Active vs. passive rifting in the South Atlantic from a petrologic perspective: an upwelling controversy
R.B. Trumbull, D.L. Reid, C. de Beer, R.L. Romer
GFZ Potsdam, University of Cape Town, Council for Geoscience
Volcanic Rifted Margins in Southern Africa

- **Seaward Dipping Reflector (SDR) wedges offshore**
- **Thick, high-velocity lower crust beneath the SDRs**
- **Continental flood basalts and central complexes onshore**
Problems with a Plume Scenario

Facies variations within the SDR zone
But no major volume changes N-S

Magnetic anomalies and spreading ages:
- south: anomaly M9 (130 Ma)
- north: anomaly M4 (126 Ma)

Rift progression from south to north
Leading Questions:

Was a thermal plume responsible for excess melting in the S-Atlantic LIP? (YES)

Did plume-enhanced melting continue the length of the volcanic rifted margin? (NO)

How can one tell?

   Petrology & Geochemistry of the volcanic rocks
   Geophysical attributes of the continent-ocean boundary
Petrology & Geochemistry of the volcanic rocks

NW Namibia

Etendeka flood basalts
~ 20 central complexes
HOD dyke swarm

Cape Peninsula

No flood basalts
~ 1 central complex
False Bay dyke swarm
**Rock compositions**

**HOD**: Diversity of magma types: tholeiitic and alkaline, higher equilibration pressure, higher MgO

**False Bay**: Only tholeiitic magmas, low-P cotectic, lower MgO
Estimating primary magma composition and temperature
Herzberg et al. (2007) G-cubed

Melt in equilibrium with olivine
HOD: max. 21 wt.% MgO
False Bay: max. 10 wt.% MgO

Olivine liquidus temperatures:
HOD: max. 1450°C
False Bay: max. 1230°C

Mantle potential temperatures:
HOD: max. 1590°C
False Bay: max. 1380°C

Temperature contrast N-S ~ 200°C
Summary of Dike Compositions

Northern Margin Segment:

- Dikes are compositionally diverse with lithospheric, asthenospheric, and crustal contributions to melting.
- Tholeiitic dolerites dominate; whole-rock and olivine compositions are Mg-rich, high magma temperature.

Southern Margin Segment:

- Dikes are all tholeiitic dolerite, probable lithospheric origin, similar in composition to north-segment tholeiites but with lower Mg (lower-temperature).
Active vs. passive Rifting: Controls on Mantle melting

Rates of mantle upwelling vs. rifting

Mantle potential temperature and bulk composition

from Korenaga et al., JGR (2002)
Geophysical attributes of the continent-ocean boundary

MAMBA 1

Thickness 24 km
Ave. Vp 7.3 km/s

\( \chi = \text{active upwelling} / \text{passive ascent} \)

\( \chi = 1 \)

\( \chi = 2 \)

\( \chi = 4 \)

\( \chi = 8 \)

Higher Tp

Oceanic crust

Active upwelling

Holbrook et al. (2001, EPSL)
Seismic petrology of high-velocity lower crust

Step 1) Seismic velocity vs. basalt composition (assemblage model)

### Graph 1
- **X-axis**: MgO (wt. %)
- **Y-axis**: Vp (km/s)
- **Data Points**
  - Black diamond: 800 °C
  - Red diamond: 900 °C

Step 2) Potential temperature vs. basalt composition (experimental calibration)

### Graph 2
- **X-axis**: MgO (wt. %)
- **Y-axis**: T (p) °C
- **Data Sets**
  - Batch melt experiments
  - Incremental batch melting
  - MELTS fractional melting

### Additional Information
- **Legend**
  - Kushiro et al. (1996)
  - Falloon et al. (1999)
  - Hirose & Kushiro, 1998
Potential Temperatures from "seismic petrology"

South margin: 1300 °C
North margin: 1500 °C

Trumbull et al. (2002) GSA Sp.Paper
Trumbull et al. (2007) SA Journal Geology
In conclusion

Dolerite dike compositions along the volcanic margin of S. Africa vary from north to south.

Northern segment: a thermal origin for excess melting produce the Etendeka-Paraná LIP for the high magma fluxes in the north, with mantle Tp as high as 1590°C.

Southern segment: „normal“ decompression melting with mantle Tp of 1300°C

Petrologic and petrophysical approaches agree, they support a passive rift model for the southern margin, and active rifting in the north.