Origin of silicic crust by rifting and bimodal plume volcanism in the Afar Depression

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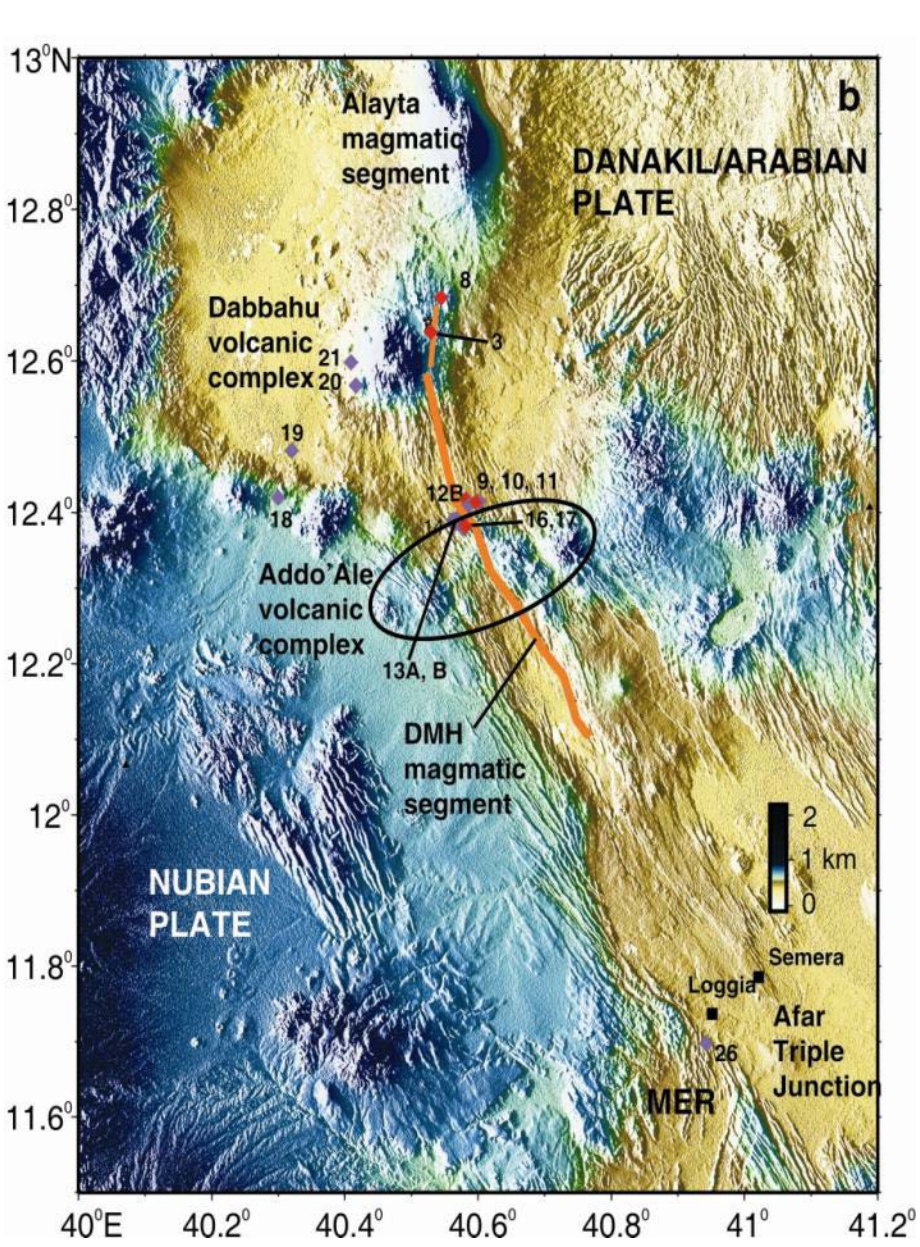
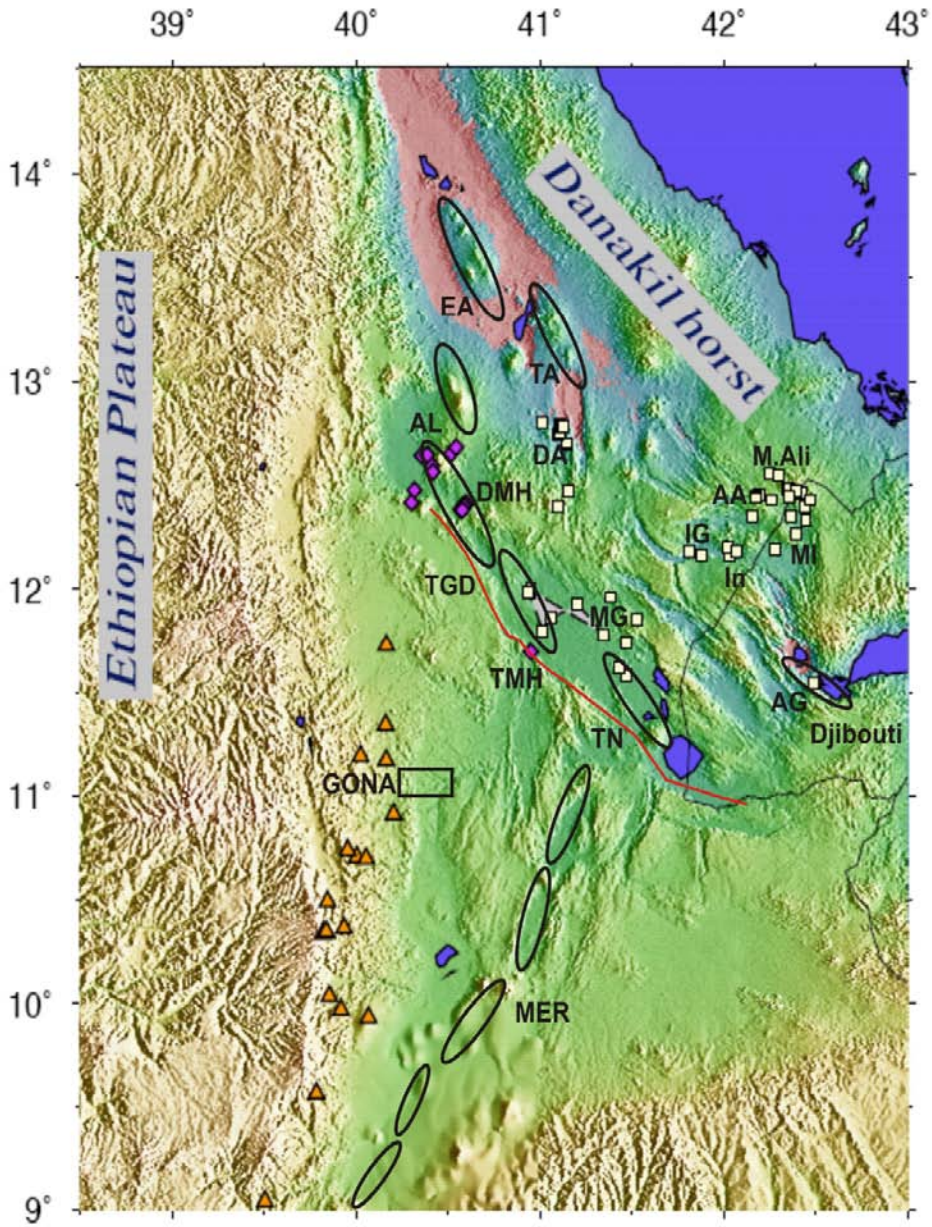
Goals

- To deduce the time history of the continental lithospheric mantle from rift onset to break up beneath Afar

- Petrogenesis of plume related silicic bimodal volcanism of an evolving continental rift zone

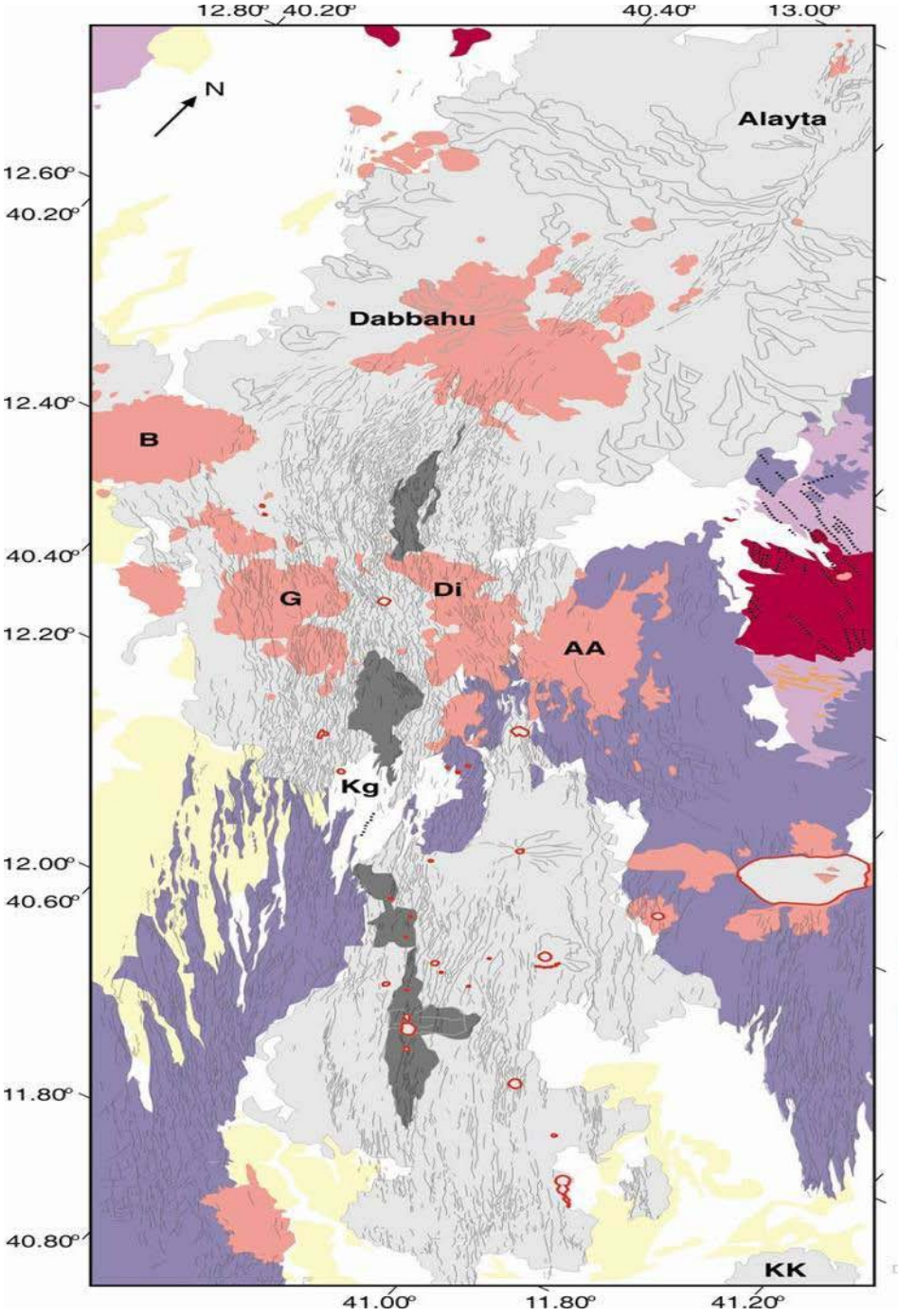
Sample Locations in the DMH Rift Segment & Gona





Volcanics of the Dabbahu Rift

Silicic lavas ~ 20% in volume

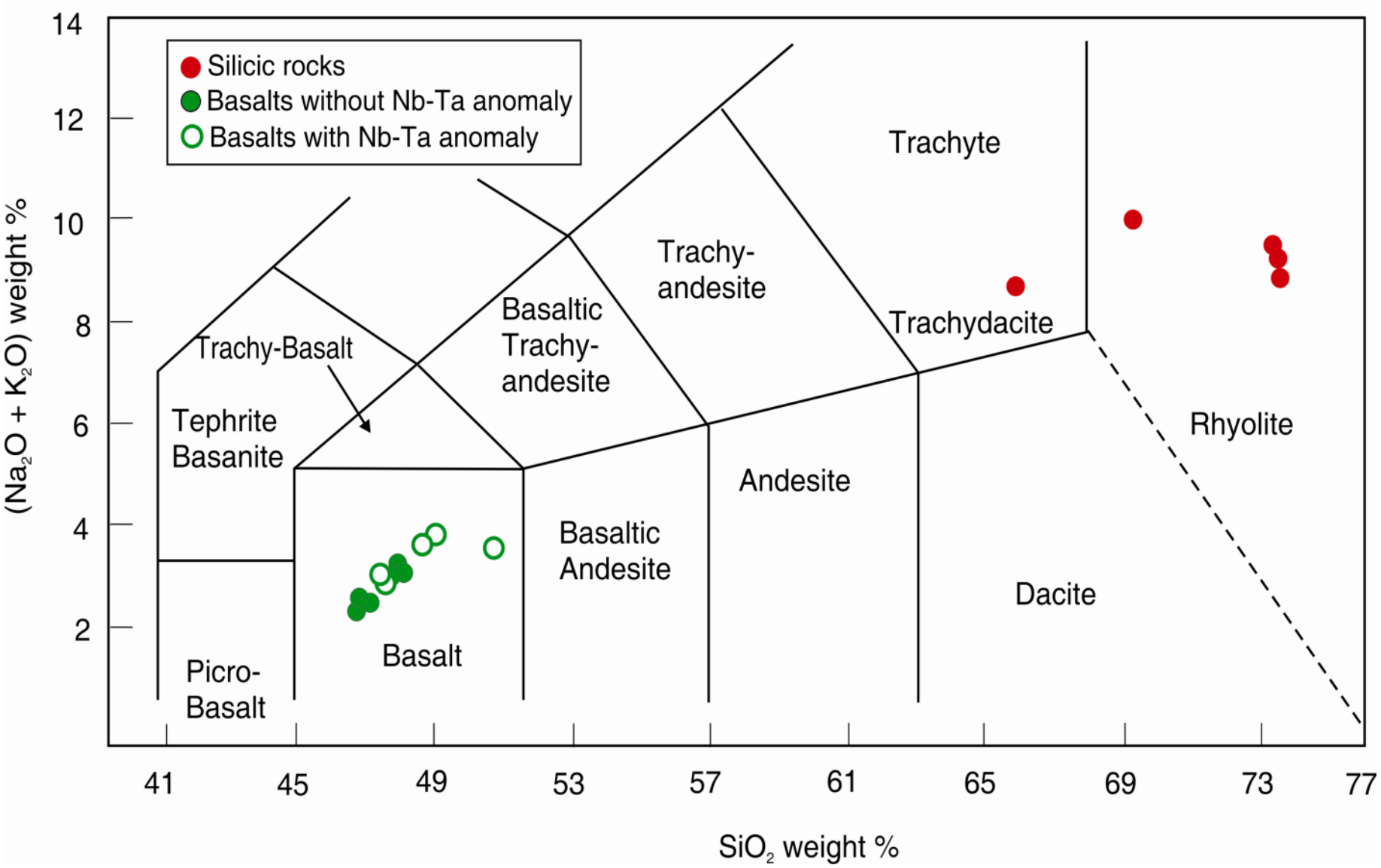


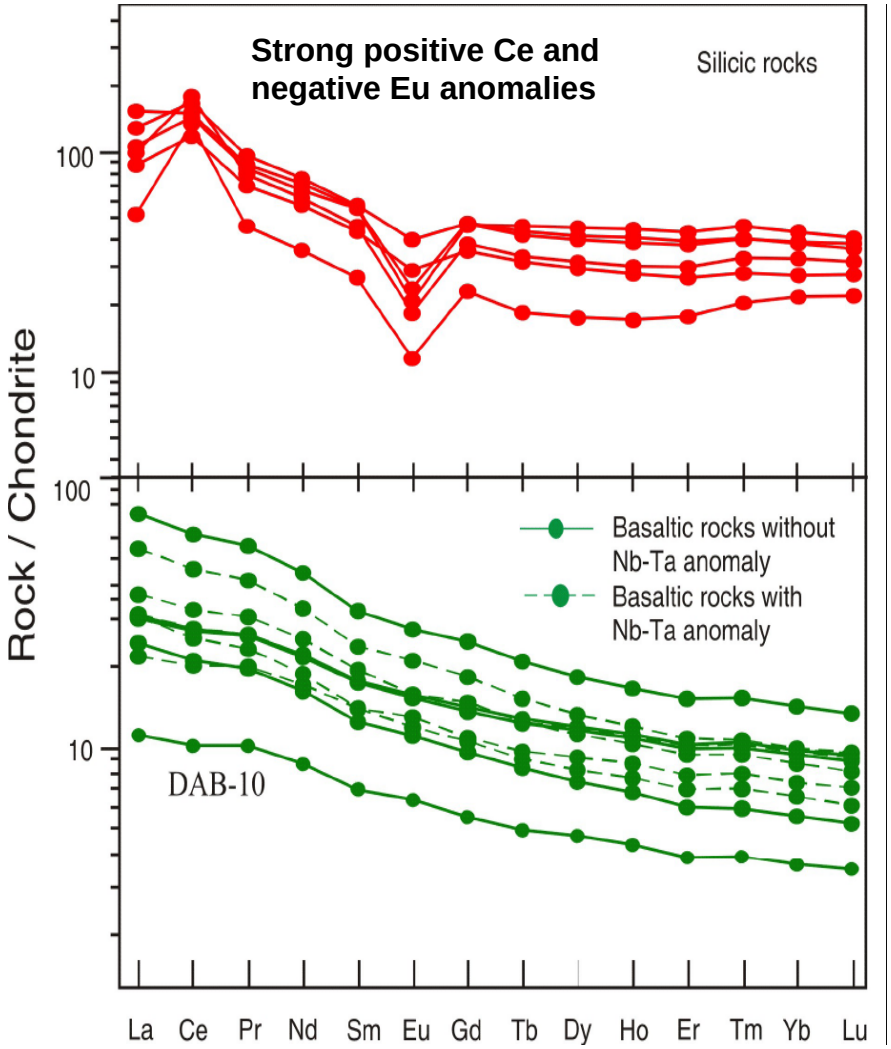
Key

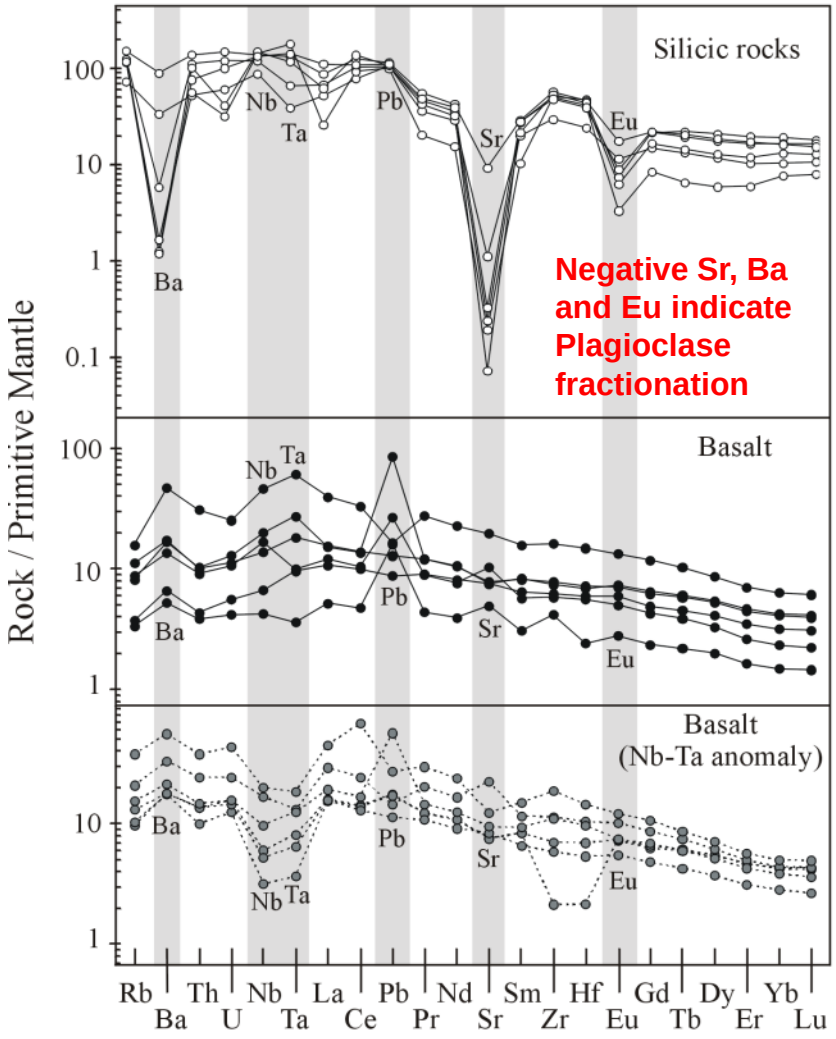
- Recent sediments
- Pleistocene fluvial sediments
- Axial Volcanics (Afar Series) (< 0.5 Ma)
- Acidic
- Younger Basalt
- Older Basalt
- Stratoid (Aden Series) (4 - 0.5 Ma)
- Pre -Stratoid (> 4 Ma)
- Granite Intrusions (26 - 22 Ma)
- Eruptive centes / Volcanic craters
- Fault
- Unknown Lineaments
- Exposded Dikes

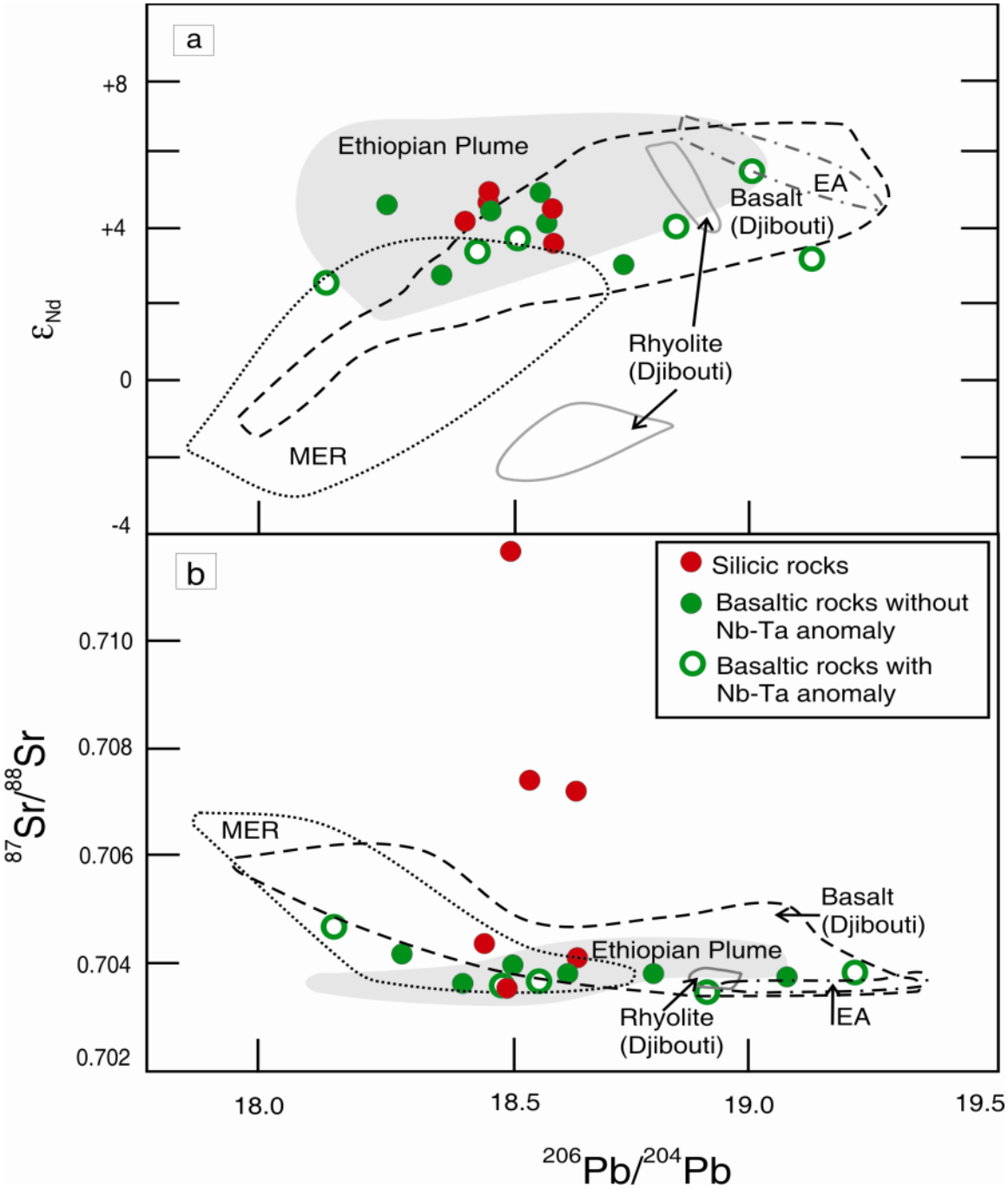
20 km

Bimodal Basaltic and peralkaline [(Na + K)/Al > 1] silicic Volcanism in the Dabbahu magmatic segment




Strong positive Ce and negative Eu anomalies
Silicic rocks
Rock / Chondrite
100
10
Basaltic rocks without Nb-Ta anomaly
Basaltic rocks with Nb-Ta anomaly
DAB-10
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu


Rock / Primitive Mantle
Silicic rocks
Basalt
Basalt (Nb-Ta anomaly)
Negative Sr, Ba and Eu indicate Plagioclase fractionation
Ba
Nb
Ta
Pb
Sr
Eu
100
10
1
0.1
Rb Ba Th U Nb Ta La Ce Pb Pr Nd Sr Sm Zr Hf Eu Gd Tb Dy Er Yb Lu

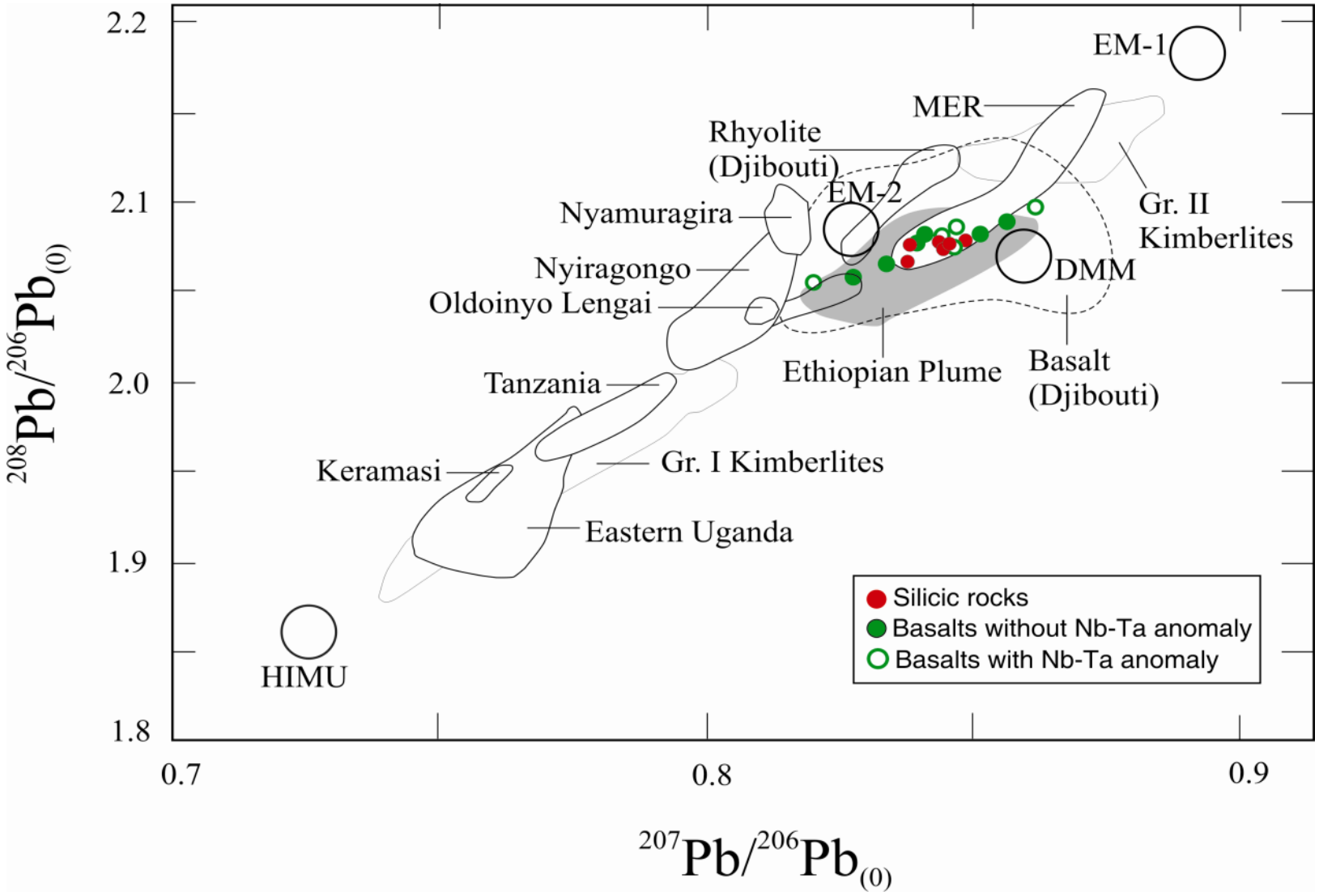


Sr – Nd – Pb isotopes in basalts and rhyolites in Afar

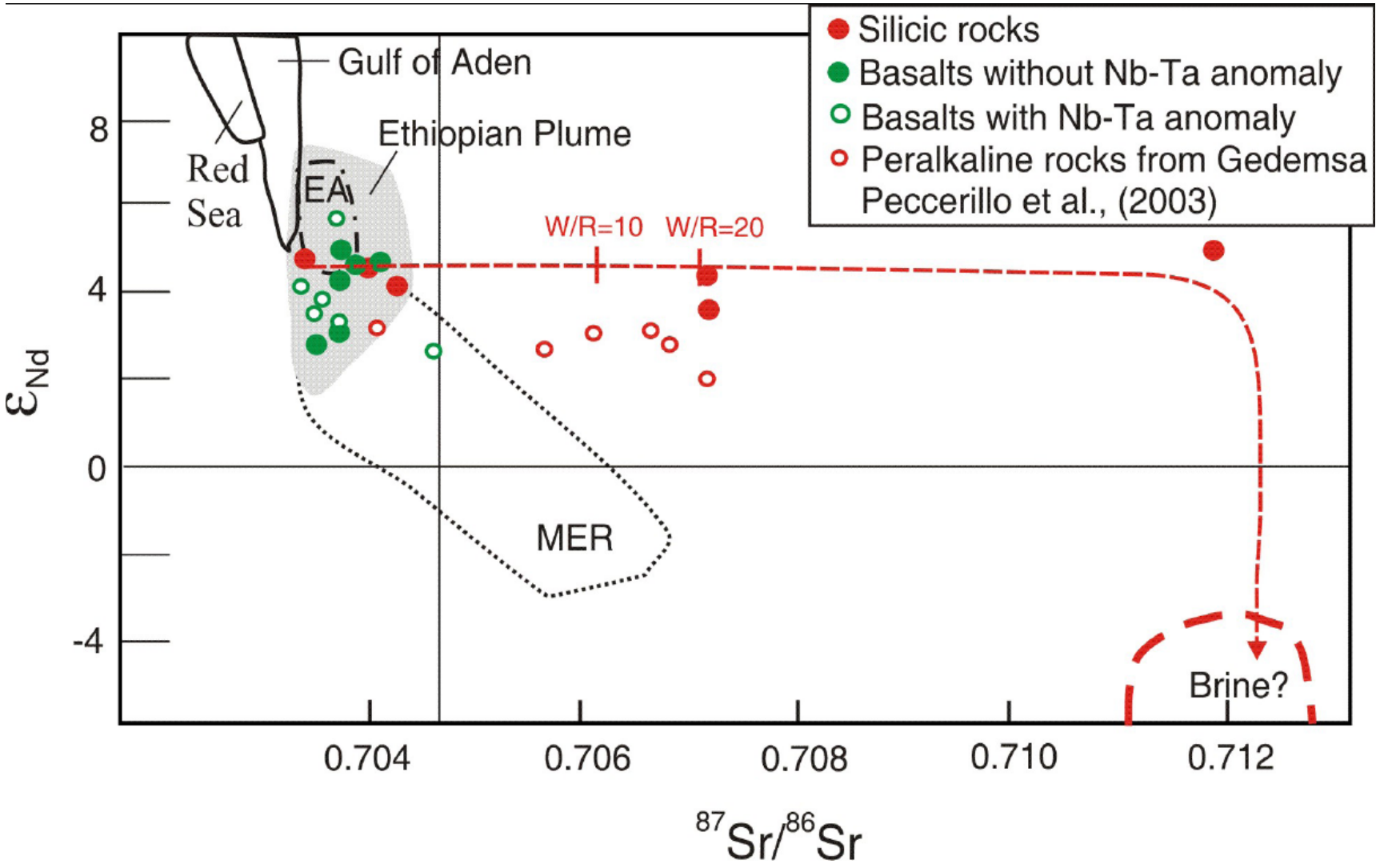
- **Nd and Pb isotopes in bimodal volcanics are same as in Ethiopian plume (Flood Basalts)**

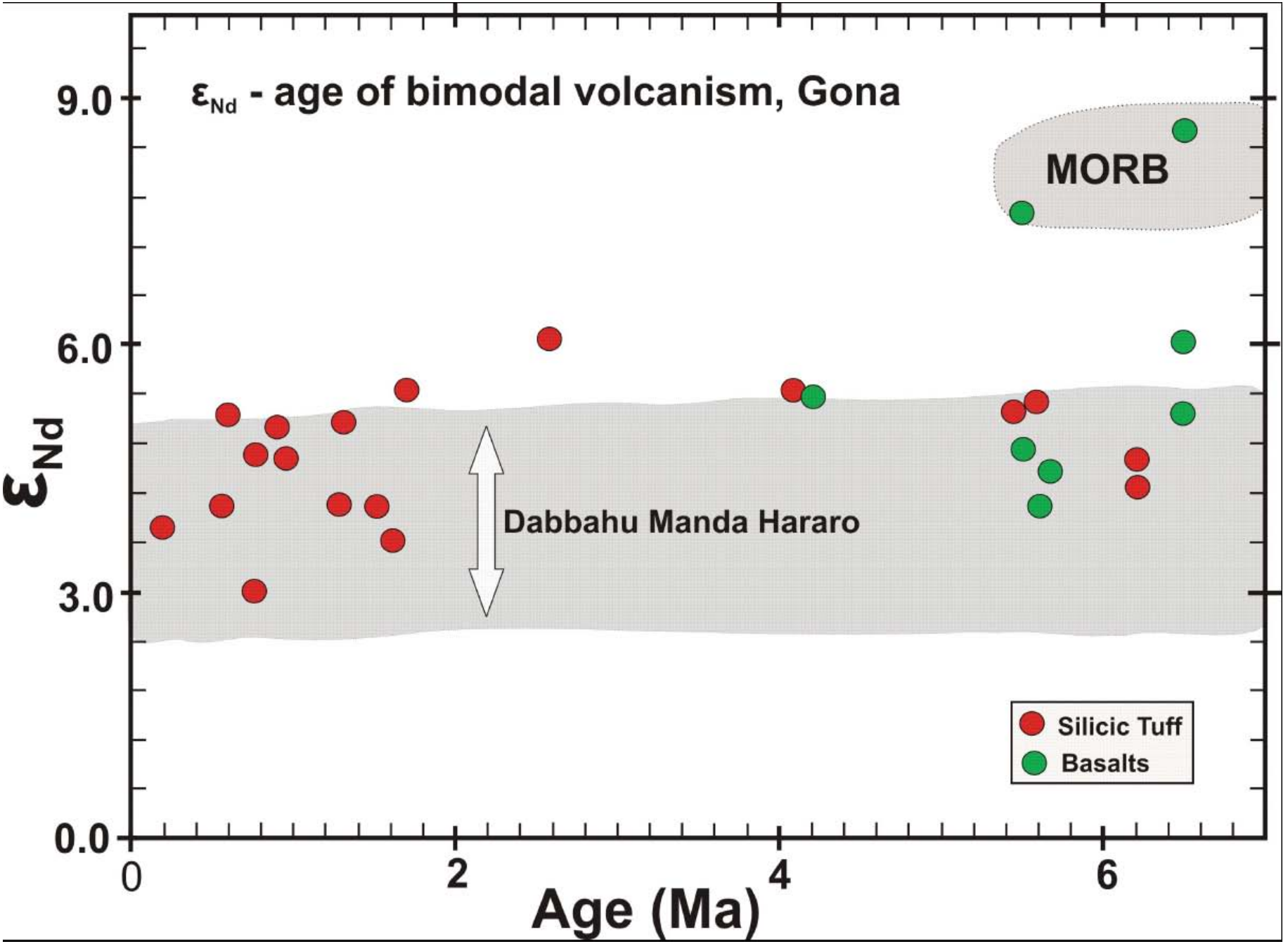
- **Sr isotopes in silicic volcanics indicate mixing with more radiogenic source**

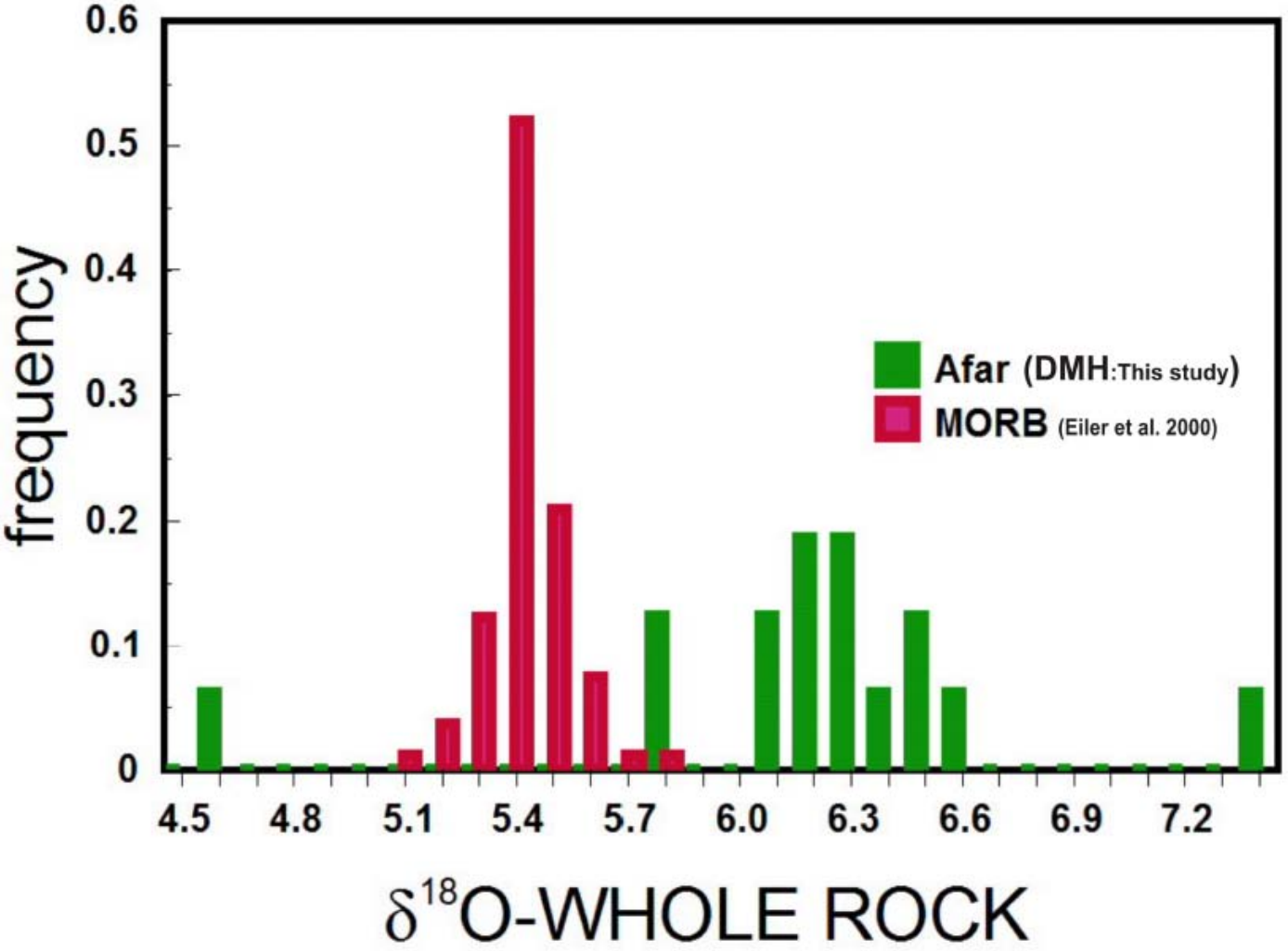
Identical Pb isotopes in Dabbahu Basalts and Silicic volcanics and the Ethiopian plume



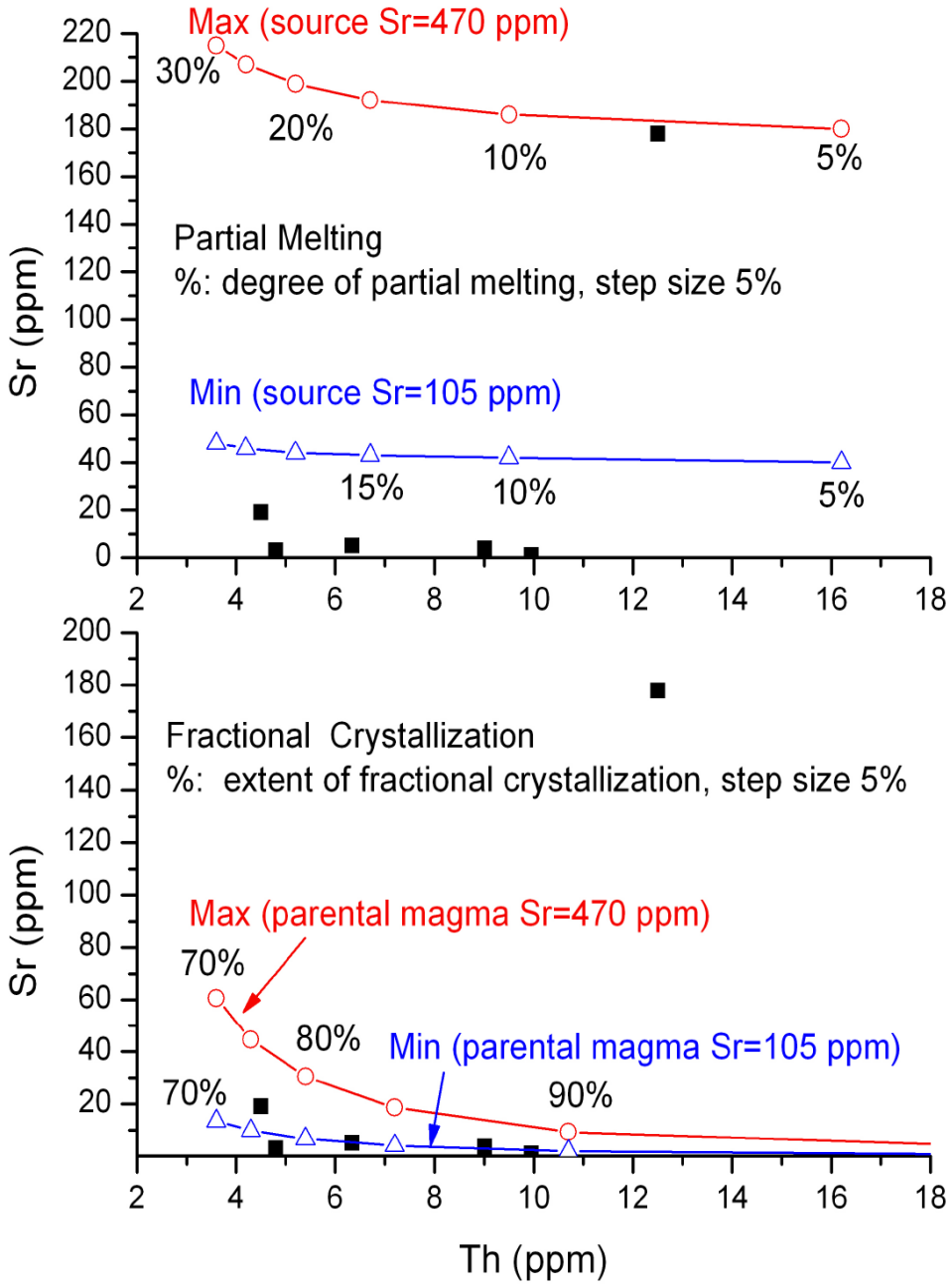
Nd and Sr isotopes in plume - derived basalts and silicic lavas - mixing with brine ?

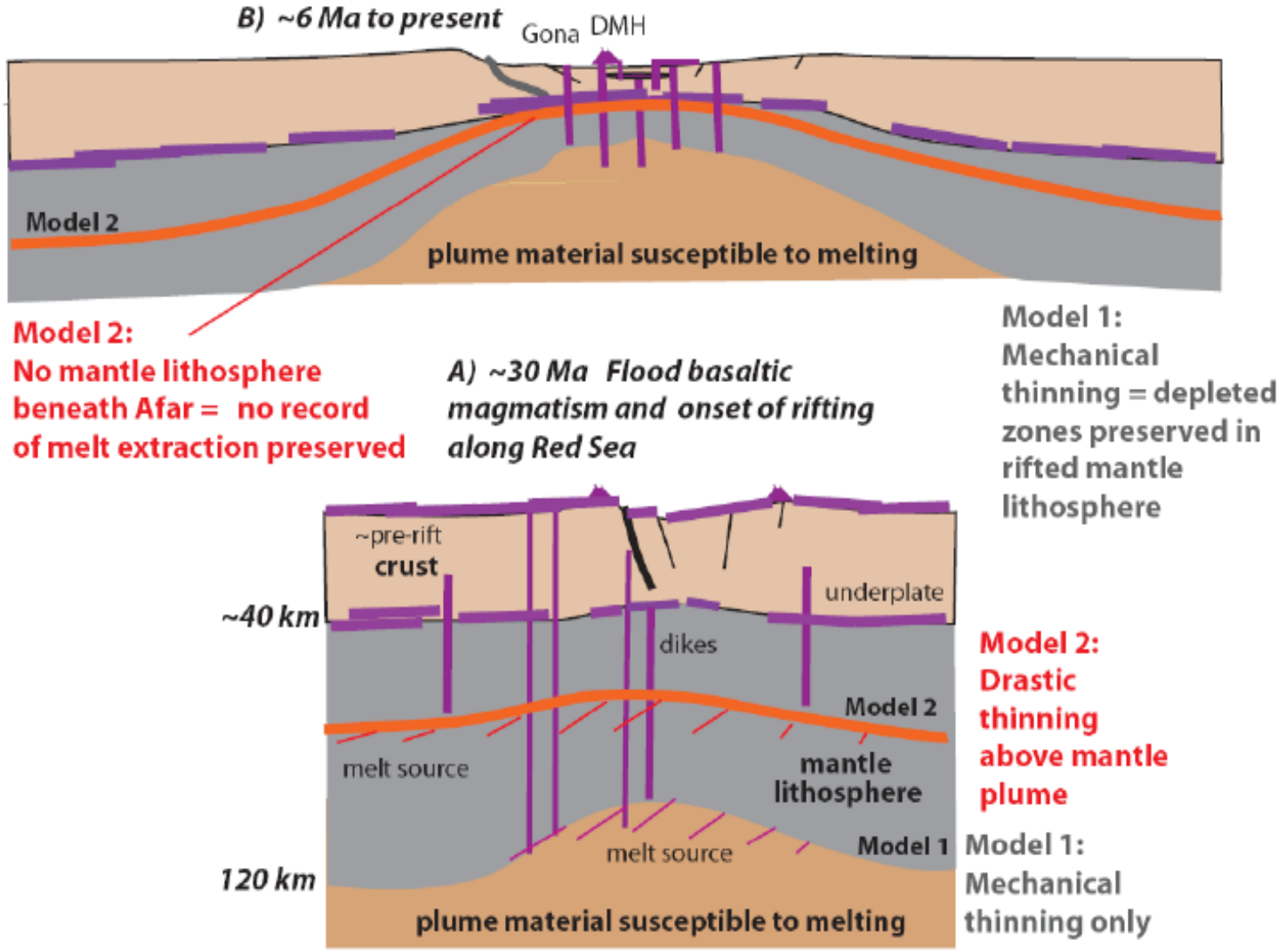



εNd - age of bimodal volcanism, Gona
MORB
Dabbahu Manda Hararo
Silicic Tuff
Basalts
εNd
Age (Ma)
9.0
6.0
3.0
0.0
0
2
4
6



Afar lavas are unlike global MORB (asthenosphere) composition. Radiogenic isotopes and trace elements in the bimodal volcanics provide constraints for hydrothermally altered common source for mafic and silicic lavas


Max (source Sr=470 ppm)
30%
20%
10%
5%
Partial Melting
%: degree of partial melting, step size 5%
Min (source Sr=105 ppm)
15%
10%
5%
Fractional Crystallization
%: extent of fractional crystallization, step size 5%
Max (parental magma Sr=470 ppm)
70%
80%
90%
Min (parental magma Sr=105 ppm)
70%
Sr (ppm)
Th (ppm)



Competing Models in the Afar depression from the onset of flood basaltic magmatism to continental break-up

Summary

- **Spectacular example of magmatism in the Afar depression is seen in < 2 Ma year old bimodal mafic and peralkaline silicic eruptions in the Dabbahu–Manda–Hararo rift.**

- **Silicic lavas are being generated in a lower mantle plume–derived basaltic magma chamber; magma source altered by interaction with the hydrosphere.**

- **Partial melting of hydrothermally altered plume-derived mafic source, without crustal contamination, produced the peralkaline liquid by plagioclase fractionation, both as a residual phase in partial melting and as fractional crystallization product in the magma.**

- **No evidence of lithosphere below DMH and Gona in Afar for the last 6Ma**

If there is no oceanic or continental lithosphere and asthenosphere below Afar, asks Tim Wright, then where did the helicopter land ?

on Geo-al-chemist's land!

15th-century European portrait of "Geber"

Raimundus Lullus alchemic painting

Abu Mūsā Jābir ibn Hayyān, known simply as Geber (born c. 721 in persia) was a prominent chemist, alchemist, astronomer, astrologer, engineer, geologist, philosopher, physicist, pharmacist and physician. Jābir is held to be the first practical alchemist