How does the presence or absence of an upper-mantle plume influence extension?

Origin of magmas from a geochemical perspective

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cenozoic volcanism

why magma ?

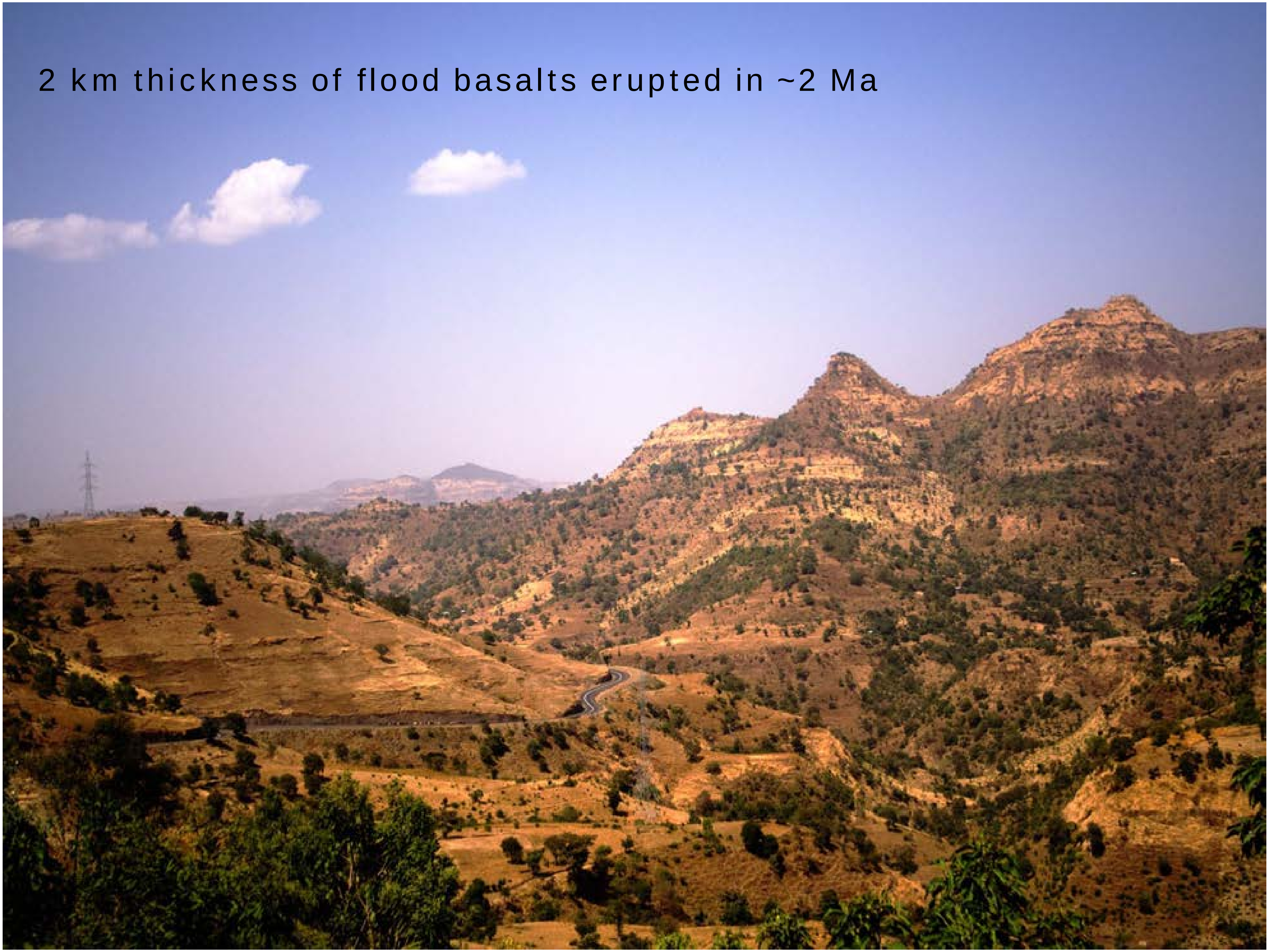
Magmas may be necessary to weaken the lithosphere to initiate rifting

Magmas directly record the thermo-chemical state of the upper mantle during rift evolution

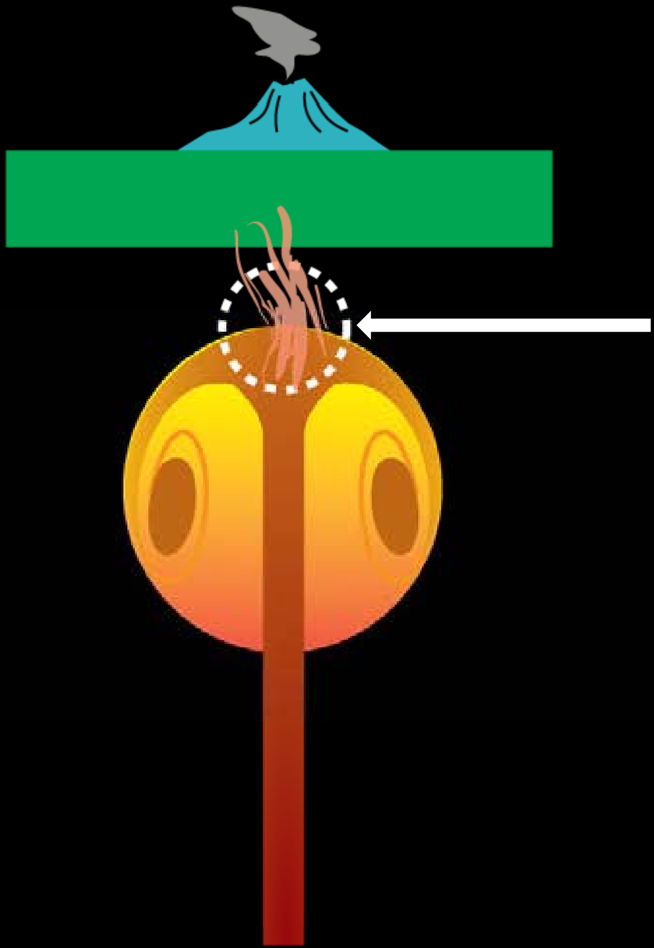
Magmas provide a time window into upper mantle processes

The presence of magma profoundly influences the interpretation of geophysical images of the asthenosphere and lithosphere

Magmas eventually accommodate lithospheric extension

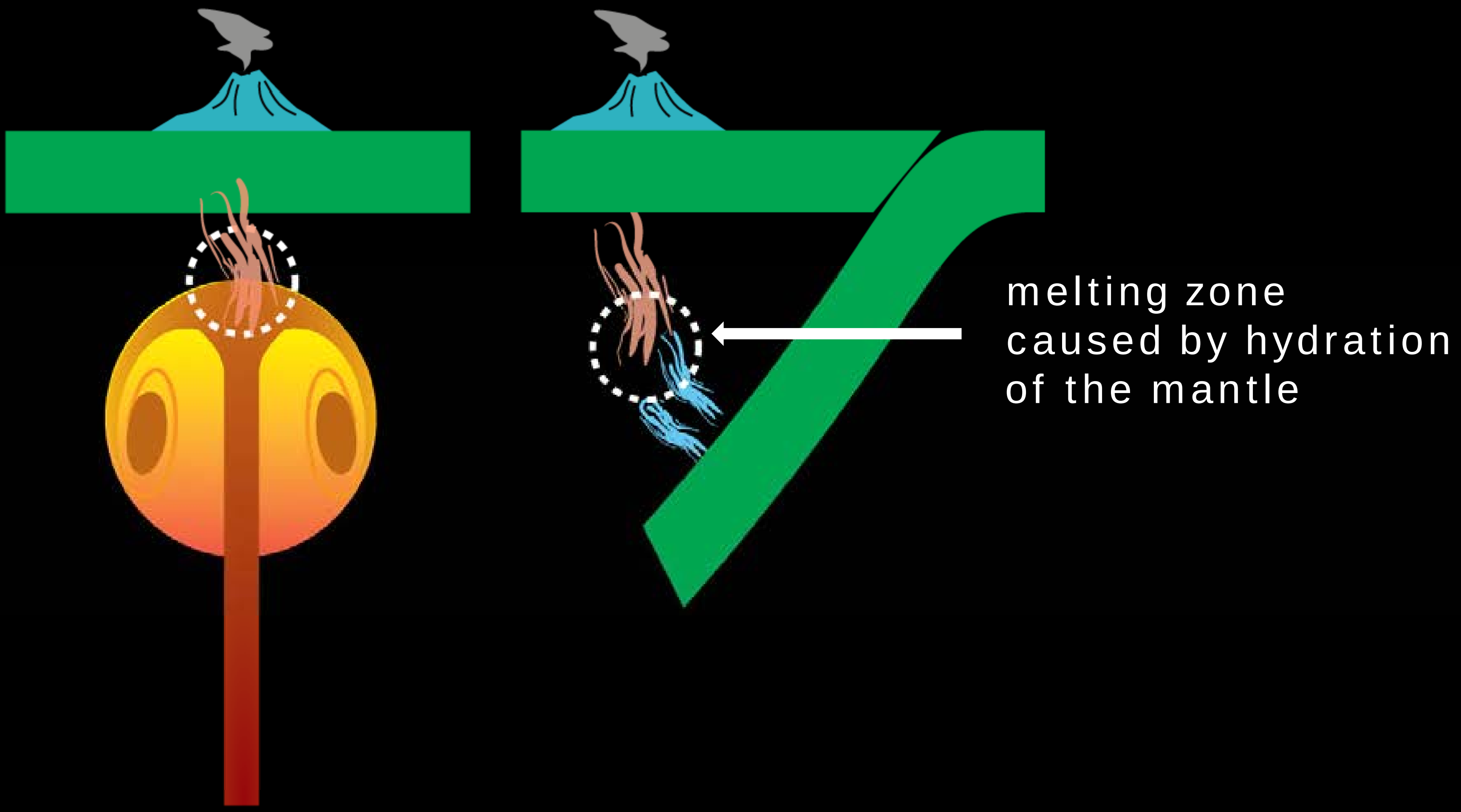

2 km thickness of flood basalts erupted in ~2 Ma

creating melts

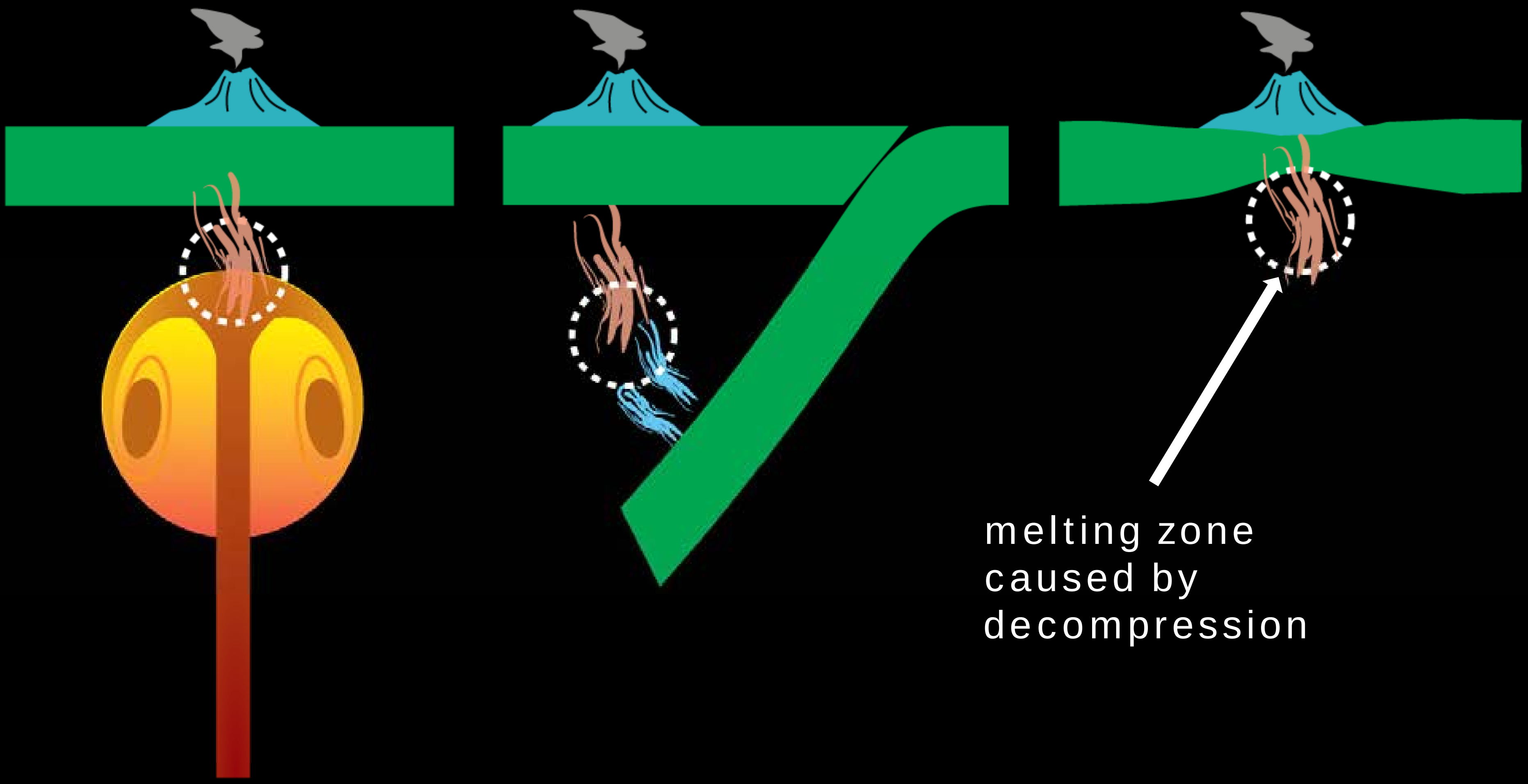


melting zone
caused by increased
mantle temperature

creating melts



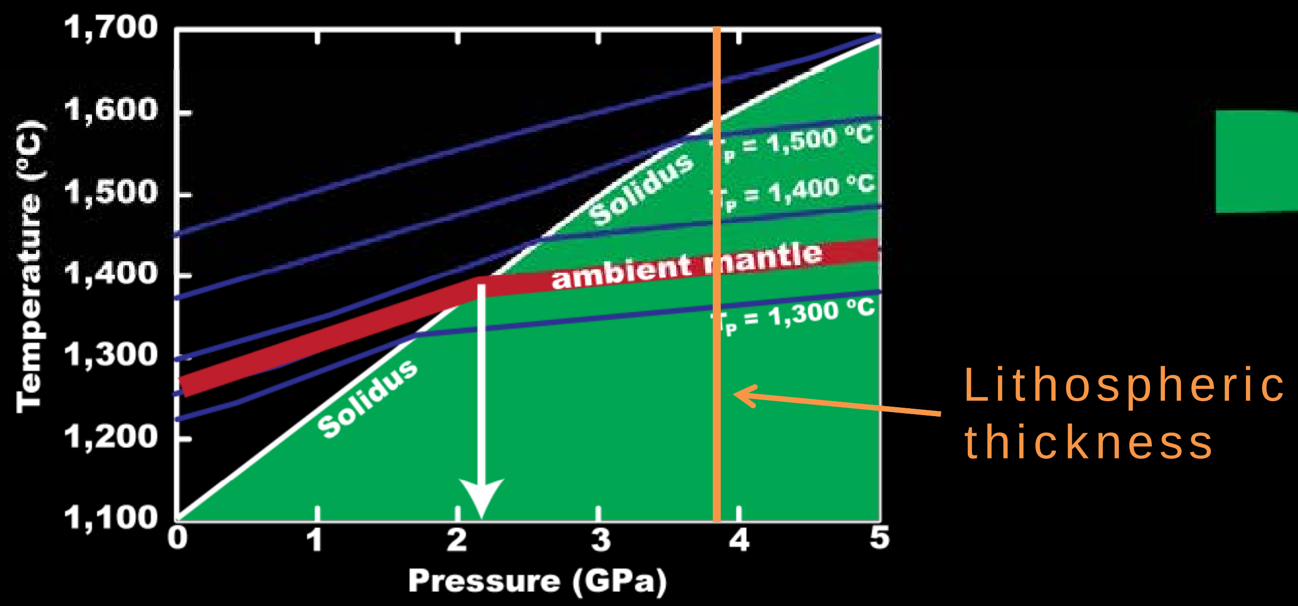
creating melts

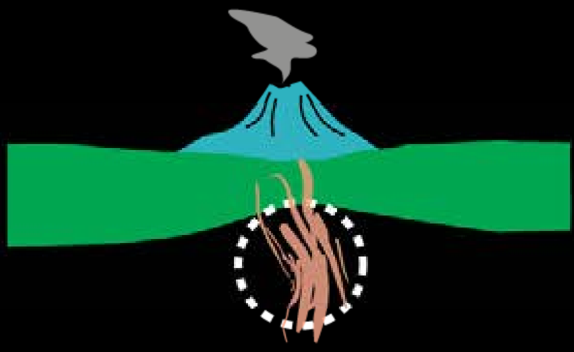


creating melts

Mantle plumes and the origin of magmas from a geochemical perspective

creating melts

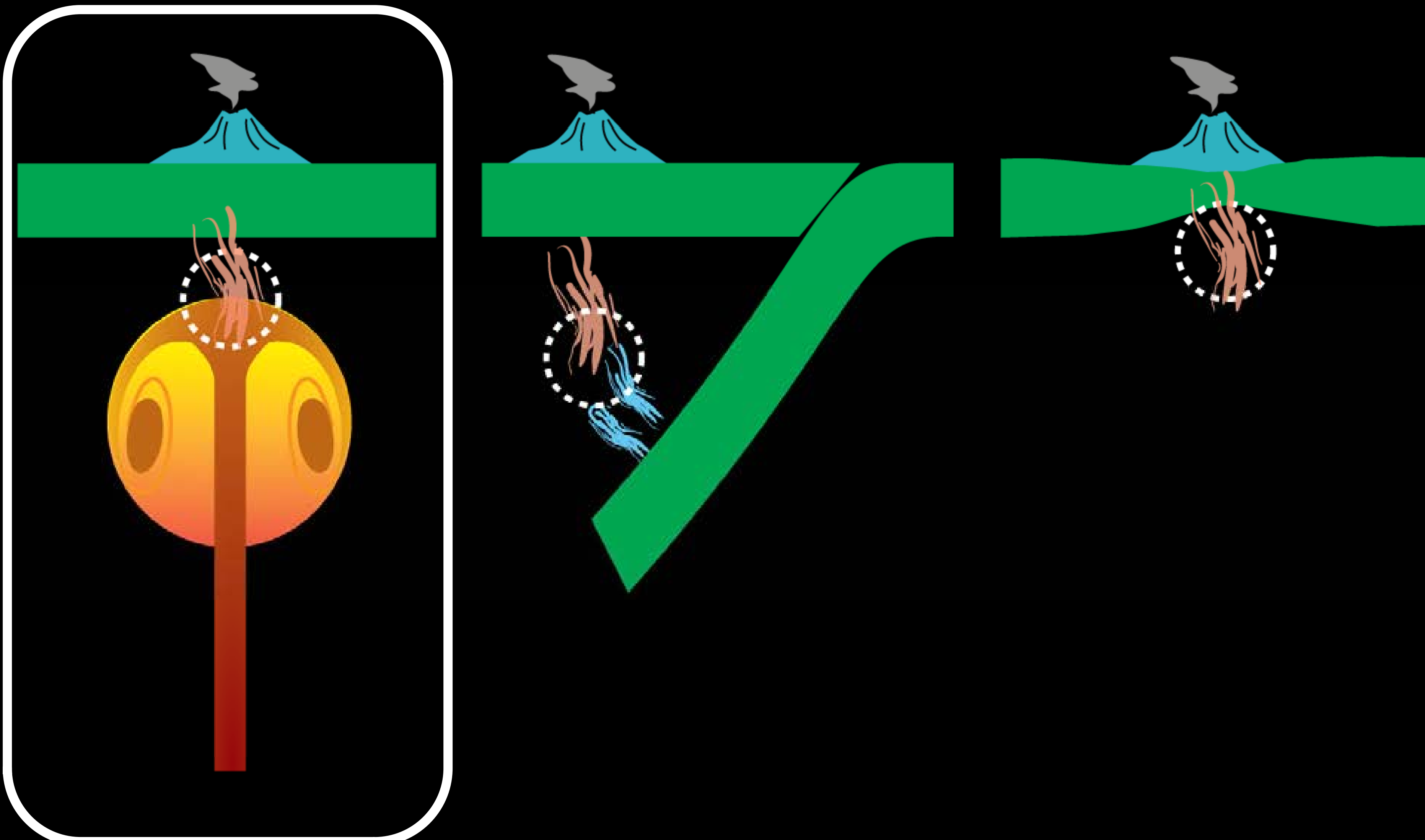




lithosphere must thin by 50% before melt may be generated

(figure derived from Herzberg & O'Hara, 2002; lithospheric thickness from Dugda et al., 2007)

creating melts



Mantle plumes and the origin of magmas from a geochemical perspective

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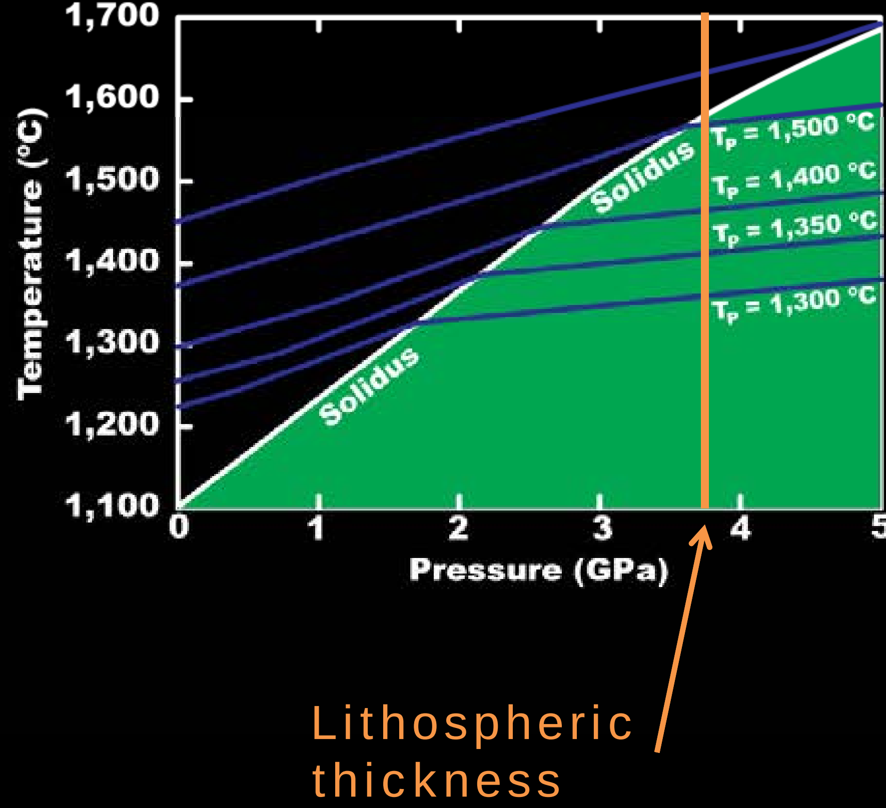
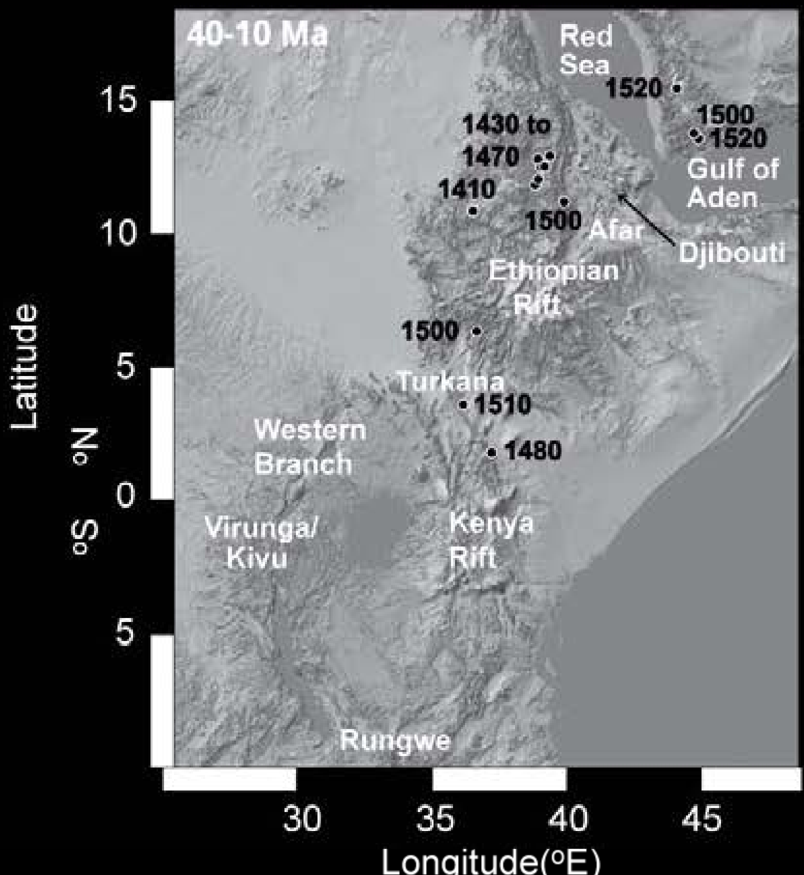
creating melts

(figure derived from Herzberg & O'Hara, 2002; lithospheric thickness from Dugda et al., 2007)

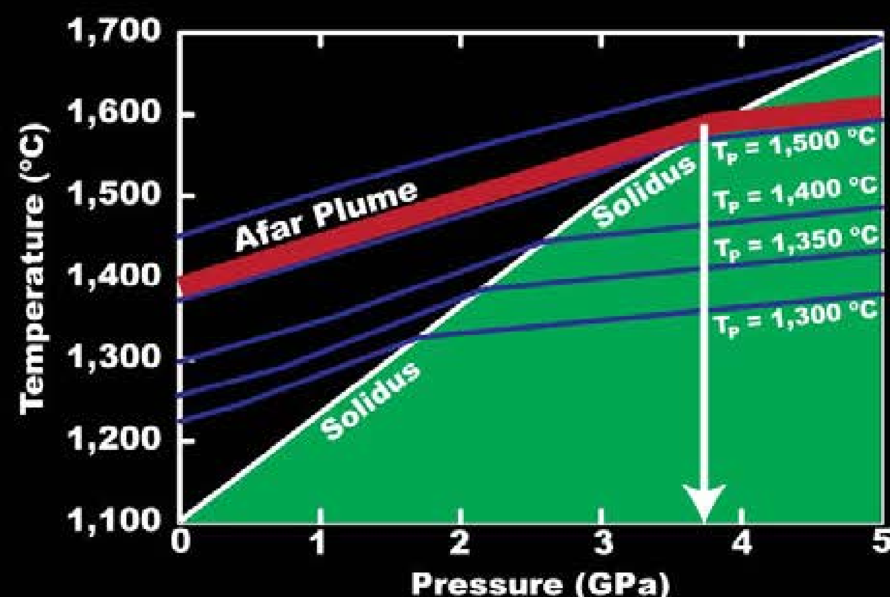


creating melts

ambient mantle – 1350°C

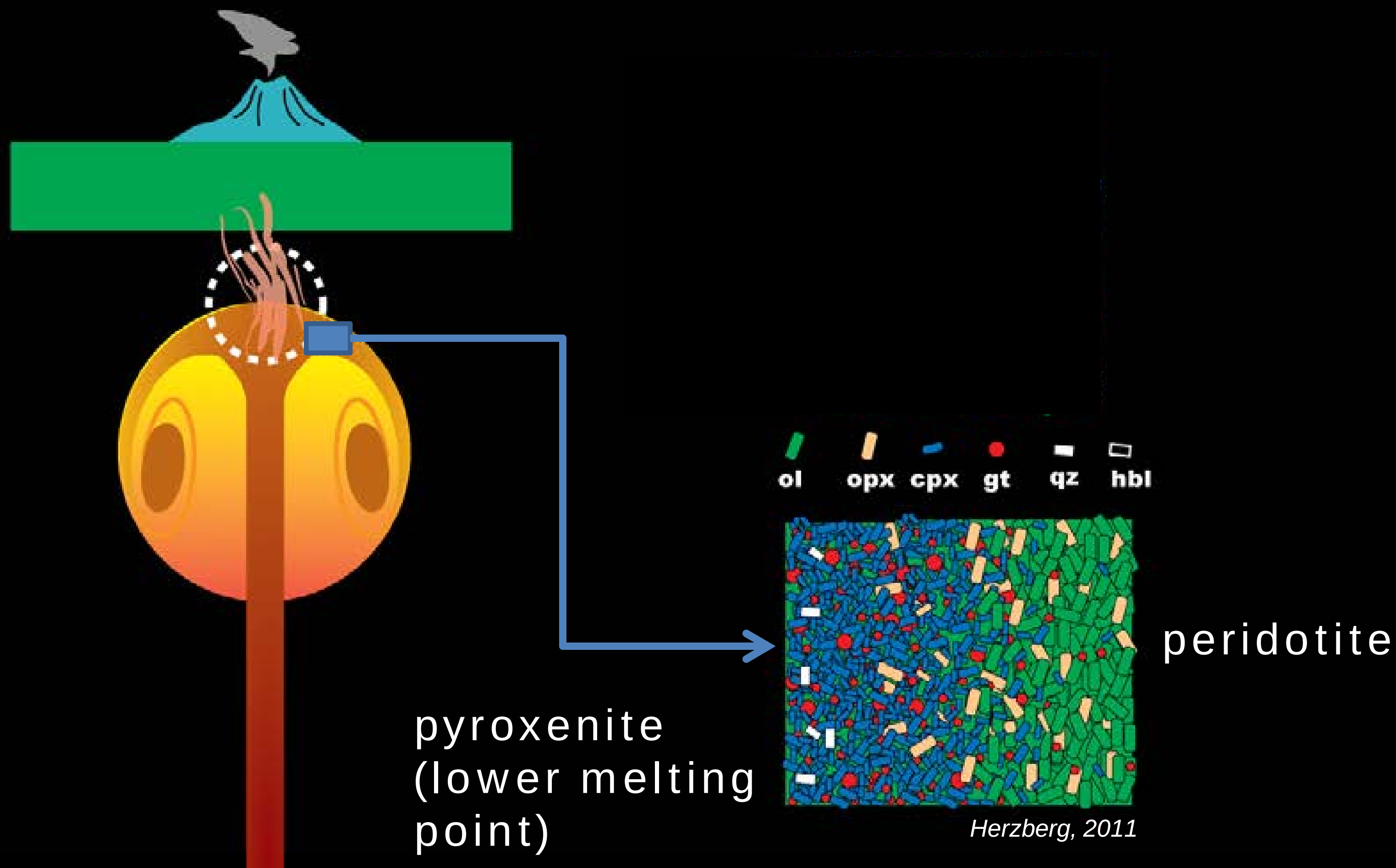


Rooney et al., (2012)



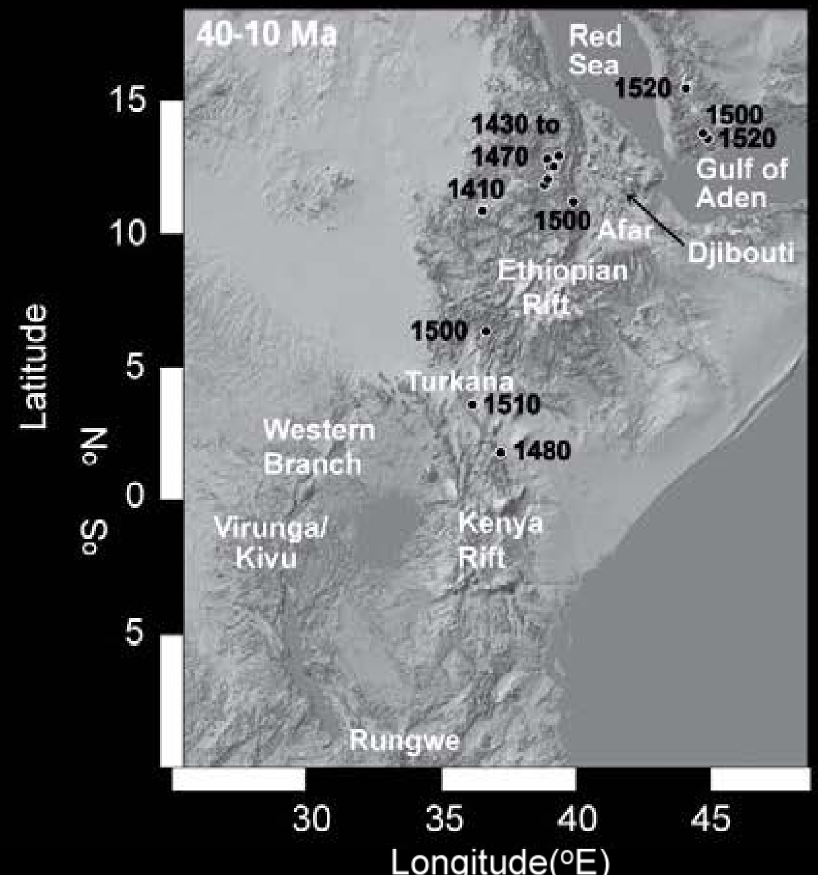
(figure derived from Herzberg & O'Hara, 2002; lithospheric thickness from Dugda et al., 2007; Tp from Rooney et al., 2012)

composition



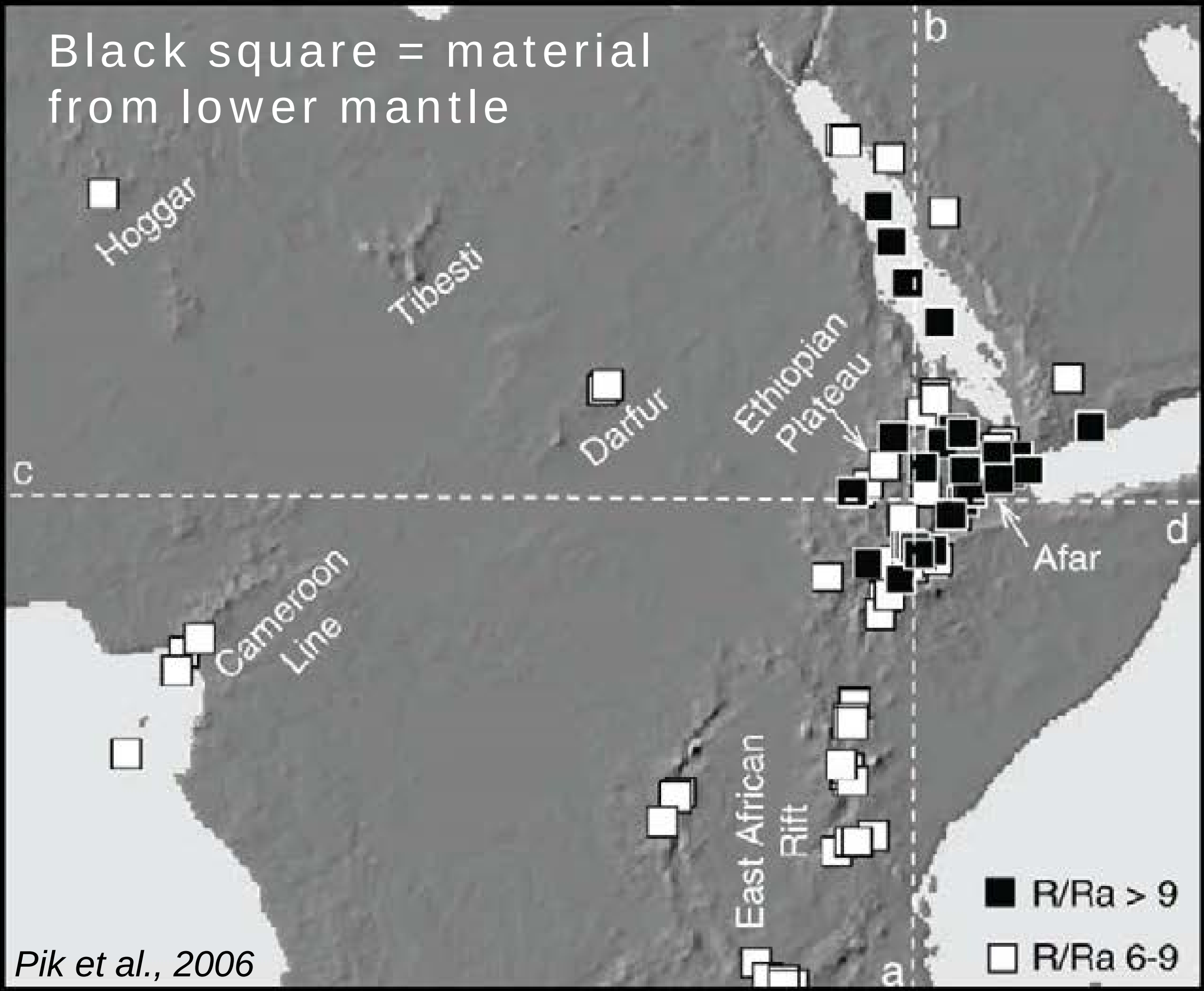
mantle temperature

So what is the role of a plume today?



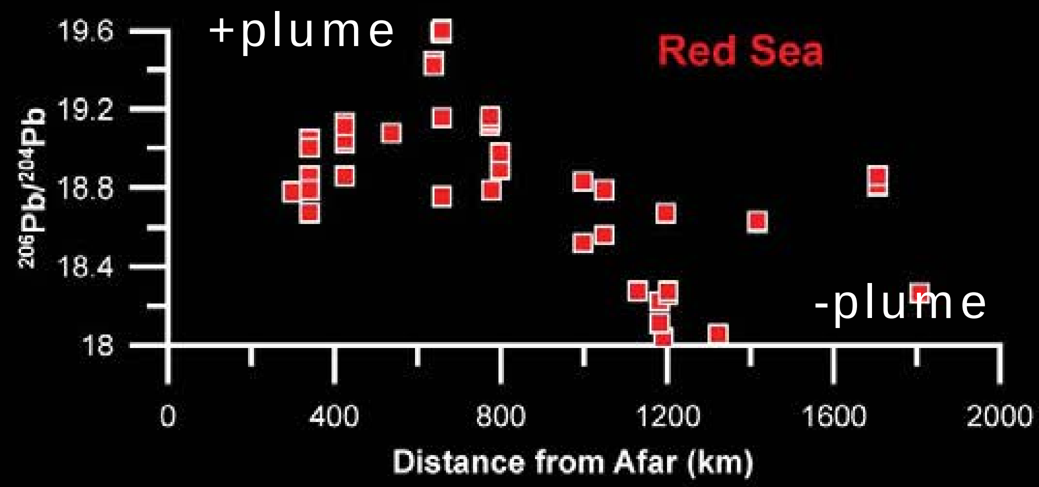
ambient mantle – 1350°C

helium isotopes



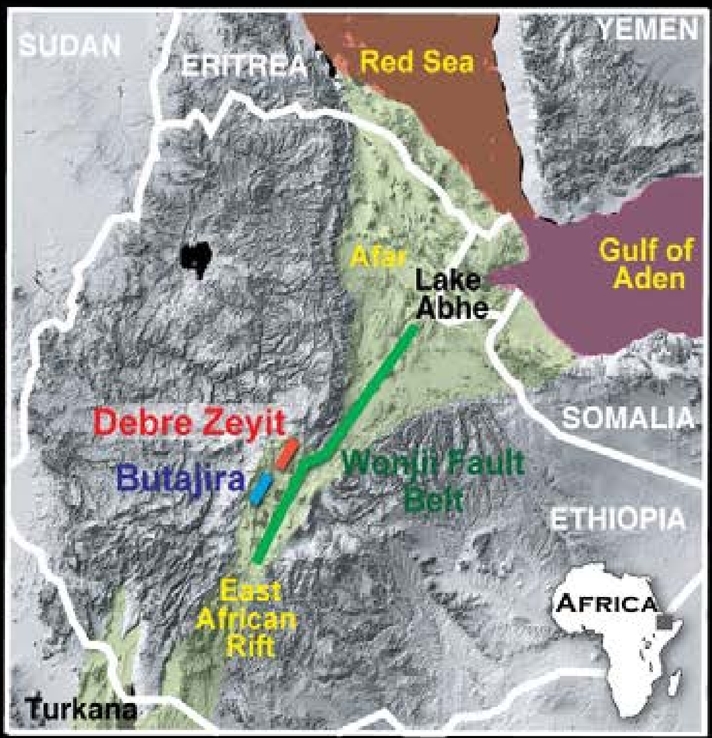
afar plume

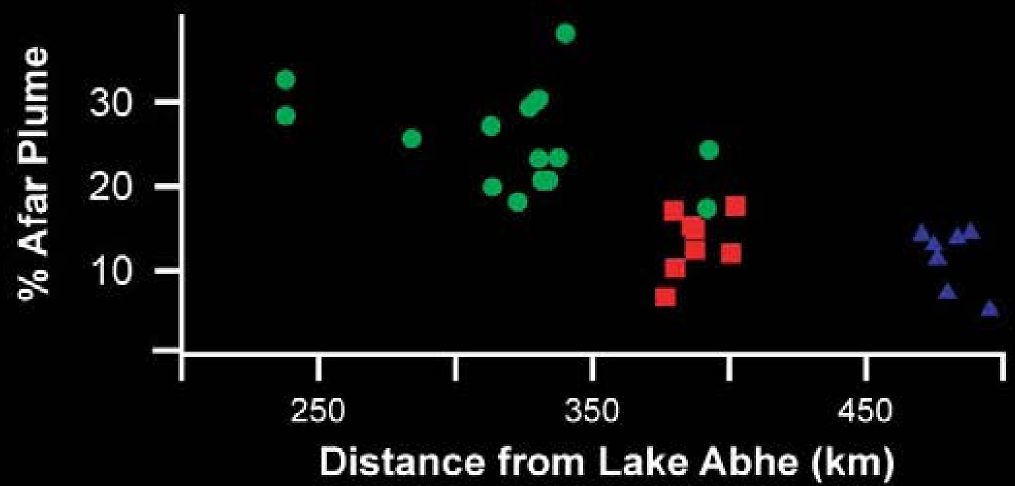
Rogers et al., 1993; Volk et al., 1997



Data from PETDB

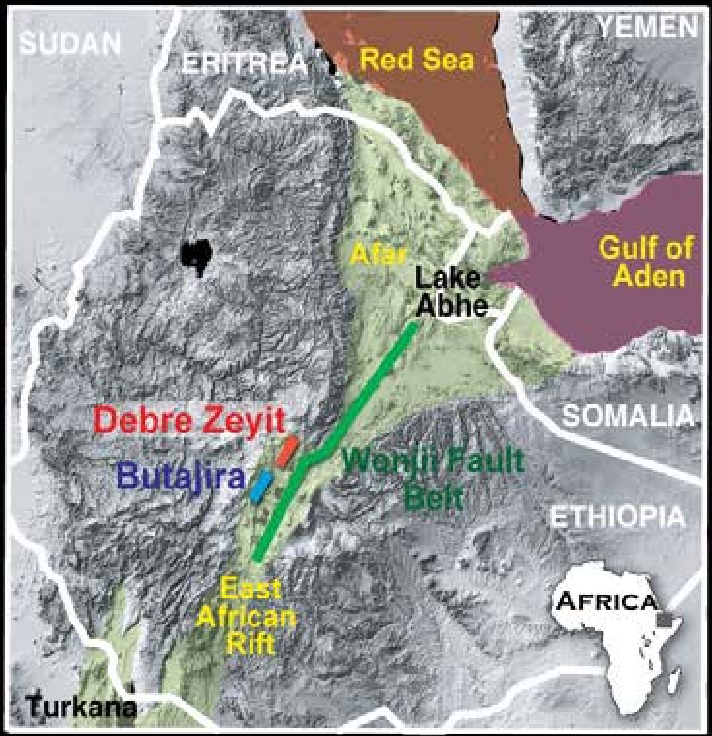
plume contribution

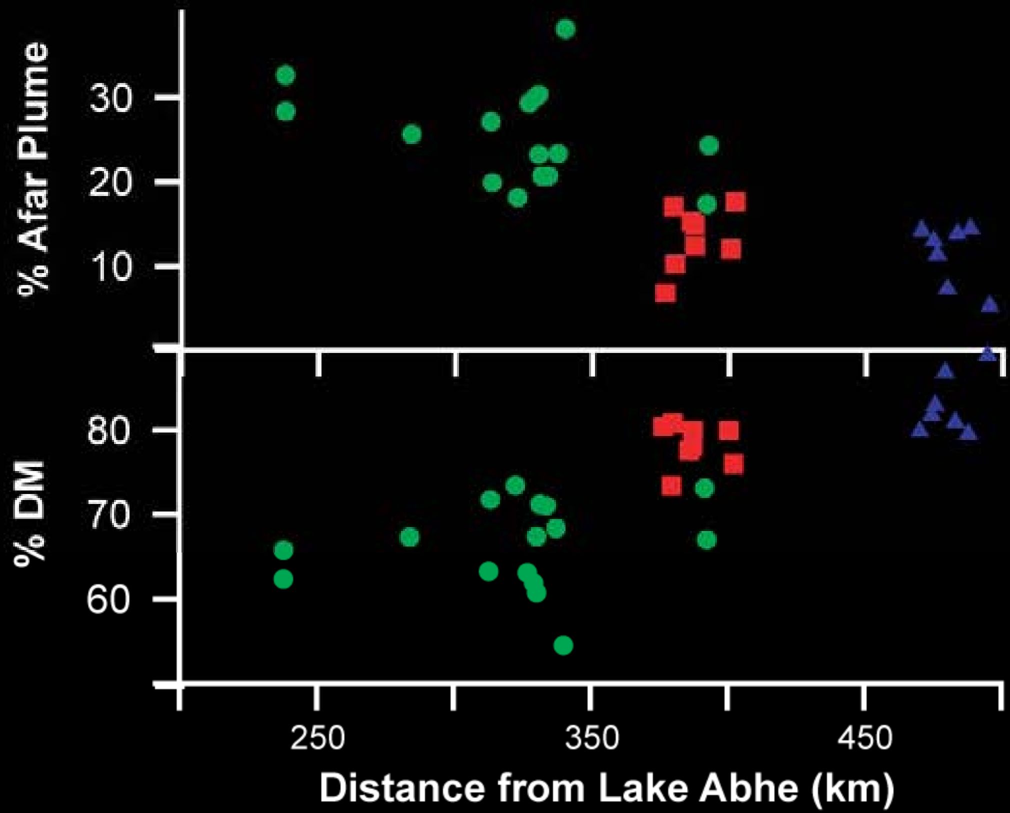




Data from Rooney et al., 2012 J. PET

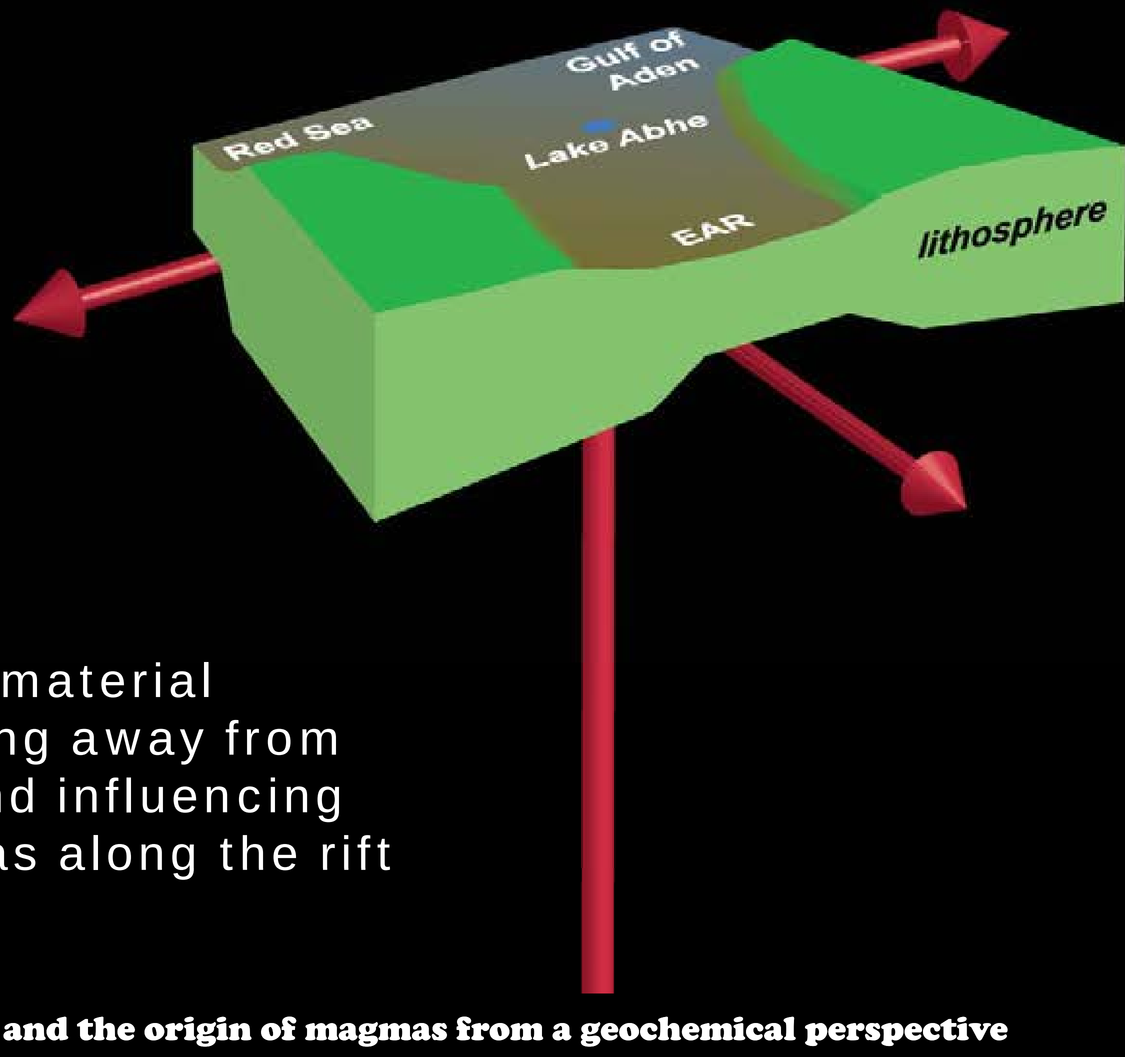
plume contribution





Data from Rooney et al., 2012 - J. PET

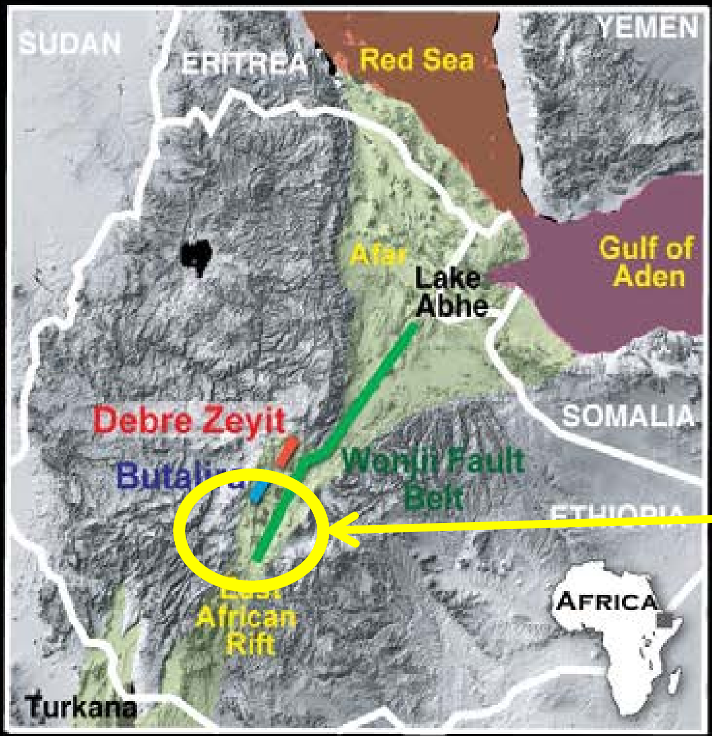
radial dispersion

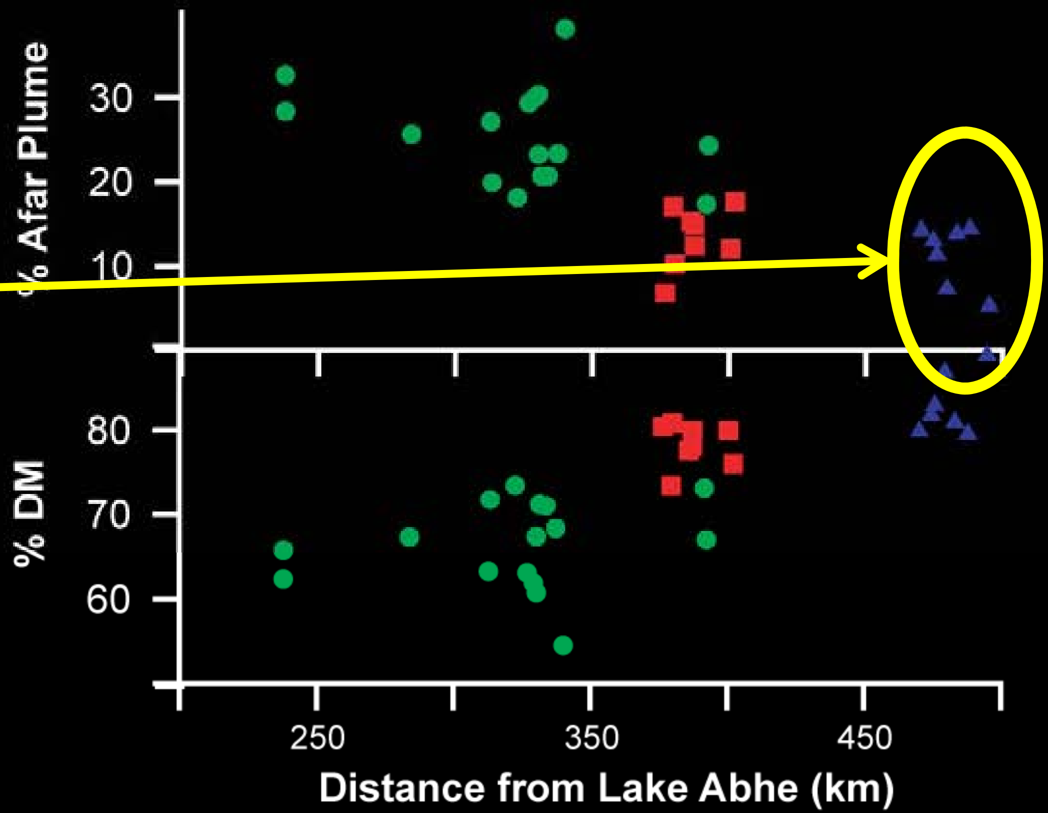


Plume material radiating away from Afar and influencing magmas along the rift

plume contribution

The problem is that we reach zero plume contribution in southern Ethiopia

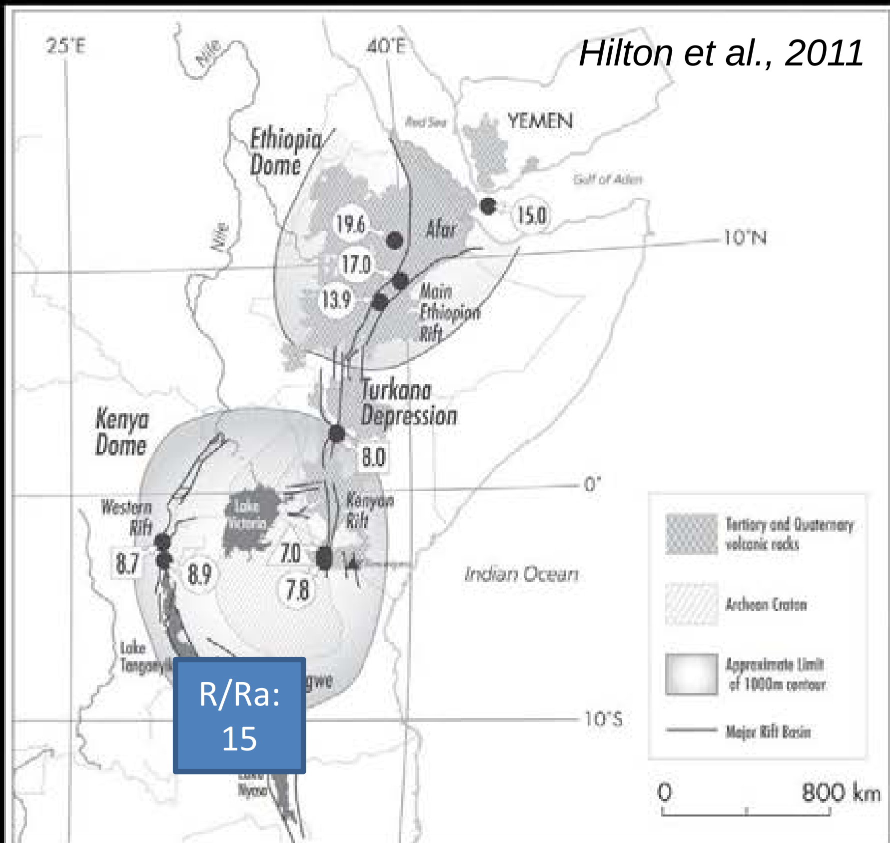


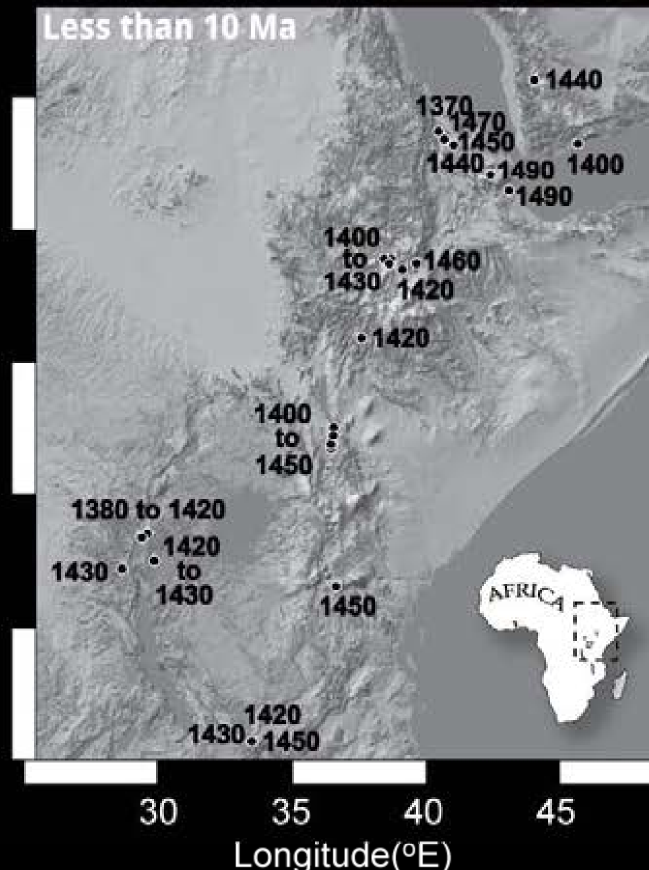


Data from Rooney et al., 2012 - J. PET

plume influence

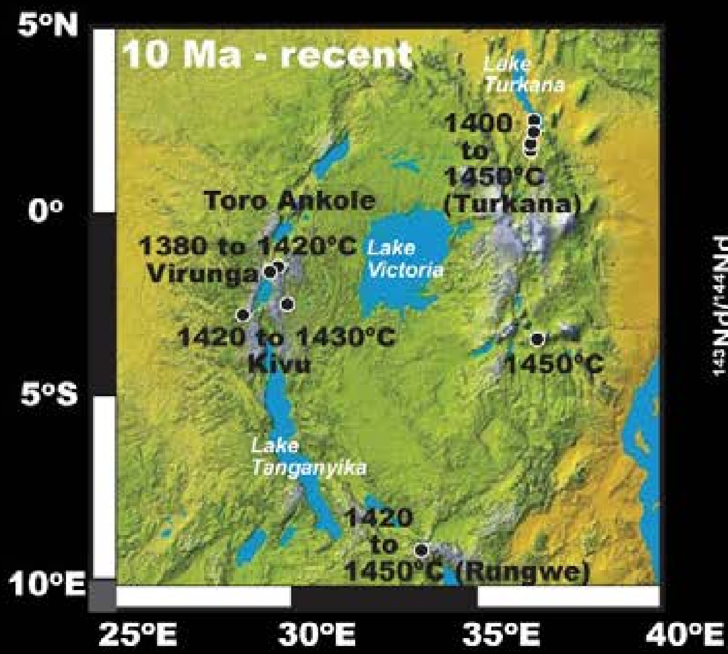
There is evidence of a plume contribution in the south too!

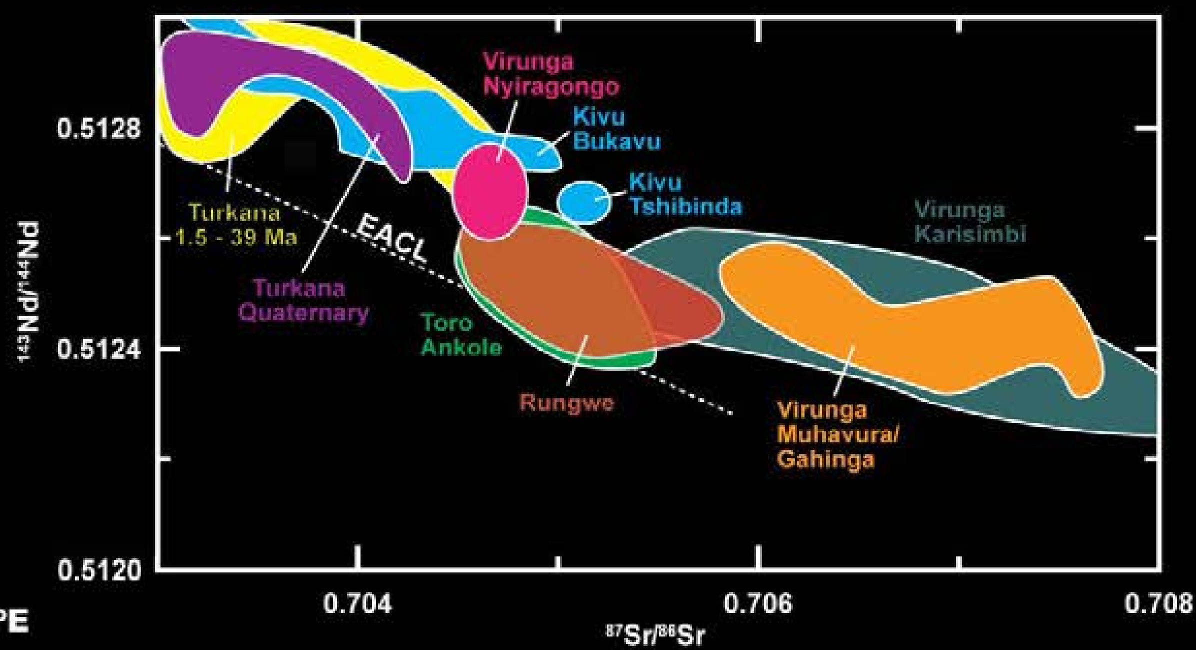




southern EAR

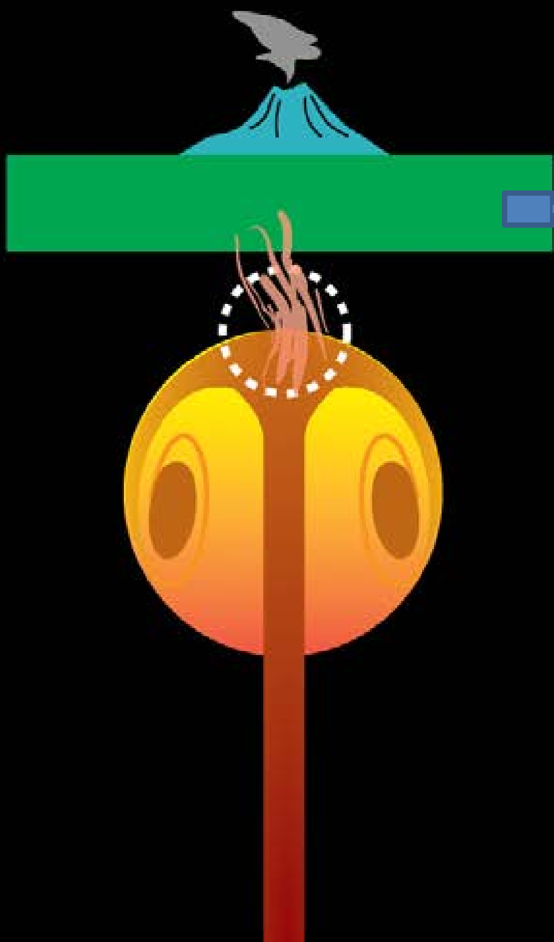
Southern portion of the EAR exhibits elevated temperature

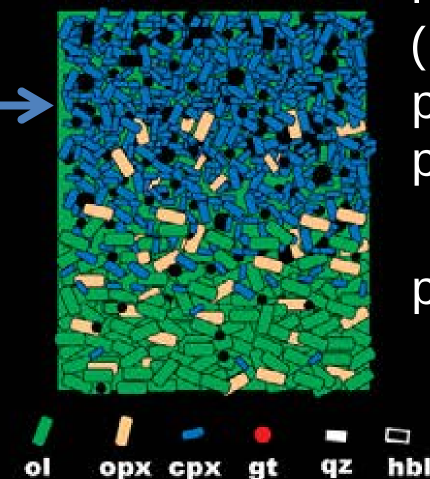




It is difficult to link magmas in the southern EAR with asthenospheric (plume) processes as the veil of the lithosphere obscures critical details.

composition





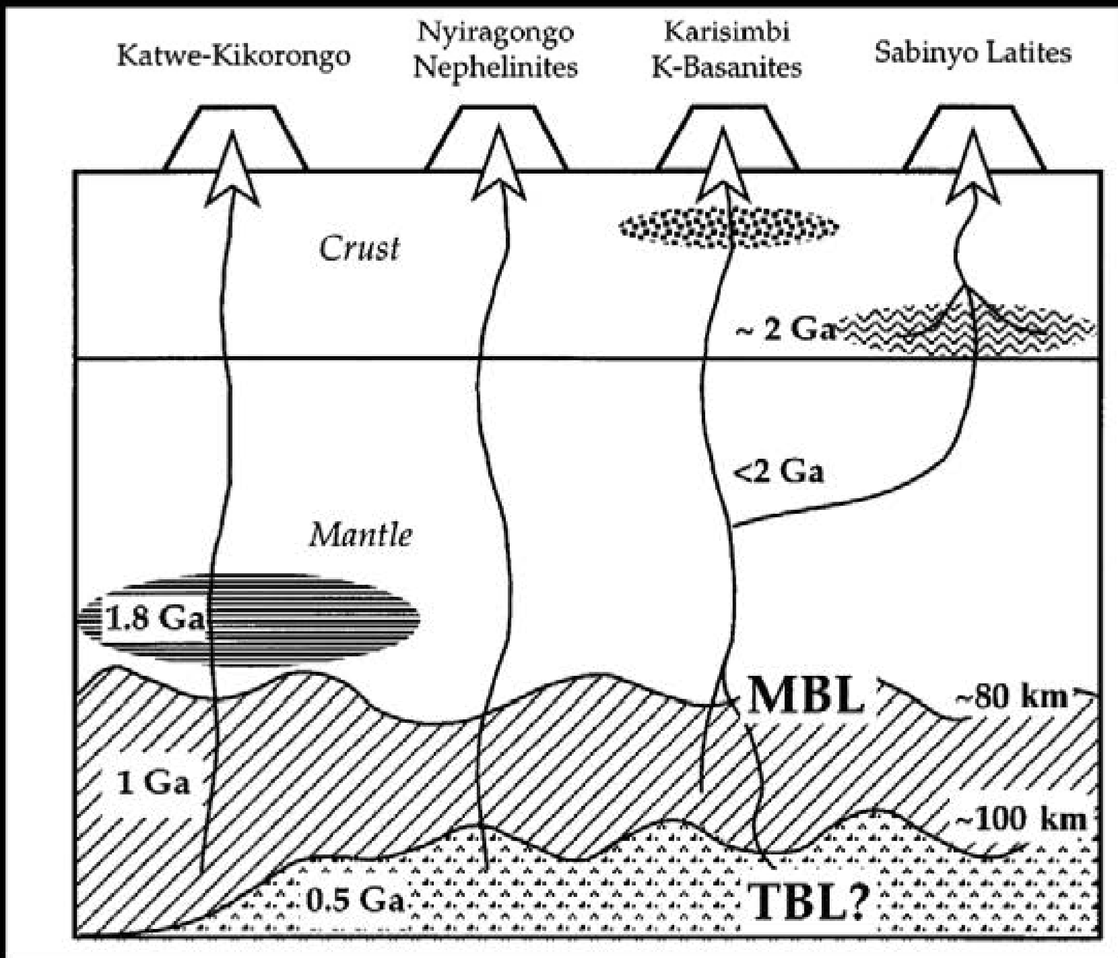
Hornblende- or phlogopite-bearing lithospheric metasome (200ºC lower melting point than dry peridotite)

peridotite

These easily fusible (meltable) parts of the lithosphere can create magmas by conductive melting or contaminate asthenospheric magmas..... (e.g., Mana et al., - Lithos 2012)

lithospheric melt

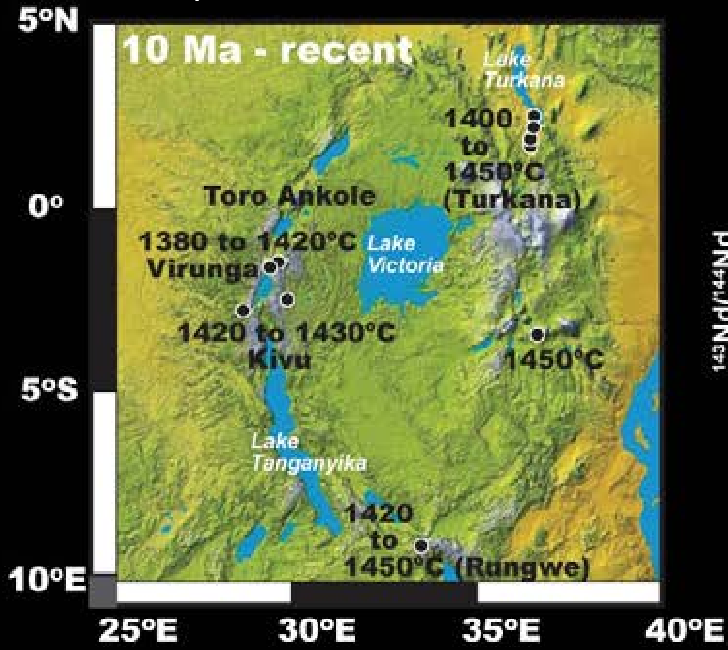
Rogers et al., 1998



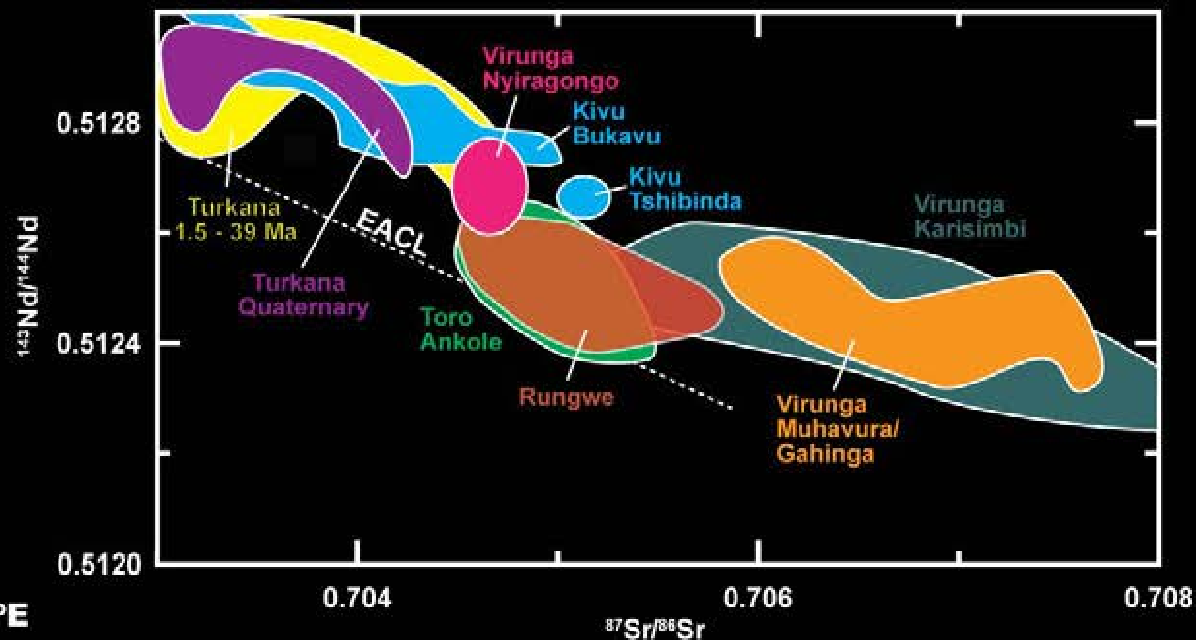
Layered lithosphere can produce a wide array of magmas at the surface

southern EAR

Rooney et al., 2012

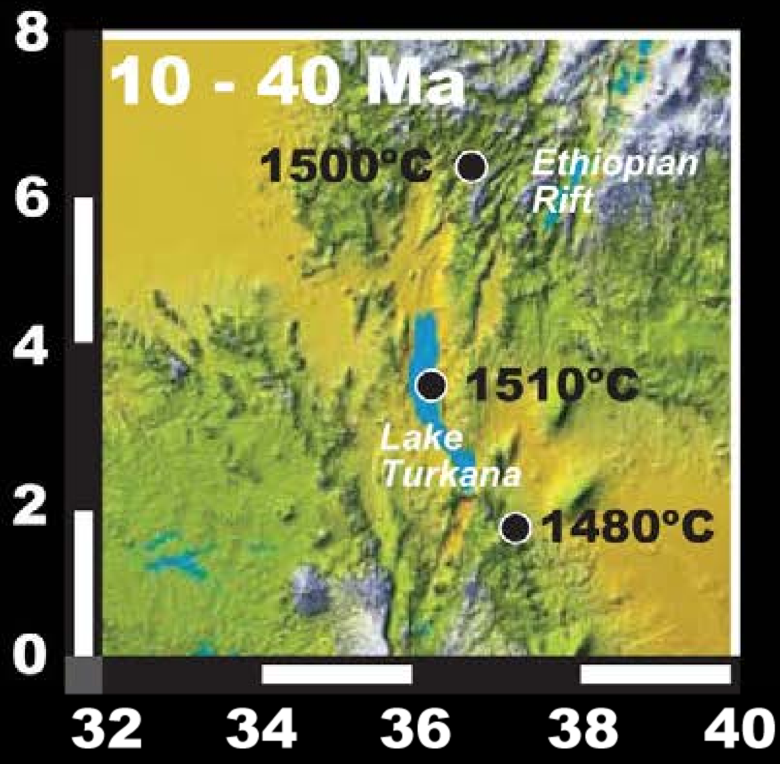


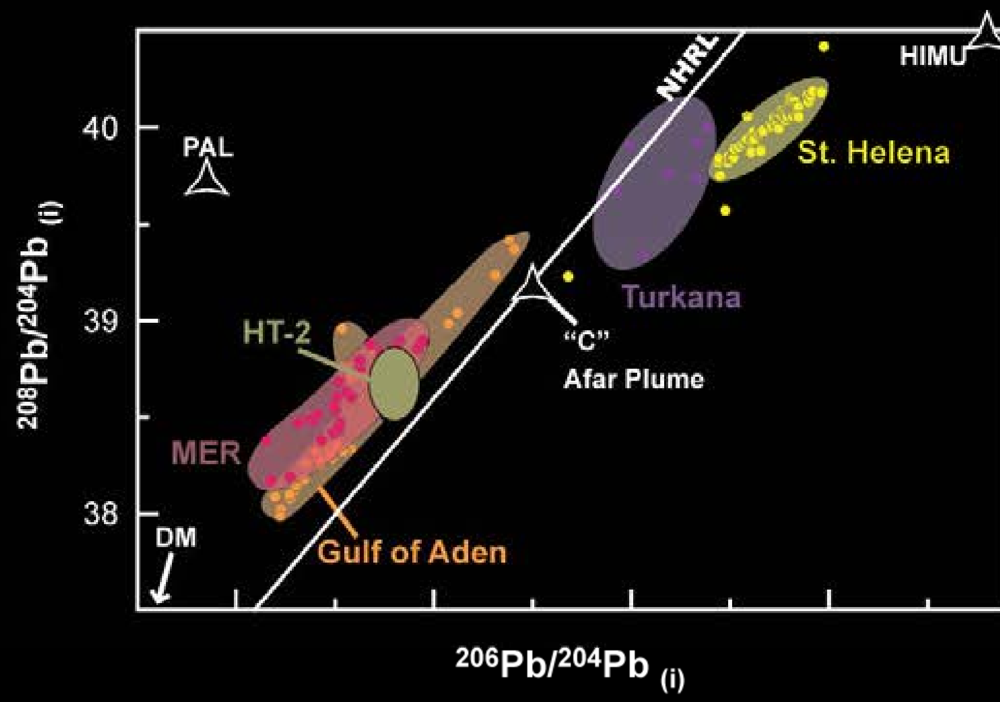
Data: Virunga- Karisimbi, Gahinga, Muhavura (Rogers et al., 1992; 1998); Virunga – Nyiragongo (Chakrabarti et al., 2009); Rungwe (Furman & Graham, 1999); Toro Ankole (Rosenthal et al., 2009); Kivu – Tshibinda, Bukavu (Furman & Graham 1999); Turkana – Quaternary (Furman et al., 2004); Turkana 1.5-39 Ma (Furman et al., 2006). The EACL is the East Africa Carbonatite line (Bell & Blenkensop 1987).



While much of the southern EAR has a lithospheric overprint – The Turkana region may offer clues as to the asthenospheric processes active here

turkana

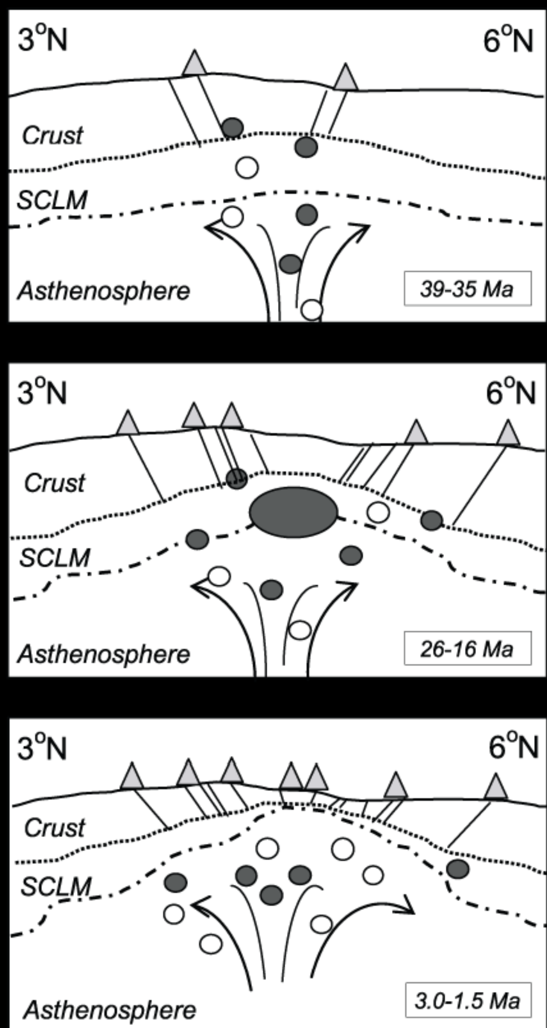




Gulf of Aden (Schilling et al., 1992; Rooney et al., 2012); St. Helena (GEOROC); Turkana (Furman et al., 2004;2006); 30 Ma HT-2 (Pik et al., 1999). MER – Main Ethiopian Rift (Furman et al., 2006a; Rooney et al., 2012). Endmembers PAL (Pan African Lithosphere); DM (Depleted mantle); "C" – Afar Plume are from Rooney et al., 2012.

turkana model

Furman et al., 2006



Model for Turkana

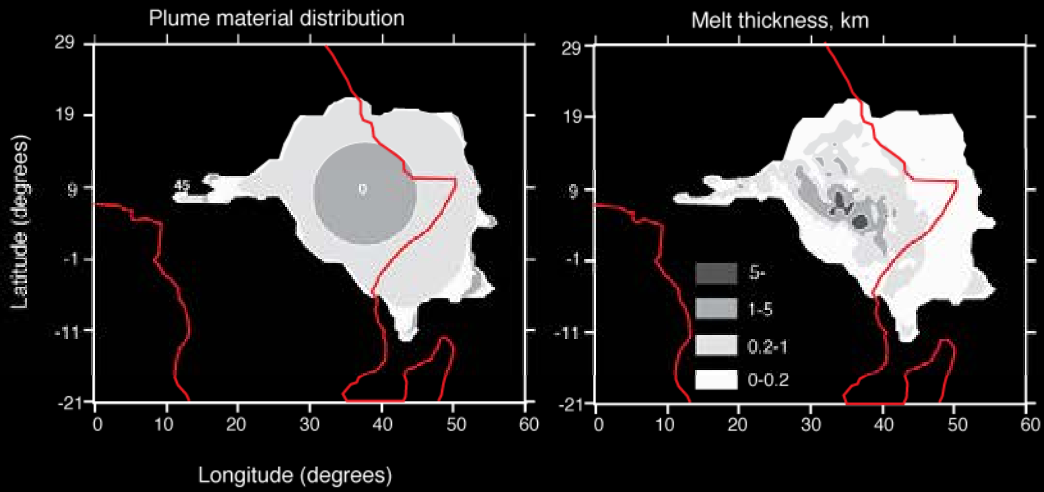
-Oligocene initial mixed plume component

-Early Miocene, the HIMU flavor dominates

-Pliocene – Quaternary, the “C” signature dominates

single plume

Ebinger & Sleep, 1998



A single plume impacted the lithosphere and radiated outwards, channeled along the base of the lithosphere.

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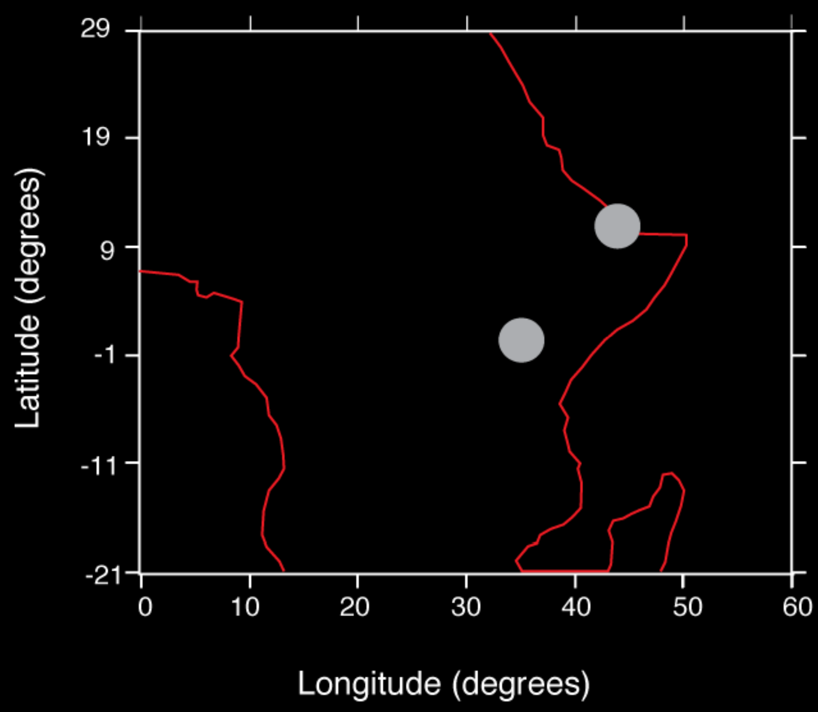
two plume

George et al., 1998; George & Rogers, (2002)



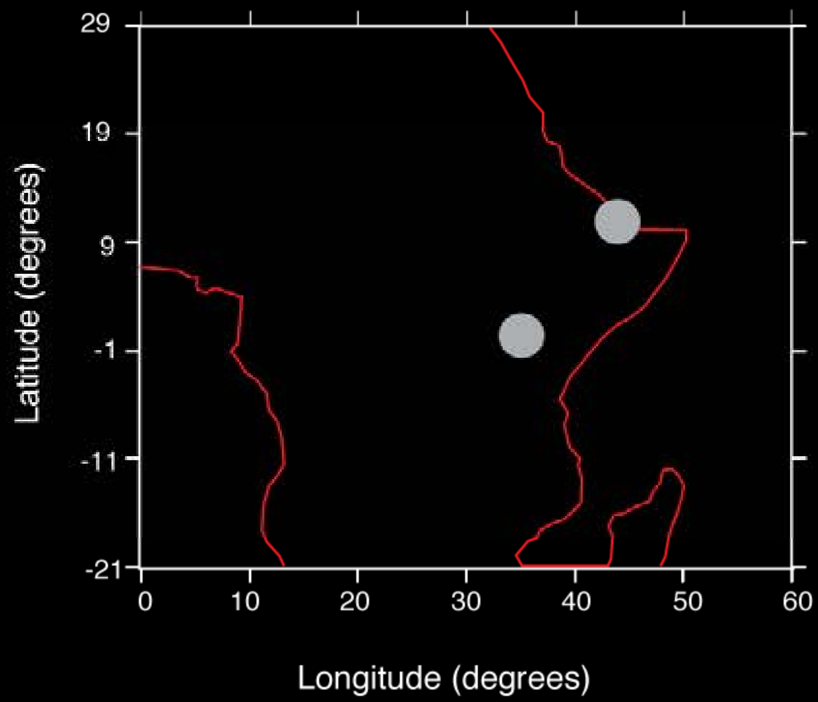
Geochemistry requires two sources

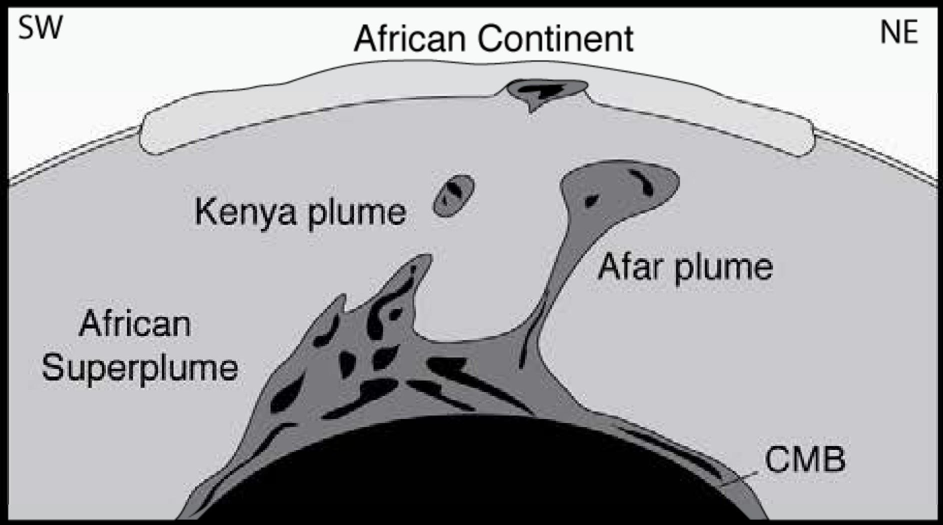
-Afar plume

-Another plume beneath Tanzania Craton?

modified single plume

Furman et al., 2006; Nelson et al., 2012





challenges

What is the extent of the temporal and spatial contribution of plume materials to rift magmas?

Are the plume(s) spatially or temporally heterogeneous?

How does plume-lithosphere interaction control rift development?

How do we distinguish lithospheric enriched zones from plume signatures?

How deep could melt be generated and how can the impact the seismic images of the region?

Can we communicate these challenges and work with the other disciplines to come to some conclusions?