Cratonic Lithosphere Group:

Reconciling geophysical and geochemical observations to understand craton lithosphere architecture

Group Members:

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Senior participants:

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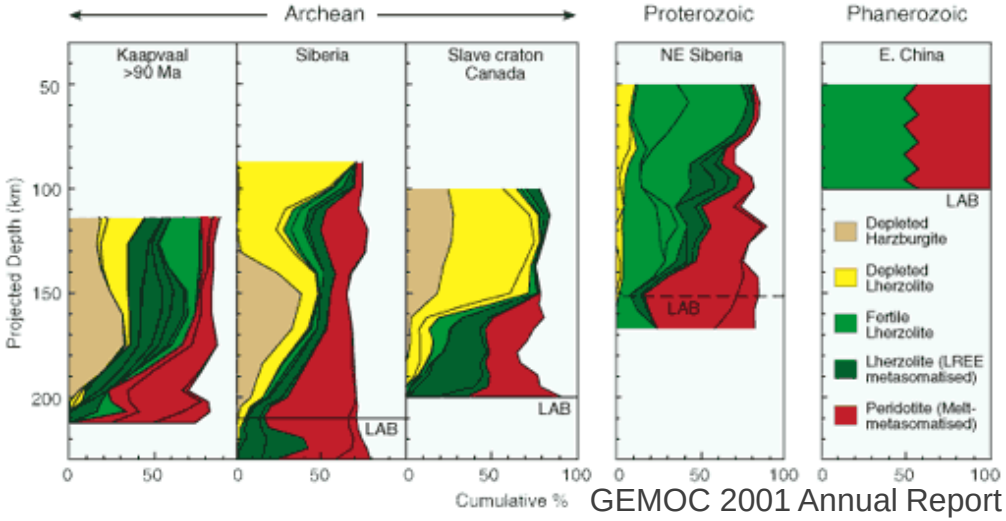
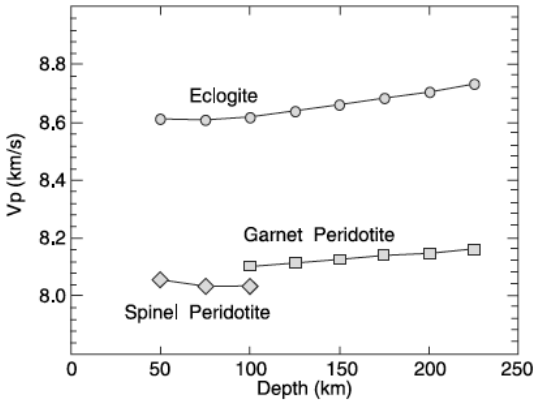
Motivation

- Understand why some cratons are stable and others are not
  - However, there is no “typical” stable craton
- Within the stable cratons, some are stratified and others are not
  - How does this relate to craton formation?
  - How is it that two cratons with differing (geophysical and chemical) internal structures persist since the Archean?

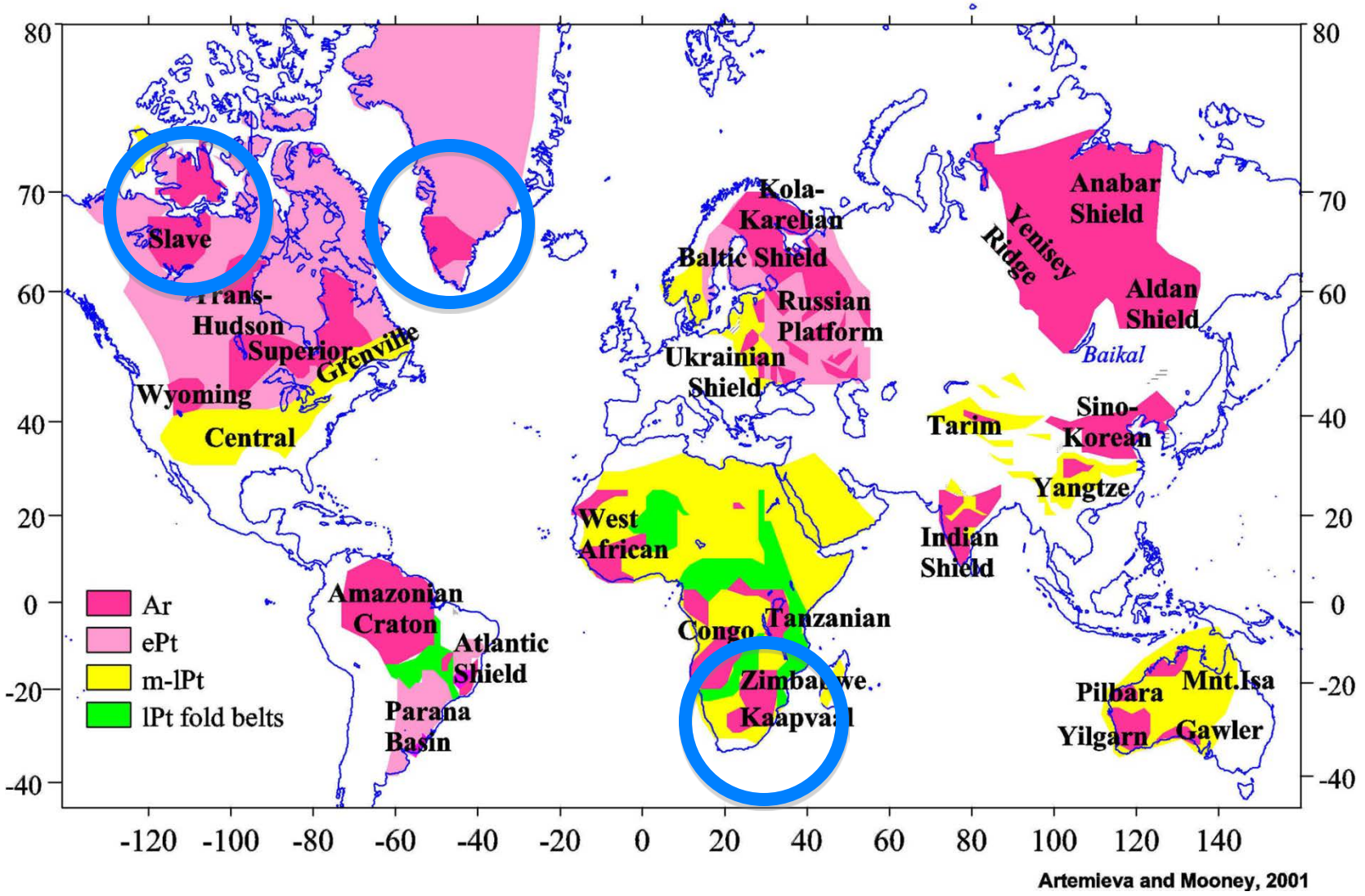


GEMOC 2001 Annual Report



Carlson et al., 2005

Distribution of Cratons by Age



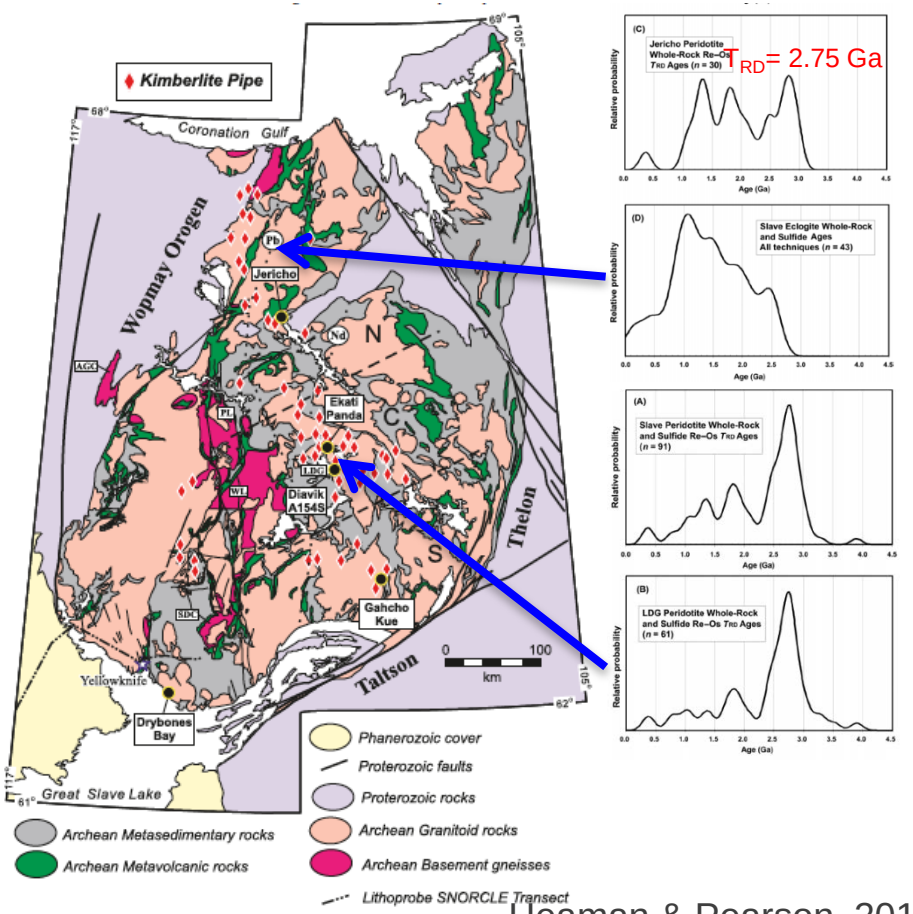
Approach

- Geochemistry:
  - Compile mantle xenolith data (composition and age) and compare between different cratons
  - Compile crustal data (composition and model ages) and compare with xenolith record
- Seismology:
  - Analyze various geophysical data and compare between different cratons
  - How do these differences compare with geochemical observations?
- Geodynamics:
  - Perform numerical simulations for different craton structures and tectonic environments (subduction vs. adjacent plume)

Geochemistry:

mantle xenolith and crustal compositions

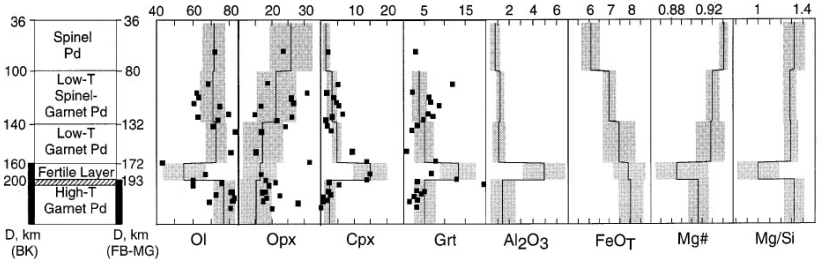
Slave Craton



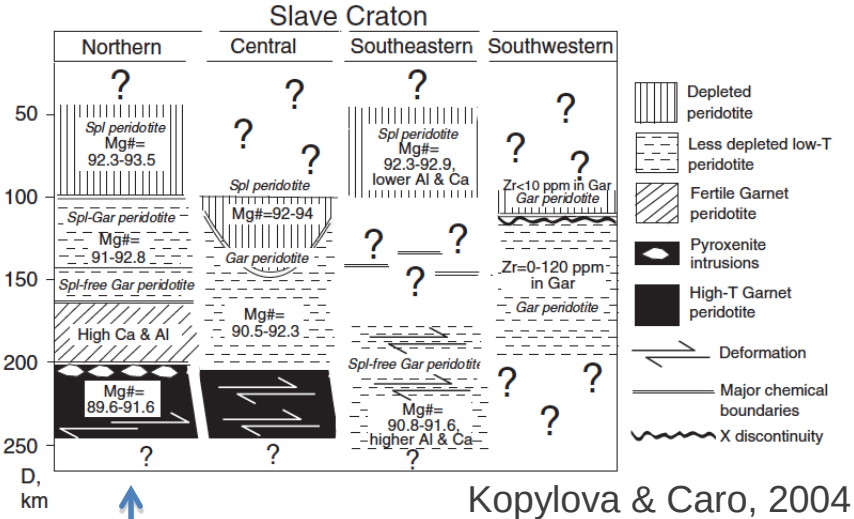
T_{RD}= 2.75 Ga

Heaman & Pearson, 2010

Northern Slave Craton



Kopylova & Russell, 2000

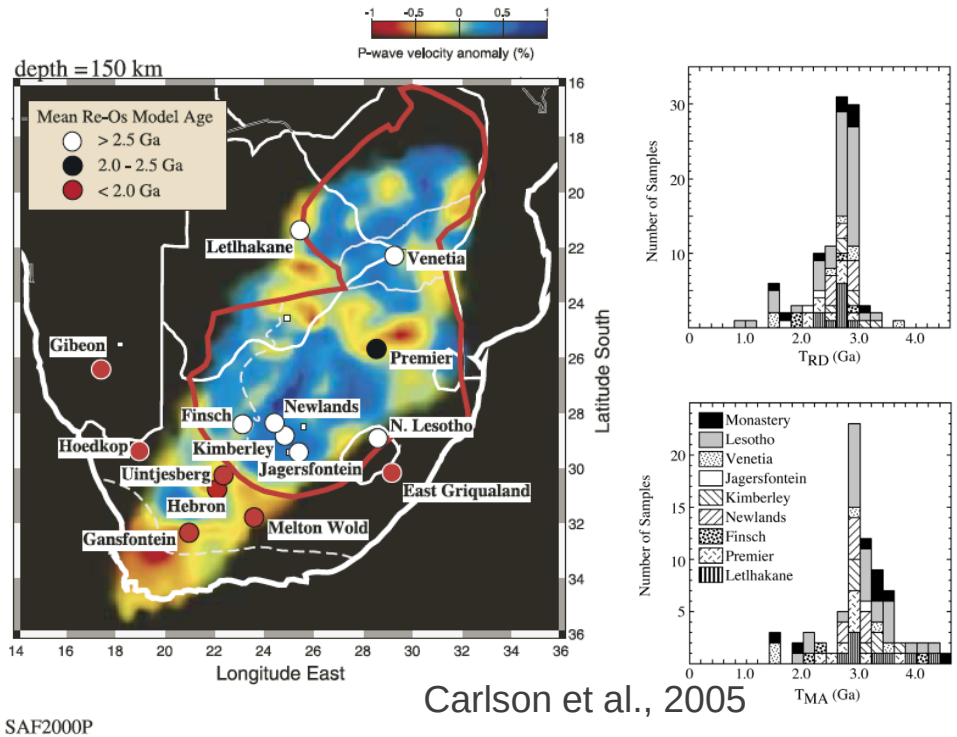


Kopylova & Caro, 2004

- T_{RD} peaks at 2.75 and 2.1-1.8 Ga.
- Harzburgites: 3.5-3.3 Ga in central region underlie sp-lherzolite
- Eclogite: formed 2.2-2.0 Ga

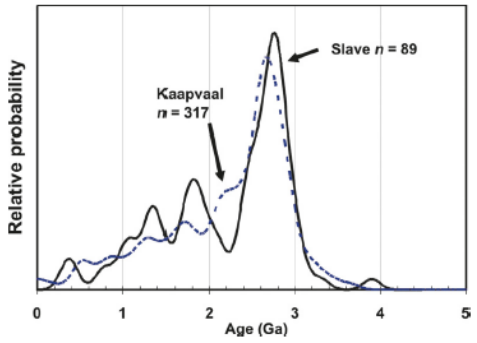
Younger w/ depth

Kaapvaal Craton



Carlson et al., 2005

SAF2000P

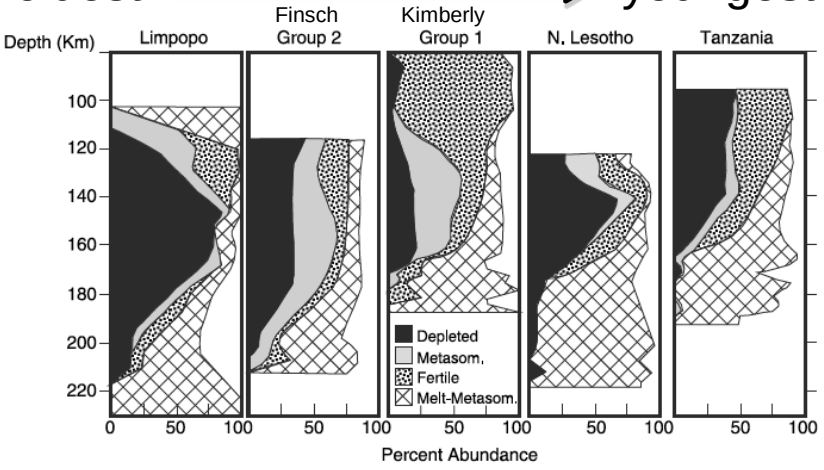


Heaman & Pearson, 2010

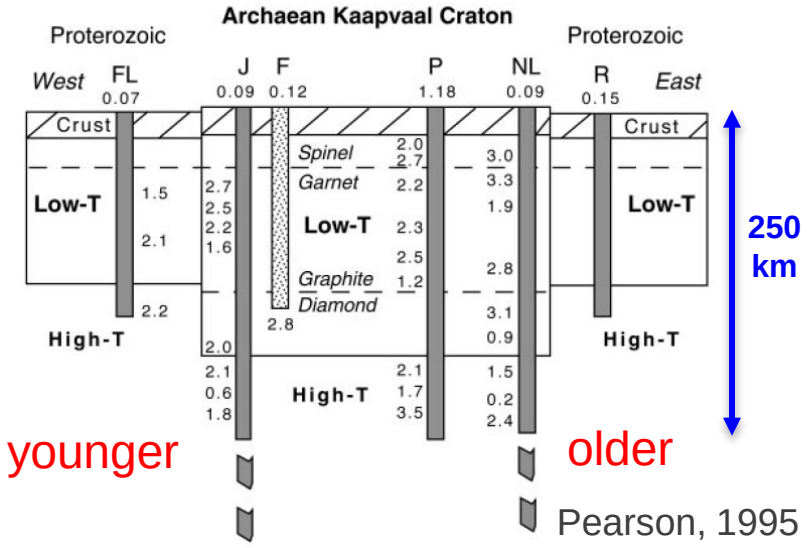
Kaapvaal:

- T_{RD} peak at 2.8
- Silica-rich (high modal opx)
- same as mean Slave age

oldest → youngest



Griffin et al., 2003

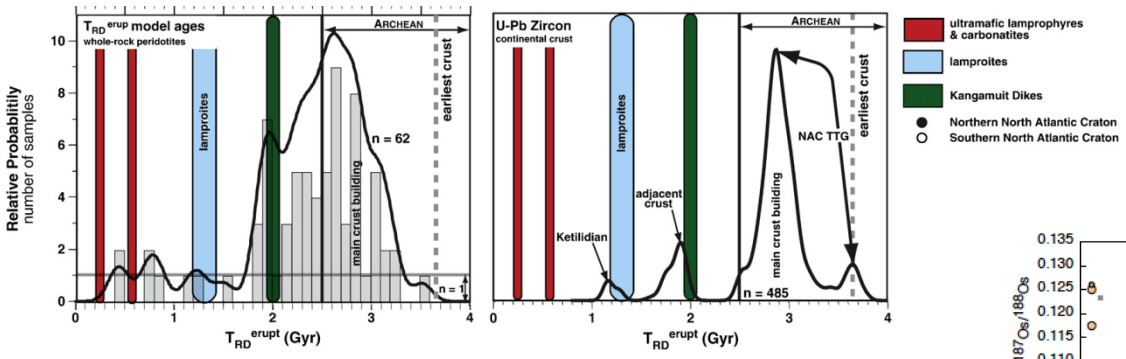


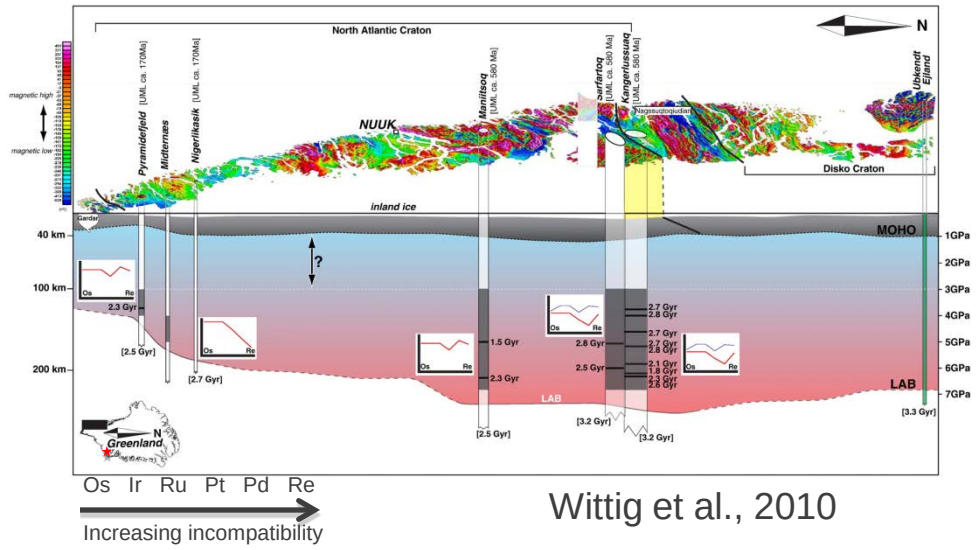
Pearson, 1995

North Atlantic Craton

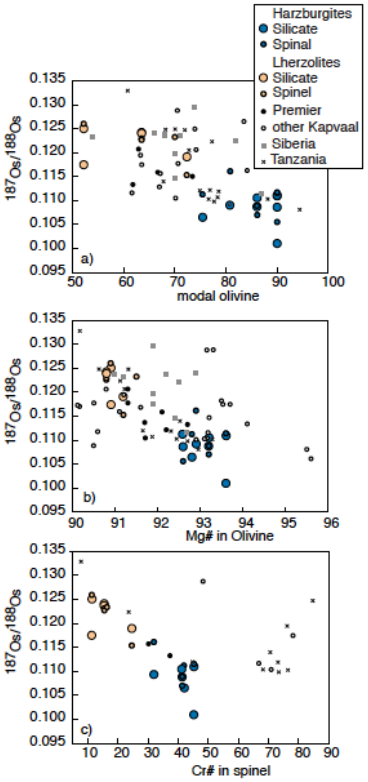
peridotite

crust



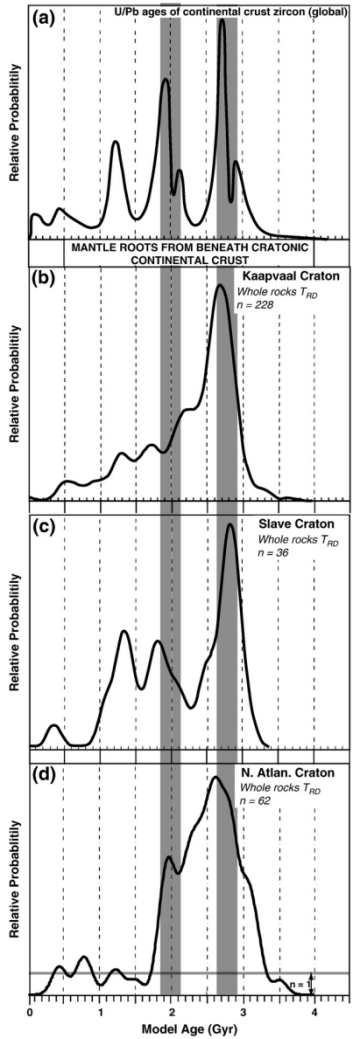


Wittig et al., 2010



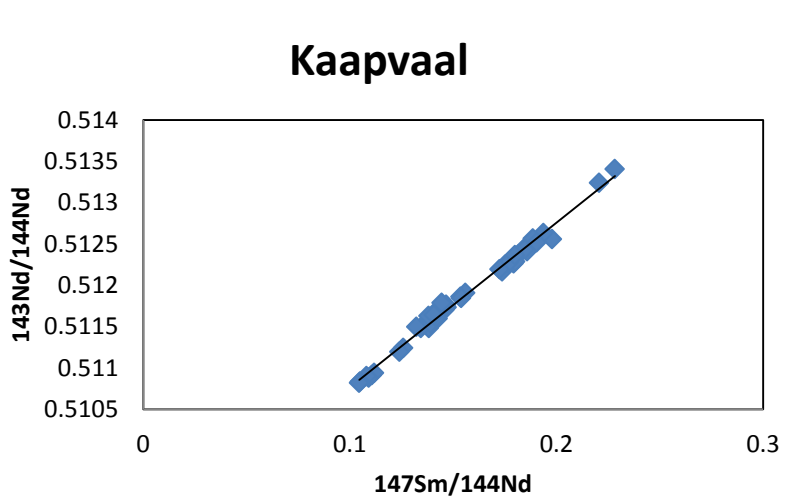
Hanghoj et al., 2001

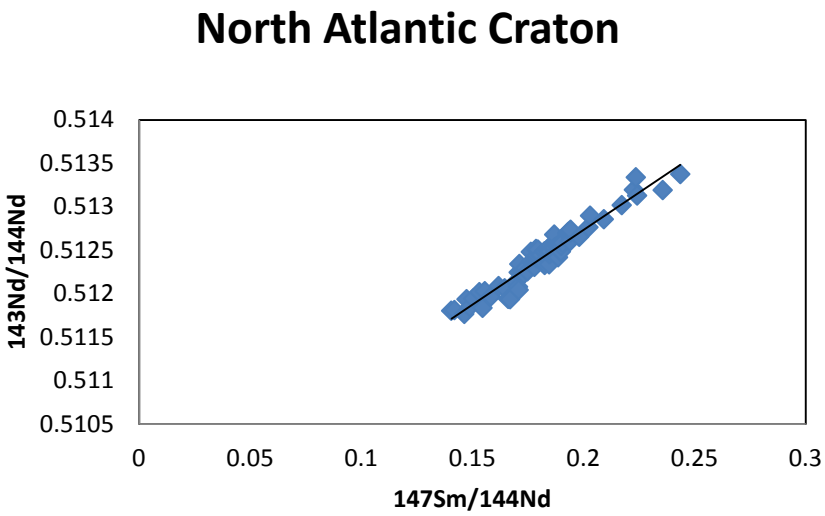
Craton comparison

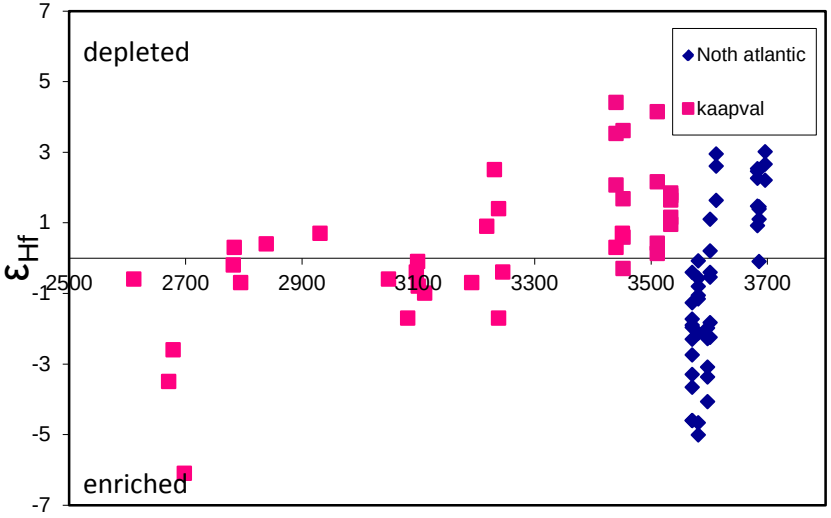


Wittig et al., 2010

Sm-Nd Crustal Ages







North Atlantic Craton: 2.6 Ga

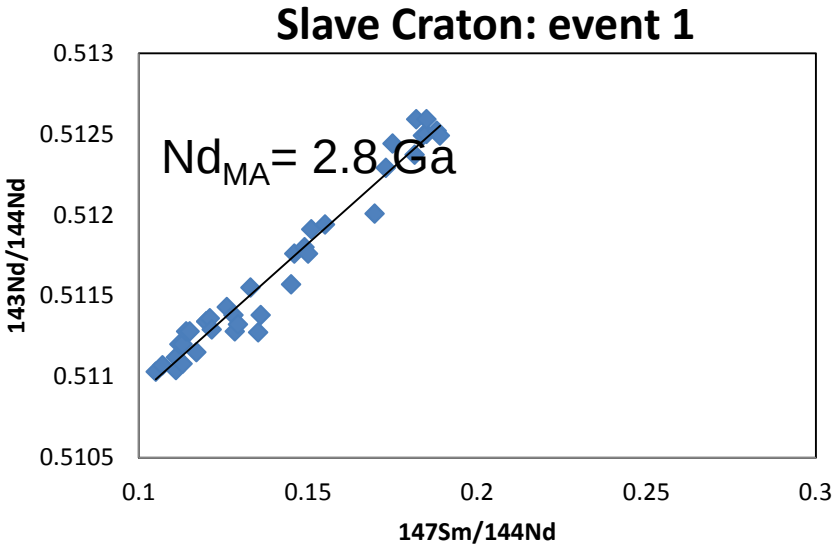
- Single trend observed but may represent multiple events

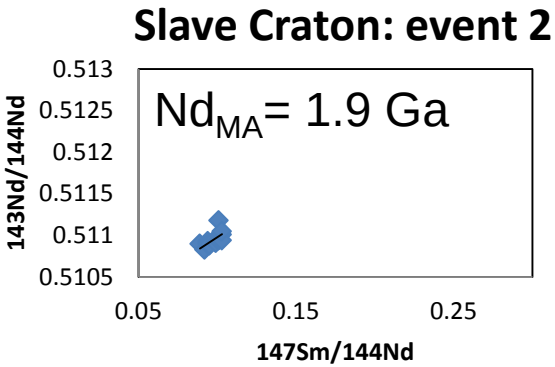
Kaapvaal: 3.0 Ga

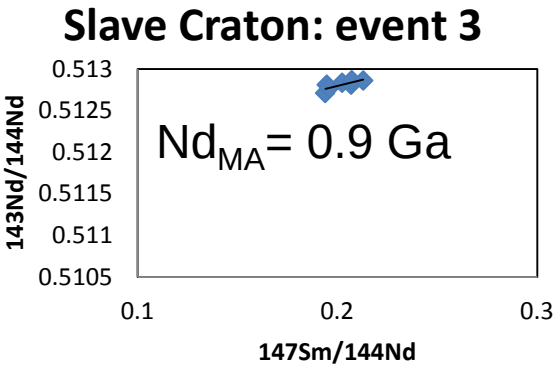
- One apparent event

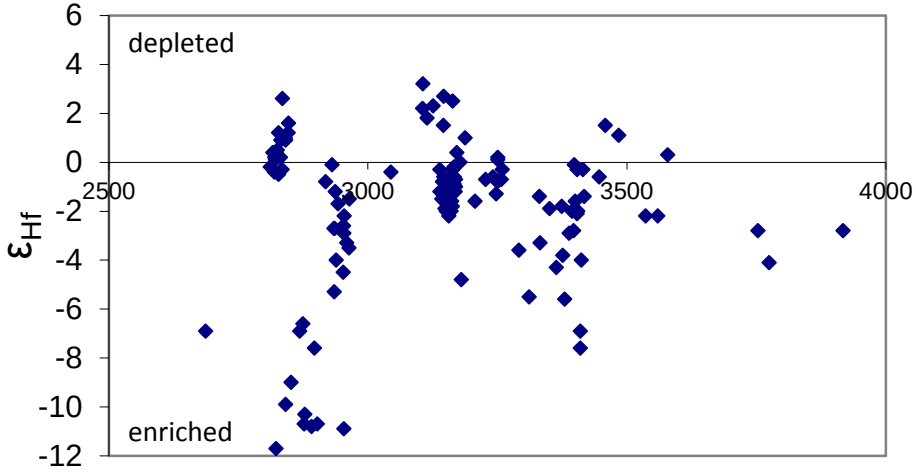
Sm-Nd compilation from: GEOROC
Hf from: Amelin, 2000 & Zeh, 2008

Sm-Nd Crustal Ages









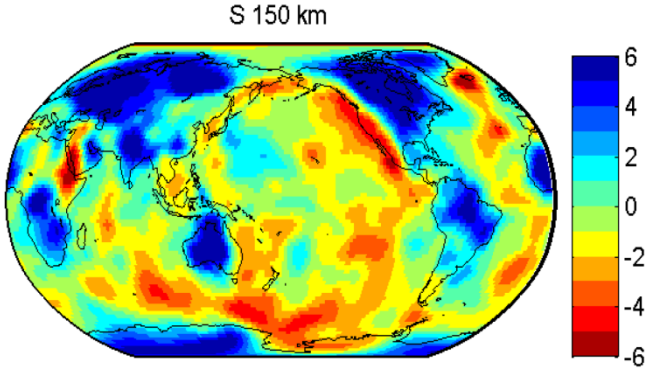
Data compilation from: GEOROC

- Three differentiation events revealed by Nd model ages
- Slave craton: detrital zircons may reflect mixture of sources (unknown)

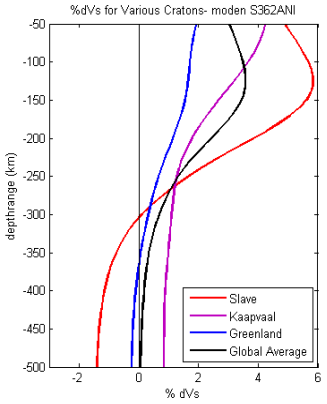
Seismology

Global Data

Global Vs Tomography

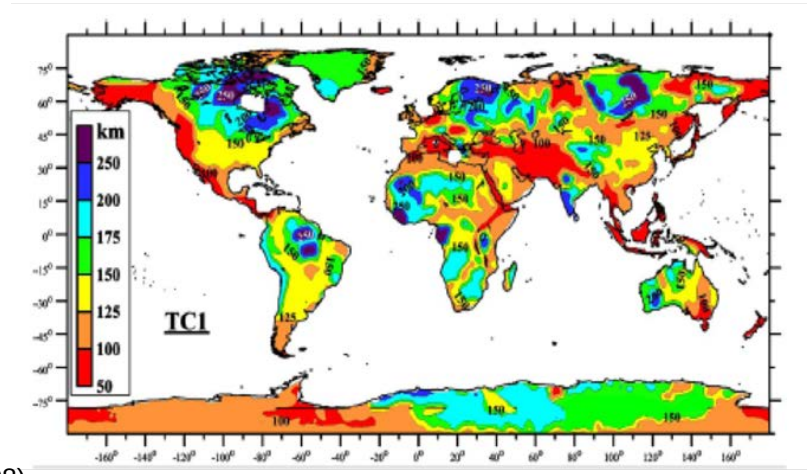


SEMum2 (French et al. 2011 AGU)



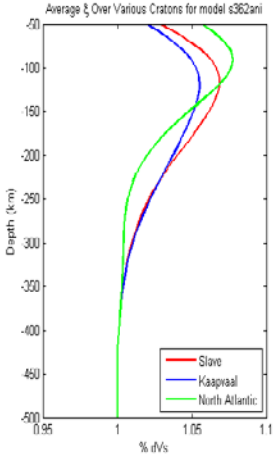
S362ANI (Kustowski et al. 2008)

Global Heat Flow



Artemieva 2006

Global Relative Anisotropy

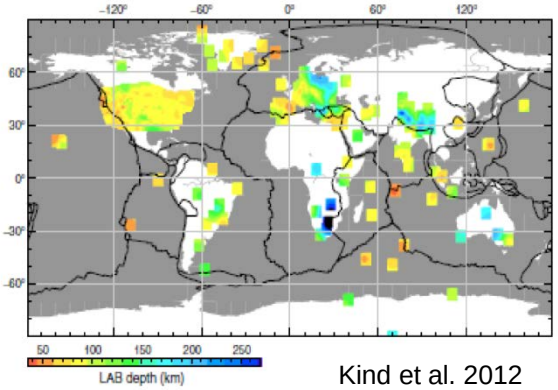


S362ANI (Kustowski et al. 2008)

- Useful for large scale comparison between cratons
- Problem-Lacks detail- tends to smooth features

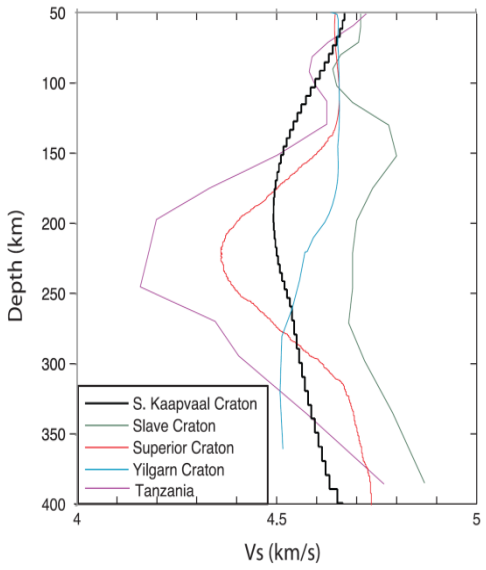
- Some Observations-
  - Slave –Faster Vs , More distinct high velocity “Lid” than Kaapvaal & North Atlantic
  - North Atlantic- Slightly higher degree of anisotropy limited to shallower depths than Slave & Kaapvaal
  - Deepest SRF LAB present in Kaapvaal
  - Lowest heat flow in Slave

SRF Data

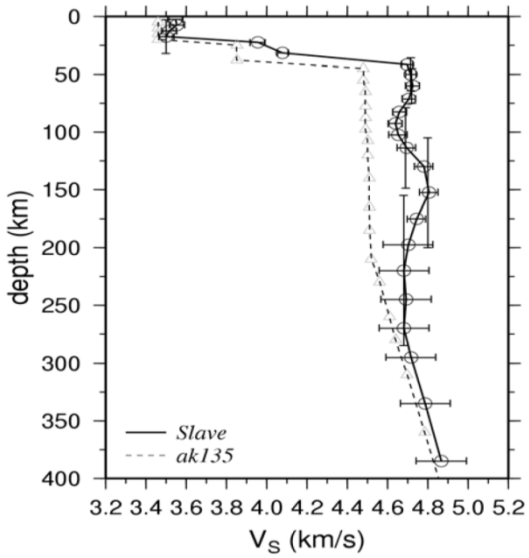


Kind et al. 2012

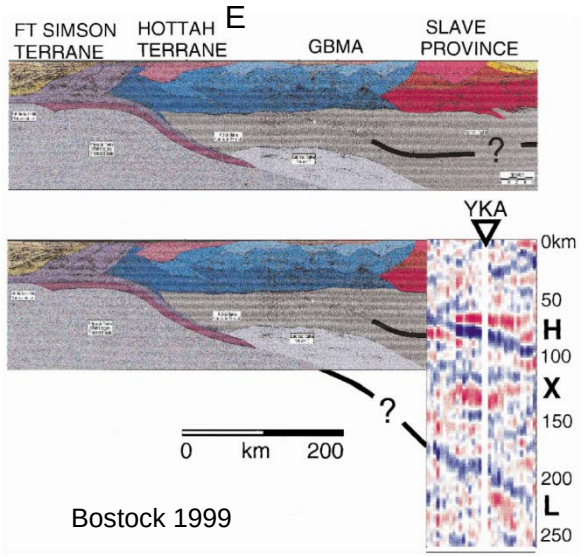
Regional Data-Slave



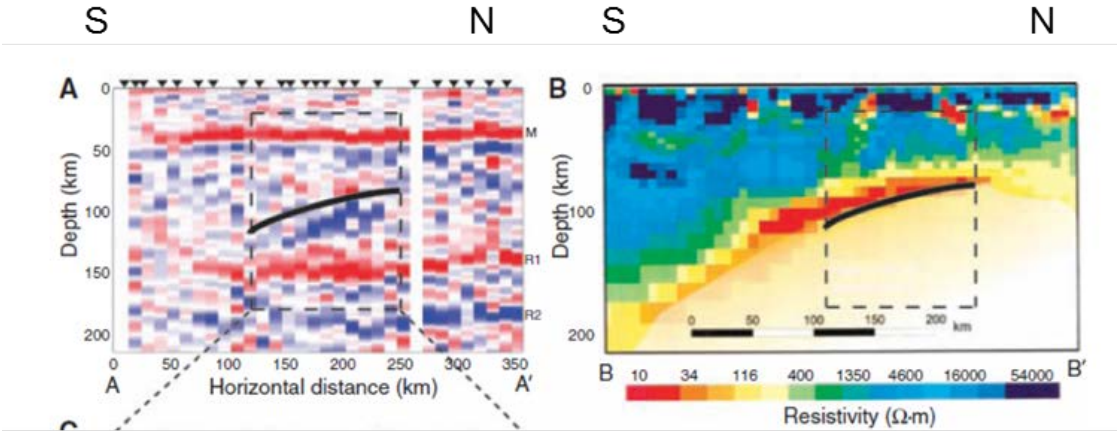
Adams & Nyblade 2011



Chen et al. 2007



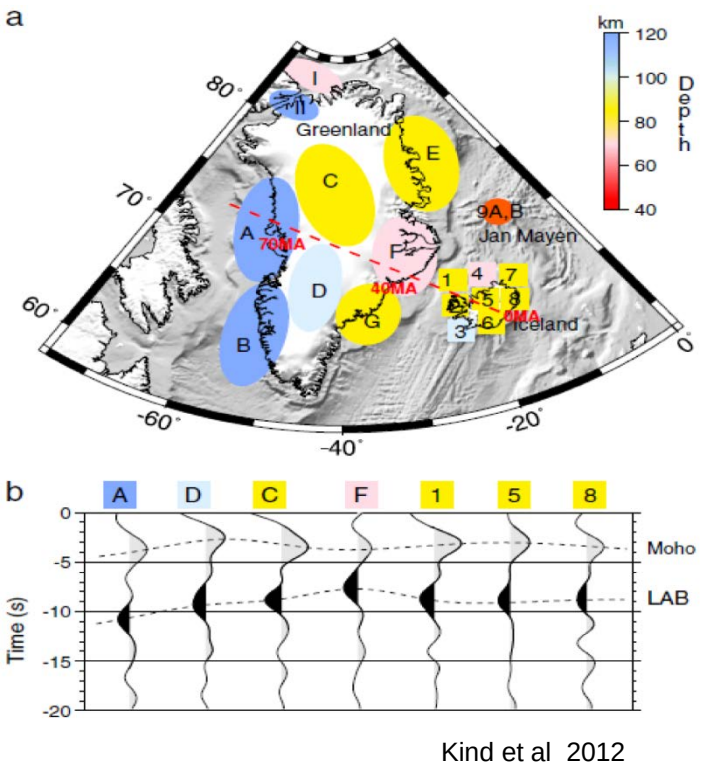
Bostock 1999



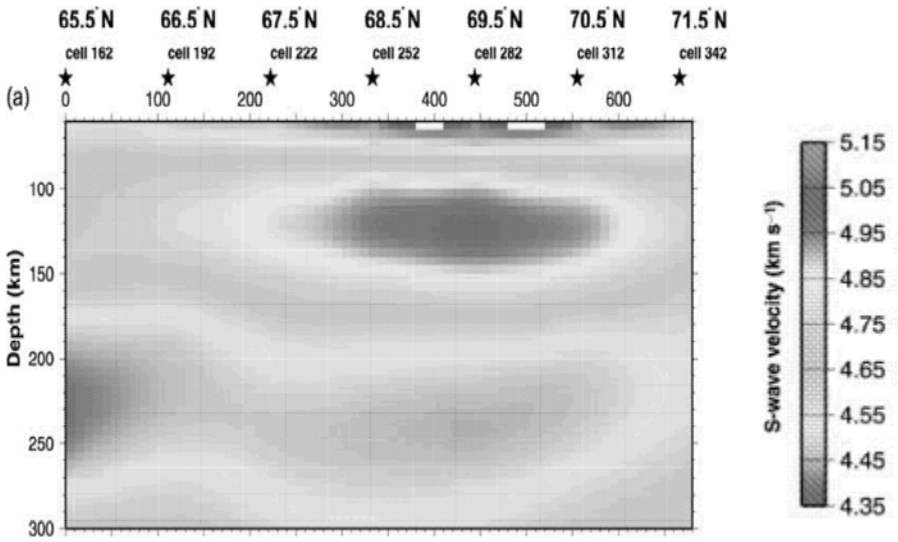
Chen et al. 2009

- Better for observing small scale structure
- Problem- Limited data in some areas
- Observations-
  - Bimodal nature of Slave velocity stucture is apparent in both Vs and receiver functions while the Kaapvaal still appears to have one layer
  - Apparent dipping structures visible in receiver function plots
  - Resistivity data show an anomaly in center of the craton, possibly due to the presence of graphite near the graphite to diamond transition zone.

Regional Data-North Atlantic



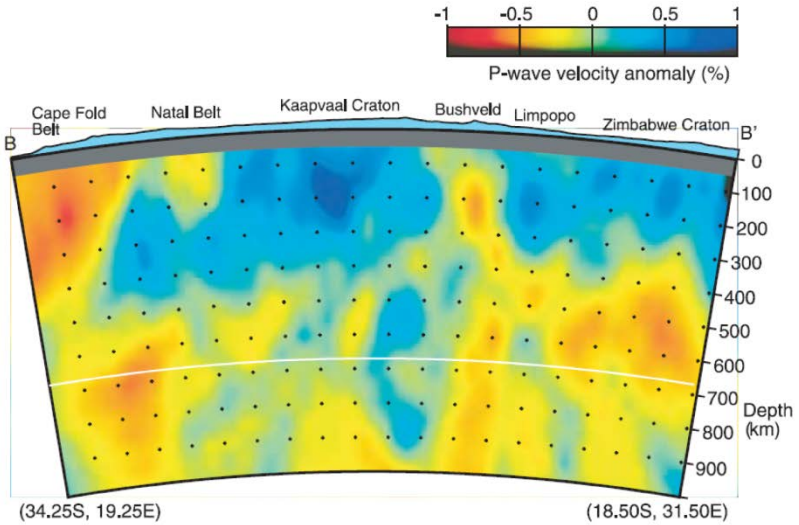
Kind et al 2012



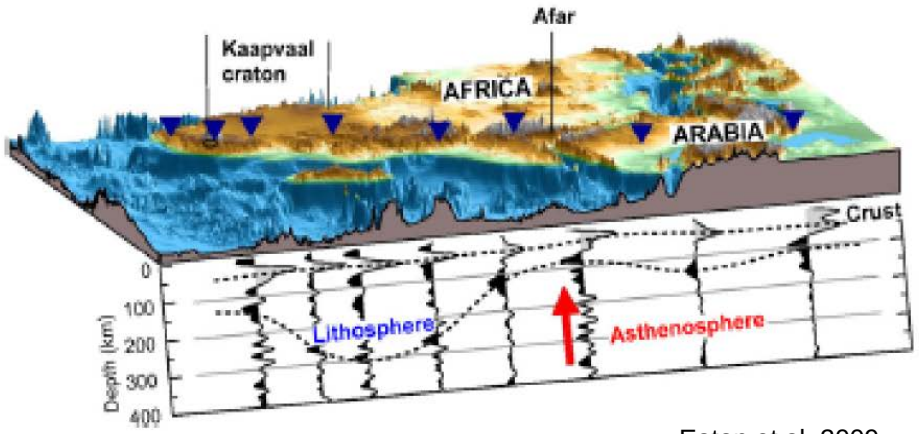
Darbyshire et al. 2004

- Observations
  - Depth to LAB (per RF's) in Greenland appears to shallow to the east
  - High velocity zone apparent in S-N Vs profile however, details are not apparent
  - In both these studies areas much larger than the North Atlantic craton are covered so detail may be lost
  - The North Atlantic craton is not well represented in the literature, and the above studies don't have high resolution in the area of interest
  - An SRF study is planned to explore the finer scale structure of the North Atlantic craton

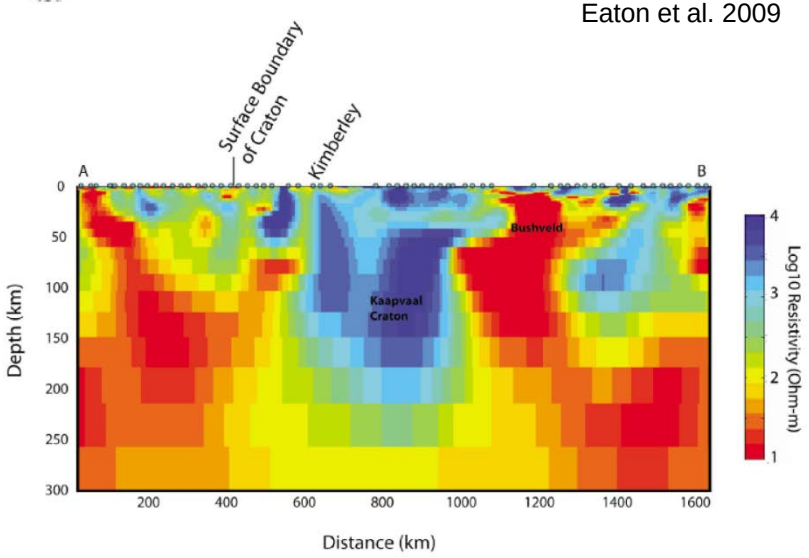
Regional Data-Kaapvaal



James, 2003



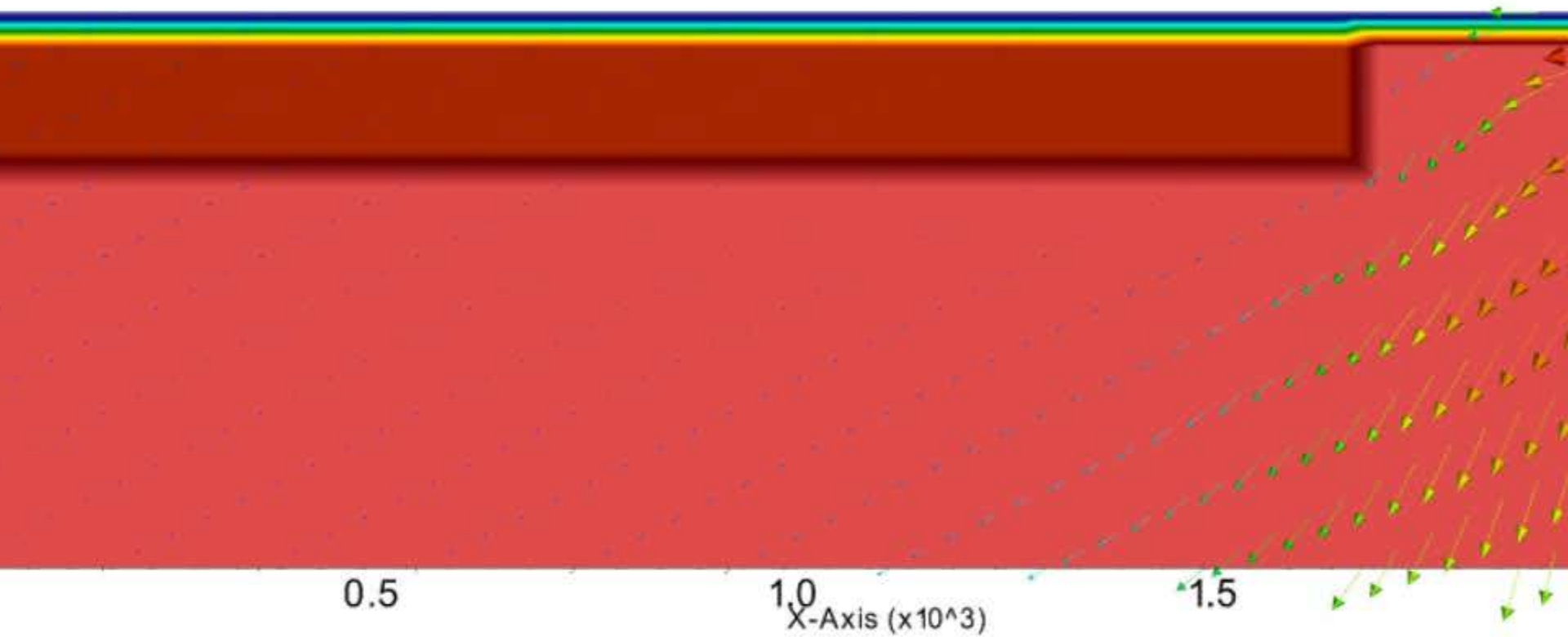
Eaton et al. 2009

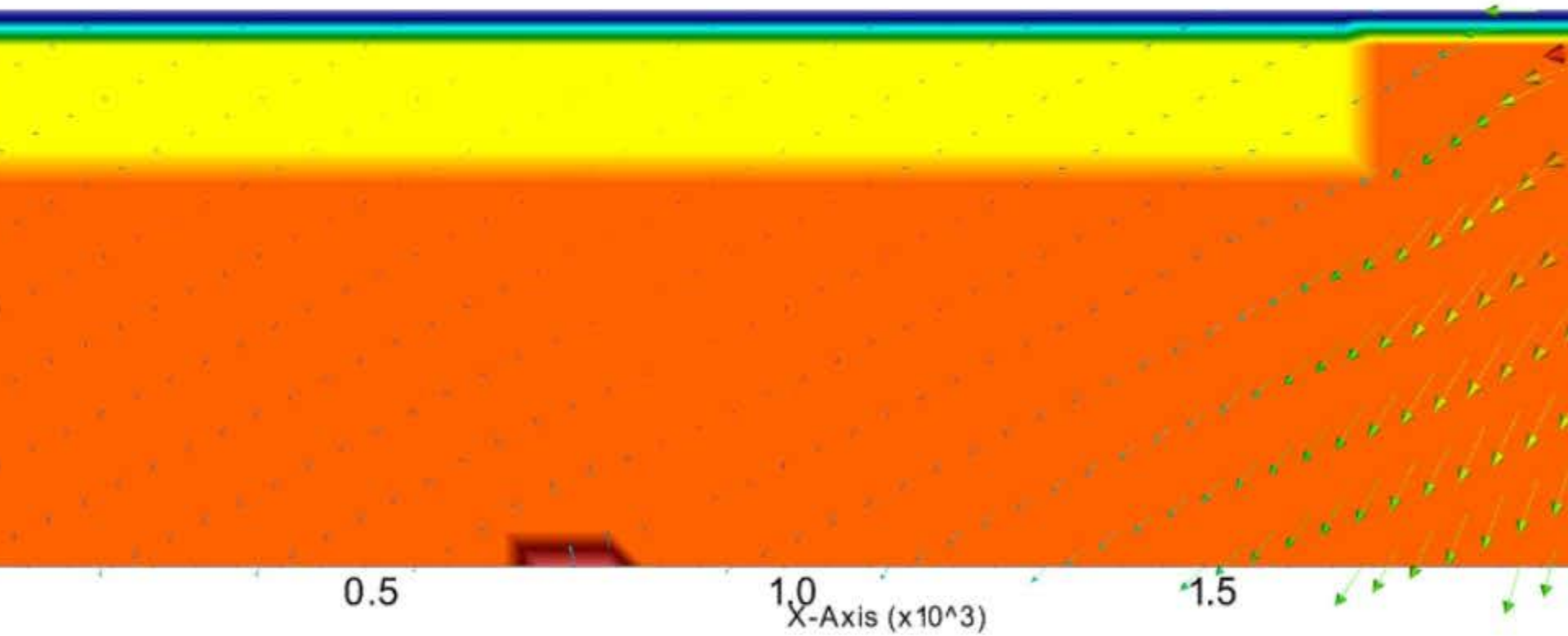


Evans et al. 2011

- Observations
  - Kaapvaal craton does not appear to show the distinct velocity layering apparent in the Slave craton
  - There is no apparent low resistivity layer present in the Kaapvaal
  - The receiver function study does not show obvious mid-lithospheric discontinuities, however, the scale of the study is probably too large to show their presence

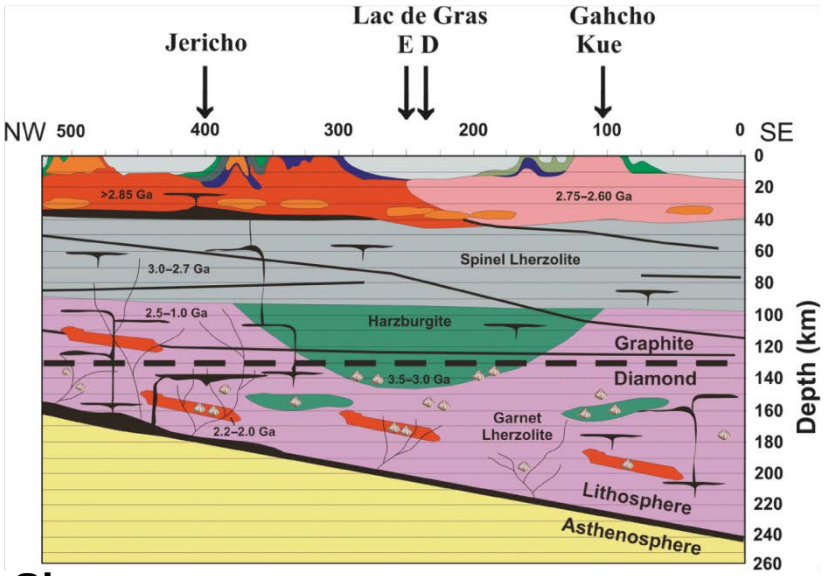
Geodynamics:
Preliminary modeling results


0.5
1.0
1.5
X-Axis (x10^3)


0.5
1.0
1.5
X-Axis (x10^3)

Summary

Slave Craton



Slave:

- Compositional layering: spinel lherzolite underlain by harzburgite and eclogite
- Low resistivity layer may be at graphite-diamond transition
- Tilted reflectors may related to subducted slab (eclogite pockets)

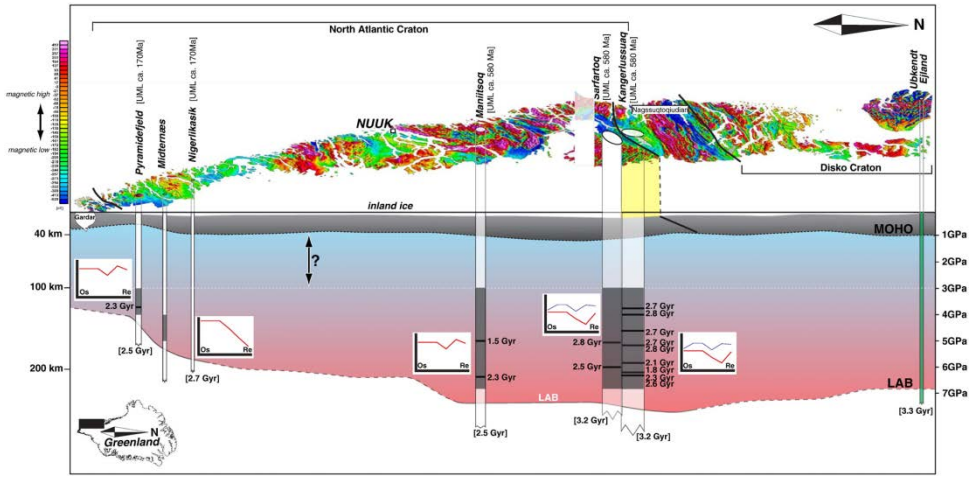
N. Atlantic Craton:

- Lithosphere stabilization at the Meso-Neoarchean boundary (2.8 Ga)
- Corresponding Sm-Nd crustal age and T_{RD}
- ε_{Hf} shows a shift at 3.6 Ga consistent with zircon crust building ages

Kaapvaal:

- Complex xenolith record—lack of age-depth relationship, but younger western block
- opx-rich harzburgites—subduction overprint of Si-rich fluids
- Apparent single crust formation event (e.g. Sm-Nd model age)
- No distinct seismic layering and no low-resistivity zone (no subducted slab?)

N. Atlantic Craton



What's next

- Short Term:
  - Team will present a poster at Fall AGU
  - Write research proposal to continue group work
  - Use compositional data to calculate V_s using perple_x and compare with seismic observation
  - Create better compilation figures for each craton (composition vs. depth placed on top of seismic reflectors)
- Long Term:
  - Beth (receiver function study of north atlantic craton)
  - Discuss possibility of writing a review paper comparing these three cratons
  - Input real data (compositional layers) into numerical model for craton survival