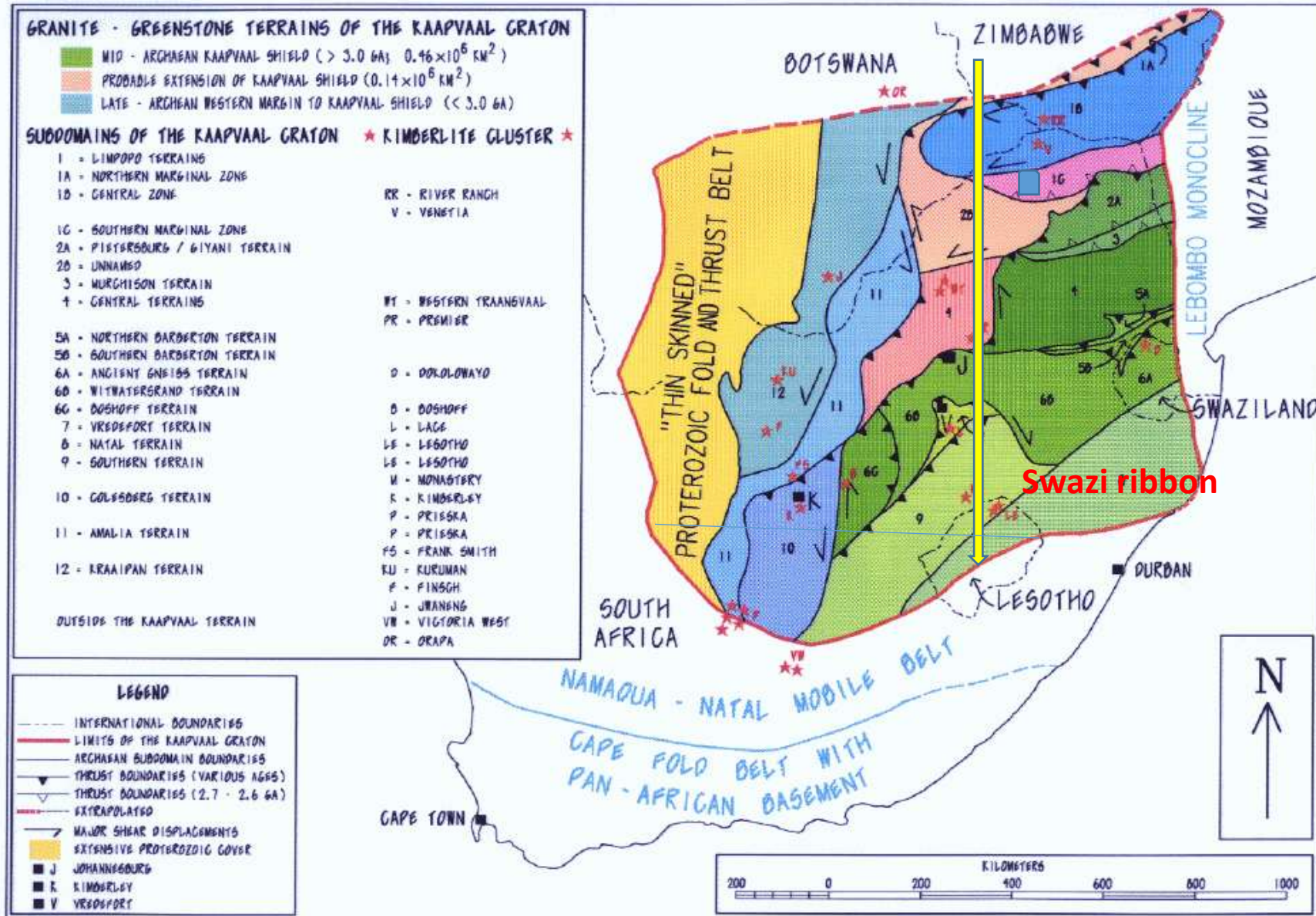


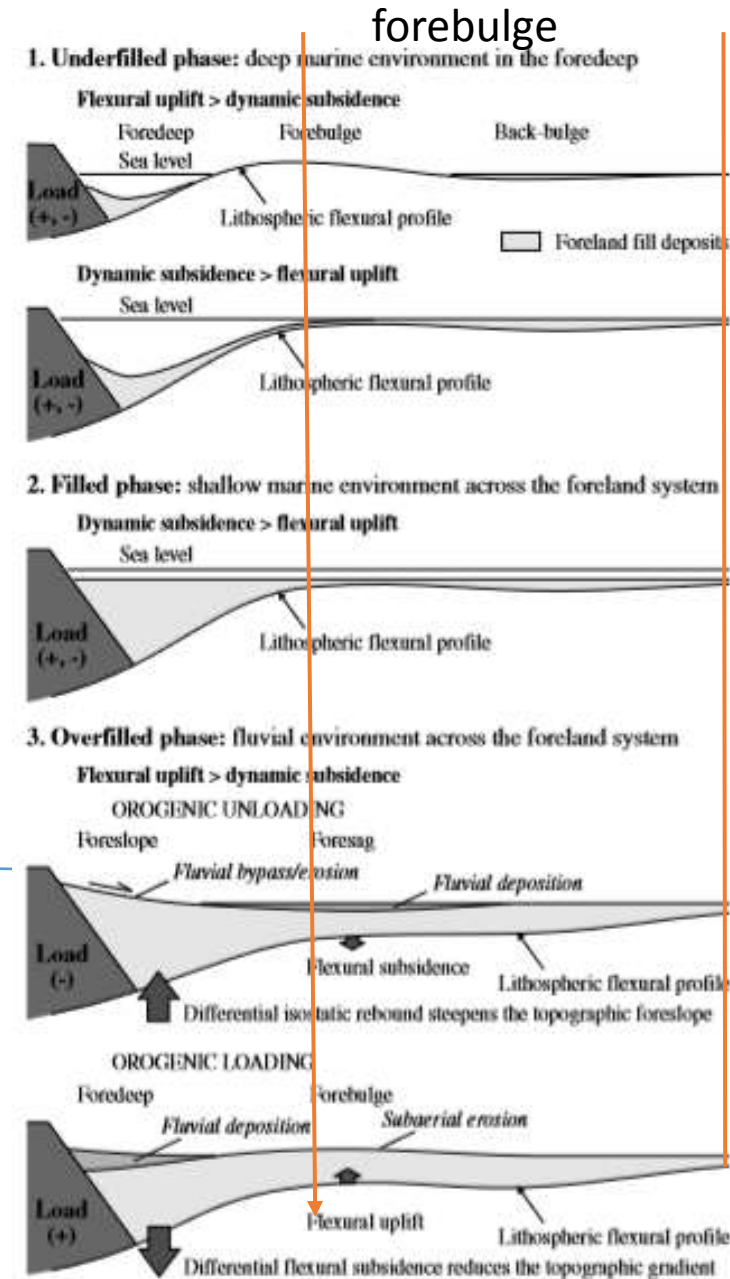
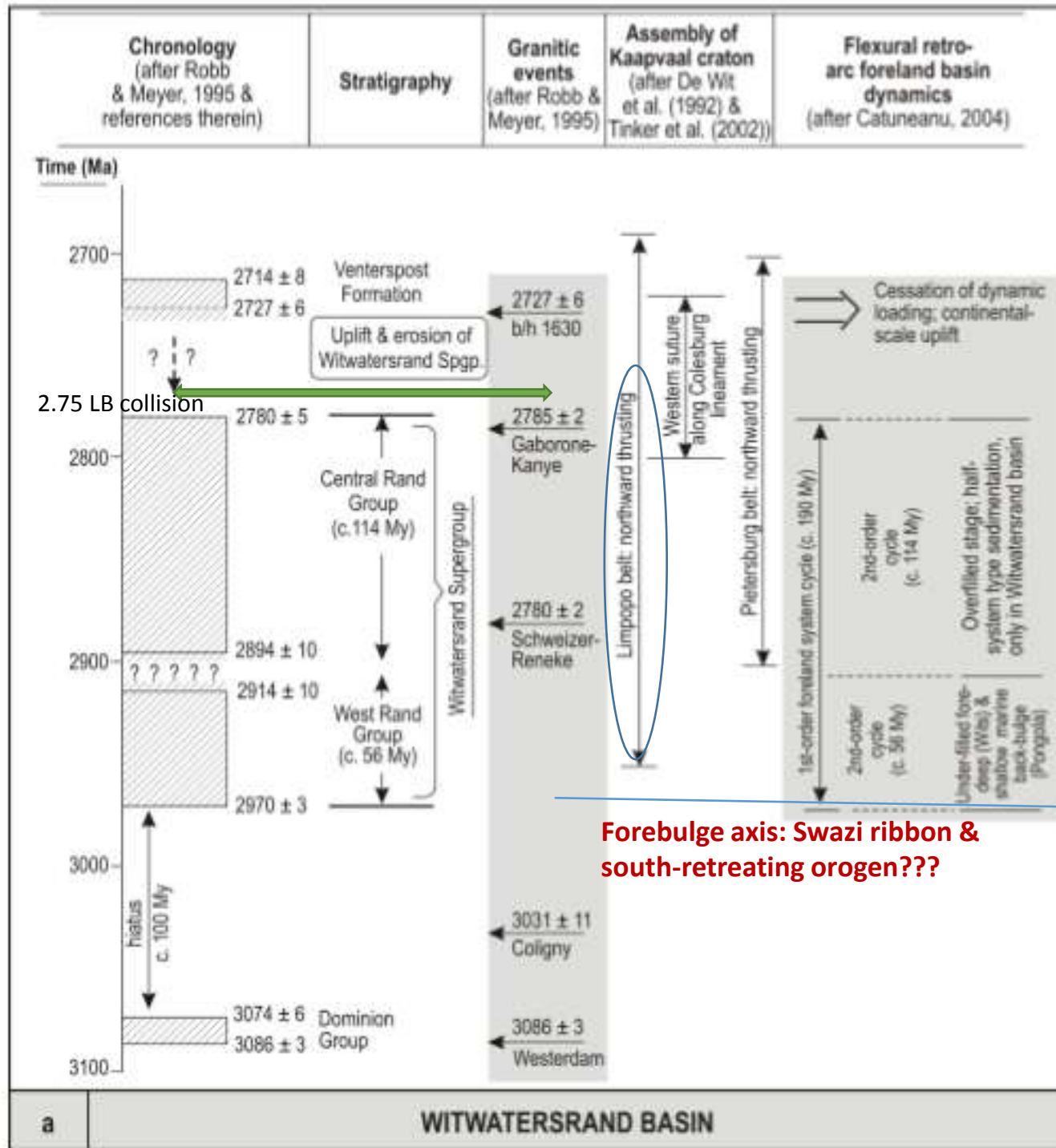
On syntaxes, secondary continental ribbons & oroclines : onset and accretion of Archean Kalahari Supercontinent cycle

Mark J Tsomondo (Minex & Archean Tectonics Researcher)

- ❑ Mobile curved boundaries “replace” 3.2-2.88Ga orogenic sutures on Kaapvaal
- ❑ 600Myr amalgamation of the continental lithosphere into one supercontinent
- ❑ Convergent-collisional-extensional (geodynamic) regimes: (growth, recycle, mix)
- ❑ Multidisciplinary: Geology, Geophysics, Geochronology, Geodynamics
- ❑ Plate-like behaviour in stiff lithospheric ribbon, hinterland indenter, plate tectonics driver?
- ❑ No supercontinent cycle before 2.0Ga ([Eriksson et al., 2009](#); [Jacobs et al., 2008](#))?

Accretionary Model (de Wit et al., 1992) modified by Oroclinal Orogeny & stiff lithospheric Swazi ribbon continent: 600Myr Kalahari Supercontinent cycle





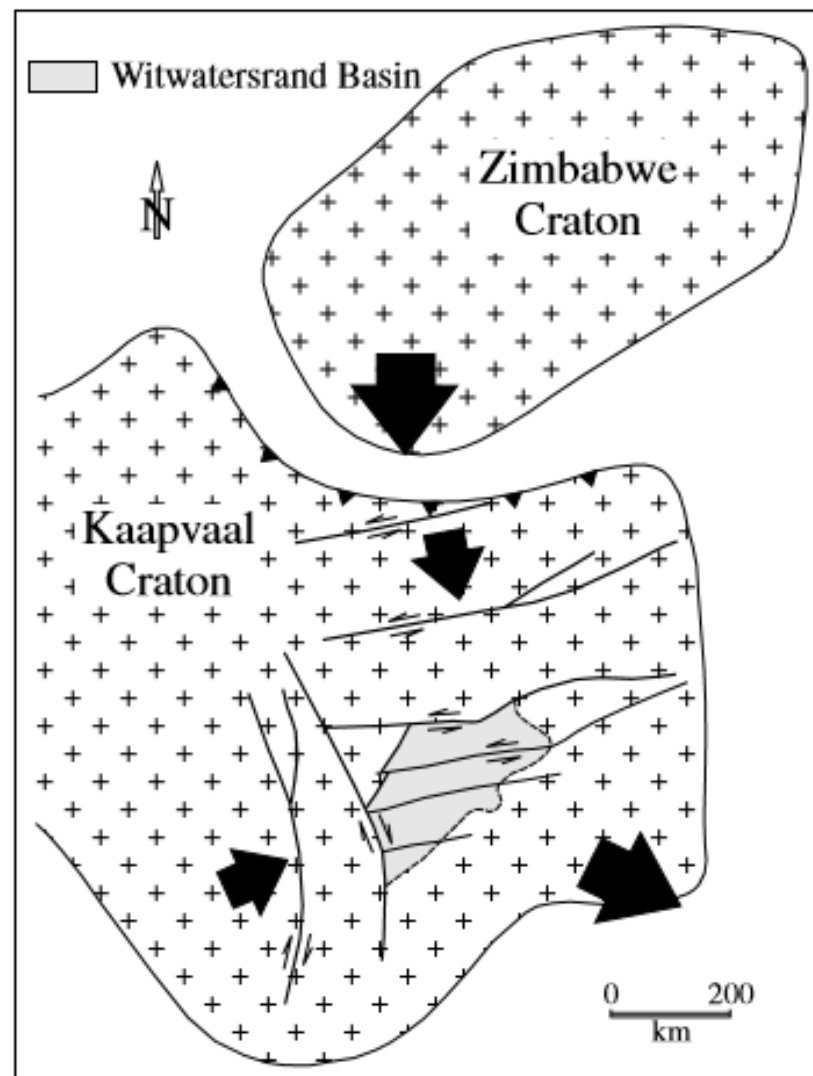
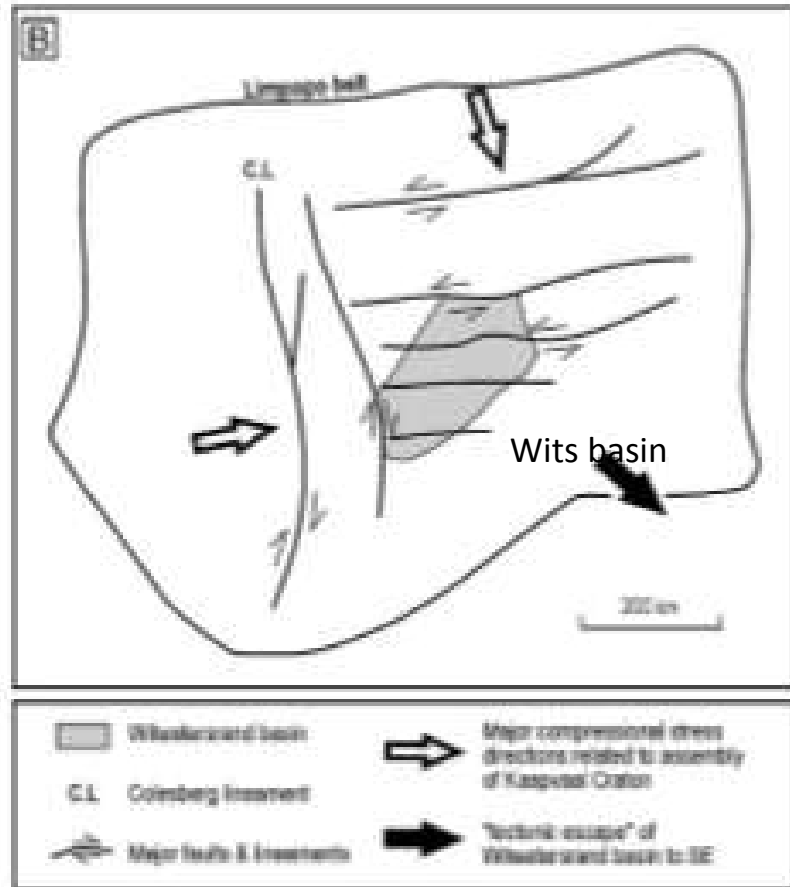


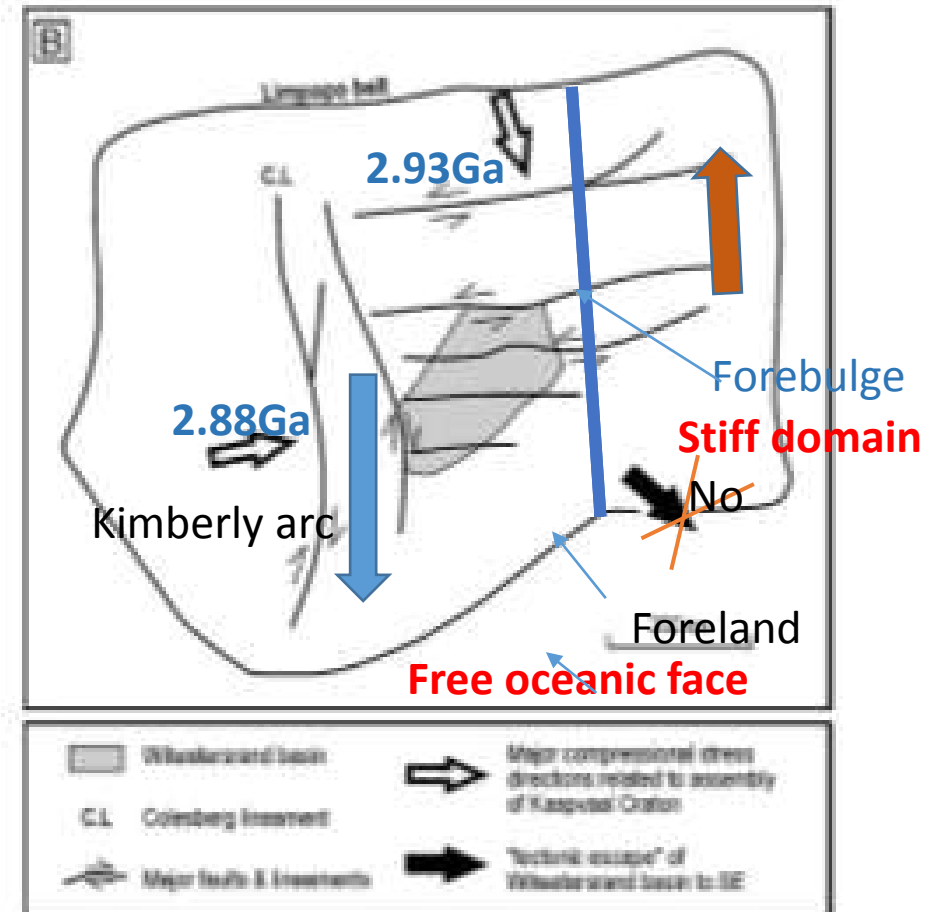
Fig. 3. Tectonic setting of the Witwatersrand Basin (modified from Robb et al., 1991; Robb and Meyer, 1995). Deformation along the northern margin of the Kaapvaal Craton led to supracrustal loading and the development of a retroarc foreland system. The large black arrows indicate the direction of compression and tectonic escape. The small paired arrows indicate strike-slip motion. Not to scale.

Regional shortening directions (100°) and **SE**-tectonic escapes of Witwatersrand foredeep basin

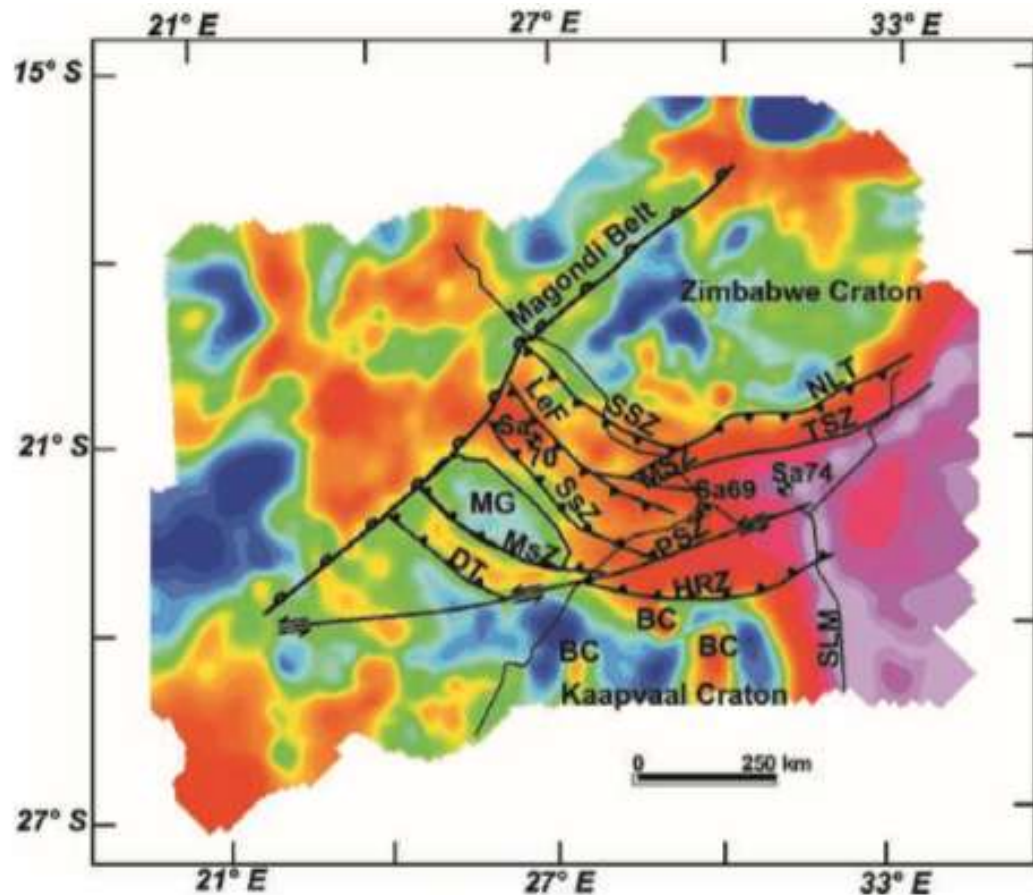
Stanistreet (1991); compression inducing tectonic escapes **SE**



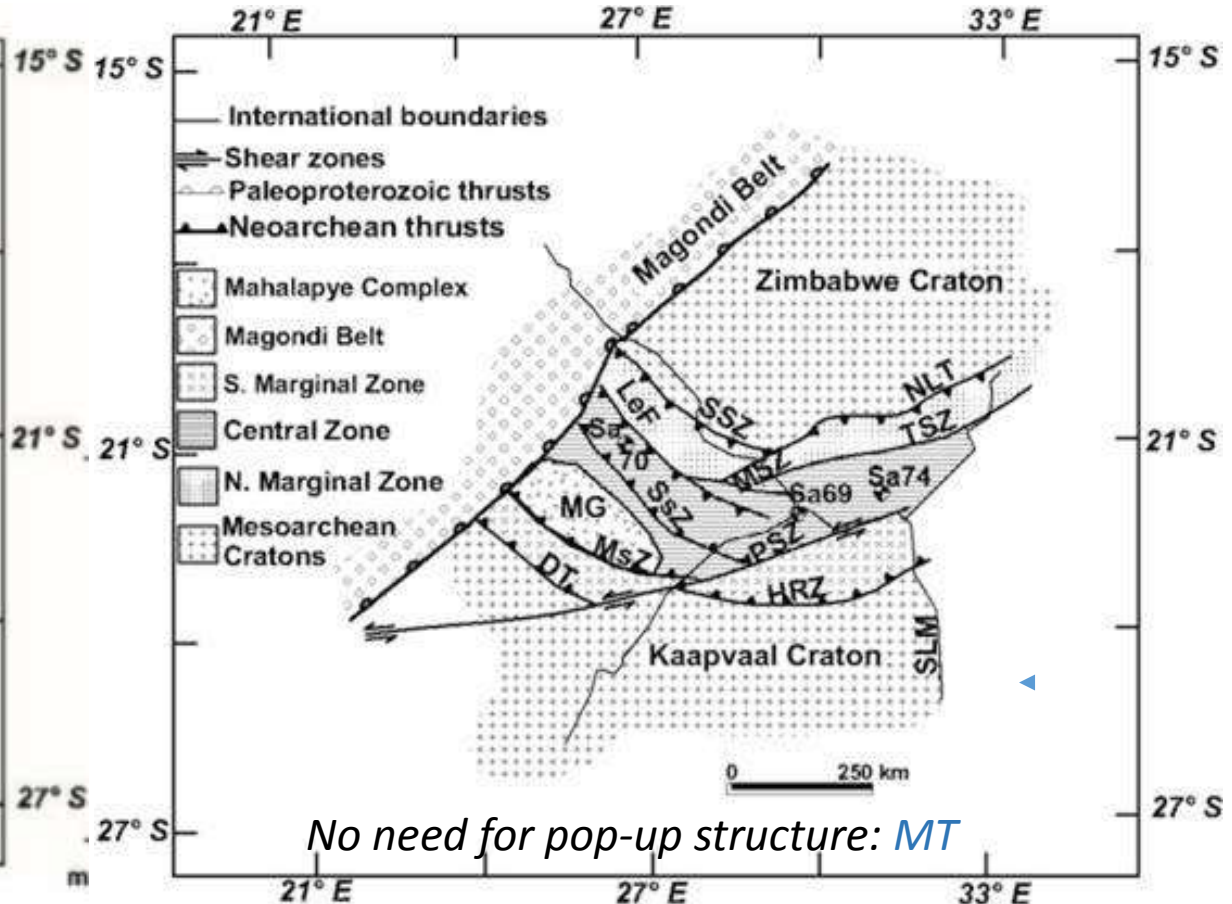
Revision: Stiff Swazi ribbon & Orocline, 'tectonic escape' southwards



Bouguer gravity high survey for south convex Limpopo orogen ([Ranganai et al., 2002](#)): shift paradigm from **linear Limpopo belt** consensus of 2011 Memoir Geol.Soc Amer. dedicated to LB towards **Oroclines or 'curvy mountains'**



See [Coward et al.](#): craton-vergent thrusts & foreland dfn



No need for pop-up structure: [MT](#)

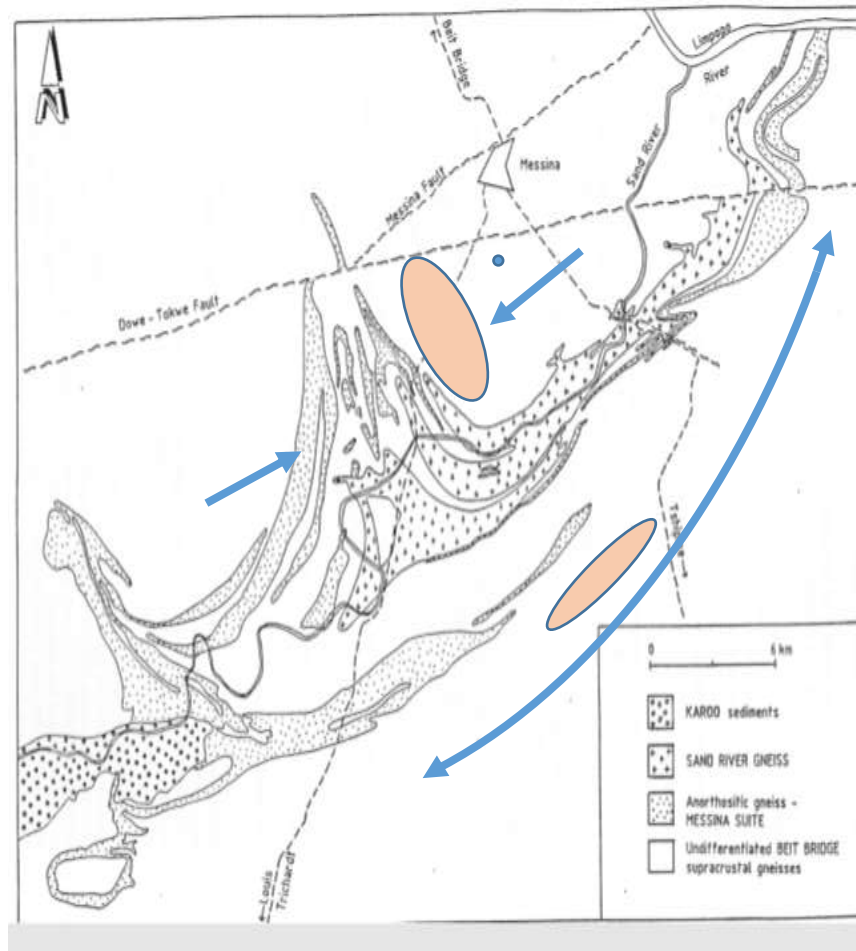
See Tschipise suture zone & [Youssof et al.2013](#)

Kinematic classification for curved orogens: a matter of timing of different deformation phases

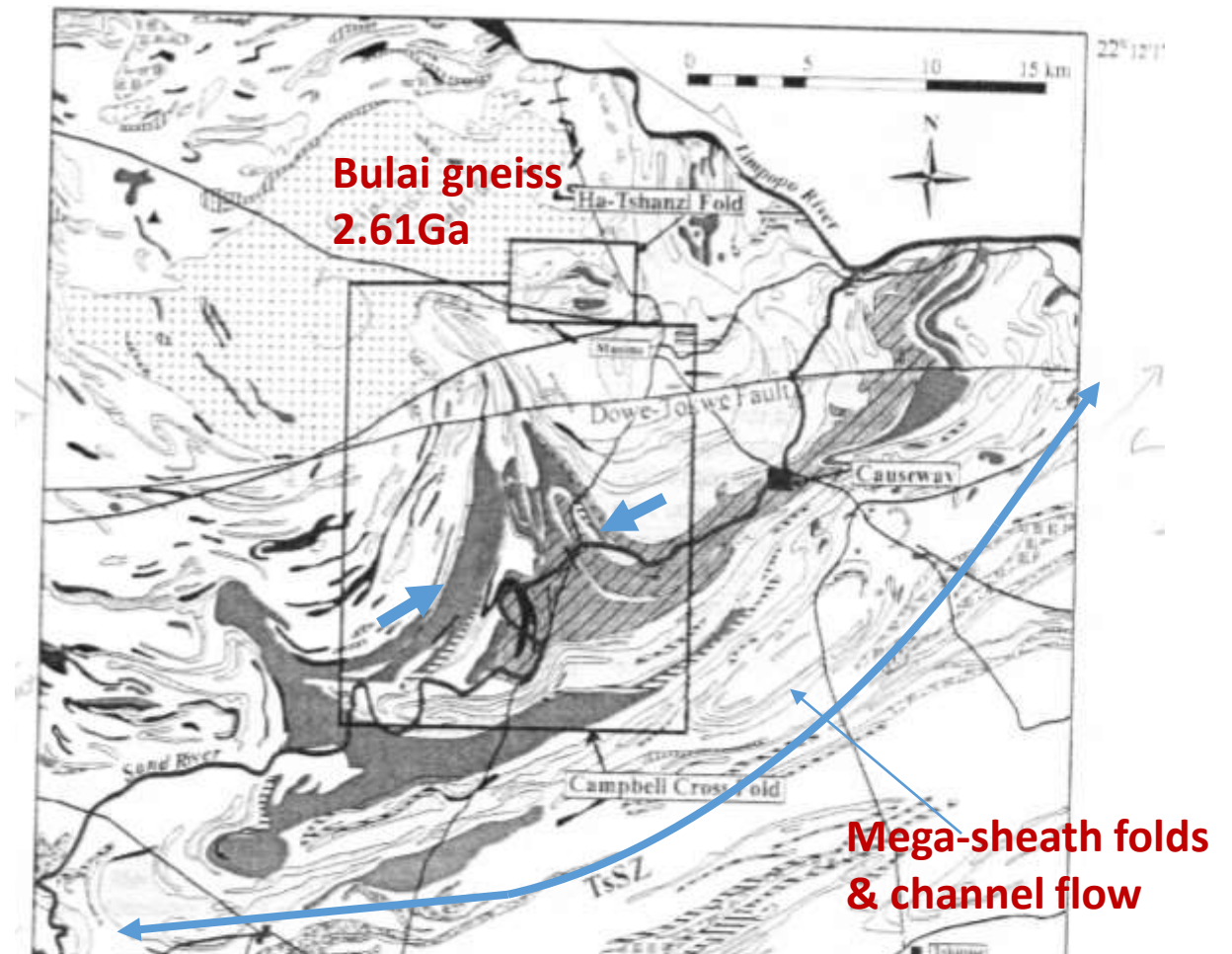
- When an orogen is initially curved & maintains that curvature without subsequent vertical axis rotation it is a primary arc ([Pastor-Galan et al. 2012](#))
- An orogenic belt that either acquires curvature during development or amplifies an initial curvature during formation, it is a progressive arc
- **When a bent orogenic belt is produced by buckling an originally more linear orogen it is an orocline or secondary arc or Carey orocline**
- In parlance with above, can we define ribbon continents as primary, progressive or secondary ribbons?
- **Is the MNK terrane a primary ribbon, and Swazi ribbon secondary?**
- **Is southern margin of Kaapvaal craton a buckled (conical) orocline?**

Not simply 'Straightening zones': (coeval) **arc-parallel stretching** and **arc-parallel shortening** under tangential longitudinal strain (see **Ries & Shackleton on oroclinal strain**): Great Dyke 2.57Ga south-fanned pattern, see later Rajesh et al., 2014 conundrum

IGCP 280 Sand River gneisses map



Geol.Soc Amer memoir map (Smit et al. 2011)



*Zim researchers for post Upper
Bulawayan Limpopo belt*

Incorrect SW-tectonic transport: Jelsma & Dirks

Missed east-escapes



False pop-up symmetry

Missed asymmetrical escapes of CZ & SMZ; but see Prandtl model guess of (Tsomondo & Blenkinsop, 1991)

2.72Ga

Impactogen (Ventersdorp)

Kaapv

with V

*Kaapvaal researchers for LB syntectonic
with Wits-Ventersdorp-Transvaal*

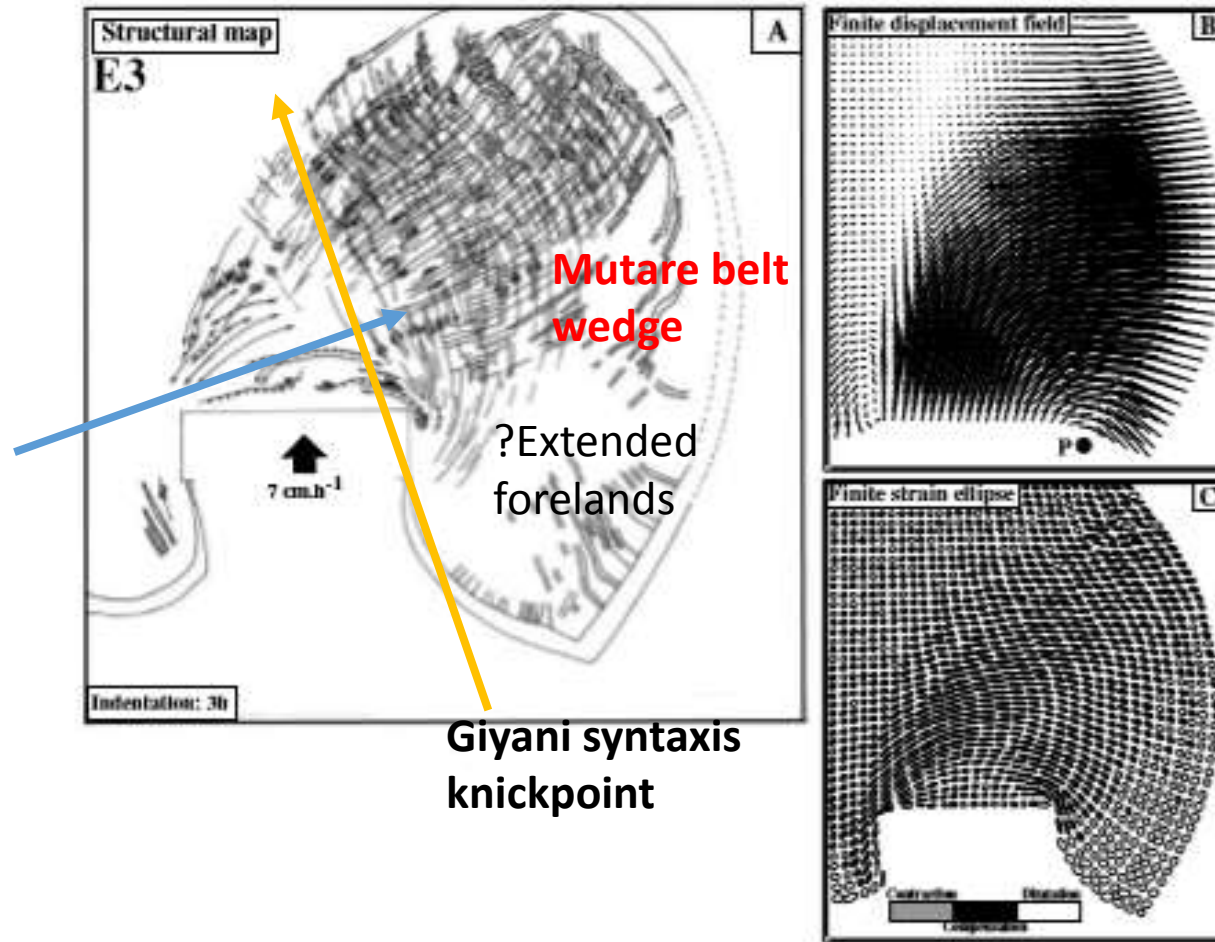
Fig. 3. Map of zone boundaries and fabric trends in the Archaean of southern Africa. Kinematics of regional scale shear zones and the gross movement direction of the var-

Rajesh et al.201

Tectonic escape **eastwards** within Tokwe: more complex orogenic curvature & escapes

- *After Clarke et al.*

See **Mashaba U**
Complex geology
and dyke systems
& brittle-ductile
fractures of Tokwe
segment



Eastern Tokwe segment “decratonised’ by K+ rich Chilimanzi granites

Schematic continental crust to Moho

Fish mouth boudins in amphib gneiss:
Murehwa batholith: horizontal extension E-W

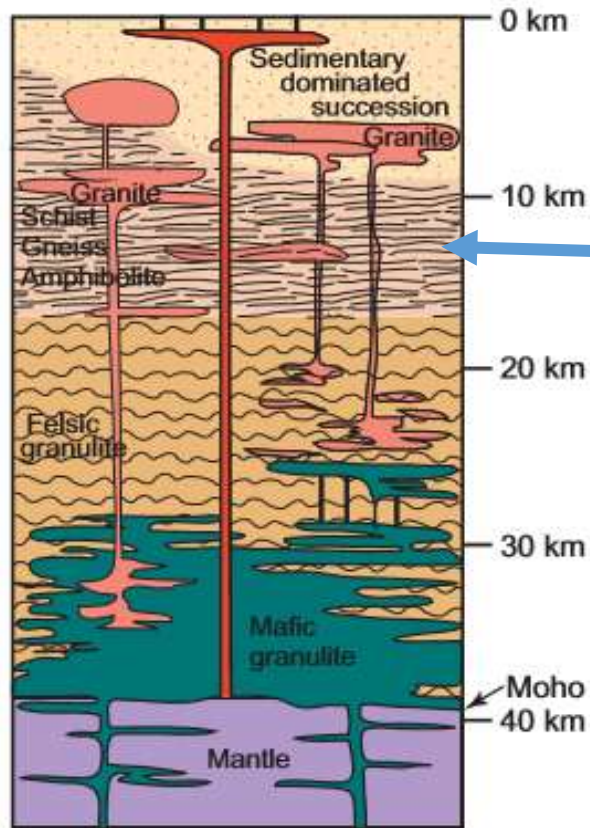
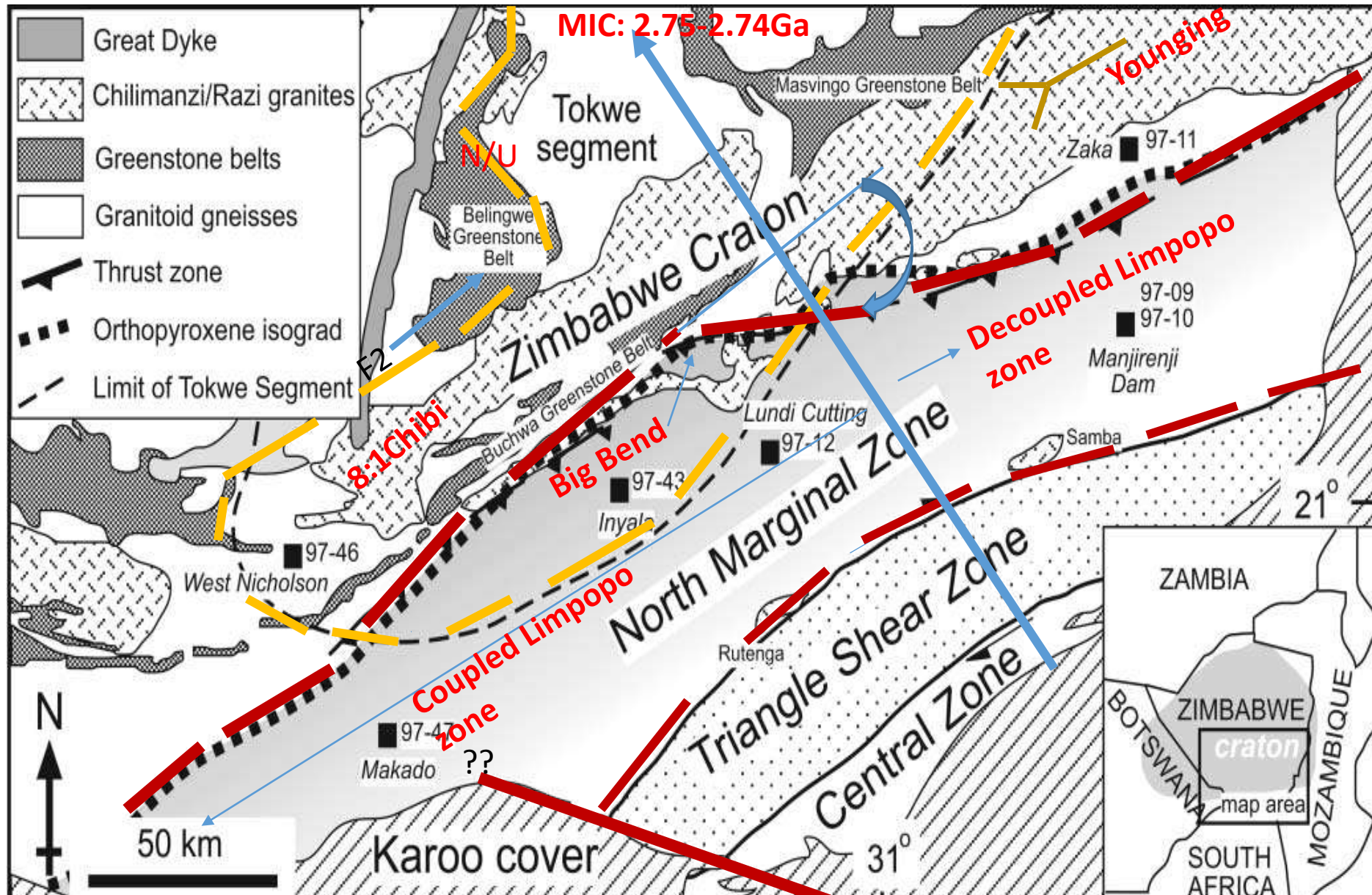


Figure 5. Schematic section of the continental crust, adapted from Hawkesworth and Kemp (2006a)



The southern tip of the Tokwe microplate



Modelling results for inter-plate coupling

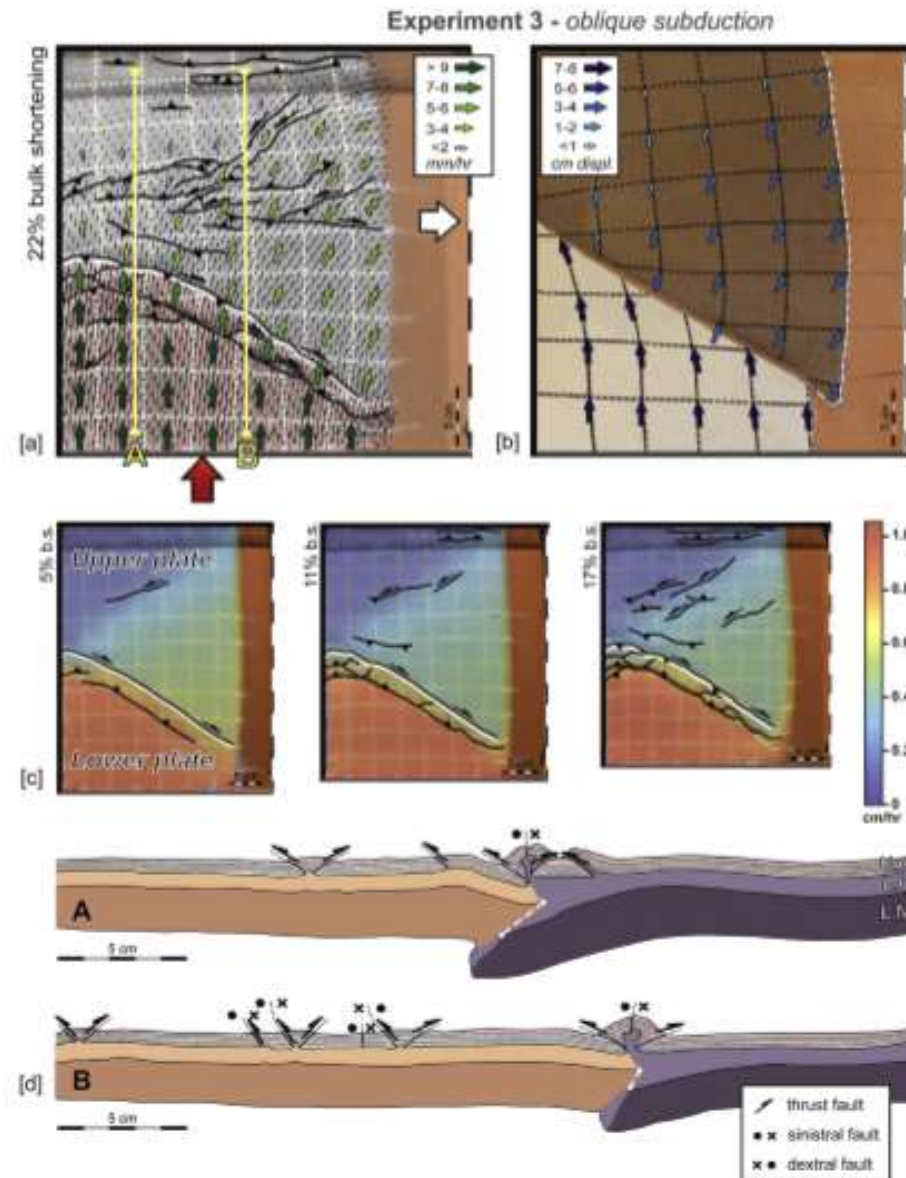
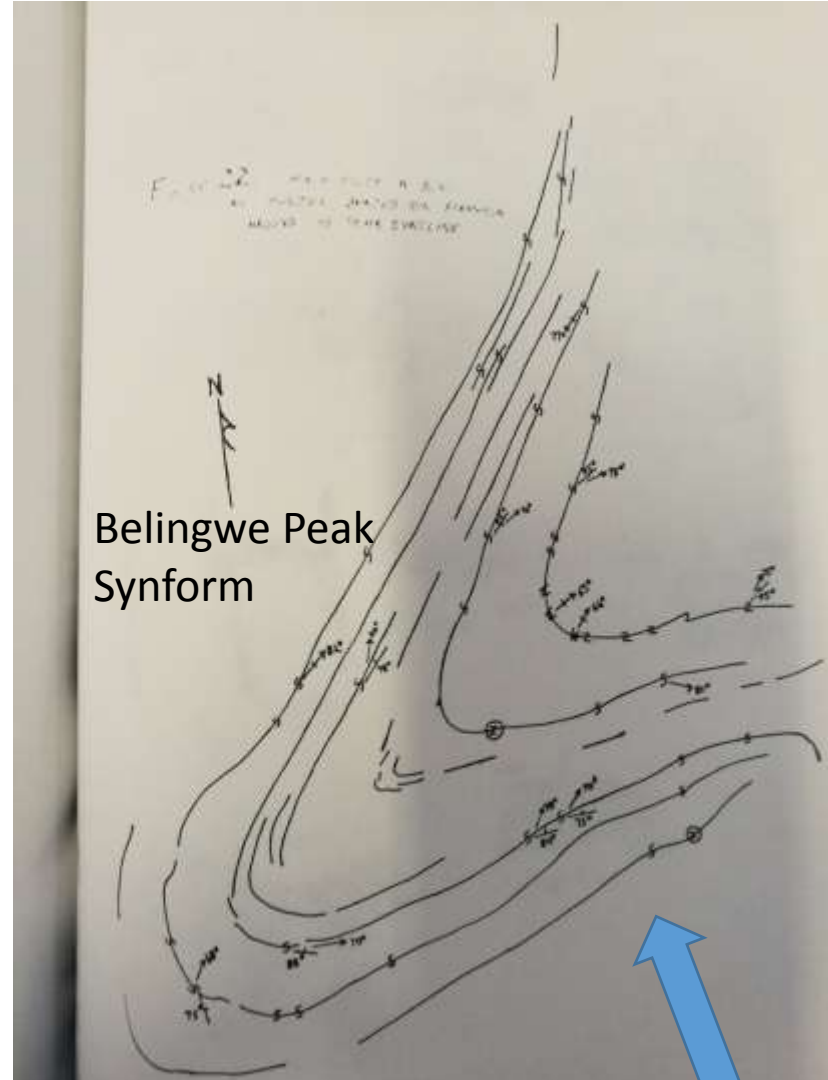


Fig. 5. Modeling results for experiment 3, see detailed figure description below [Fig. 3](#).

Belingwe south: **s**-asymmetry on both limbs of regional synform (Orpen, 1978) Is this evidence of pure shear strain (Ramsay & Huber 1987) & shallow detachment tectonics: **Beyond the National unconformity**



Poorly defined Foreland tectonics on Tokwe protocrator

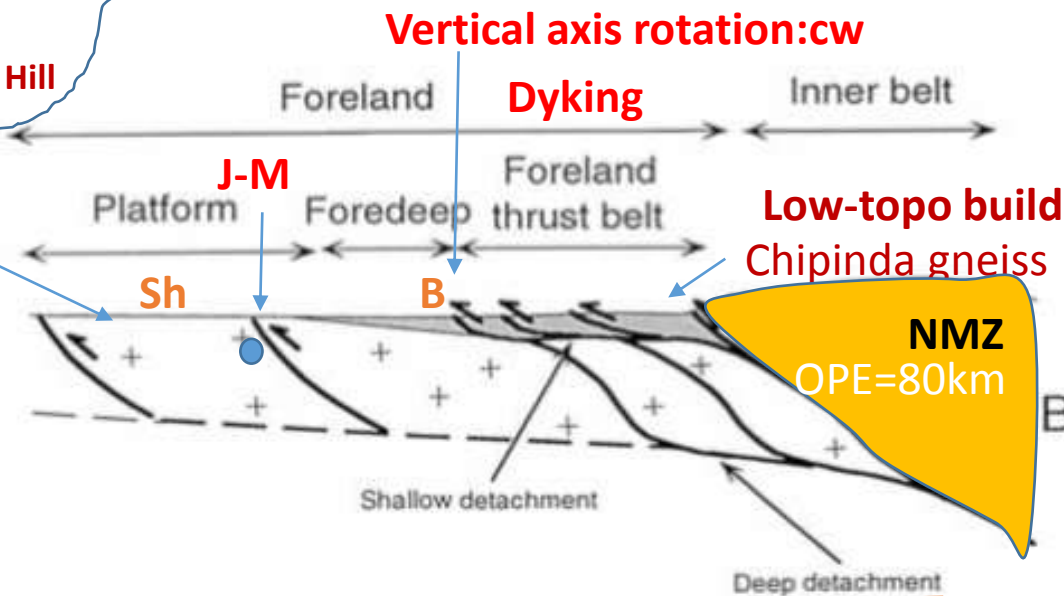
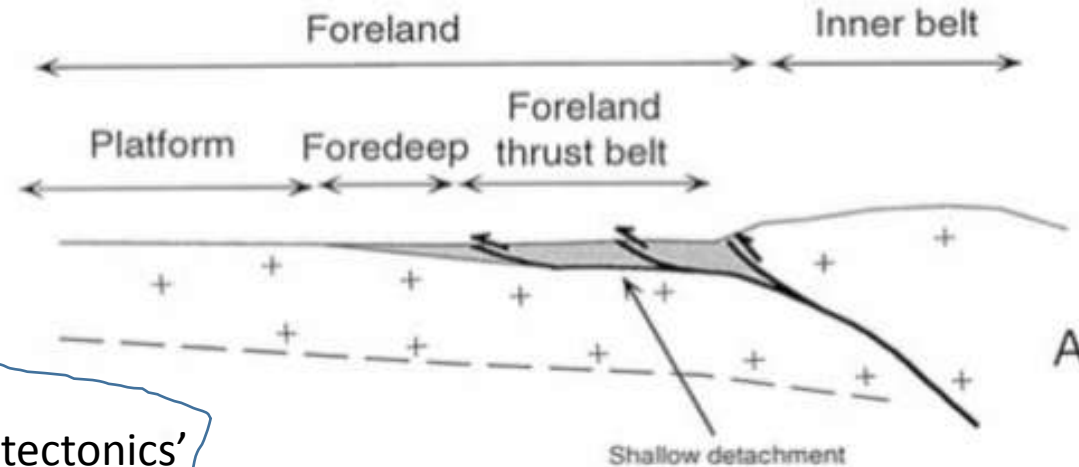
"Basement-involved thin-skinned tectonics"

Camperdown sheath-like "nappe"

GPE: Easter Hill klippe

Depth to decollement & basement-cored Mont d'Or uplift

Three detachment levels, backthrust, Fossen's decollement overfold (Tsomondo et al. 1990): Shortening & extension & mismatched Mont d'Or north boundary



Hinterland Swazi indenter

Figure 1. Conceptual view of tectonic styles in the forelands of orogens. (a) Shallow detachment tectonics. The fold-thrust belt mainly consists of the shortened cover detached from the nearly undeformed basement above a shallow basal ductile horizon. (b) Shallow and deep detachment tectonics. The fold-

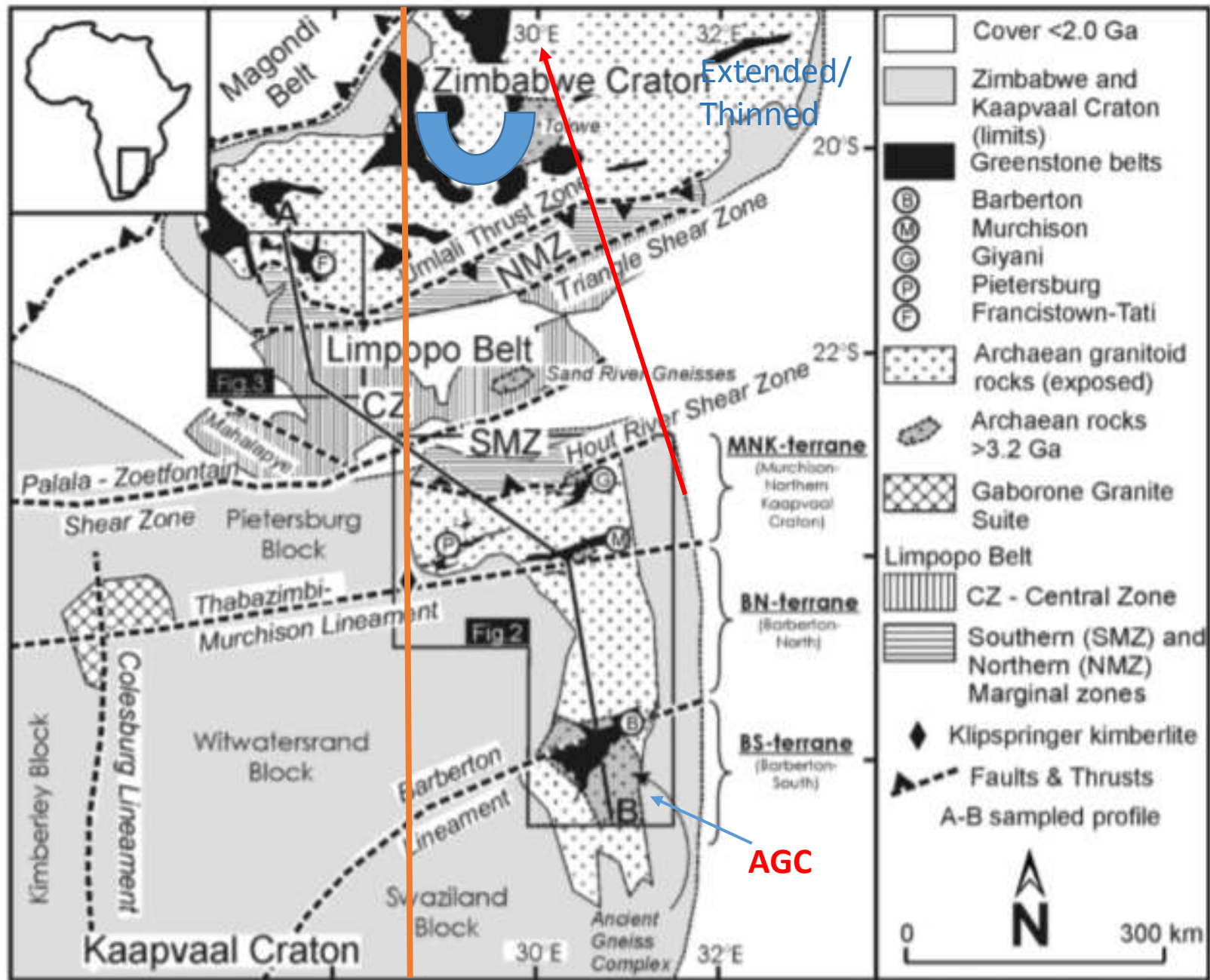
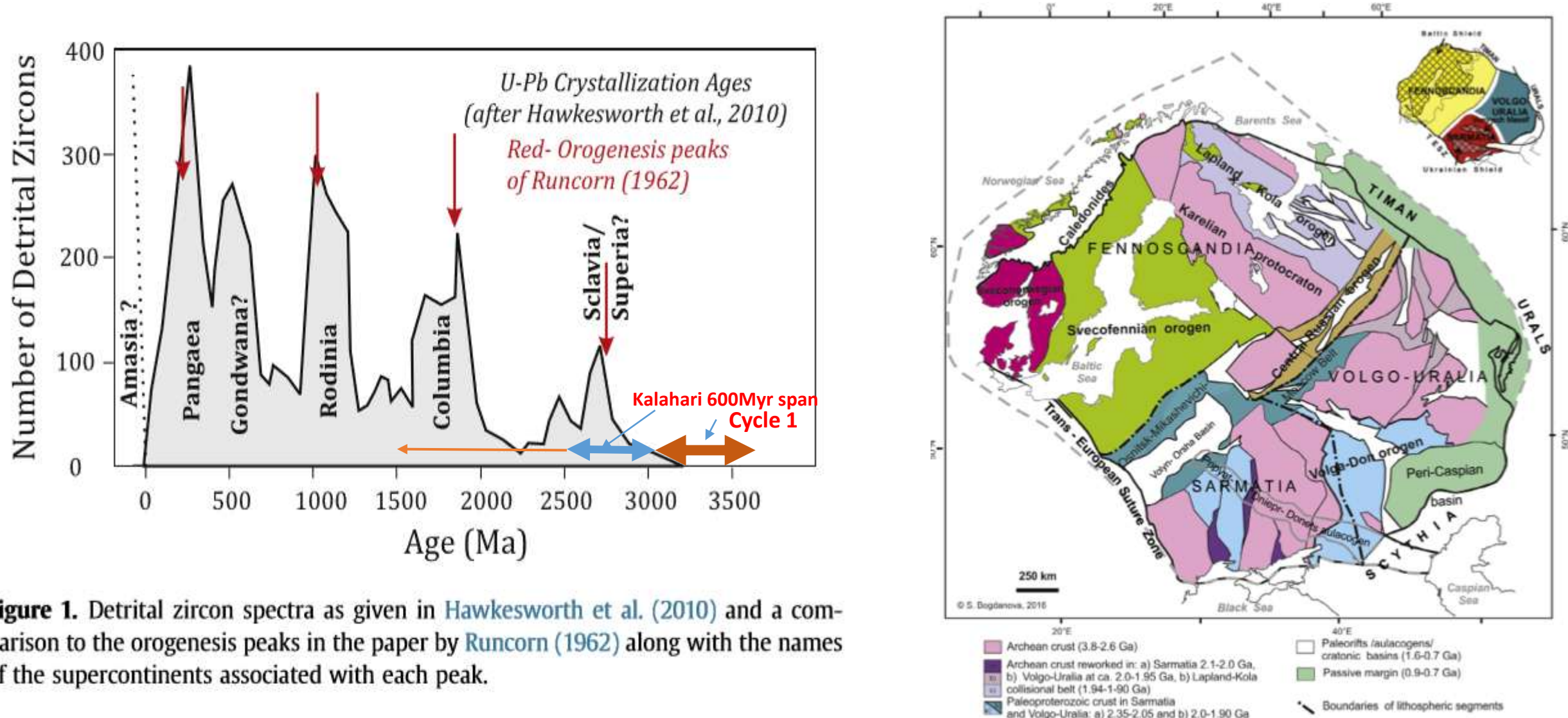


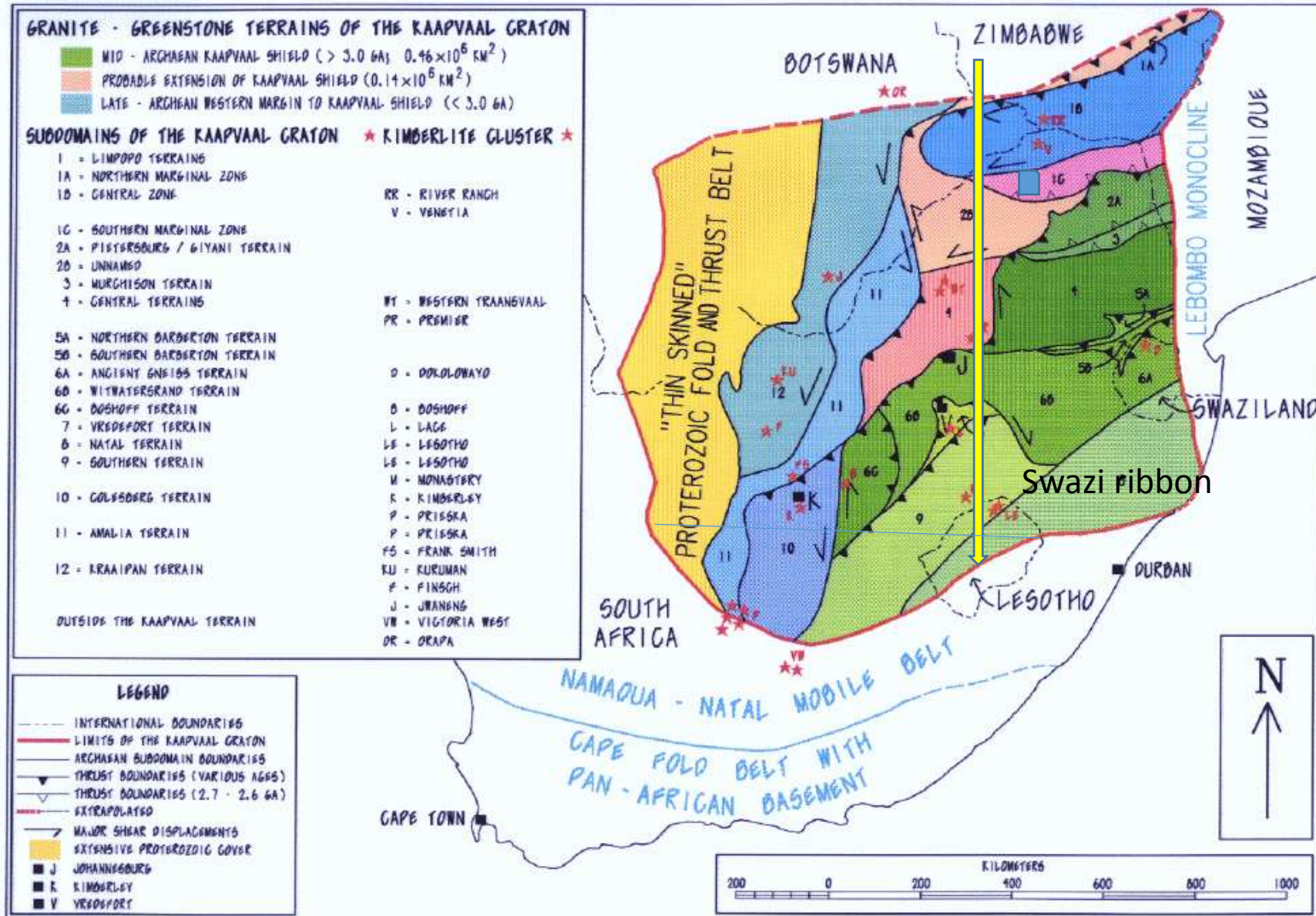
Fig. 1. Simplified geological map of the Kalahari Craton of southern Africa showing the location of the Kaapvaal Craton, Limpopo Belt and Zimbabwe Craton.

Zeh et al. 2009; Kalahari craton see my Kalahari supercontinent

Question Again>: How does an equant Kaapvaal craton acquire orogenic curvature during accretionary orogenesis overlapping continent-continent collision?



Accretionary Model (de Wit et al., 1992) modified by Oroclinal Orogeny & stiff lithospheric Swazi ribbon continent: 600Myr Kalahari Supercontinent cycle



Oroclinal Kaapvaal craton & ear-shaped New England Orocline

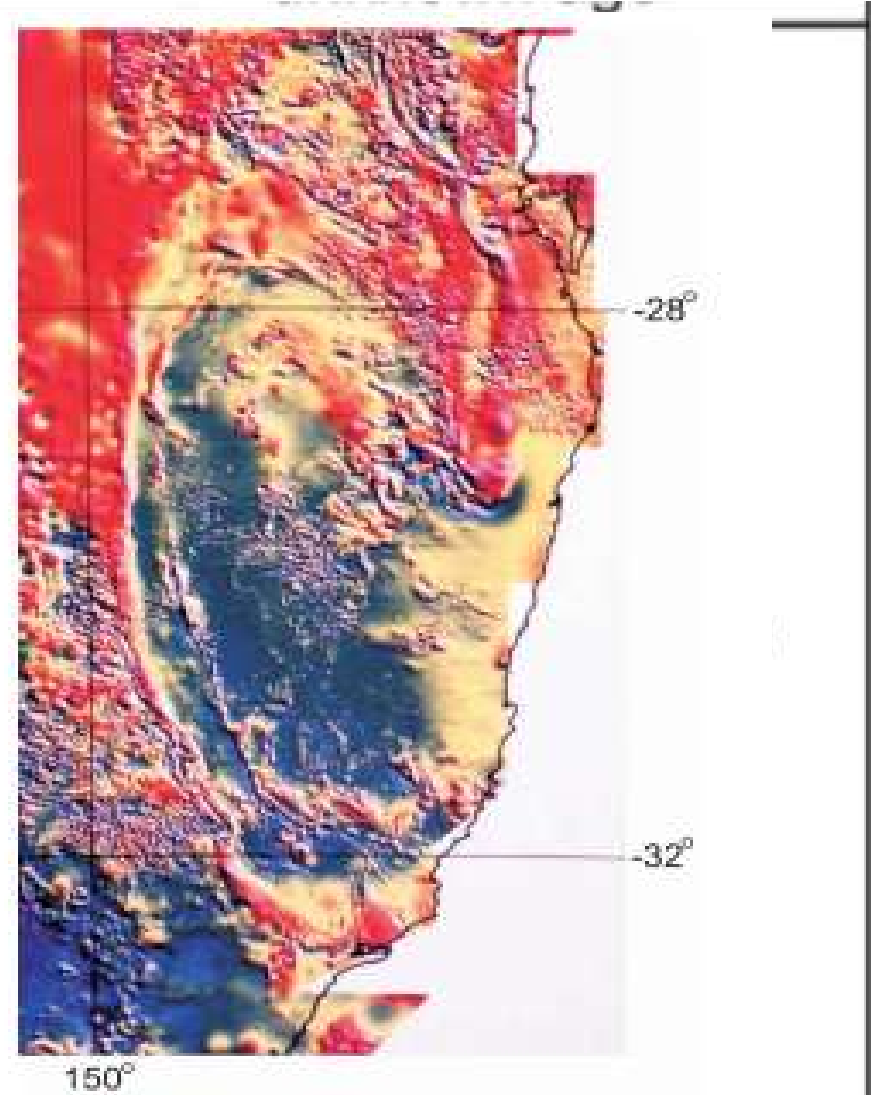
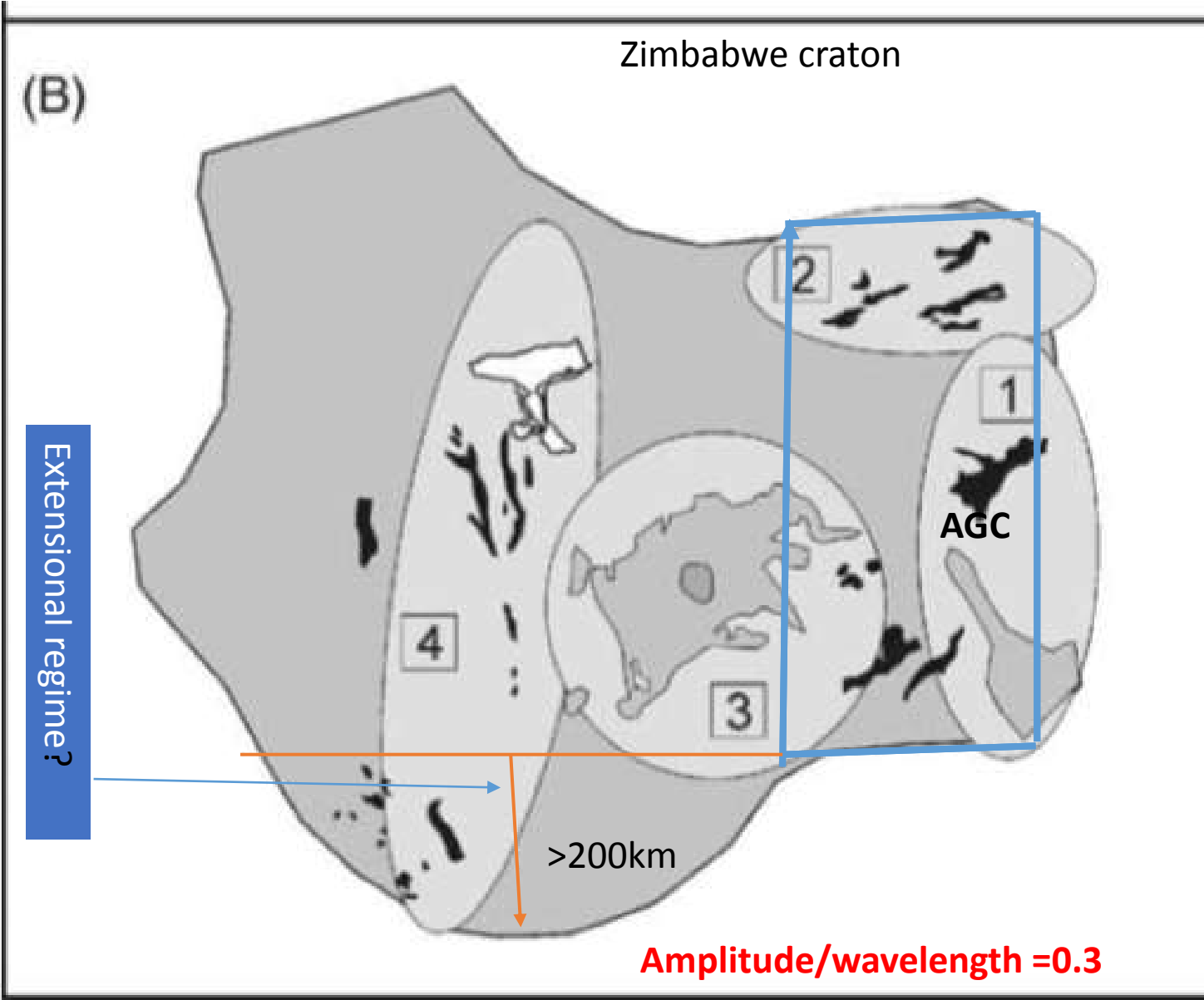
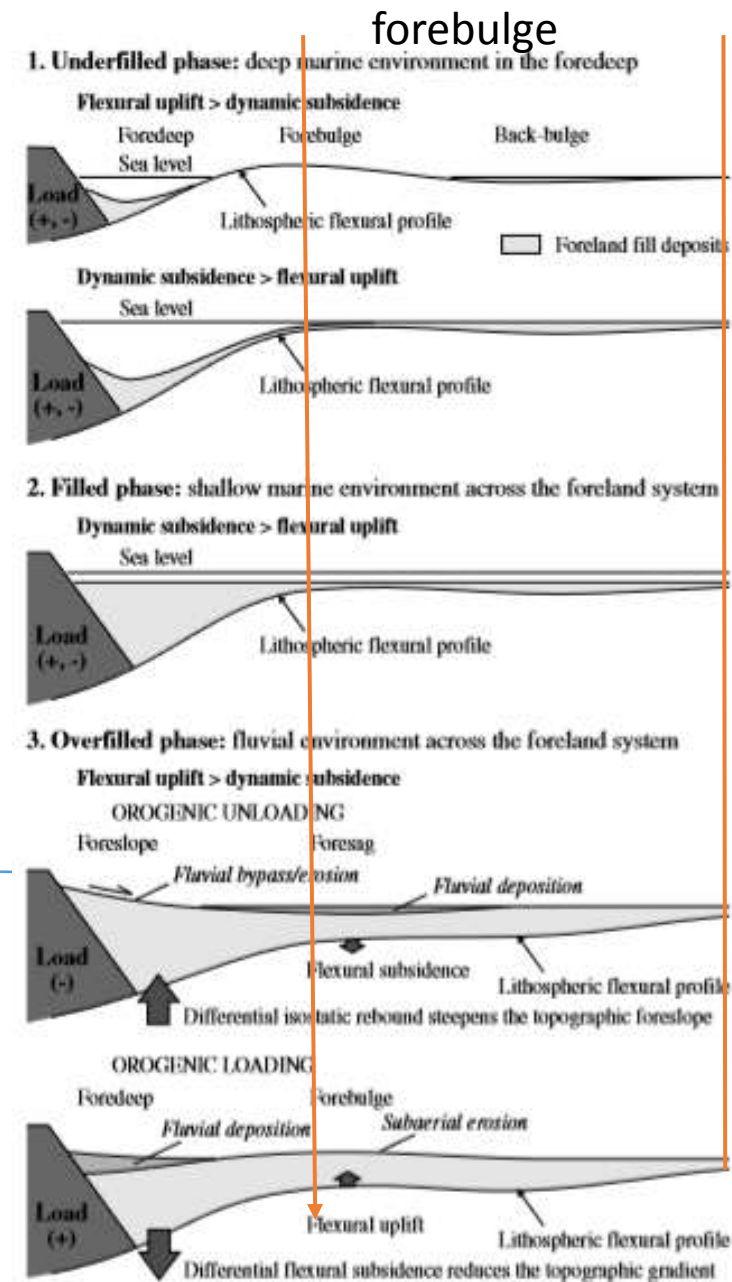
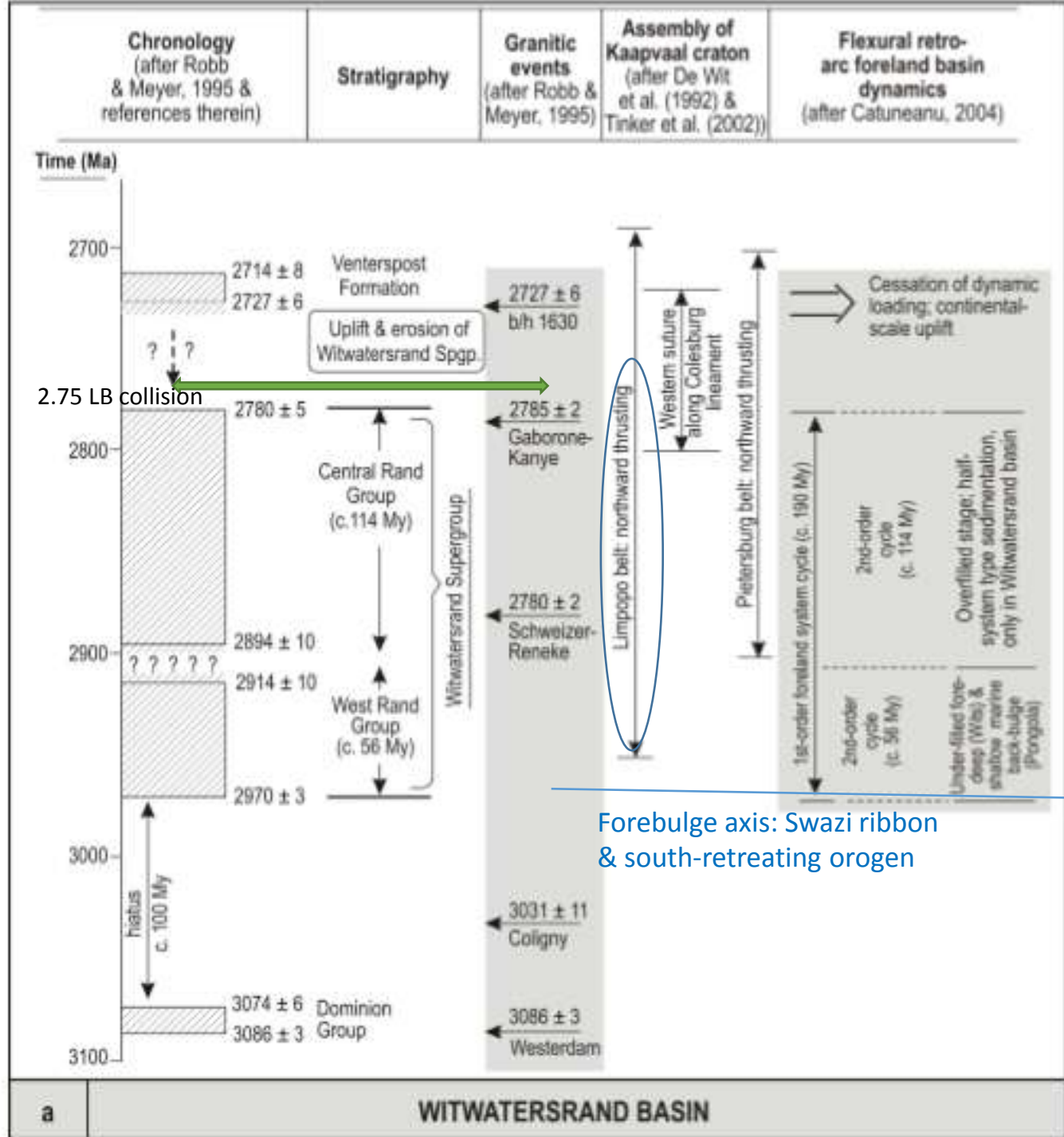
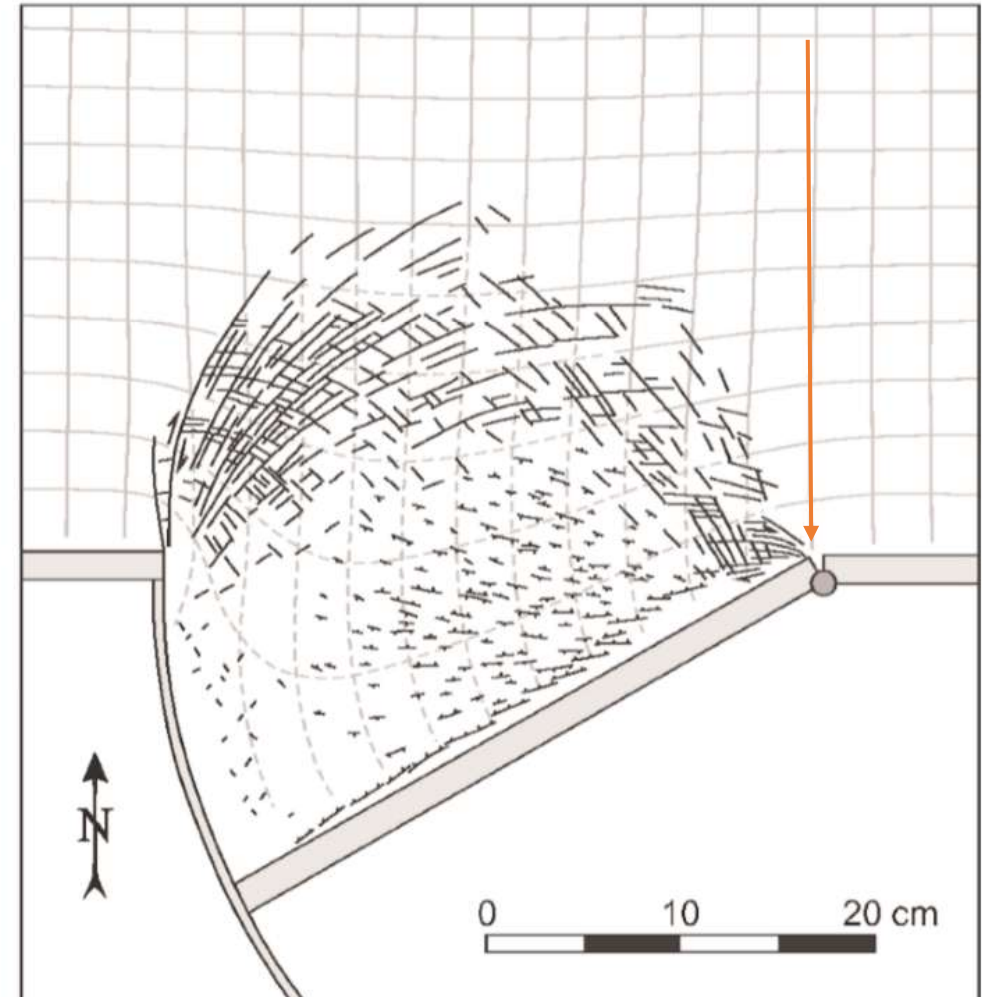
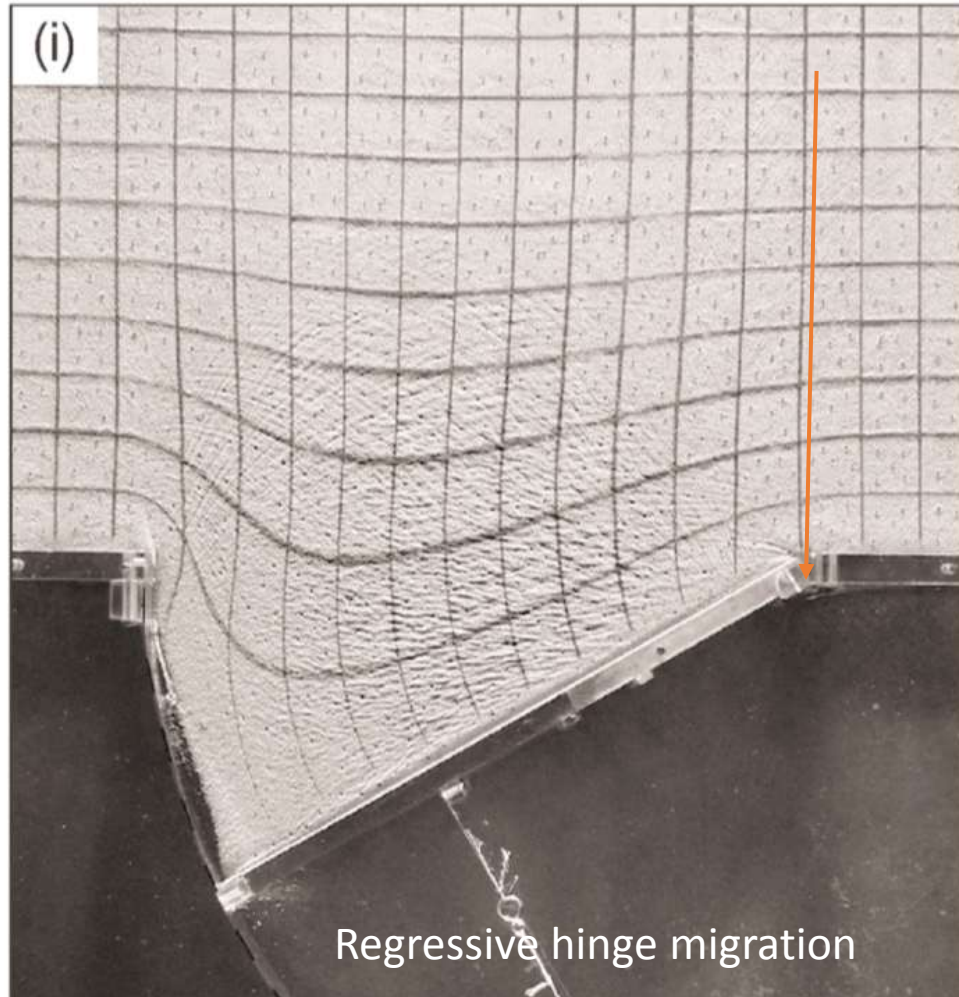


Figure 4. Aeromagnetic anomaly map for eastern Australia covering the southern New England fold Belt showing Texas-Coffs Harbour and Manning-Hastings segments of the New England orocline.



Analogue experiment on back-arc extension & pinned deformation; [Schellart et al. 2002](#). Possible formation of a Swazi ribbon



Current STEP regions: retreating trench

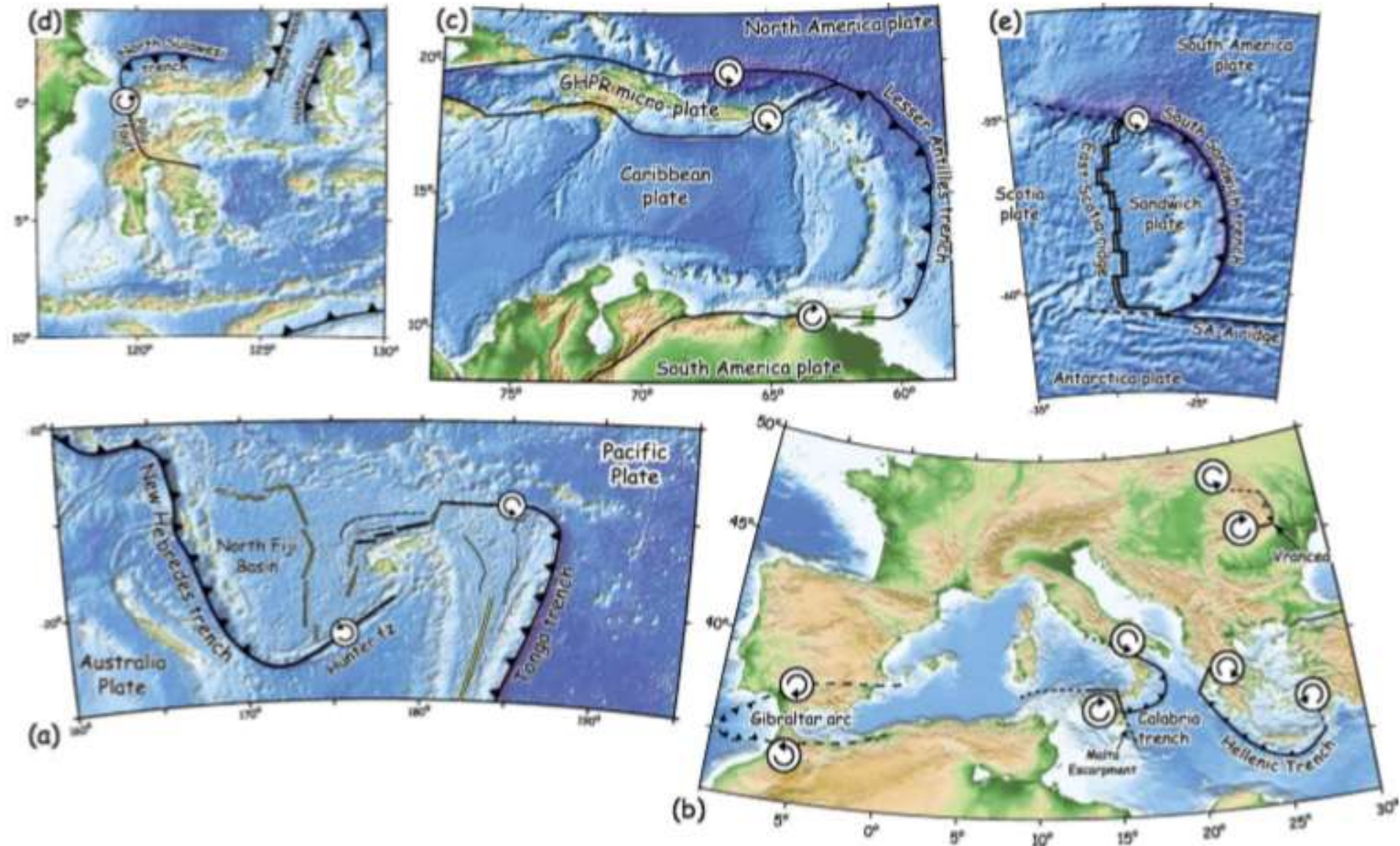


Fig. 2. Current STEP regions. Lines schematically indicate active plate boundary zones. Rotation symbols show the regionally observed sense of motion on transform faults, or paleomagnetic rotations about a vertical axis.

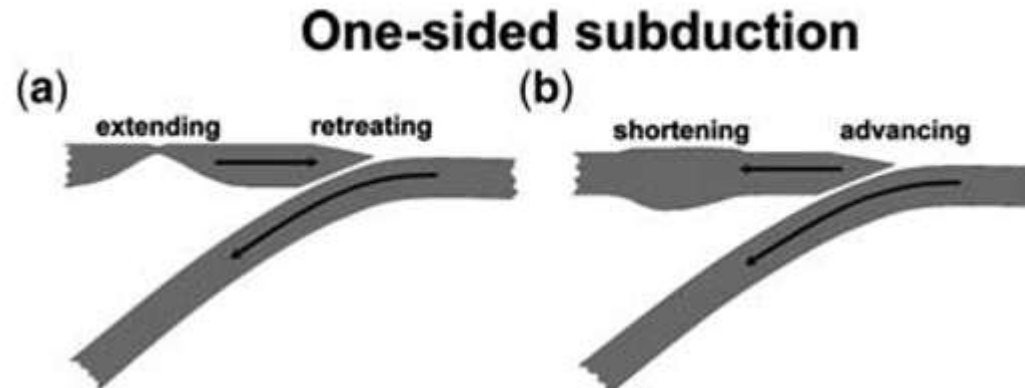
Subduction, rollback & back arc basins: orocline link

Wits basin BA-extension:

southern orocline followed
orthogonal 2.88Ga Andean
collisional events



Kimberly arc Cordilleran
shortening induced
retreating subduction in
(a)



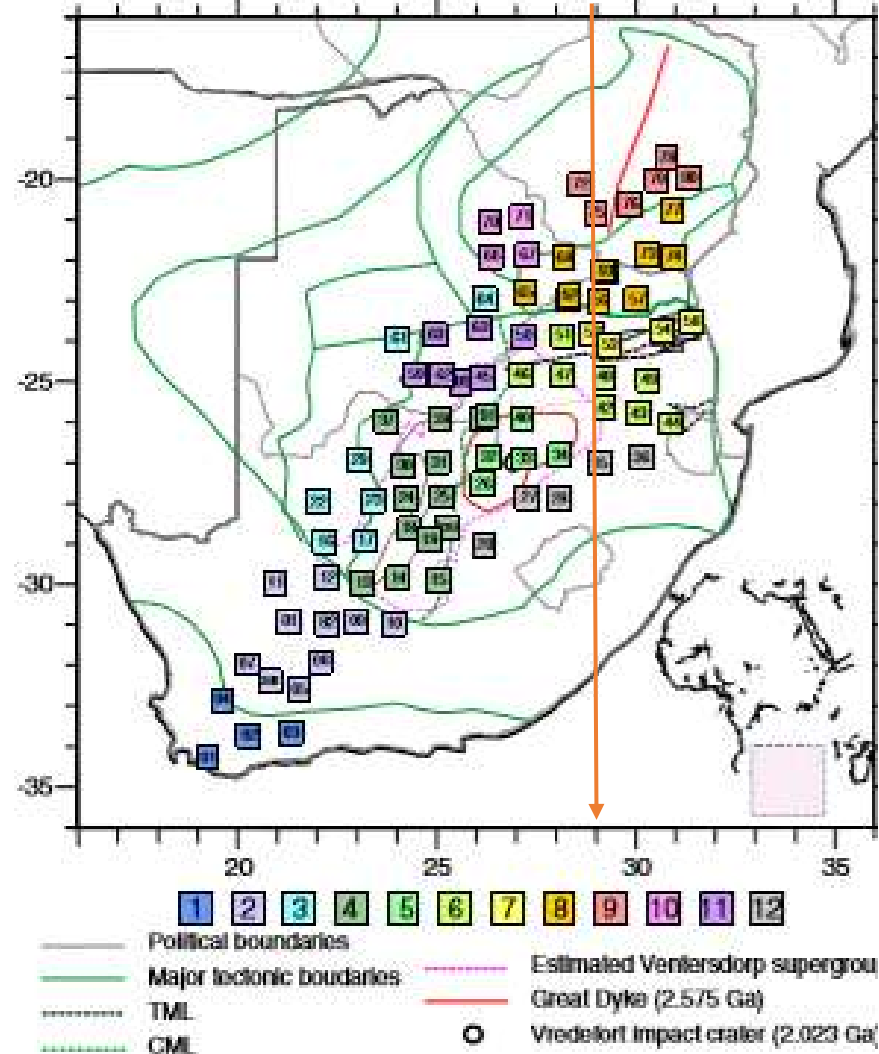


Fig. 2. Map showing the locations of the 82 stations of the SASE array and 3 permanent GSN seismic stations. Note that three pairs of stations are located at almost the same coordinates: stations SA91, SA92, and SA93 are behind stations SA39, SA55, and SA69. Co code for the SASE array corresponds to the numbering of tectonic blocks as follows. Cape Fold Belt (CFB), 2: Namaqua-Natal Mobile Belt (NNMB), 3: Kheis-Olwa Mol Belt (KOMB), 4: Western Kaapvaal – Ventersdorp LIP (VG-LIP), 5: Central Kaapvaal Witwatersrand Basin (WRB), 6: Northern Kaapvaal – Bushveld Igneous Complex (BI), 7: Northern Kaapvaal – Pietersburg-Giyambi-Murchison (PGM), 8: Limpopo Mobile B (LB), 9: Zimbabwe Craton-Tokwe gneiss block (ZCT), 10: W Zimbabwe Craton-T Granite-Greenstone (TGGT), 11: NW Kaapvaal-Late Archean Gaborone granites (GG), 12: Eastern Kaapvaal (EK).

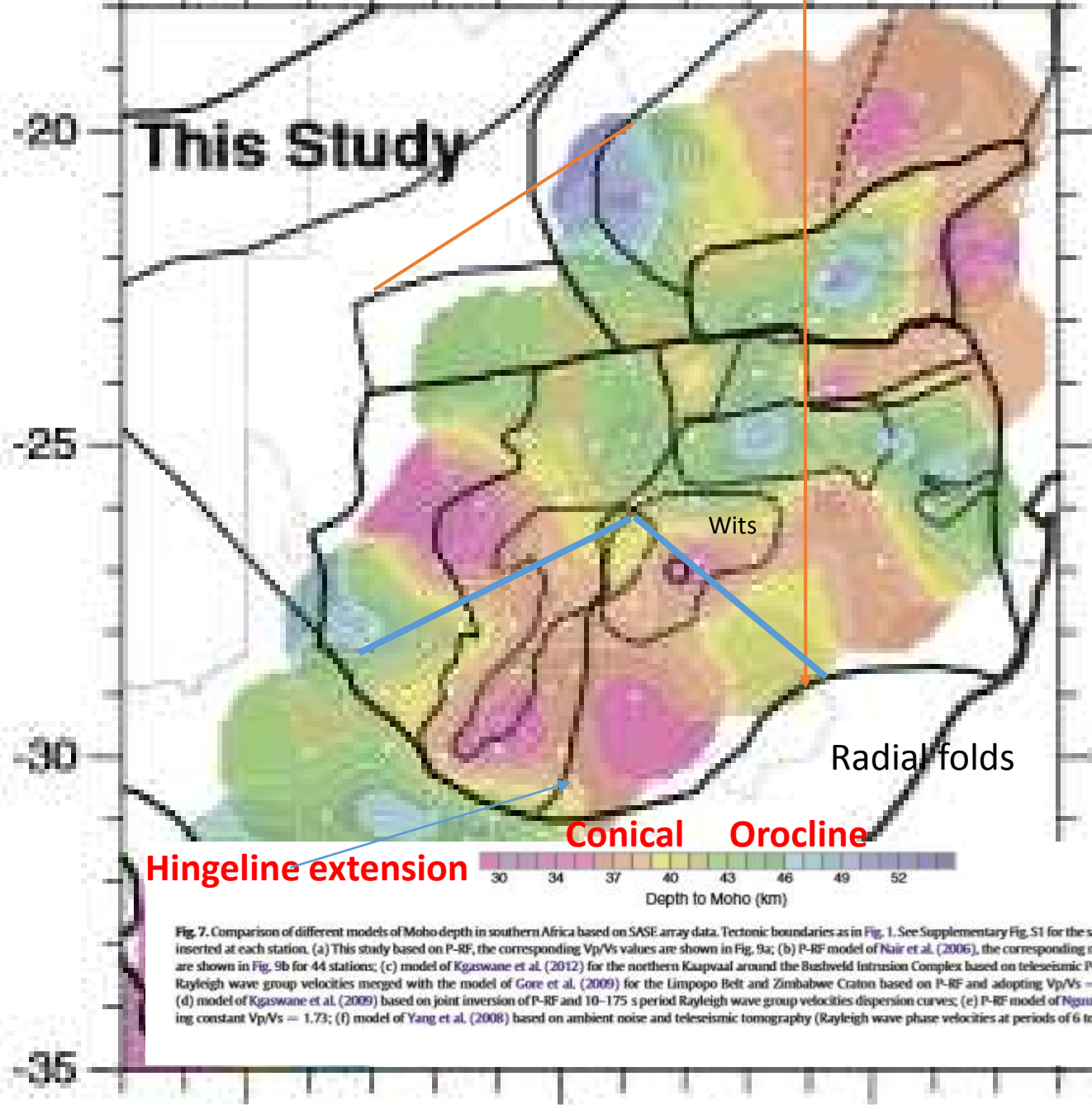


Fig. 7. Comparison of different models of Moho depth in southern Africa based on SASE array data. Tectonic boundaries as in Fig. 1. See Supplementary Fig. S1 for the same maps with values inserted at each station. (a) This study based on P-RF, the corresponding Vp/Vs values are shown in Fig. 9a; (b) P-RF model of Nair et al. (2006), the corresponding modelled Vp/Vs values are shown in Fig. 9b for 44 stations; (c) model of Kgaswane et al. (2012) for the northern Kaapvaal around the Bushveld Intrusion Complex based on teleseismic P-RF and 2–60 s period Rayleigh wave group velocities merged with the model of Gore et al. (2009) for the Limpopo Belt and Zimbabwe Craton based on P-RF and adopting Vp/Vs = 1.75 for this region; (d) model of Kgaswane et al. (2009) based on joint inversion of P-RF and 10–175 s period Rayleigh wave group velocities dispersion curves; (e) P-RF model of Ngweni et al. (2001) assuming constant Vp/Vs = 1.73; (f) model of Yang et al. (2008) based on ambient noise and teleseismic tomography (Rayleigh wave phase velocities at periods of 6 to 143 s).

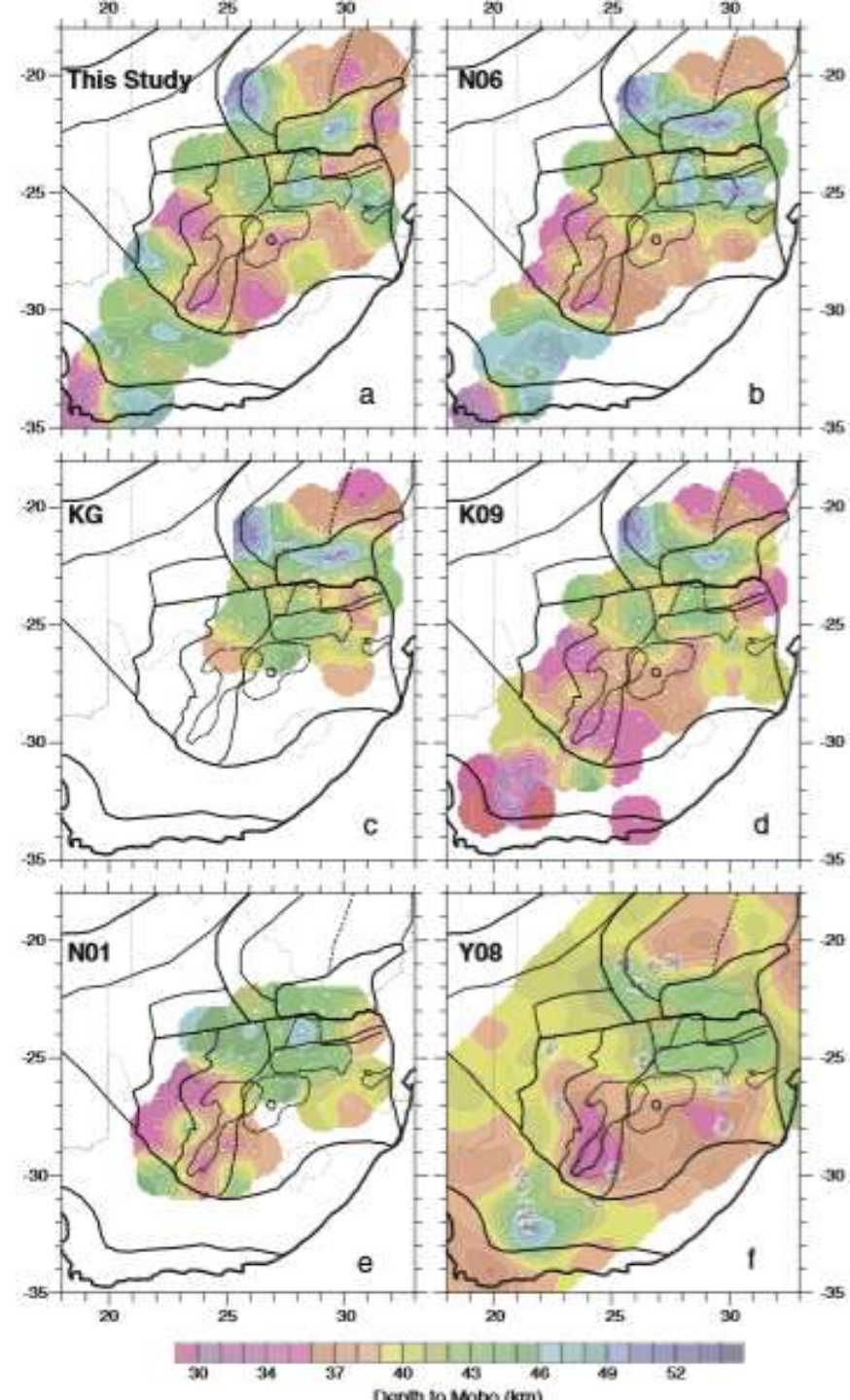
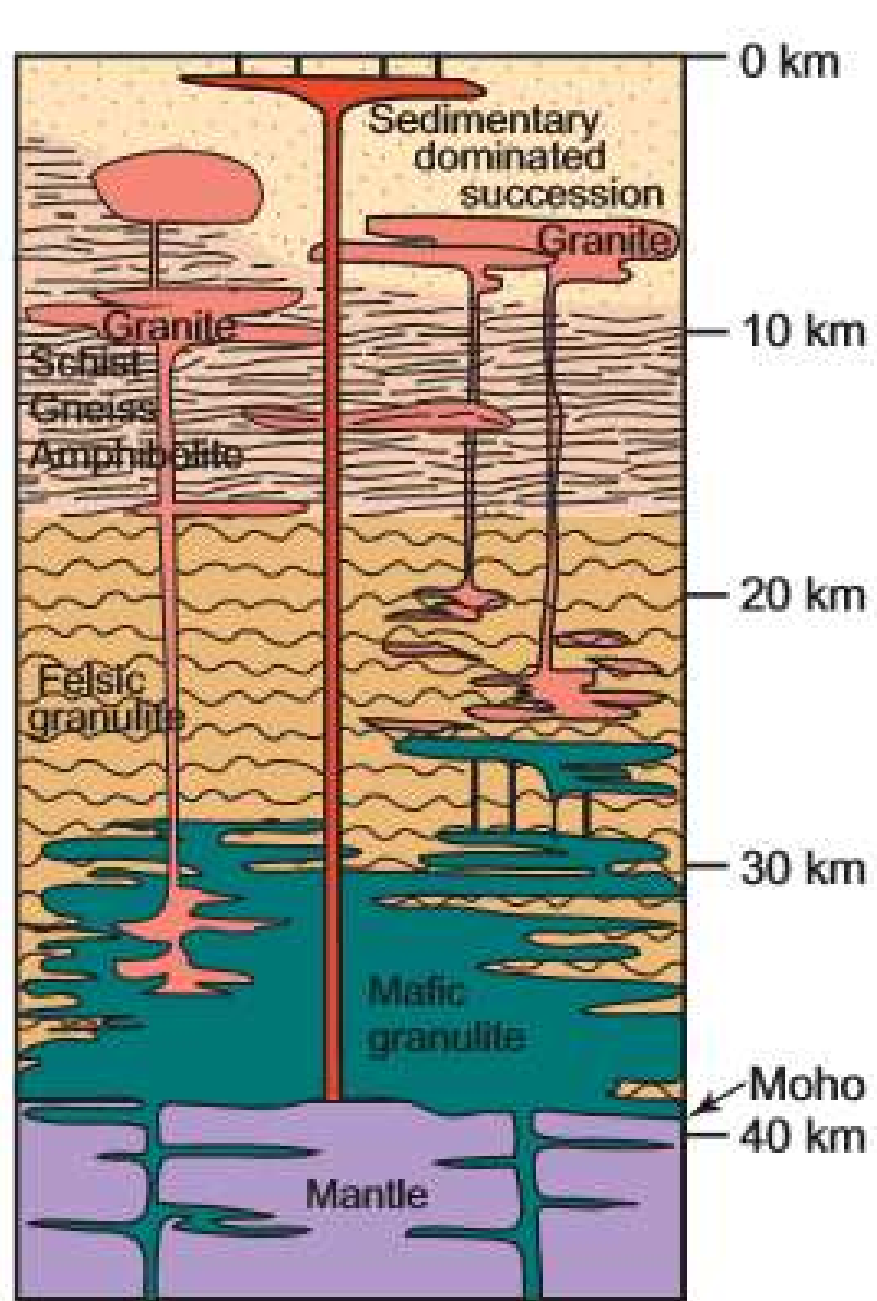
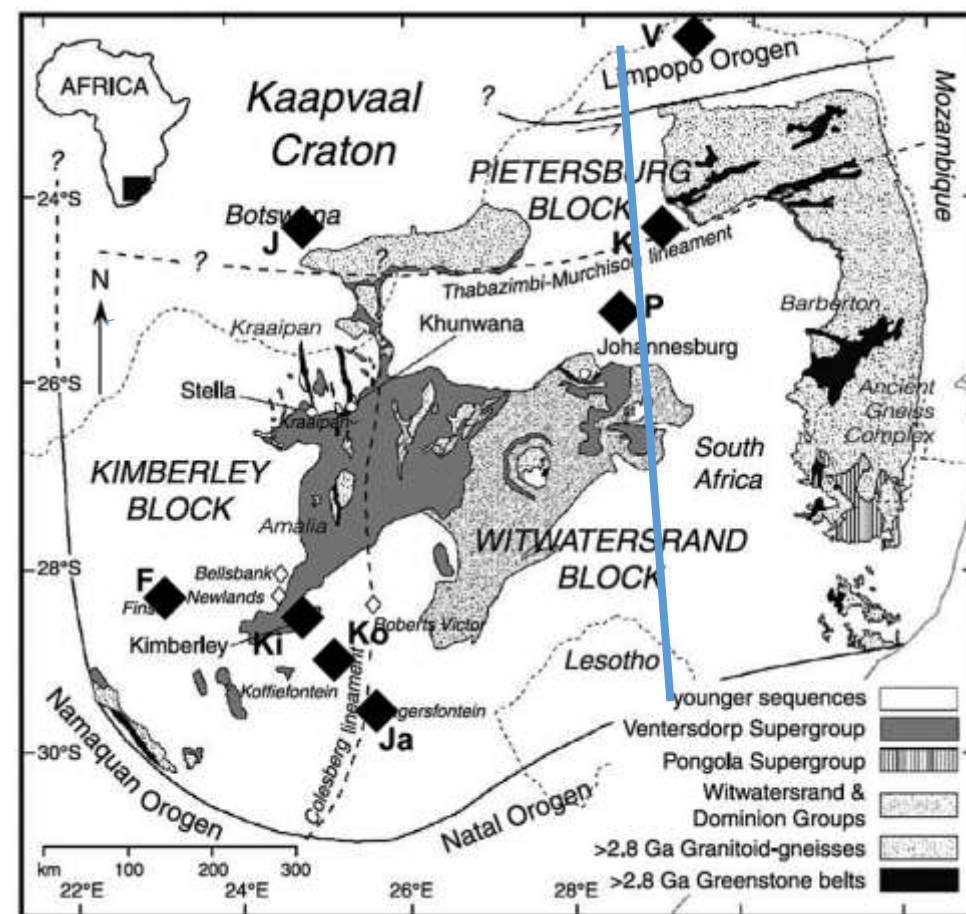
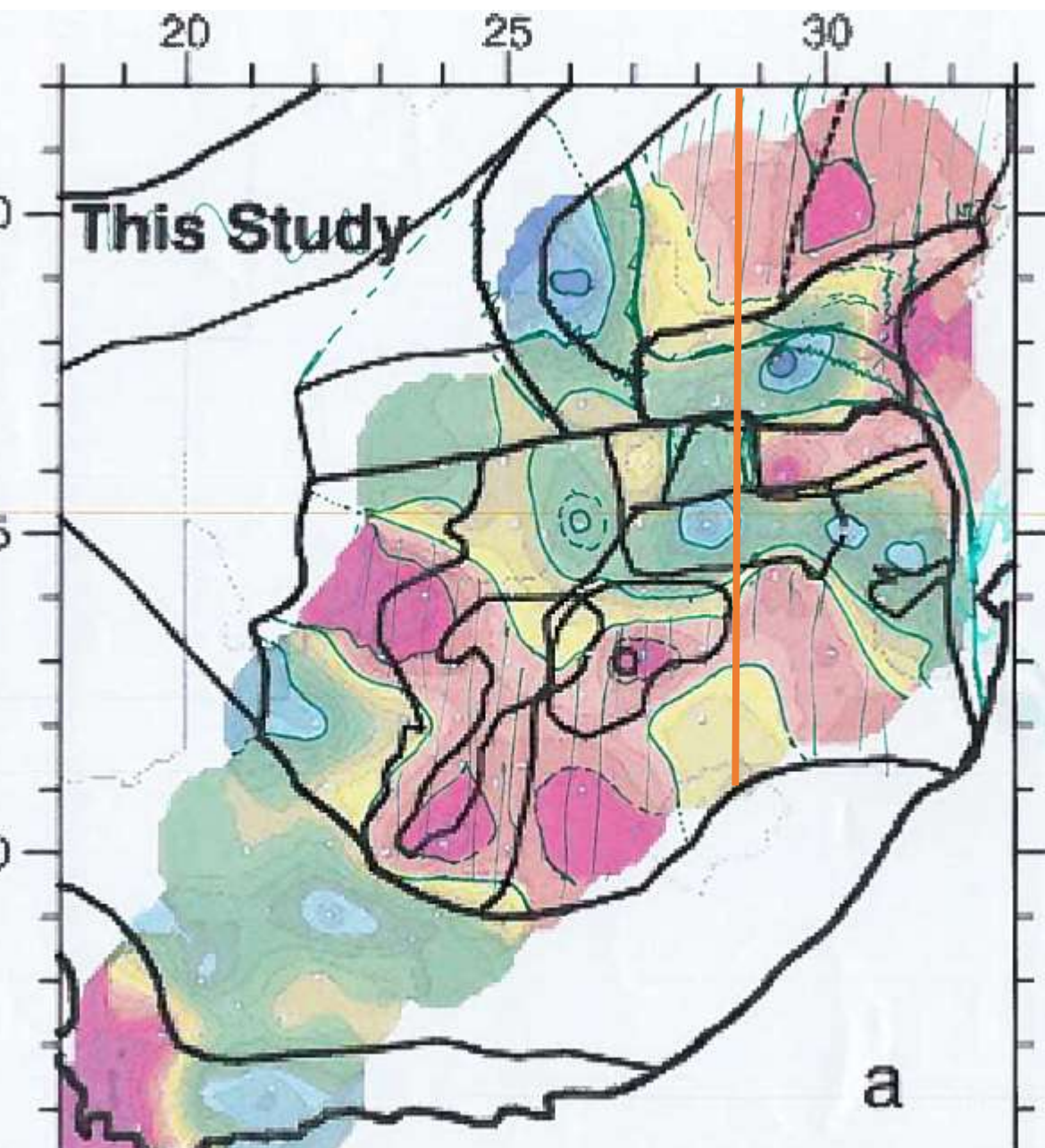


Figure 5. Schematic section of the continental crust adapted from Hawkesworth



Interpreted seismic profiles oblique to Colesburg lineament: east-ward thrusting and basinward thrusting direction

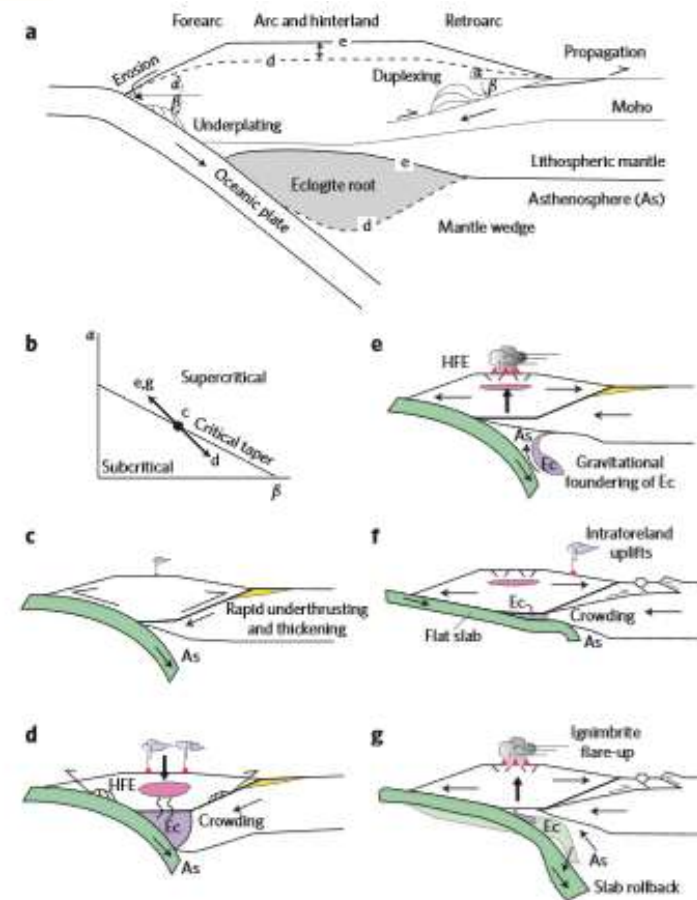
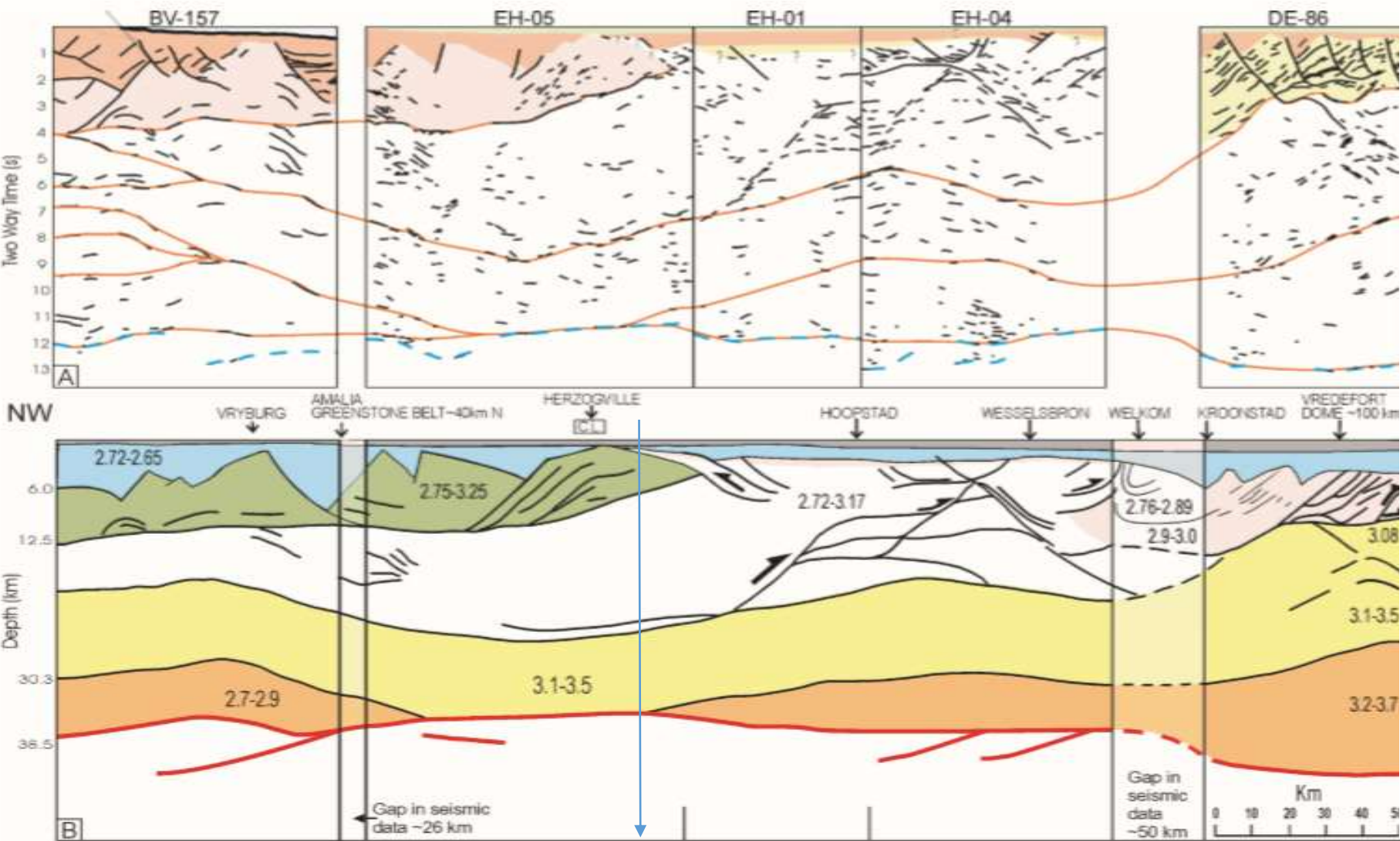


Figure 3 | Evolution of Cordilleran orogenic systems. **a**, Schematic cross-section (not to scale) of a Cordilleran orogenic system with a sediment-starved trench, illustrating the effects of eclogite root development and removal on isostatic and orogenic wedge taper ($\alpha + \beta$). For clarity, the magmatic arc is omitted. All lettered labels refer to other parts of this

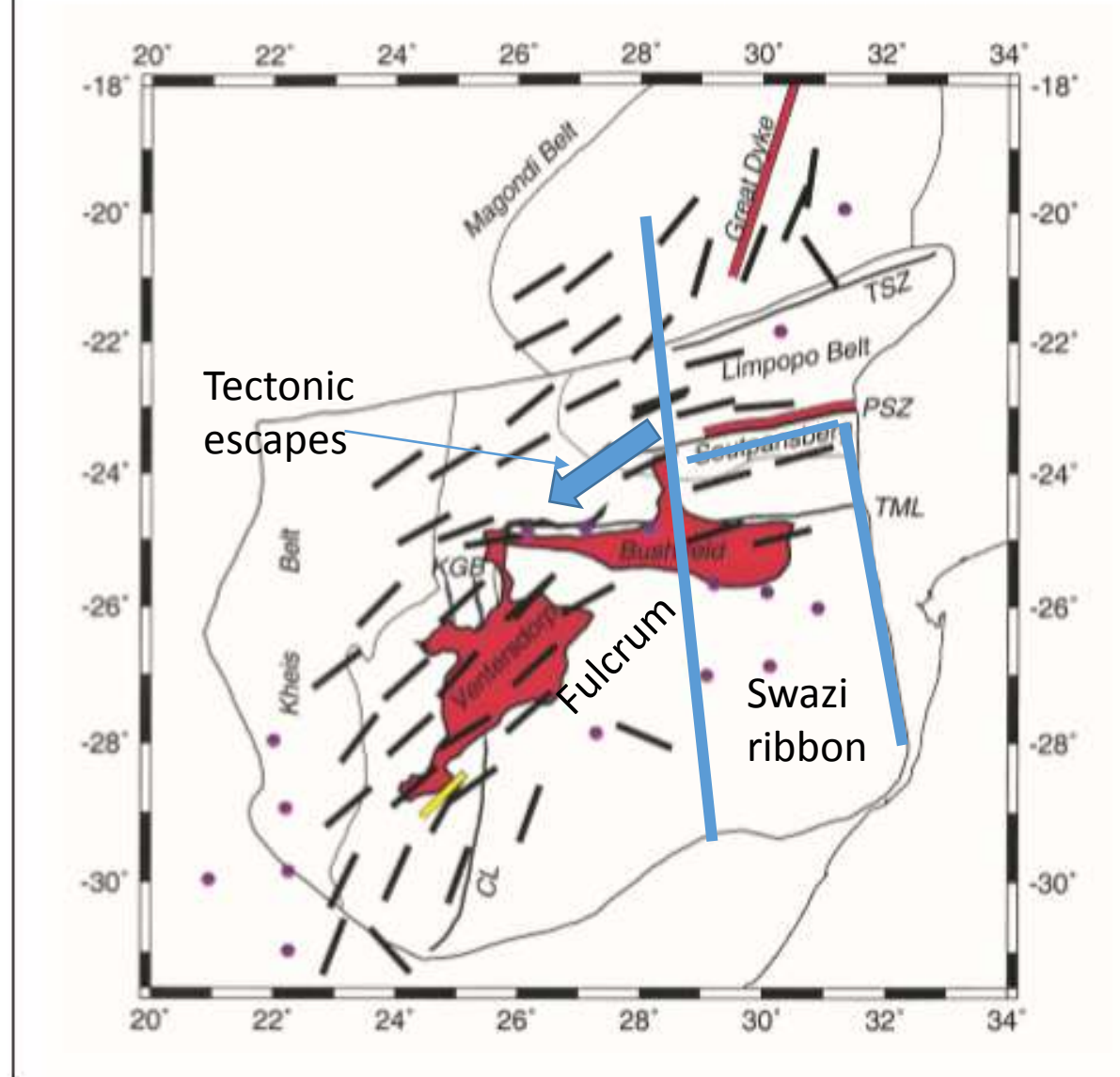


Figure 1. Map showing orientations of shear wave splitting fast polarization directions, ϕ , from the Kaapvaal Seismic Array (black bars) and from the high-resolution Kimberley Seismic Array (yellow bar, array average). Only highest-quality splitting measurements are shown. Purple dots represent measurements with zero or near-zero splitting delay times. Also shown are relevant geological features. Abbreviations: TML: Thabazimbi Murchison Lineament, CL: Colesberg Lineament, KGB: Kruatpan Greenstone Belts, SZ, shear zone. Major rift systems with basaltic magmatism: Great Dyke, Ventersdorp (surface exposures shown), Bushveld and Soutpansberg shown in red. The splitting reveals several interesting features: (1) an arc of values of ϕ from the southwestern Kaapvaal craton to the Limpopo and northern Kaapvaal Craton, with ϕ parallel to the trend of the arc. (2) Values of ϕ that are parallel to the Great Dyke in the Zimbabwe craton. (3) The contrast between relatively weak anisotropy within the eastern Kaapvaal shield, and stronger anisotropy in surrounding areas to the west and north. (after Silver *et al.*, 2001).

A problem awaiting solutions

2 A. Gumsley et al.: U–Pb baddeleyite geochronology and geochemistry

GFF 00(2016)

