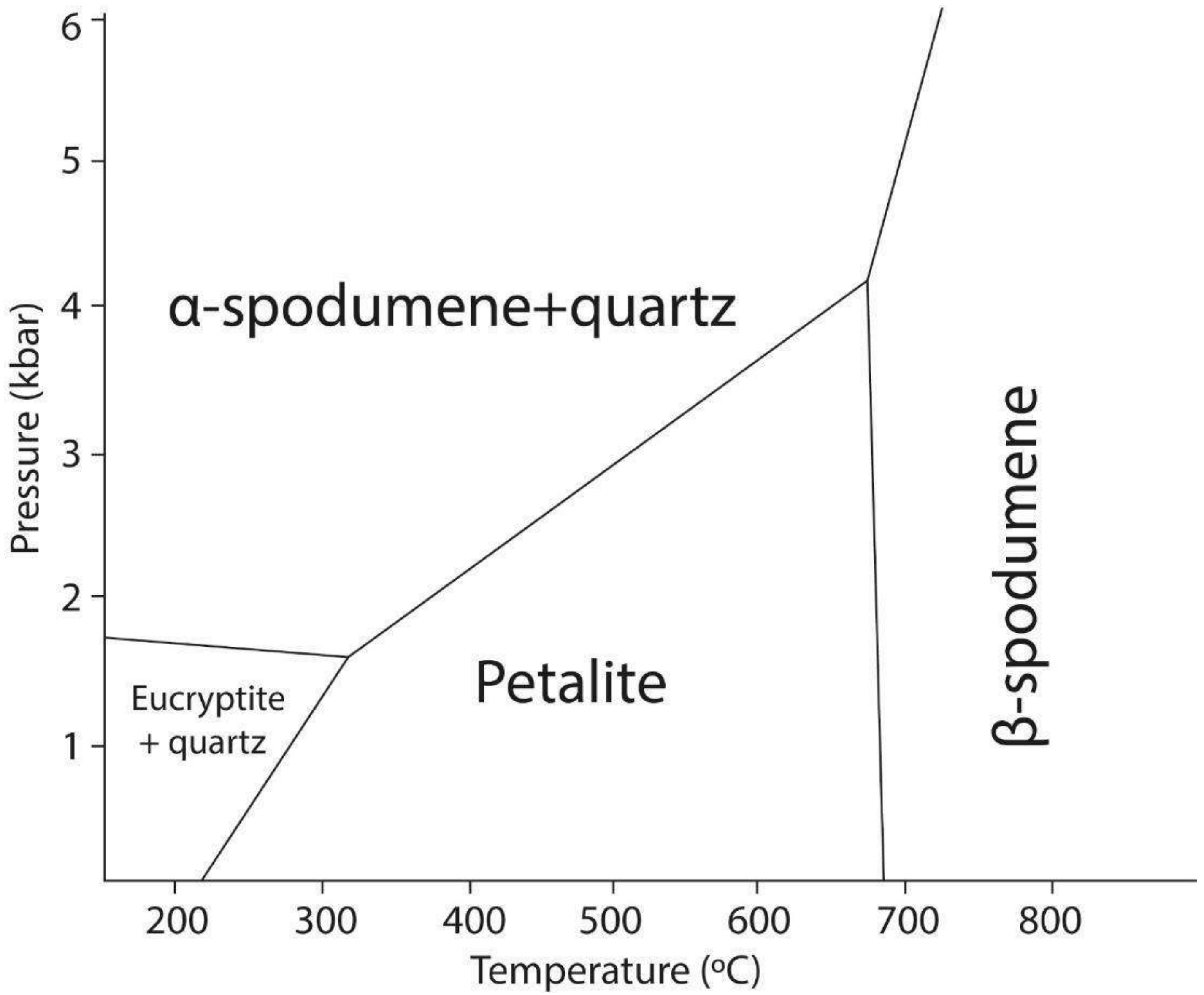
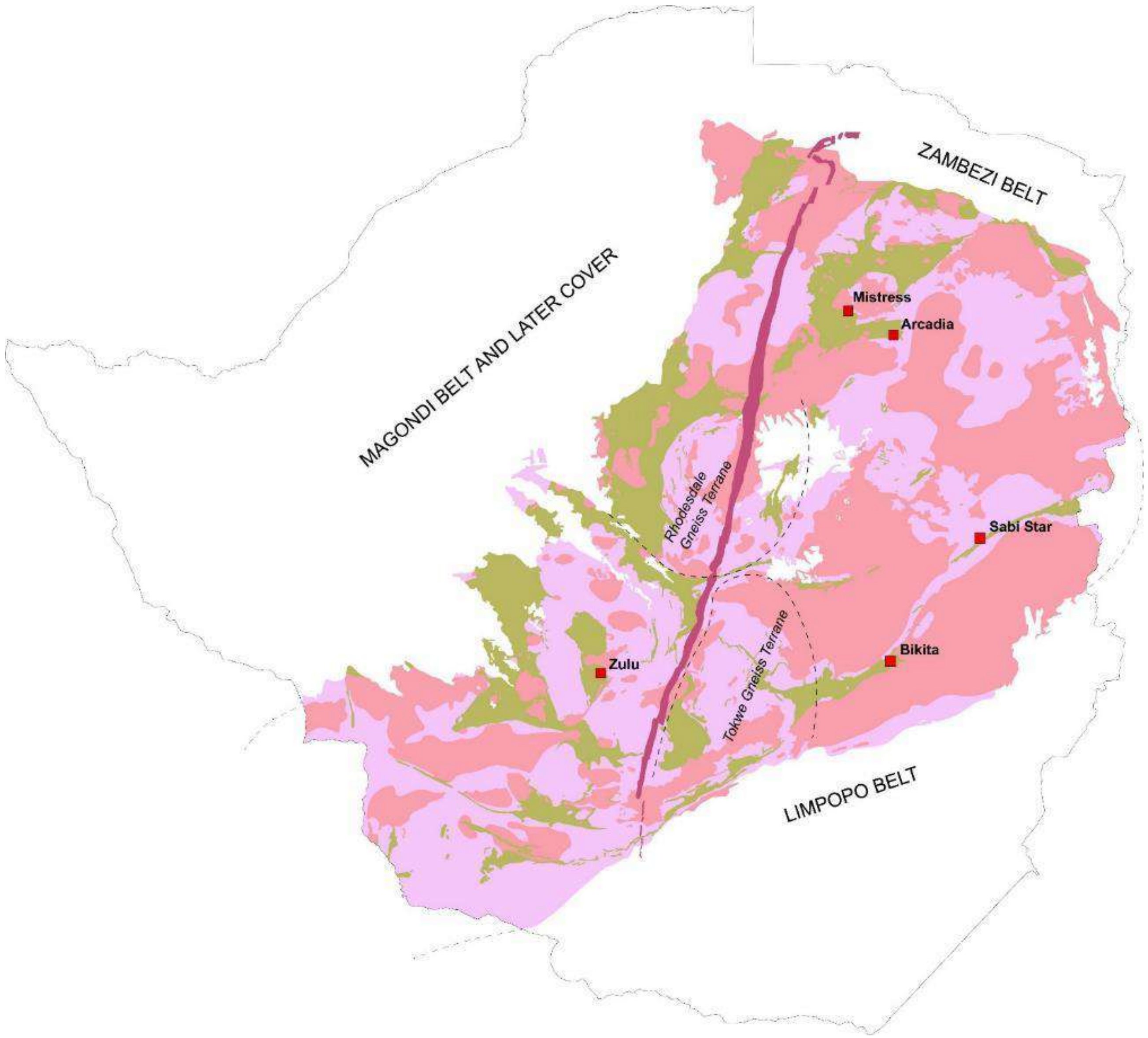
Models of pegmatite formation



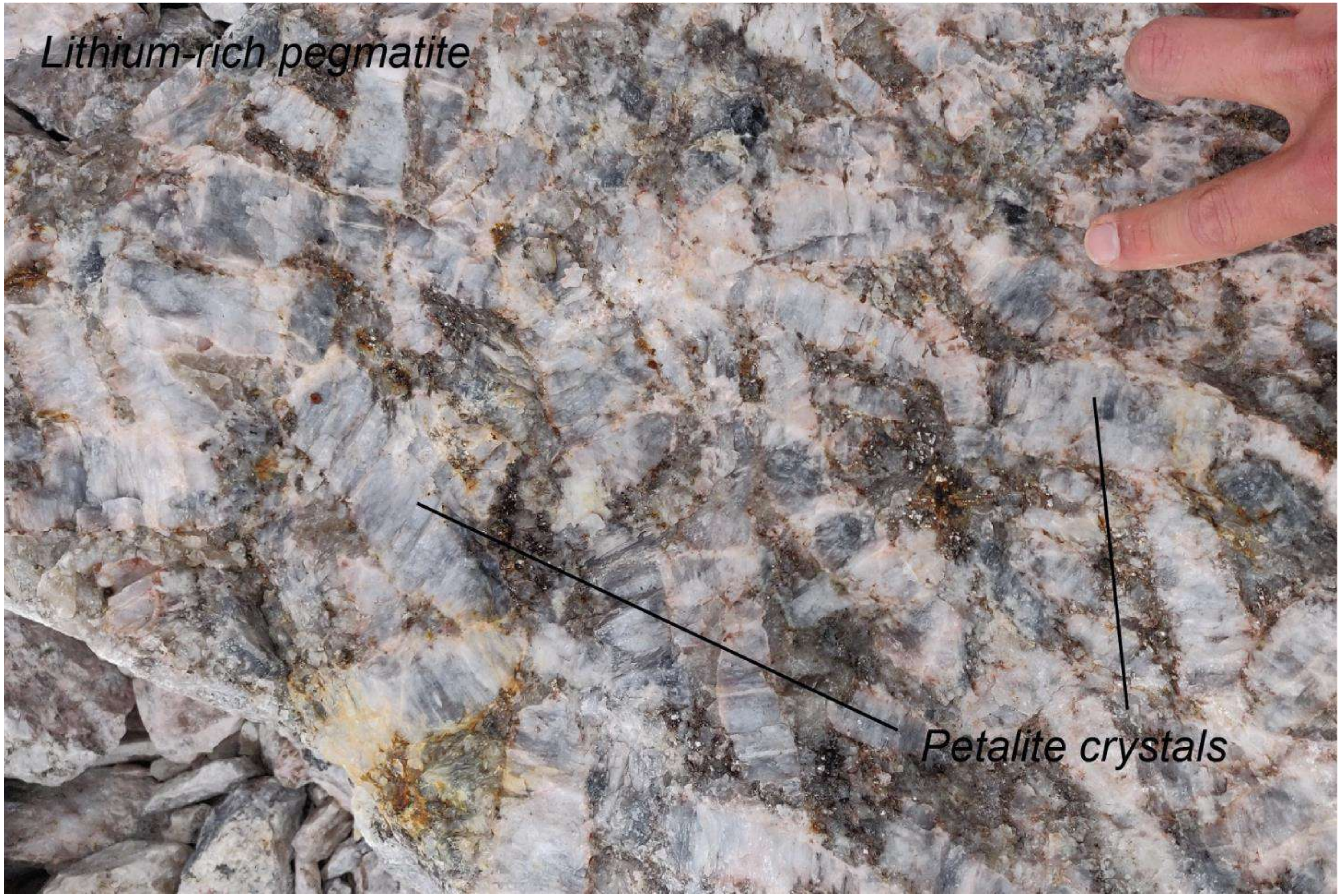
Li-phase stability



What do we see in Zimbabwe?

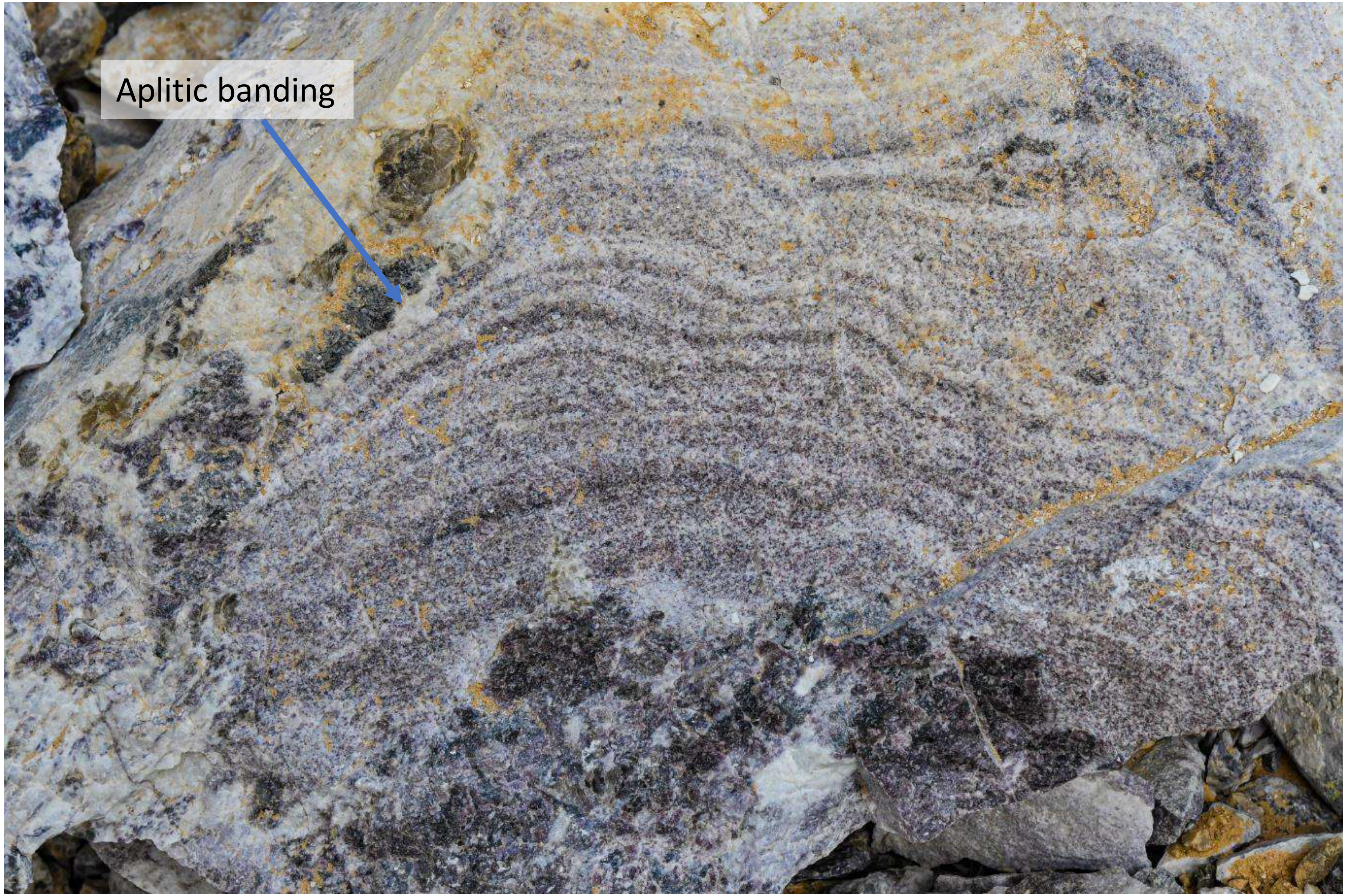


Arcadia

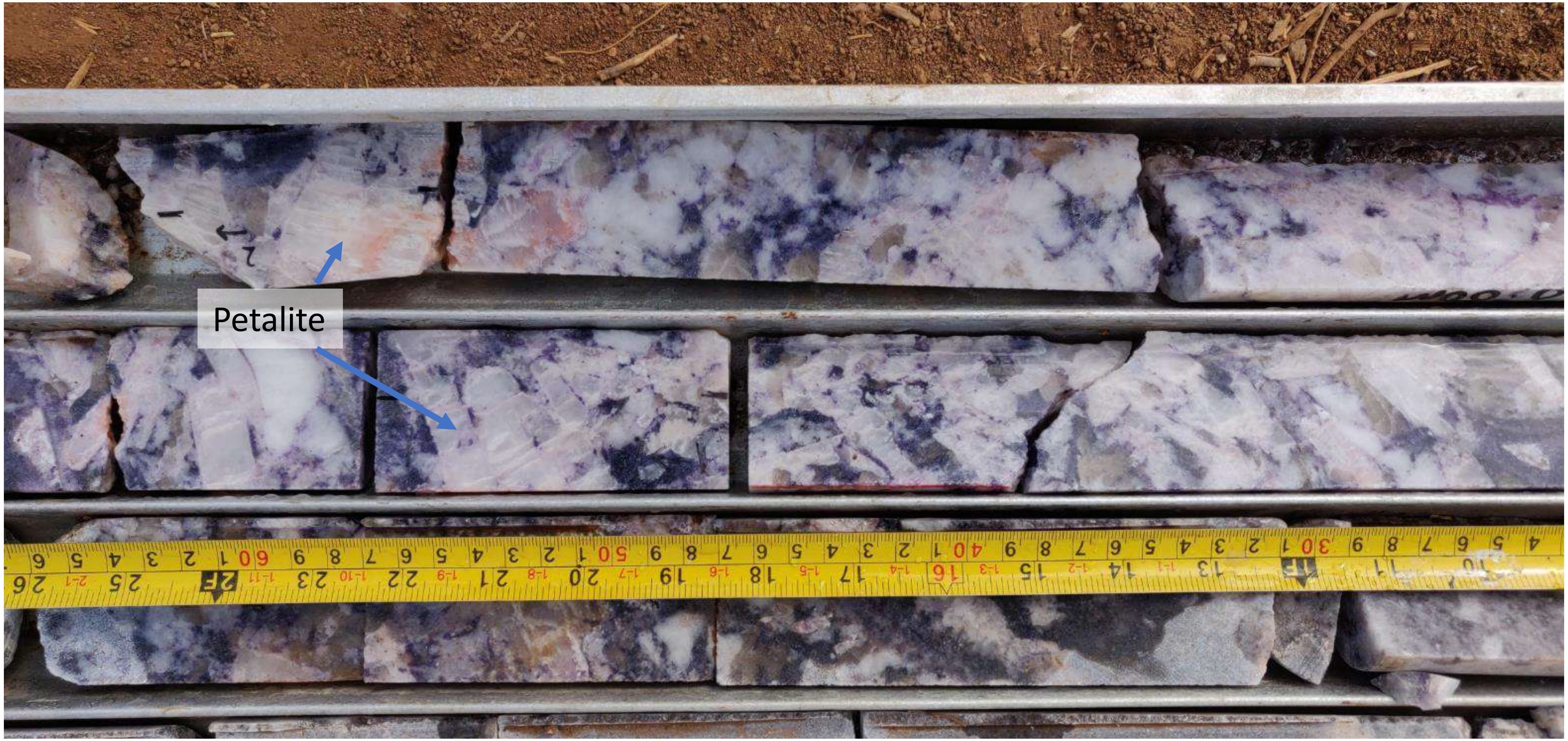


Mistress

Mistress



Zulu



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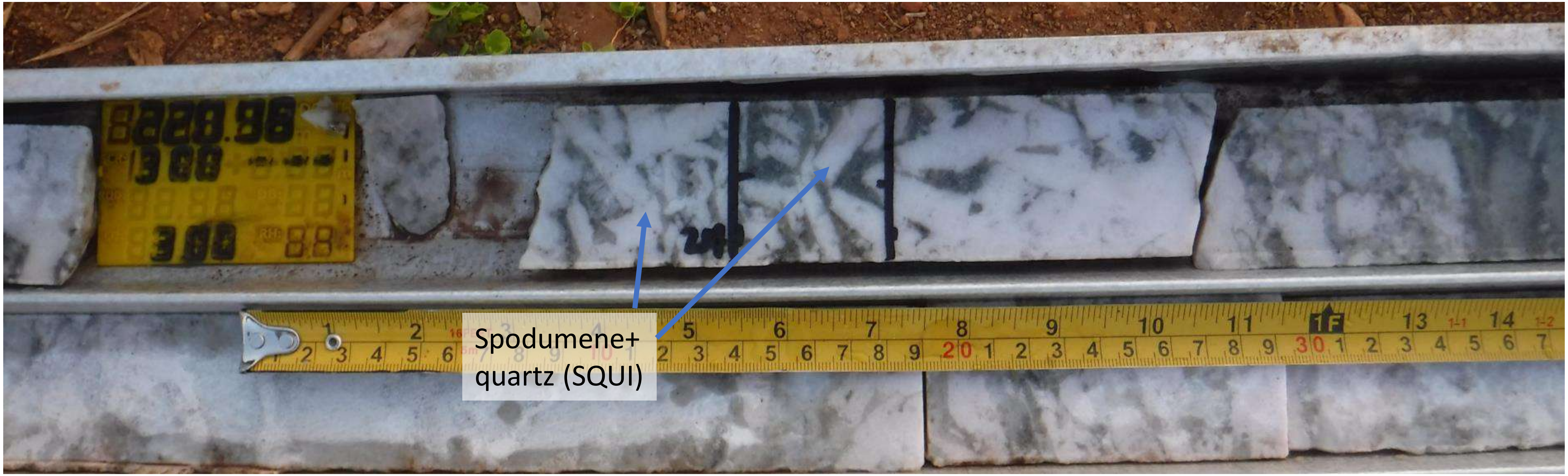

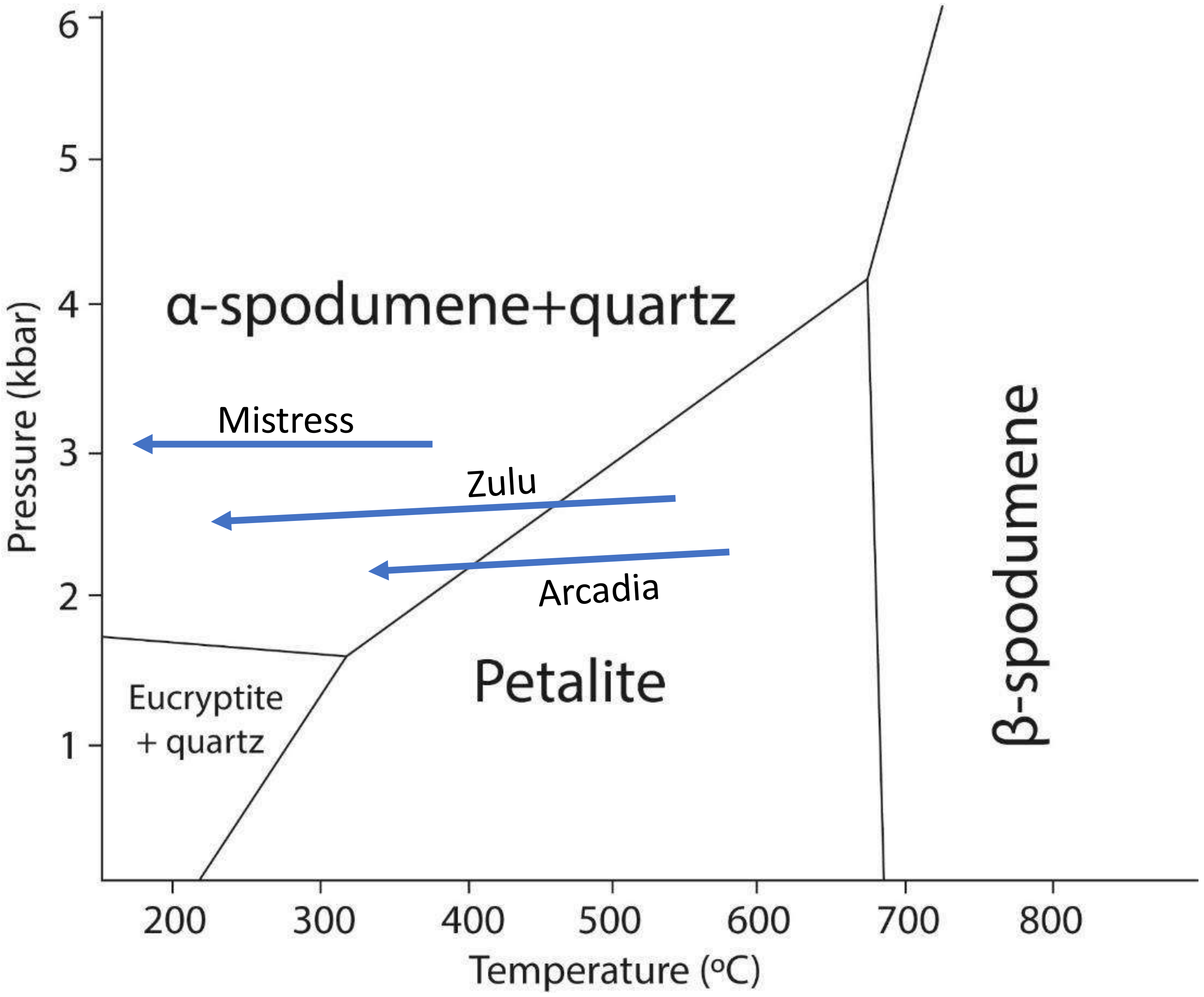

α-spodumene+quartz
Mistress
Zulu
Arcadia
Eucryptite
+ quartz
Petalite
β-spodumene
Pressure (kbar)
6
5
4
3
2
1
200
300
400
500
600
700
800
Temperature (°C)

Concluding remarks

- The Zimbabwe craton has both dome-like and orogen-like TTG terranes
- Geochemically TTGs suggest a shallow melt source, with later TTGs and granites incorporating more sedimentary material
- Incorporation of sediments is correlated with mineralization potential
- Zimbabwe Li pegmatites were emplaced relatively shallowly
- We may be able to use them to decipher late cratonic evolution further