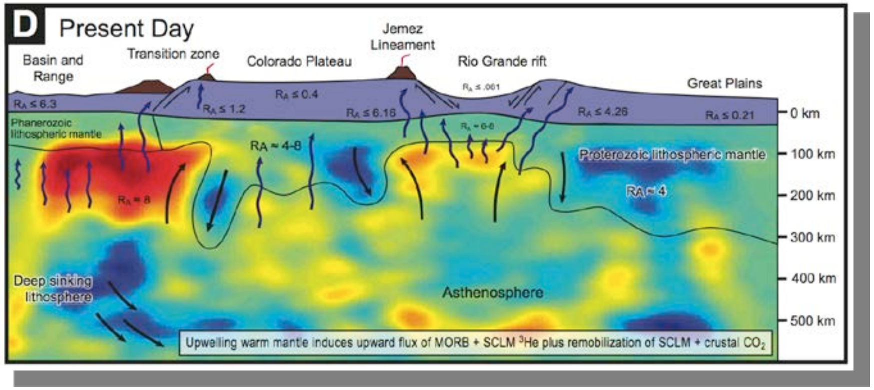
Volcanoes and the Mantle in Rifts

Tobias Fischer
University of New Mexico
Albuquerque, Rio Grande Rift

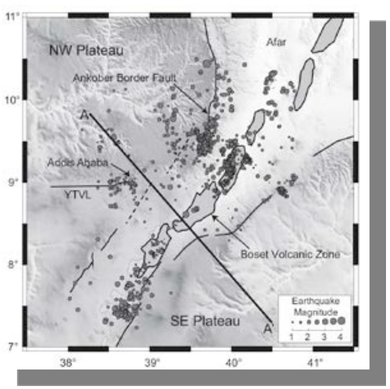
Rio Grande Rift

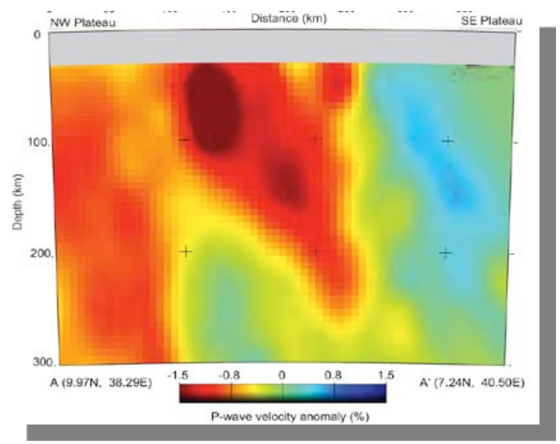


Hydrated lithosphere during earlier subduction (60 Ma)

Crossey et al., 2010
Sine et al., 2008

Northern East African Rift





Mantle Plume

Bastow et al., 2010

Nature and Role of Mantle Fluids (melts, volatiles)
Importance of integrated studies (cross-discipline and geography)

QuickTime™ and a
decompressor
are needed to see this picture.

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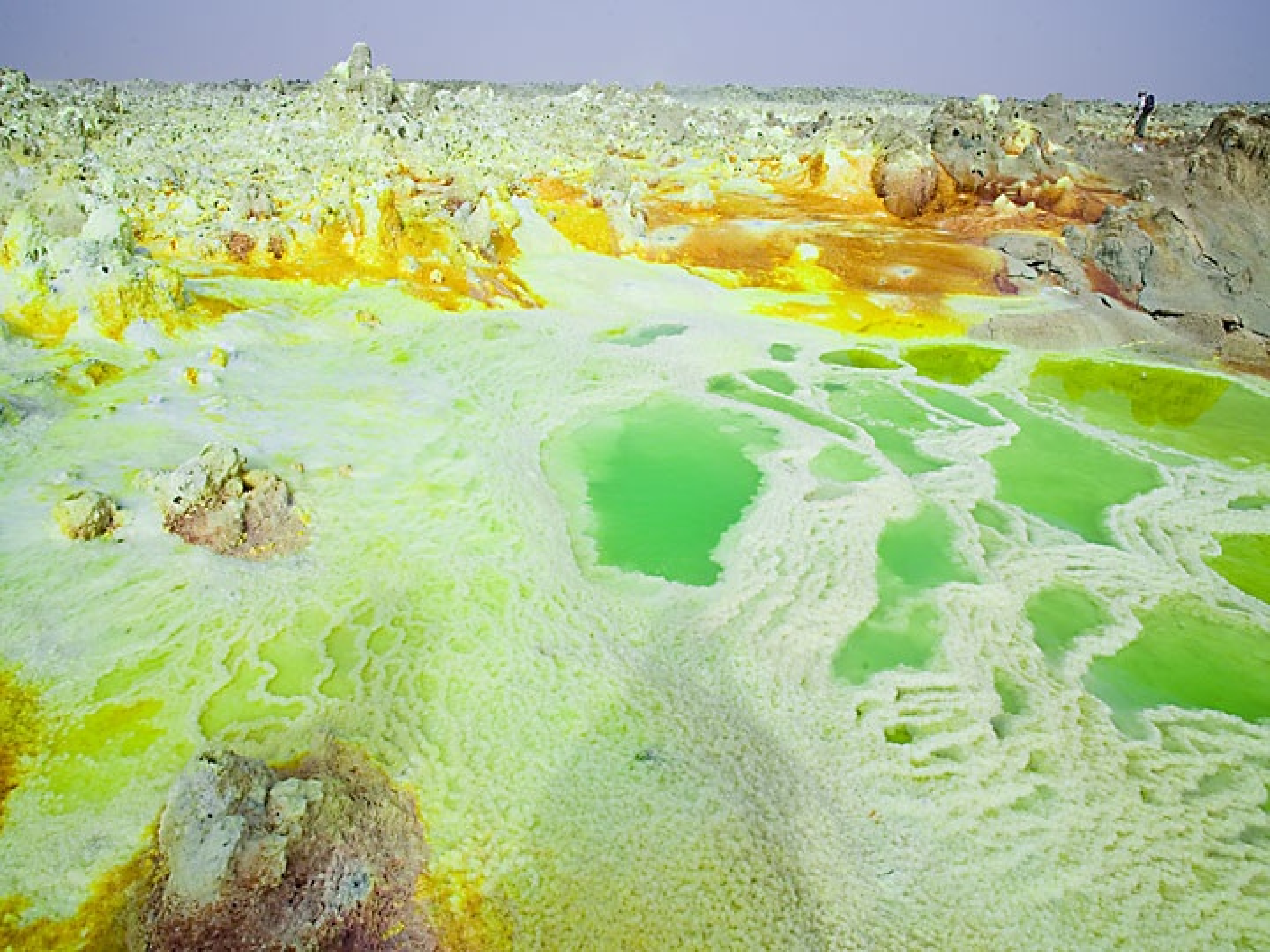

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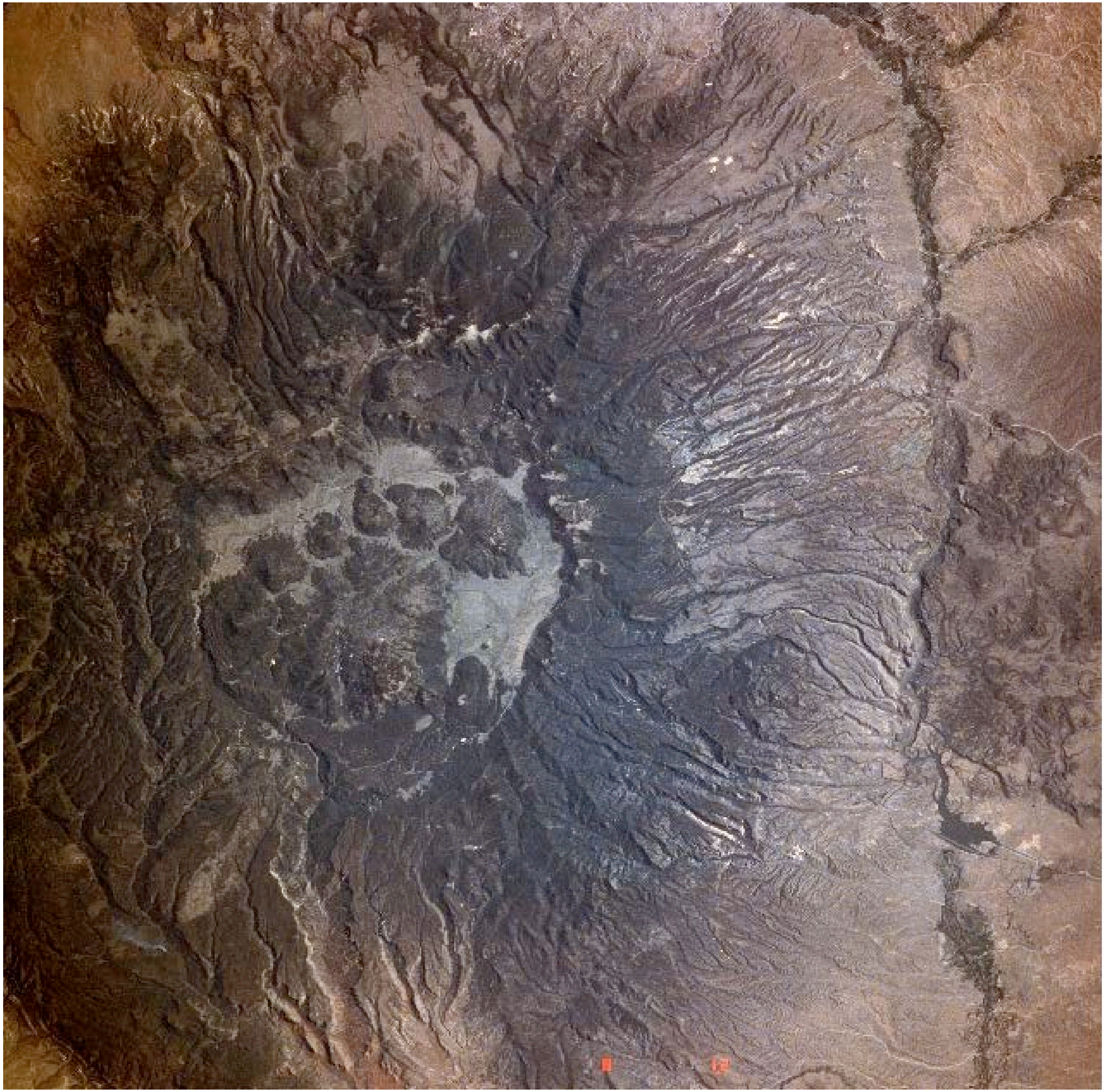


Nyiragongo

QuickTime™ and a
decompressor
are needed to see this picture.

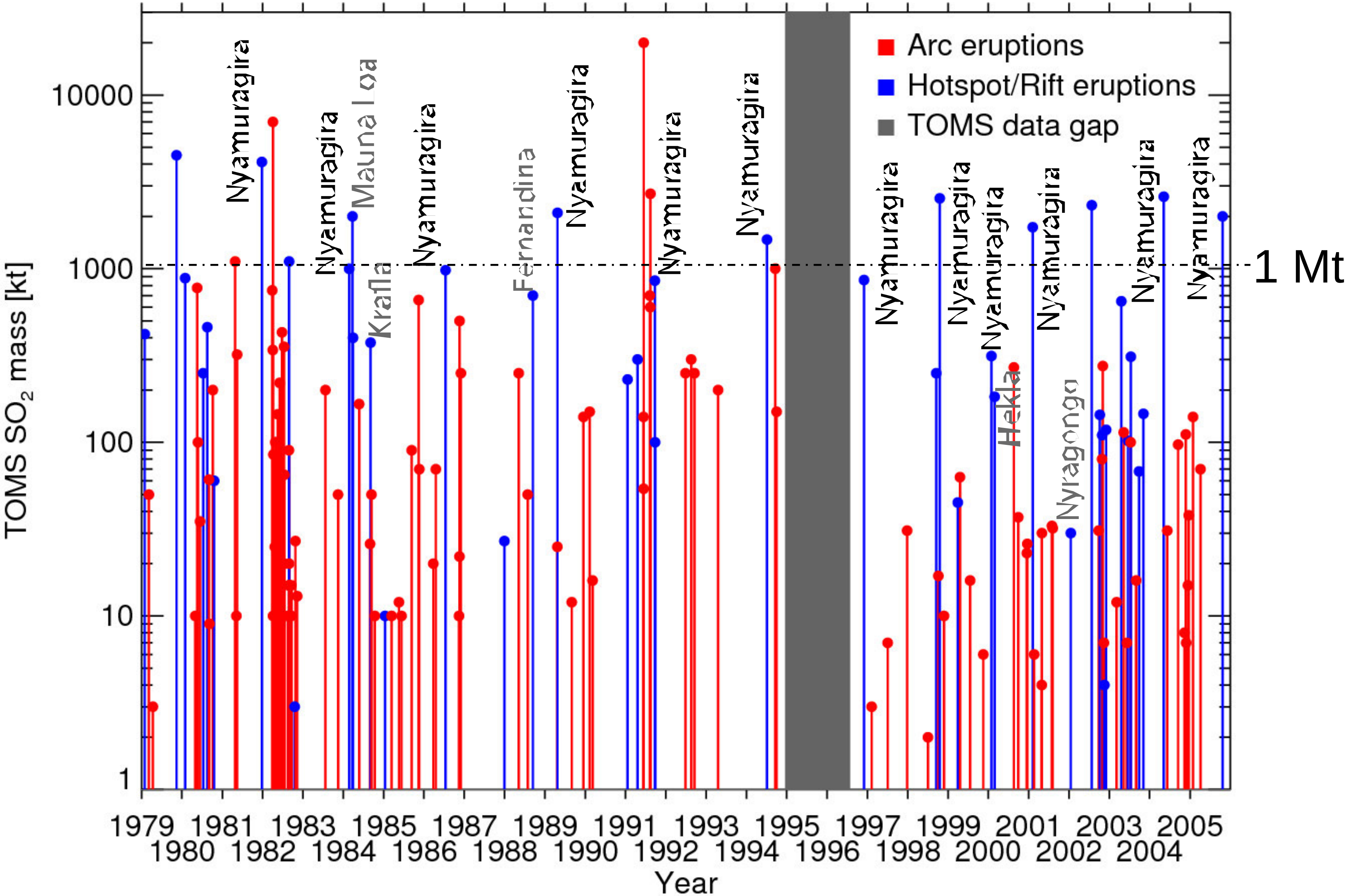
Nyamuragira

Depiction of the Nyiragongo and Nyamuragira volcanoes, based on data from the Shuttle Radar Topography Mission, Advanced Spaceborne Thermal Emission and Reflection Radiometer, or Aster, and Landsat. Some lava flows (not all) from the 2002-01-17 eruption are shown in red.

QuickTime™ and a
decompressor
are needed to see this picture.

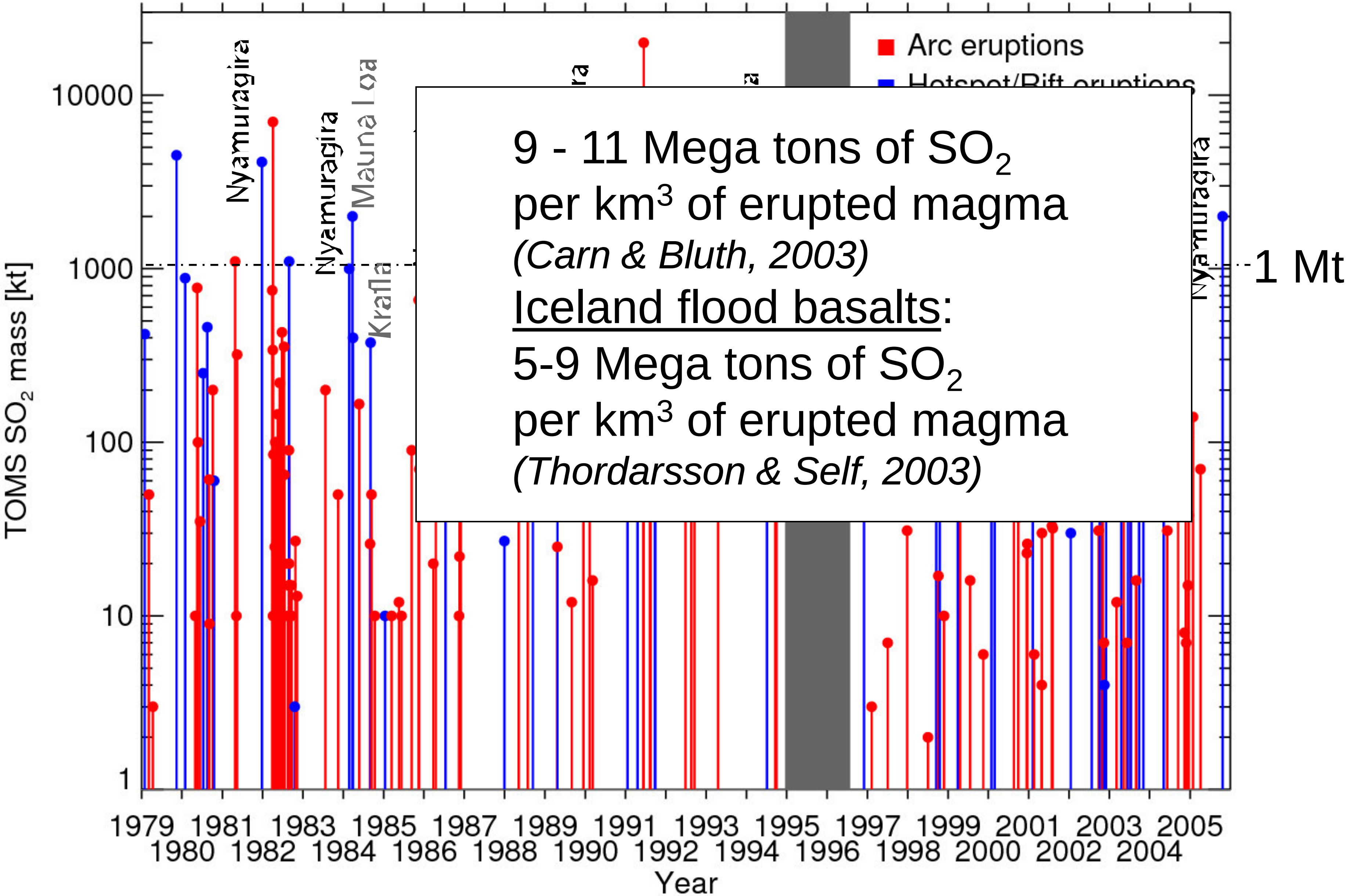
Around 10:00 p.m. local time on November 27, 2006, Mount Nyamulagira erupted.

Stratospheric SO_2 emission during eruptions



TOMS group, NASA

Stratospheric SO_2 emission during eruptions



9 - 11 Mega tons of SO_2 per km^3 of erupted magma

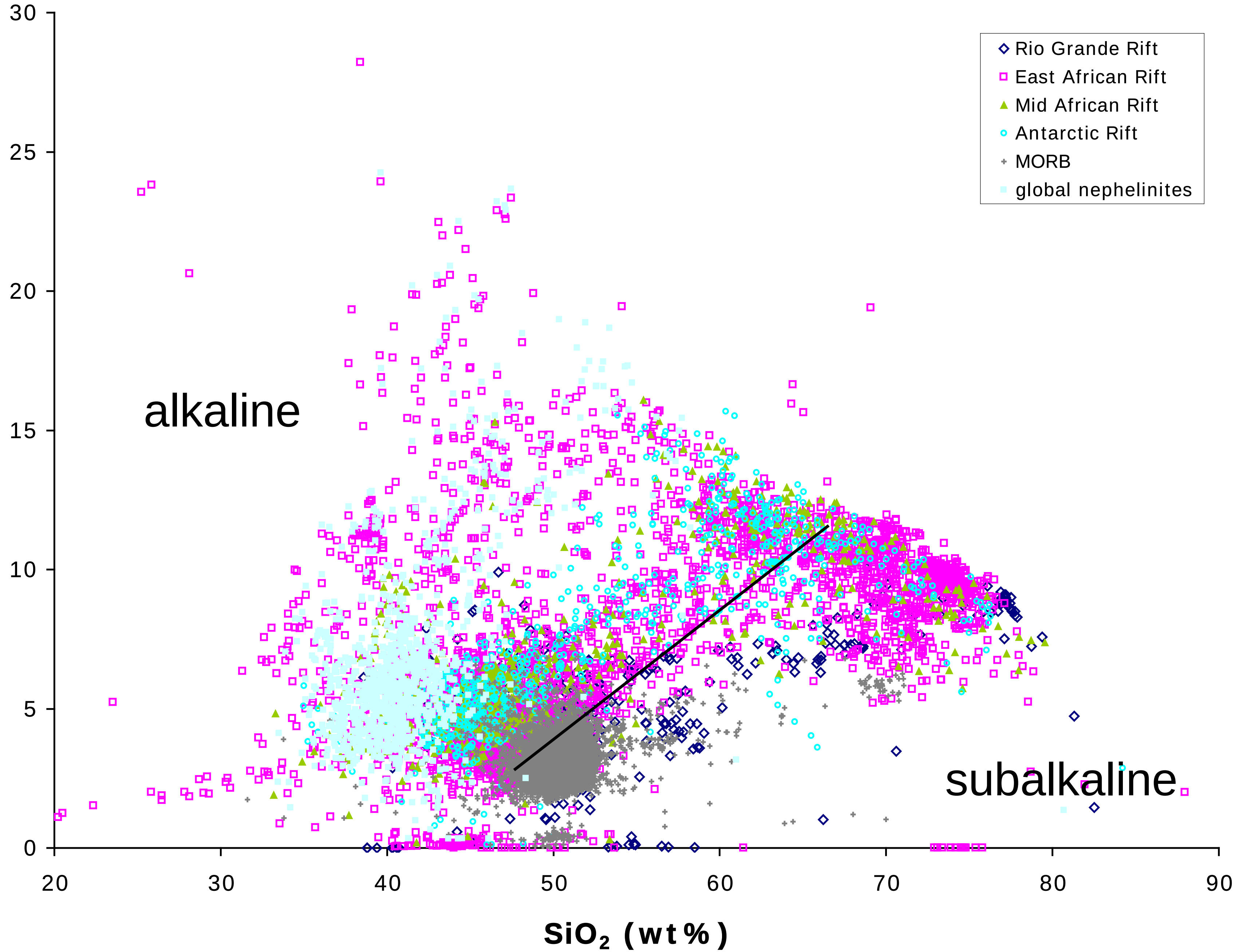
(Carn & Bluth, 2003)

<u>Iceland flood basalts</u>:

5-9 Mega tons of SO_2 per km^3 of erupted magma

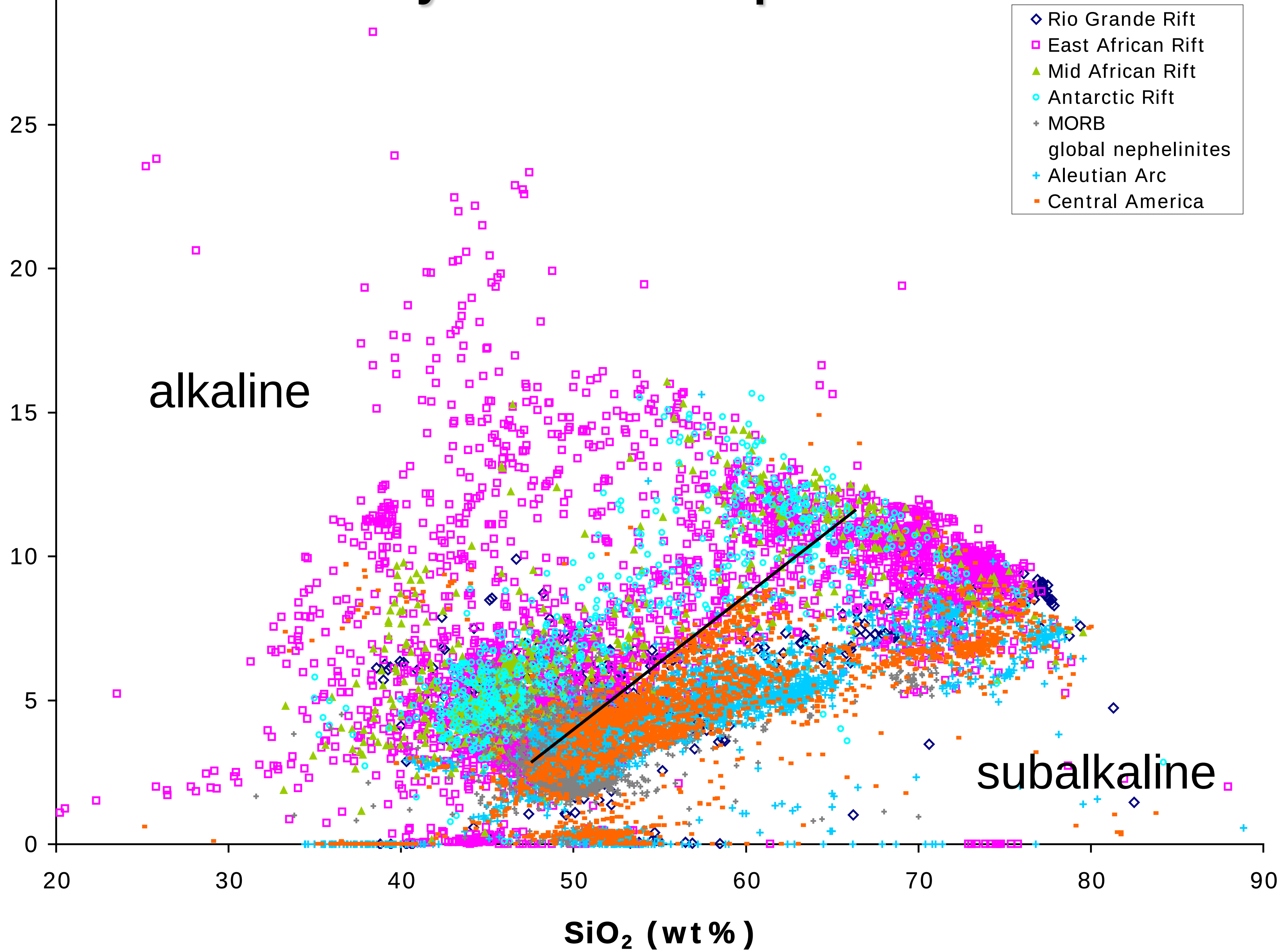
(Thordarsson & Self, 2003)

TOMS group, NASA

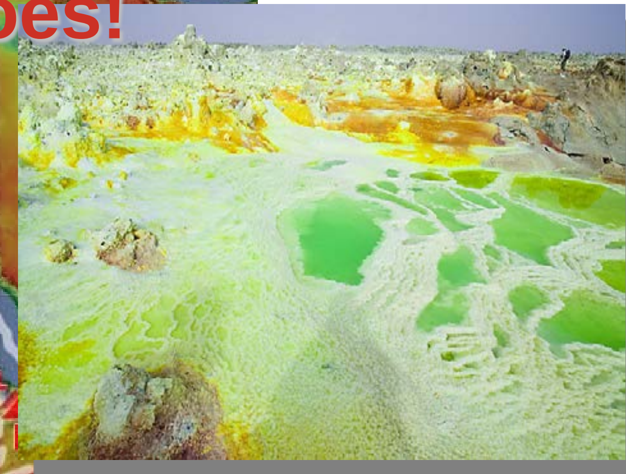


alkaline
subalkaline
Rio Grande Rift
East African Rift
Mid African Rift
Antarctic Rift
MORB
global nephelinites
SiO2 (wt%)
0
5
10
15
20
25
30
20
30
40
50
60
70
80
90

Great Variety of Rock Compositions!



Spectacularly Active Volcanoes!



The East African Rift

~ 3000 km long

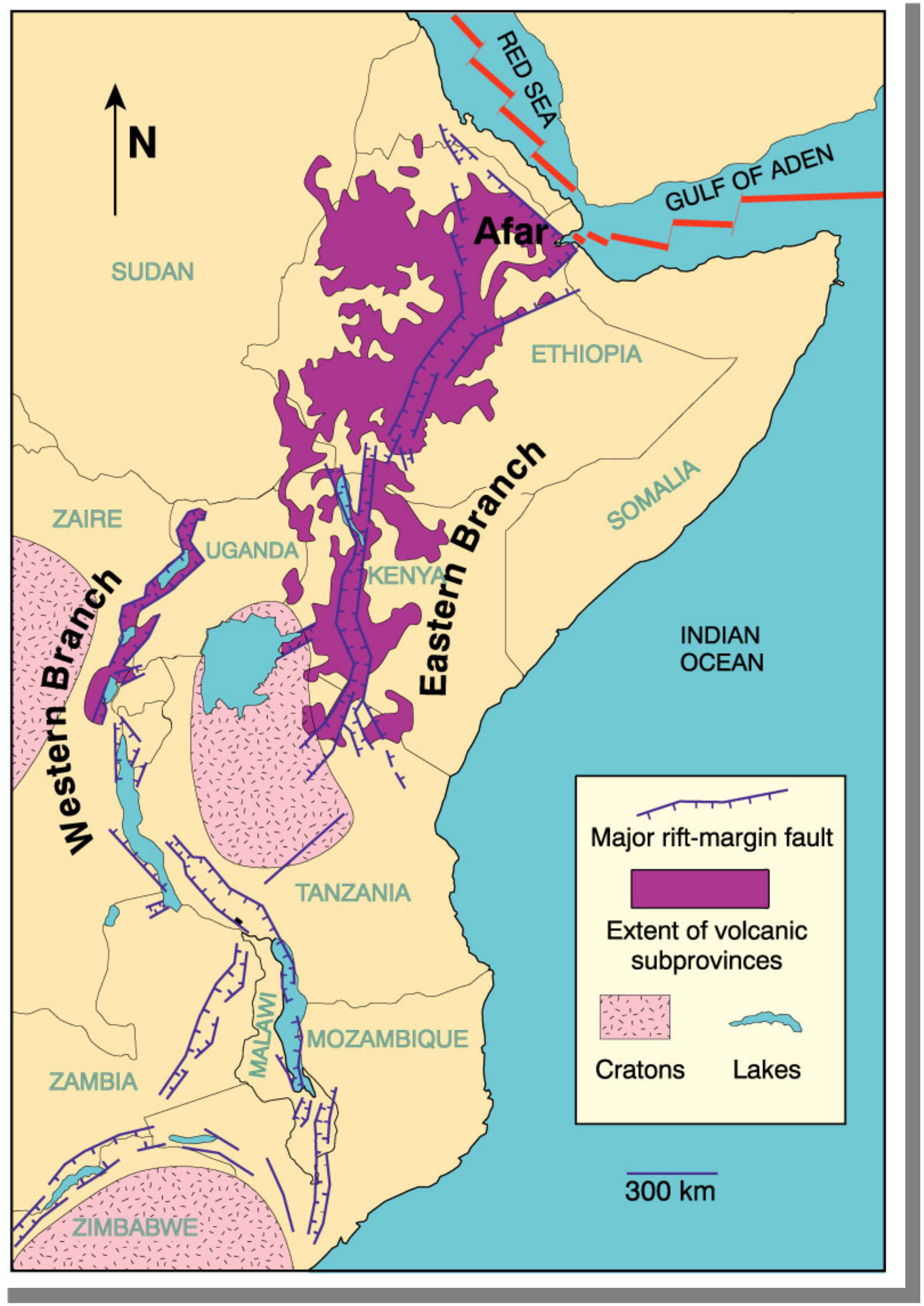
Western and Eastern Branch

Extensive volcanism
(~20% rhyolites/ignimbrites)

Earliest Volc. 45 Ma
(S-Ethiopia)

Huge Shield Volcanoes

Ethiopia Flood basalts (30 - 1 Ma)



Map of the East African Rift system (after Kampunzu and Mohr, 1991), Magmatic evolution and petrogenesis in the East African Rift system. In A. B. Kampunzu and R. T. Lubala (eds.), *Magmatism in Extensional Settings, the Phanerozoic African Plate*. Springer-Verlag, Berlin, pp. 85-136. Winter (2001) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

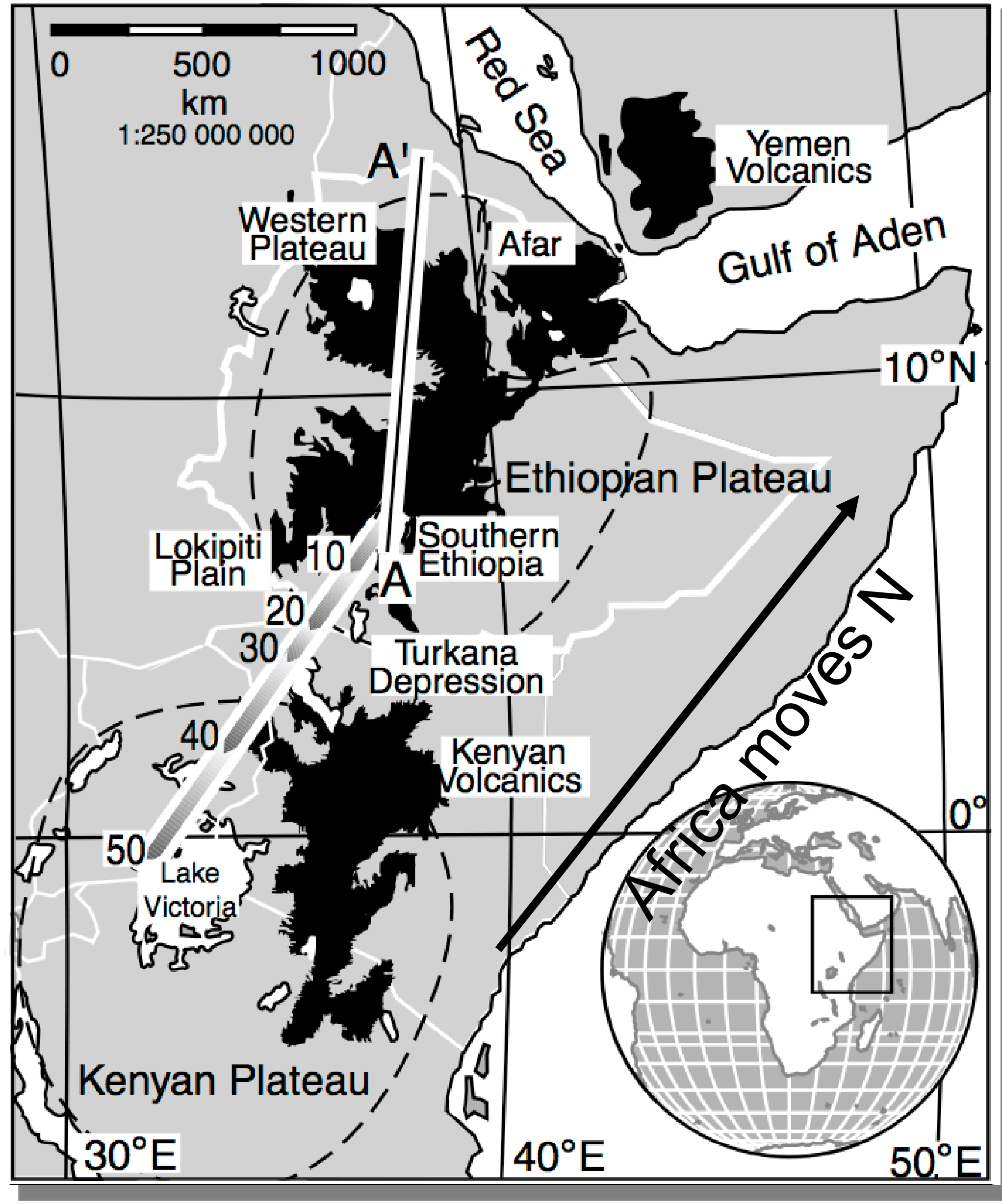
Continental Flood Basalt Provinces are related to mantle plumes

(*e.g. White and McKenzie, 1995*)

Tertiary volcanic rocks
plate trajectories
from 50 m.y. to
10 m.y.

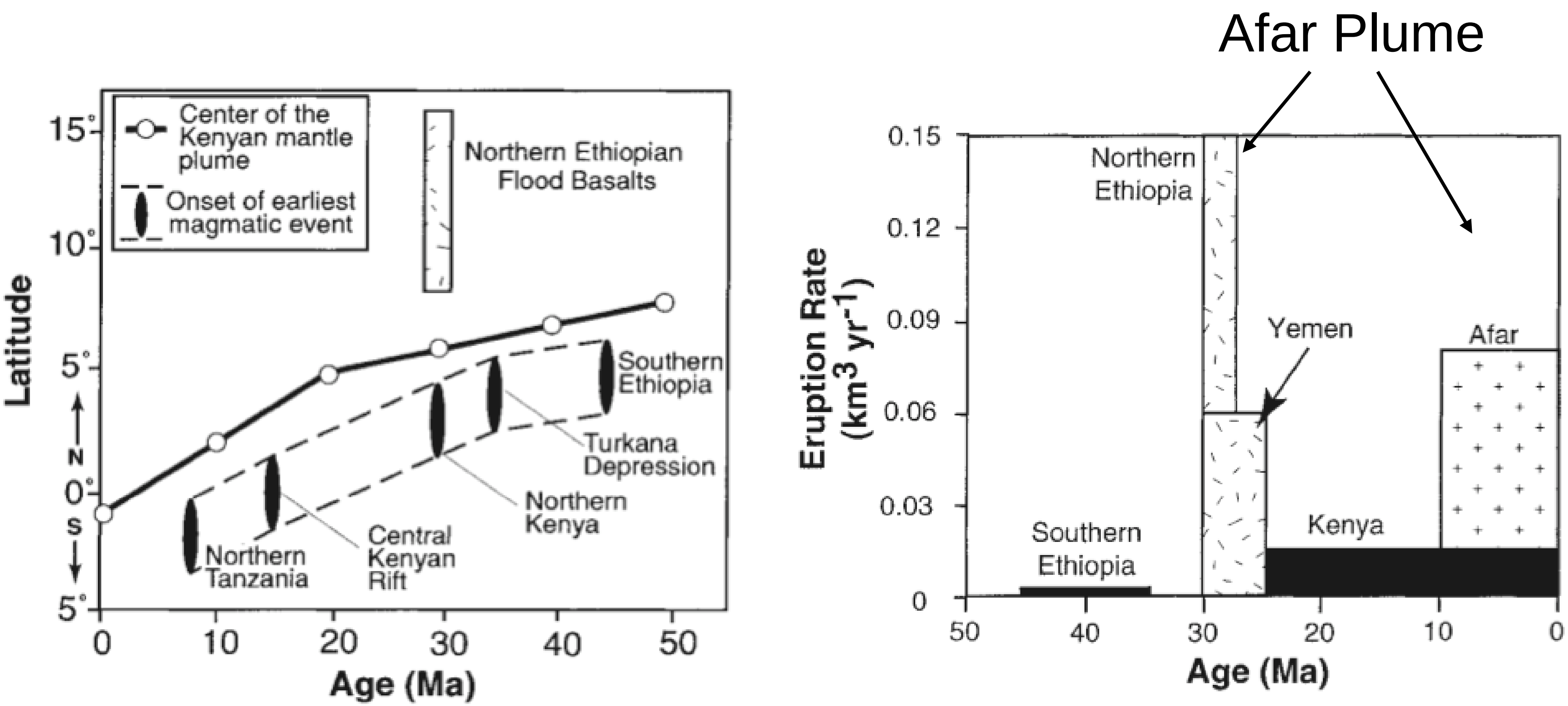
S-Ethiopia was positioned
over Kenya plume
50 m.y. ago

Two Plumes
Afar and Kenya
(e.g. Ebinger et al., 1989)



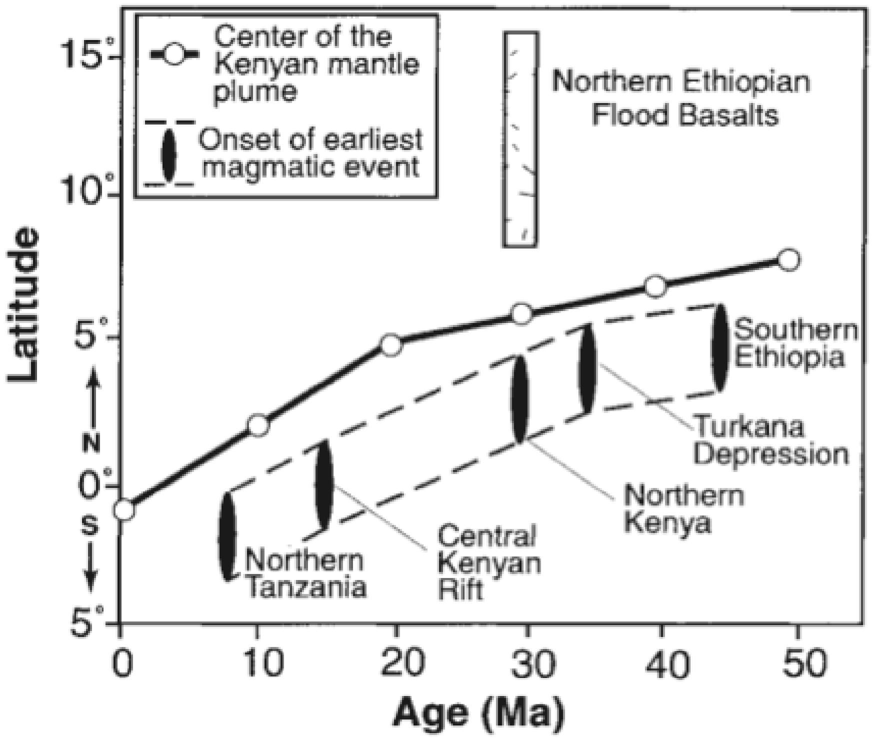
George et al., 2010

Plume locations and eruption rates

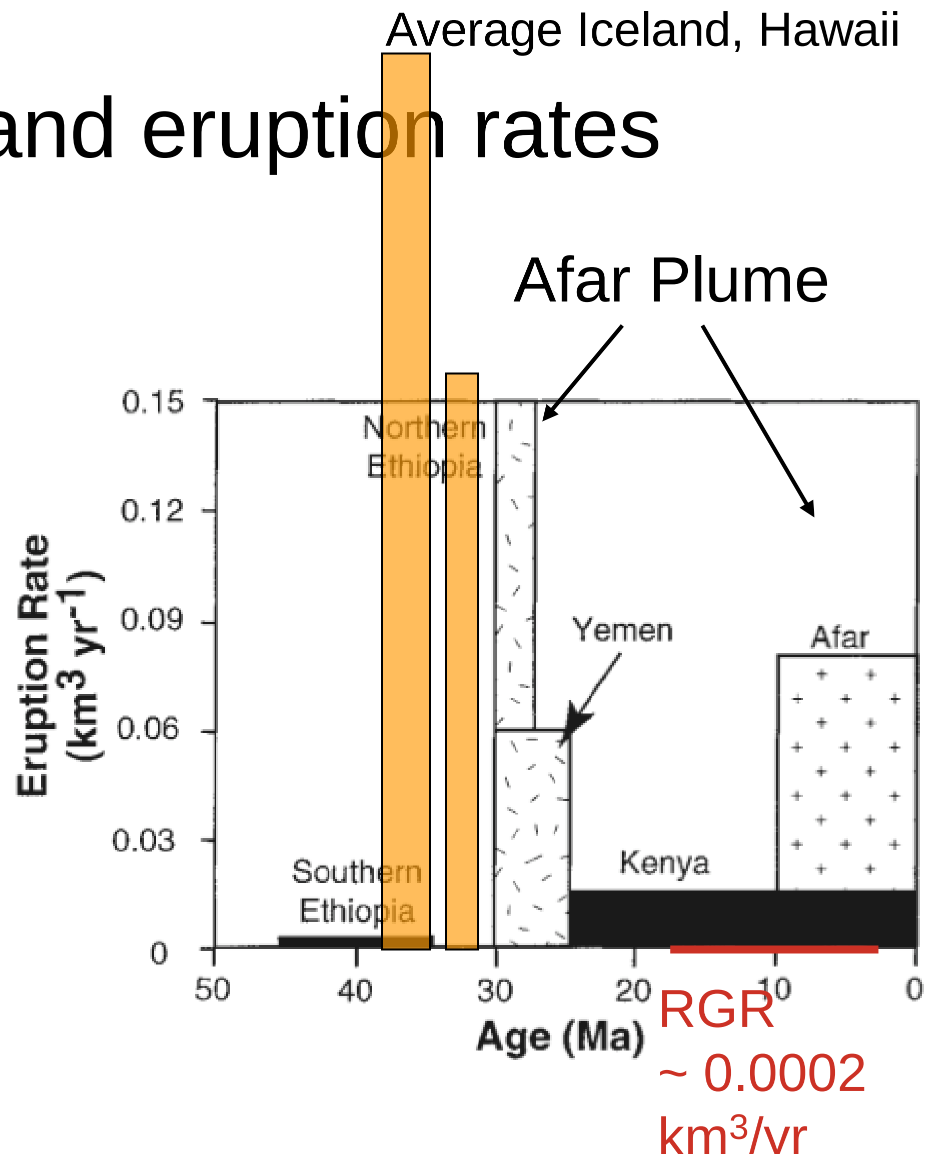


George et al., 2010

Plume locations and eruption rates



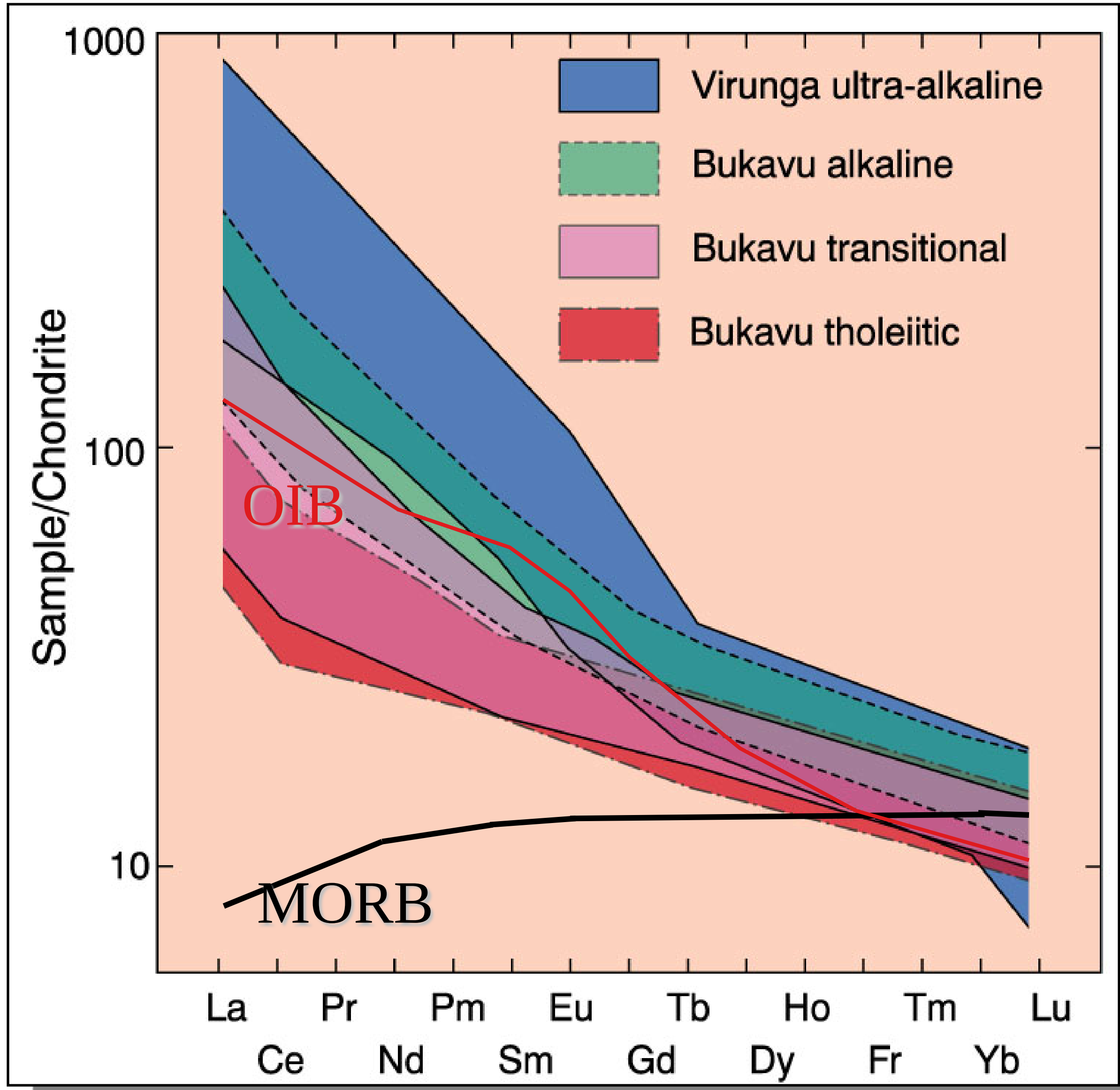
George et al., 2010



Southern NM Calderas
~ 33 - 28 Ma
Additional ~ 5000 km^3
0.01 km^3/yr

The East African Rift

Enrichment in LILE compared to MORB -> similar to OIB or Plume



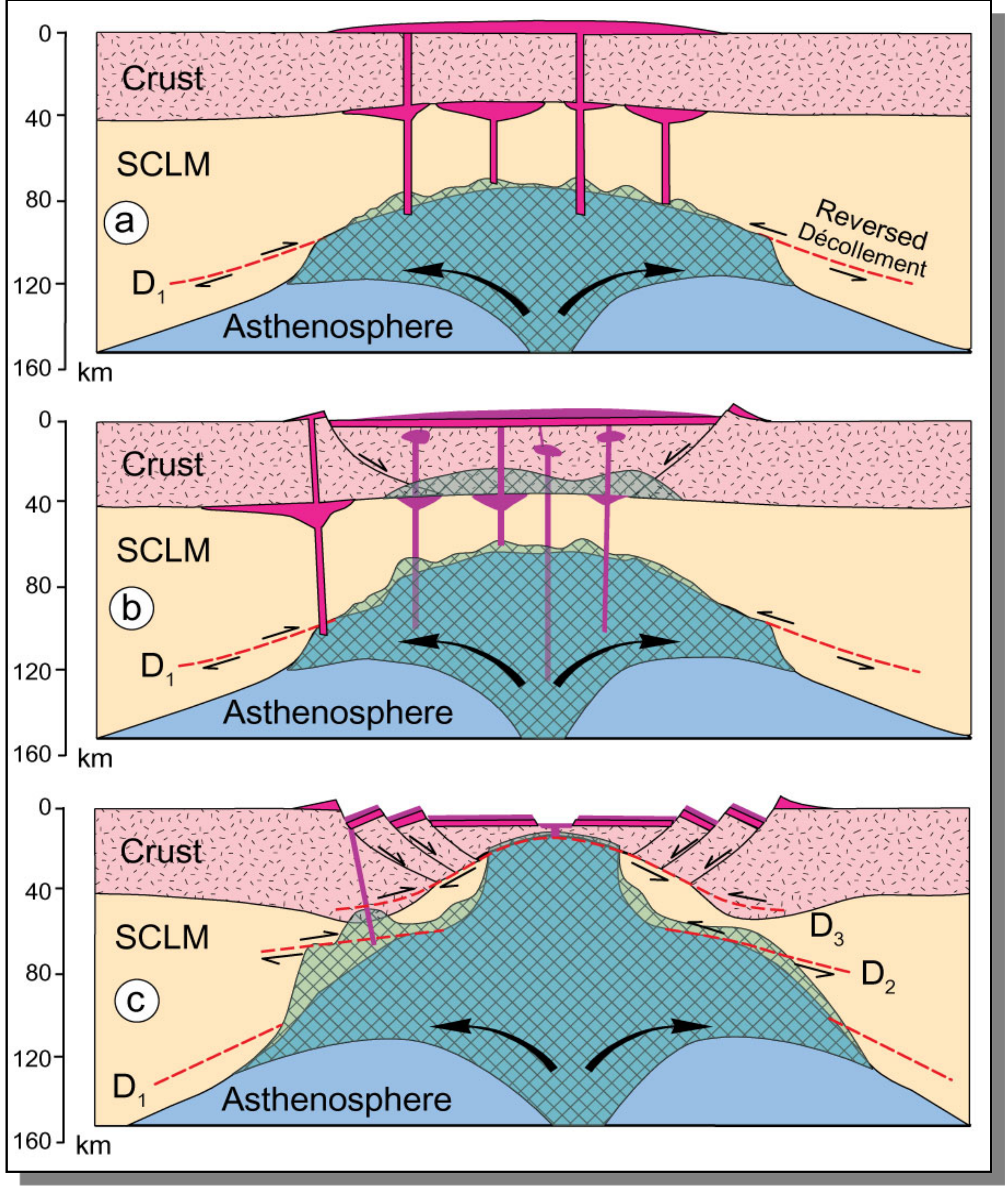
Chondrite-normalized REE variation diagram for examples of the four magmatic series of the East African Rift (after Kampunzu and Mohr, 1991), Magmatic evolution and petrogenesis in the East African Rift system. In A. B. Kampunzu and R. T. Lubala (eds.), *Magmatism in Extensional Settings, the Phanerozoic African Plate*. Springer-Verlag, Berlin, pp. 85-136. Winter (2001) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

East African Rift System.

a. Pre-rift stage, asthenospheric mantle rises into the lithosphere. Decompression melting produces variably alkaline melts. Some partial melting of the metasomatized sub-continental lithospheric mantle (SCLM) may also occur.

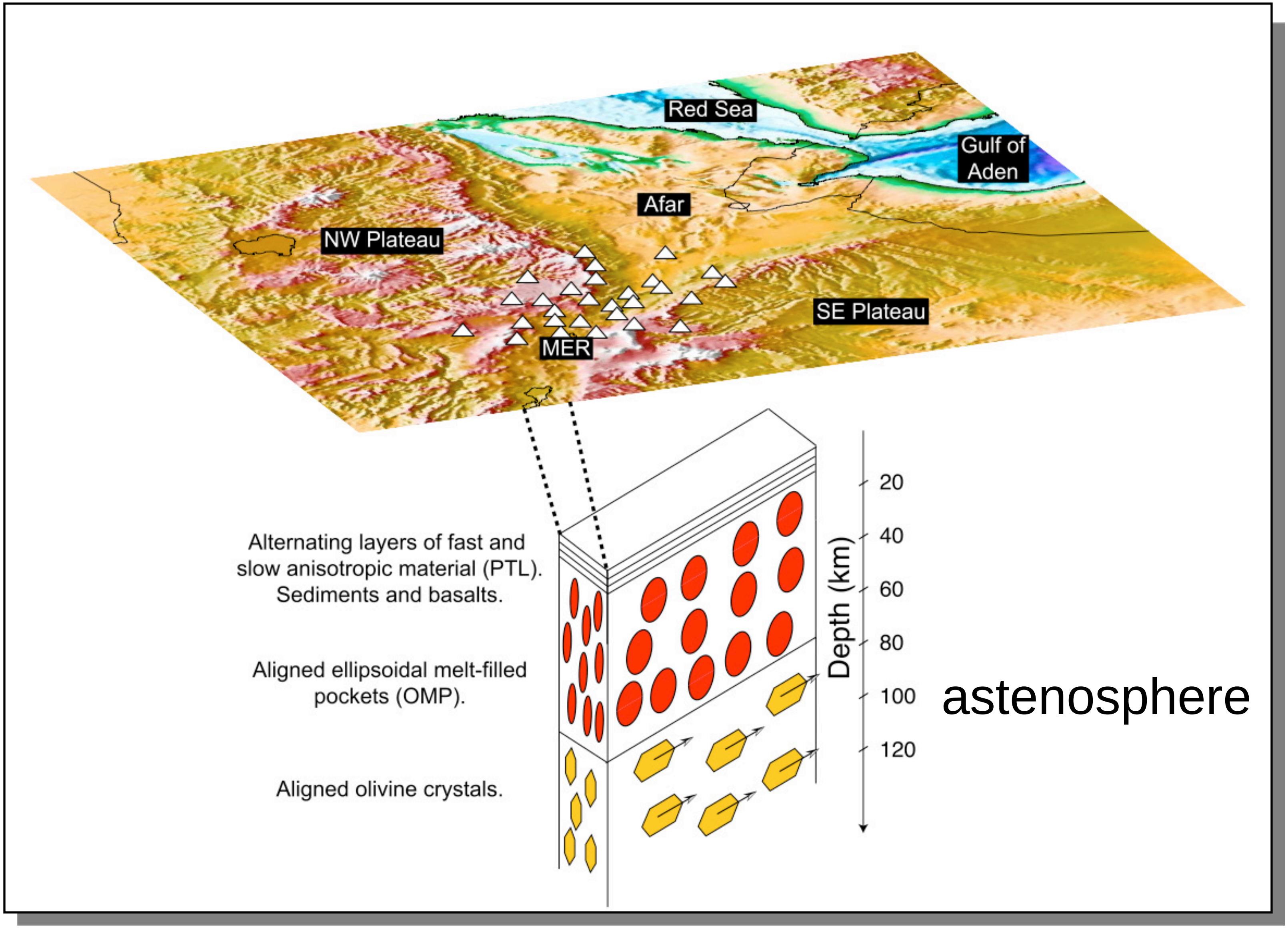
b. Rift stage: development of continental rifting, eruption of alkaline magmas (red) mostly from a deep asthenospheric source.

c. Afar stage, in which asthenospheric ascent reaches crustal levels. This is transitional to the development of oceanic crust.



After Kampunzu and Mohr (1991), Winter (2001) An Introduction to Igneous and Metamorphic Petrology.

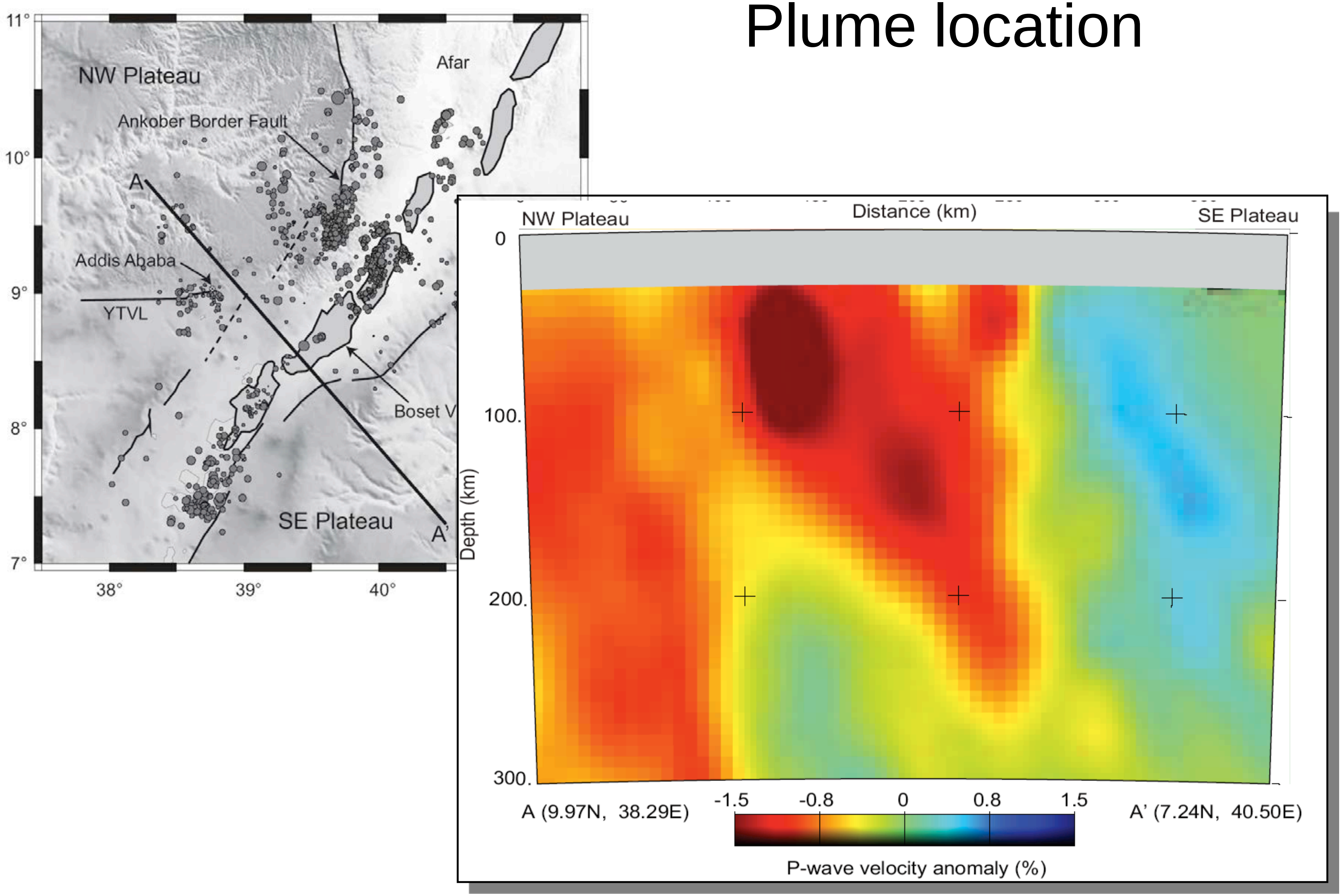
Anisotropy: Large-scale mantle flow in astenosphere associated with the superplume



astenosphere

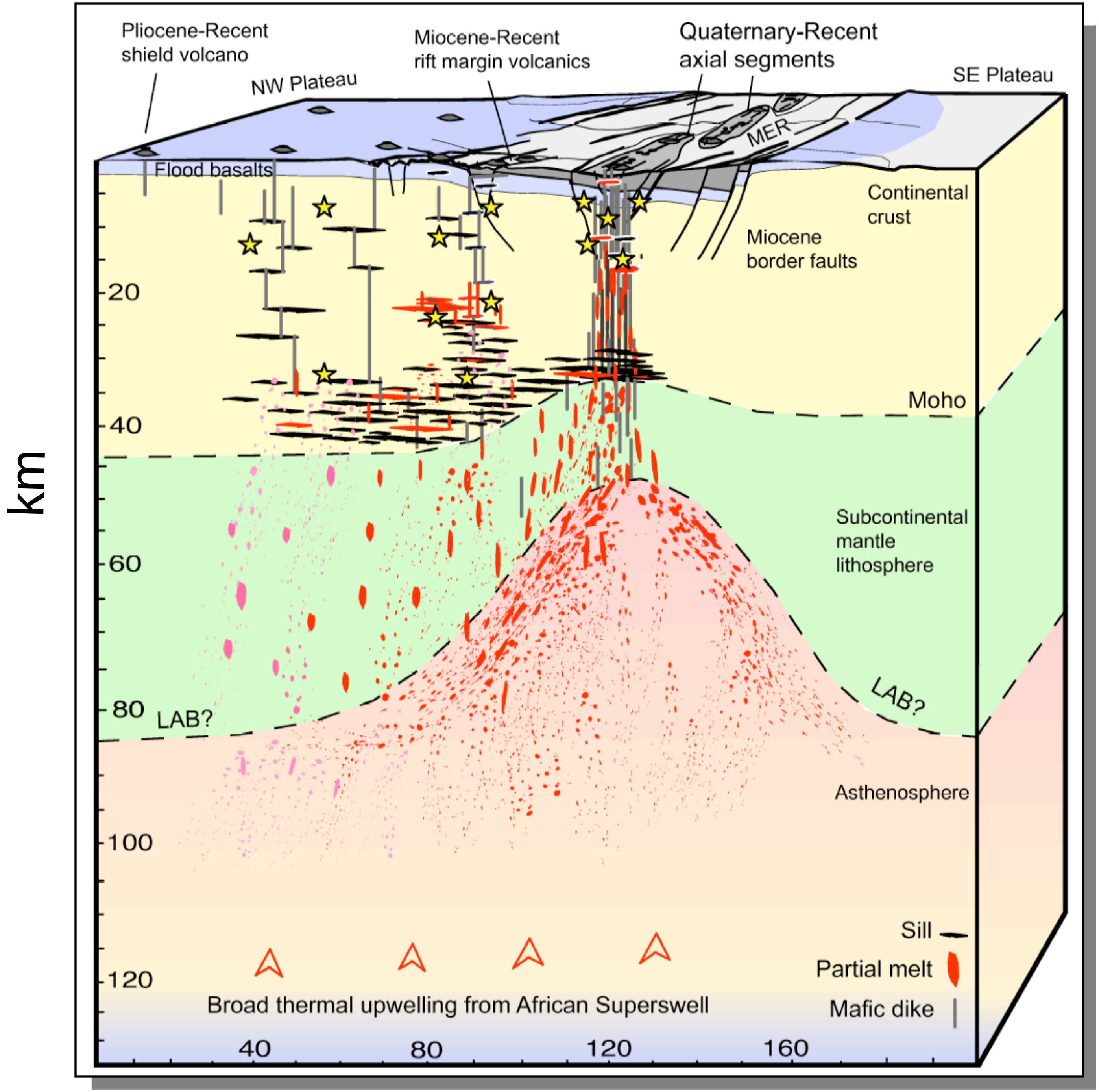
Bastow et al., 2010

Plume location



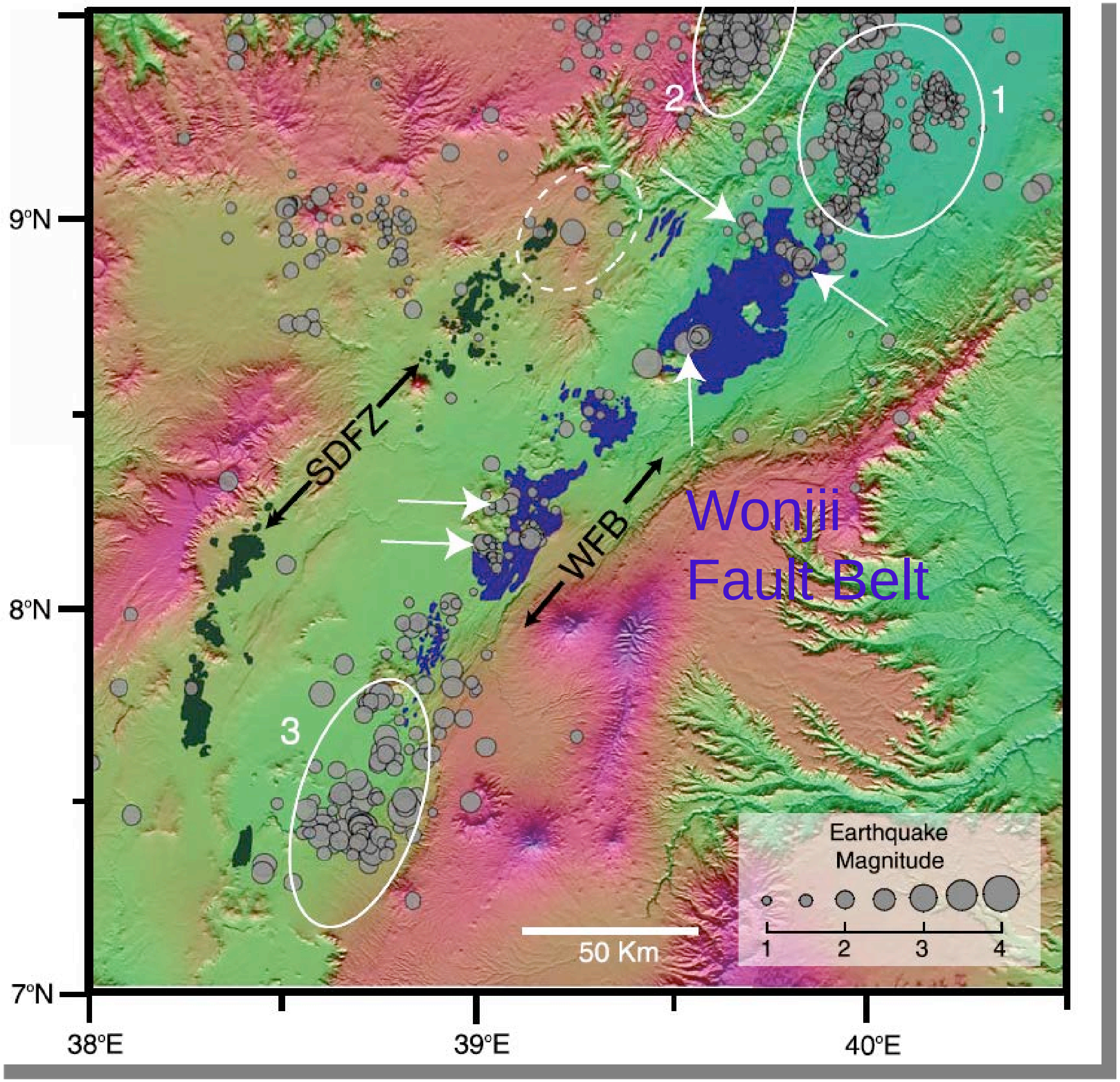
Bastow et al., 2010

EAGLE



Bastow et al., 2010

Geochemical/petrologic considerations



Rooney et al., 2007

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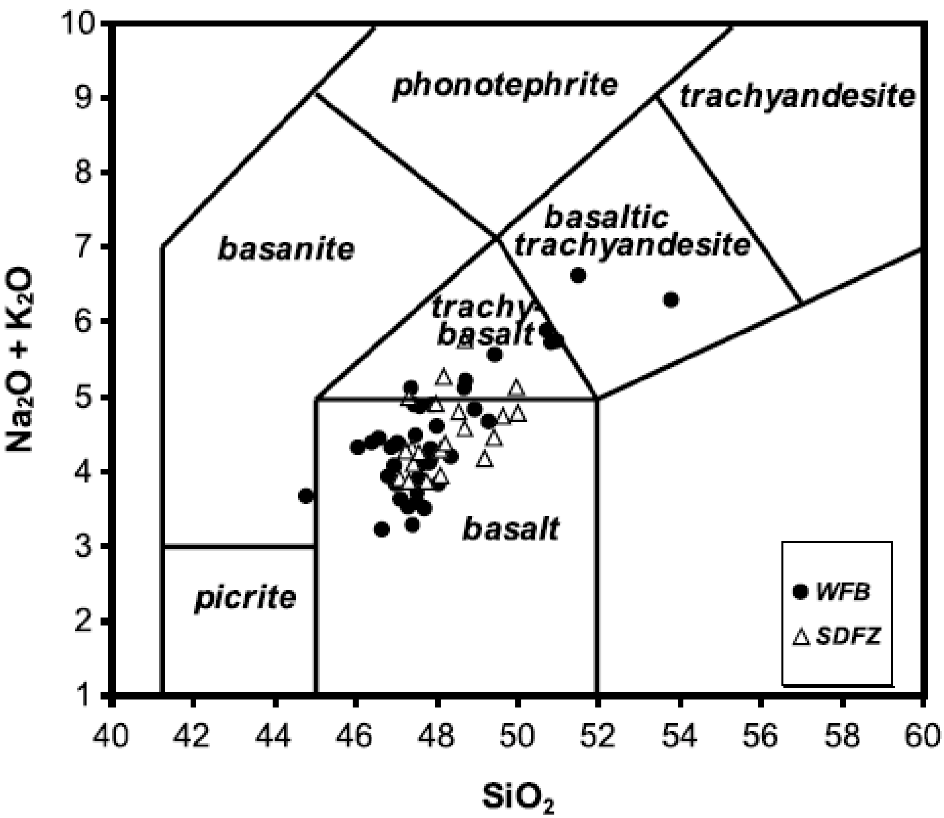

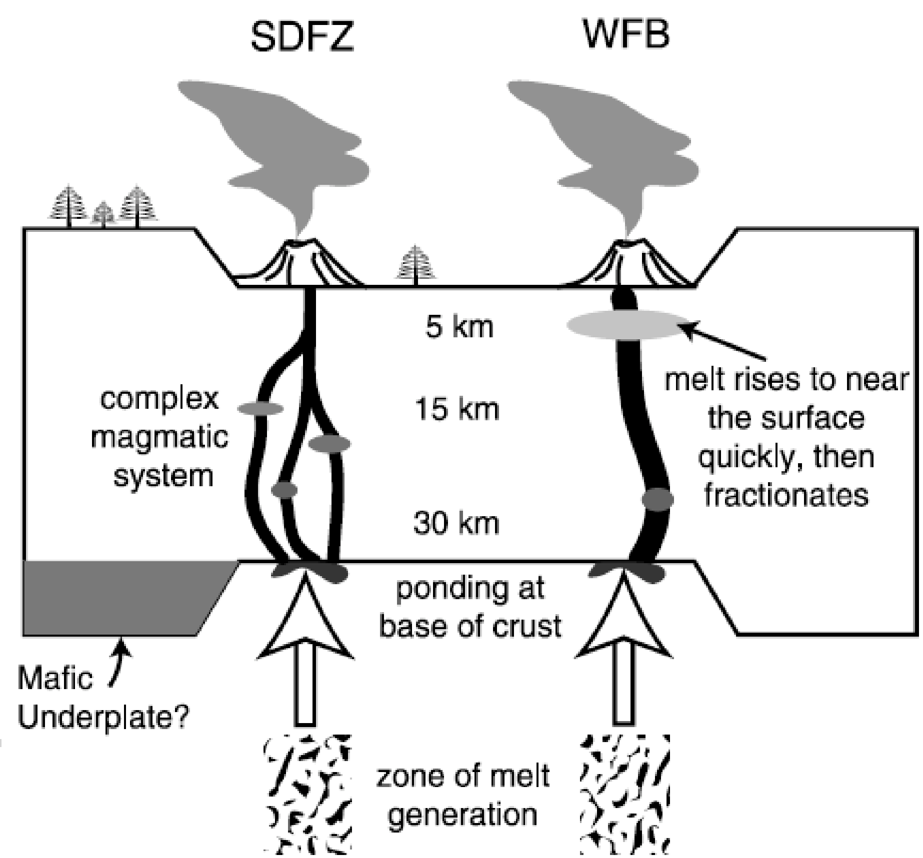

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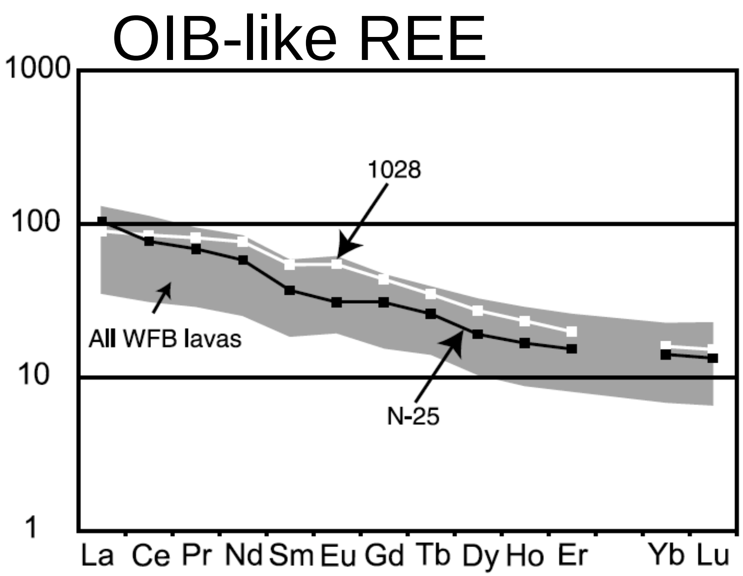
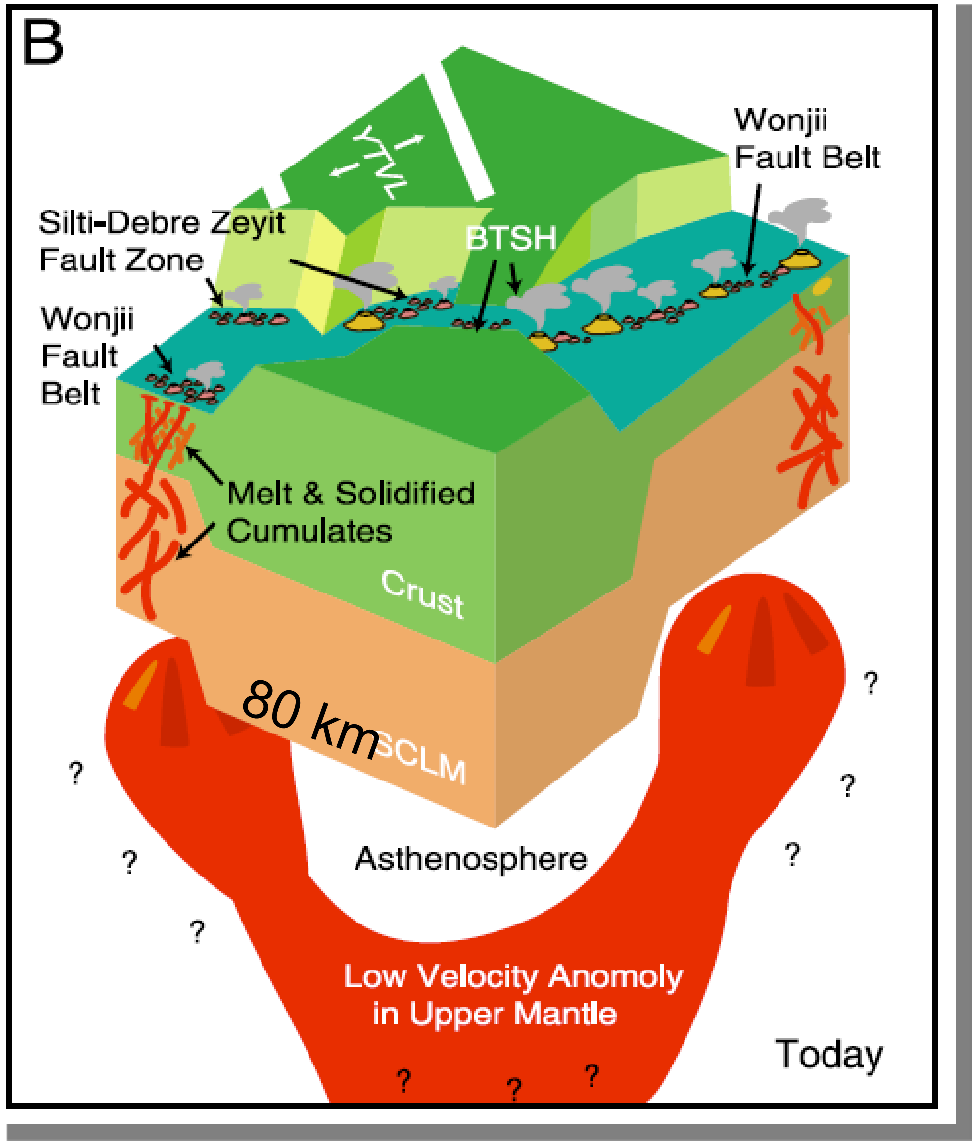
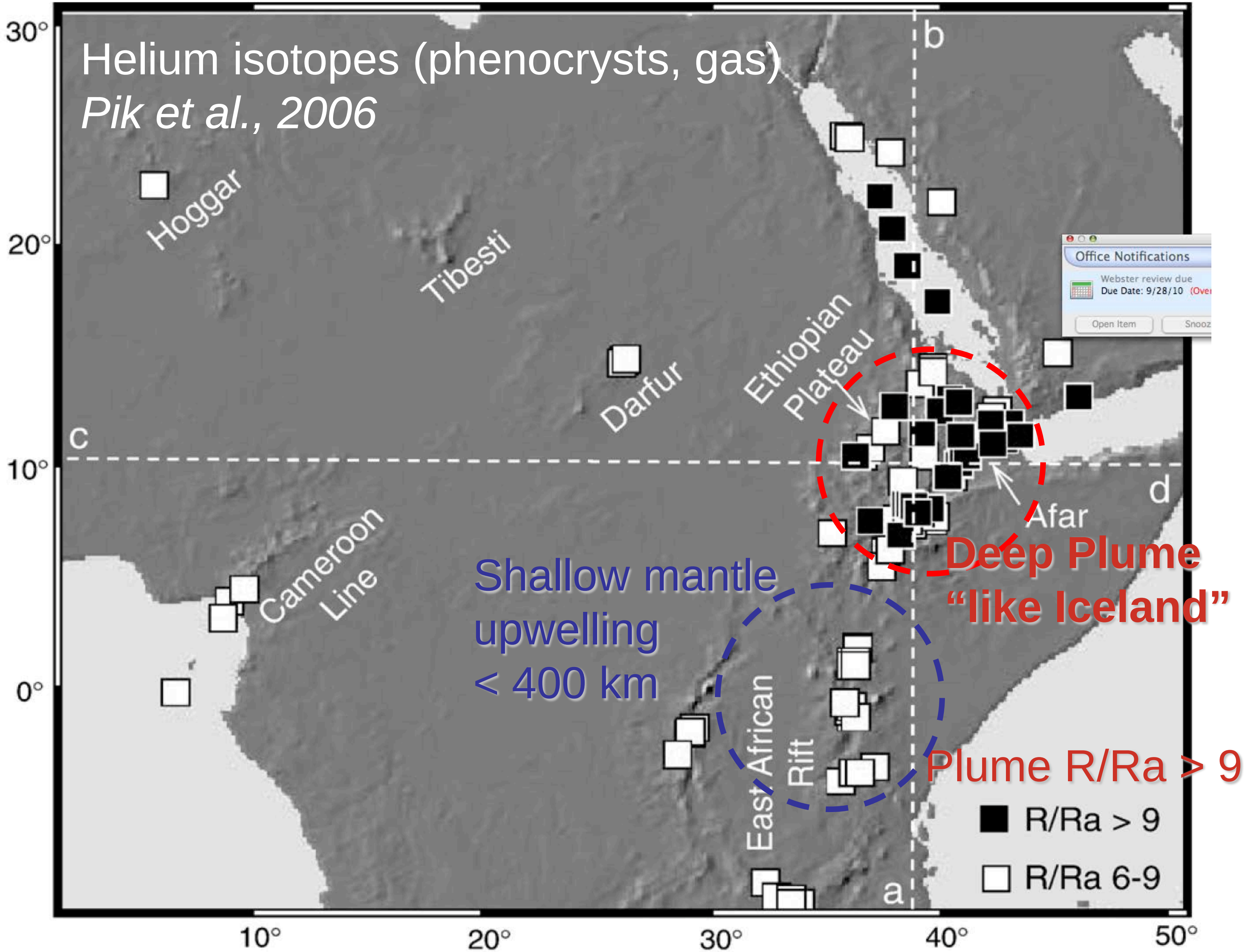
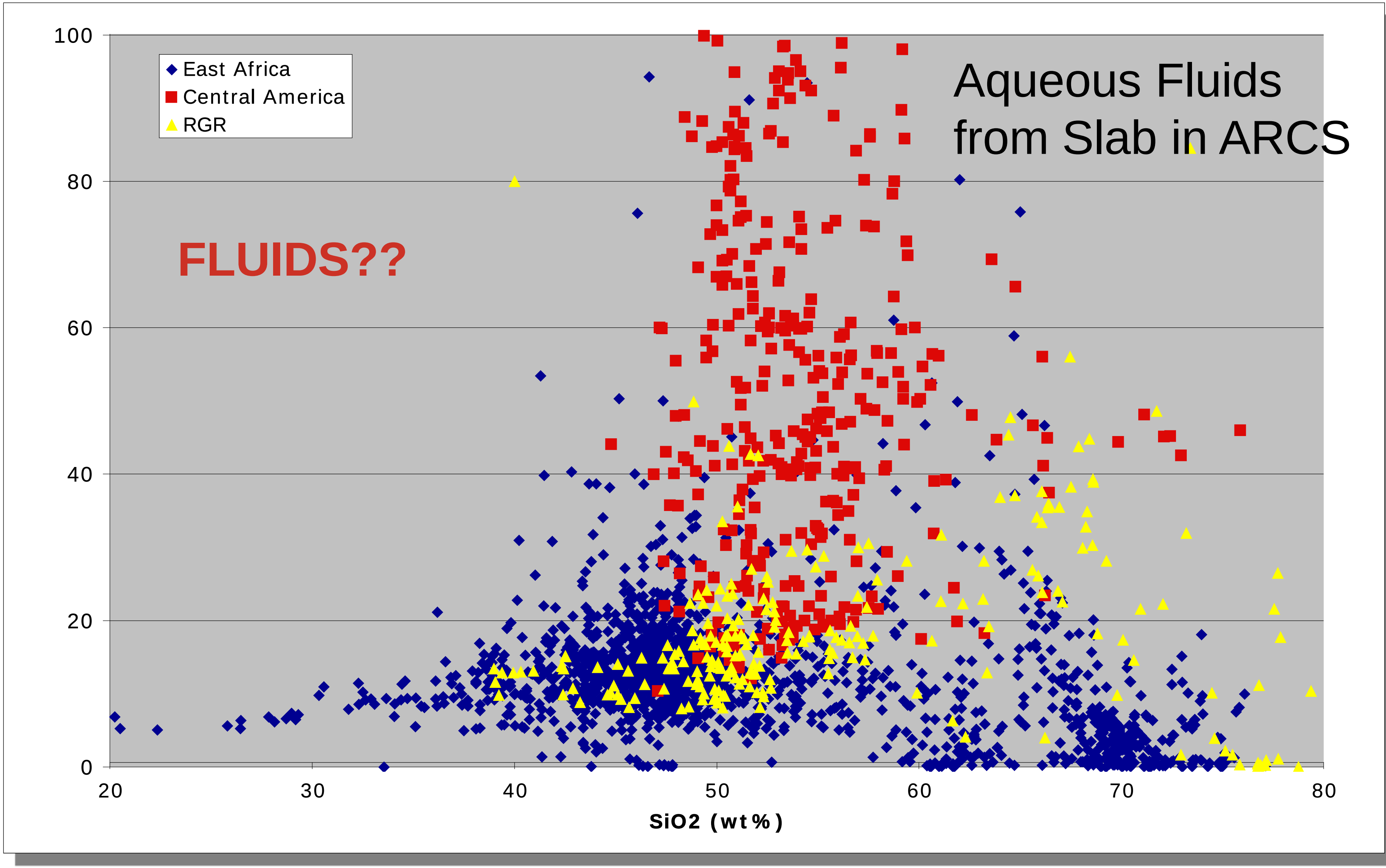




Rooney et al., 2007



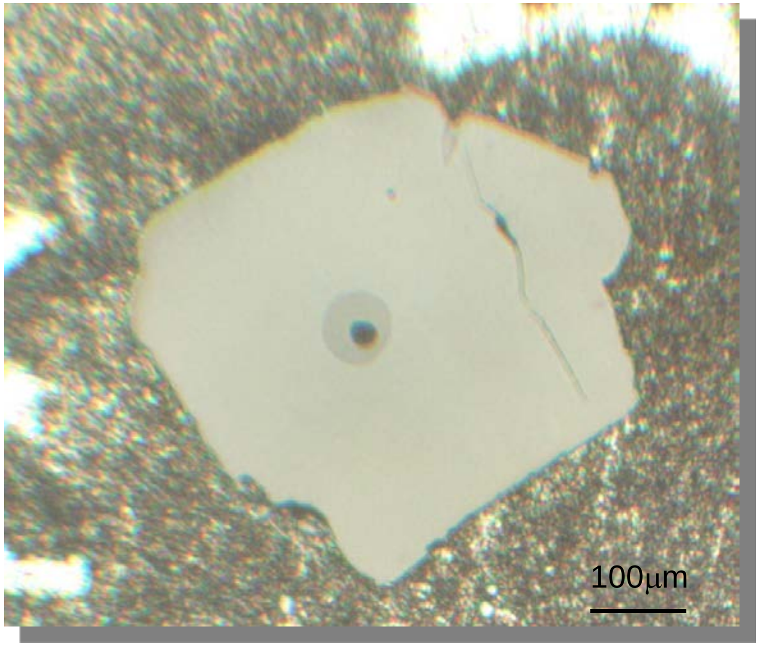
Helium isotopes (phenocrysts, gas)
Pik et al., 2006
Hoggar
Tibesti
Darfur
Ethiopian Plateau
Afar
Cameroon Line
East African Rift
Shallow mantle upwelling < 400 km
Deep Plume "like Iceland"
Plume R/Ra > 9
R/Ra > 9
R/Ra 6-9
b
c
d
a
30°
20°
10°
0°
10°
20°
30°
40°
50°
Office Notifications
Webster review due
Due Date: 9/28/10
Open Item

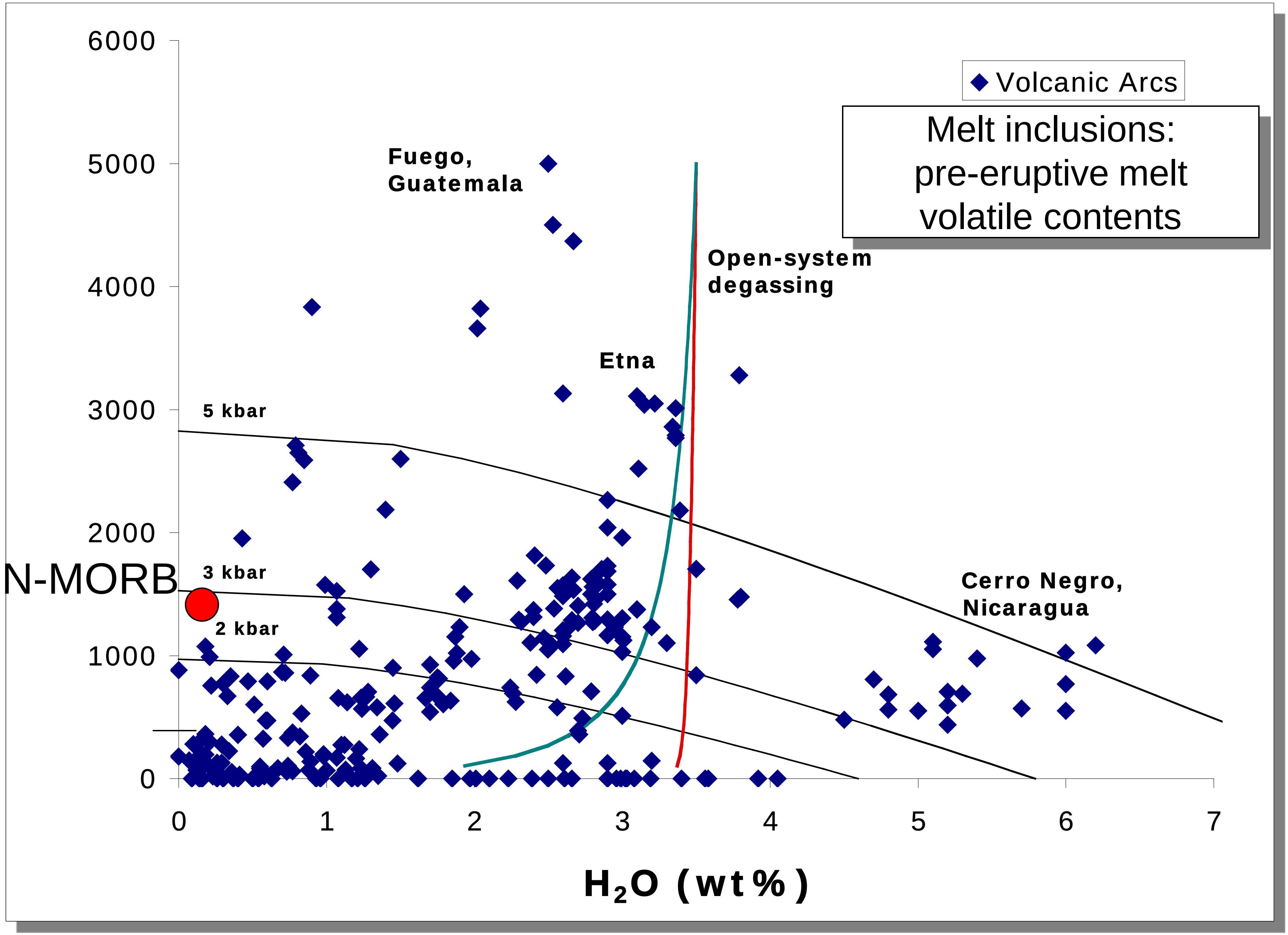


Georoc database and Mike Carr’s data base

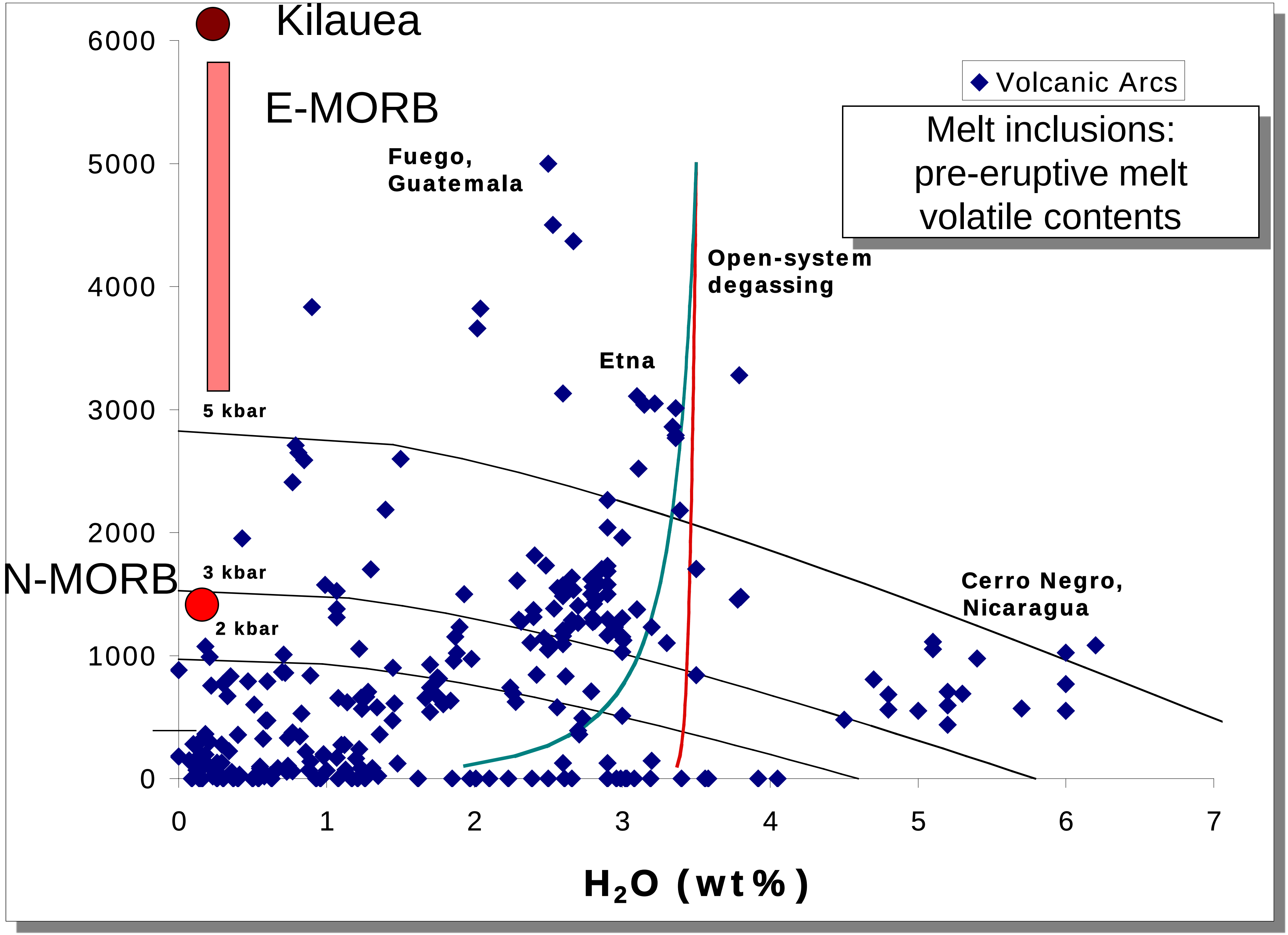
Melt inclusions: pre-eruptive melt volatile contents

Allow for assessment of pre-eruptive melt composition since they are assumed to be less susceptible to degassing and contamination than glasses





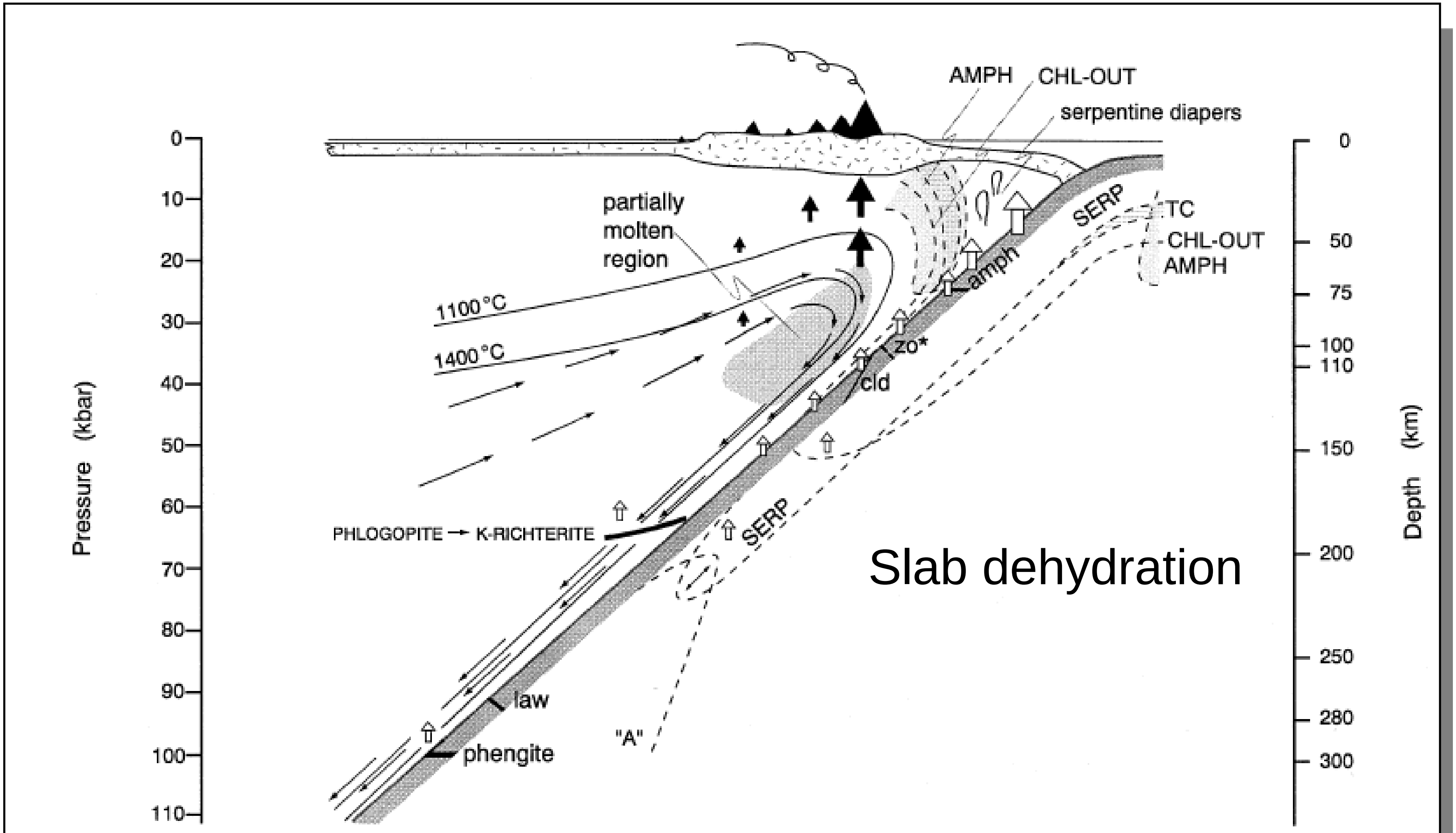
Georoc database and Roggensack et al., 2001



'fields' from Wallace, 2005

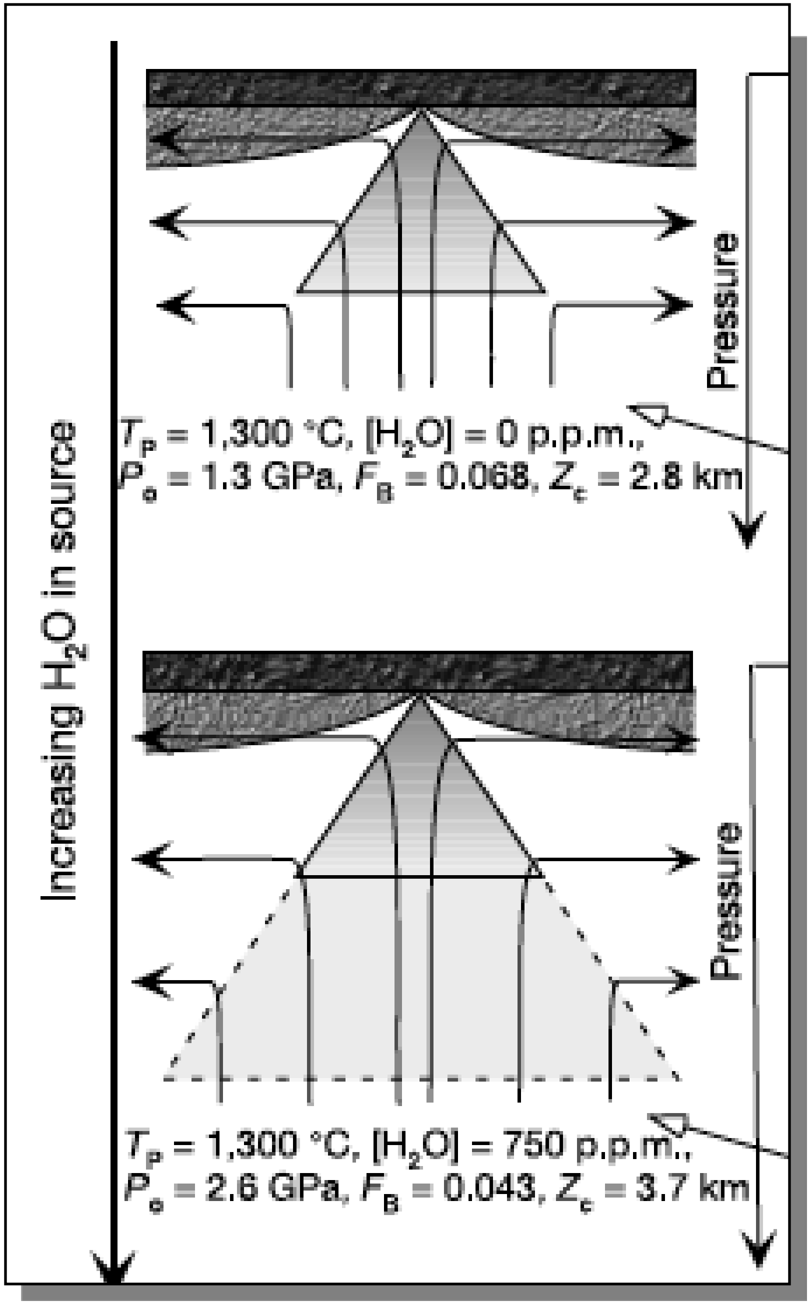
Georoc database and Roggensack et al., 2001

In Arcs fluids come from the slab



Schmidt+Poli, 1998

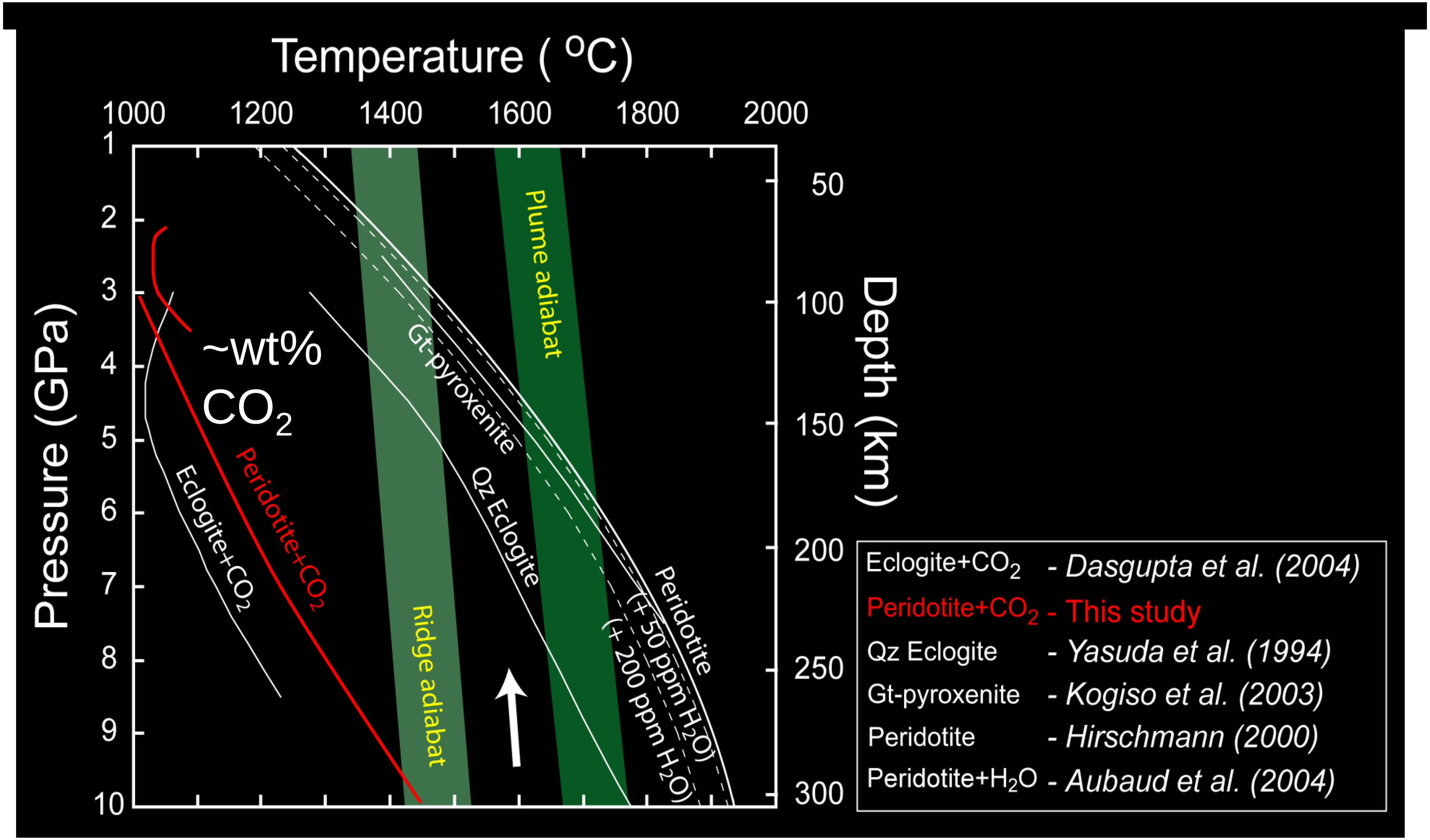
Trace amounts of H_2O enhance melting….



Hirth & Kohlstedt, 1996;
Asimow & Langmuir, 2003

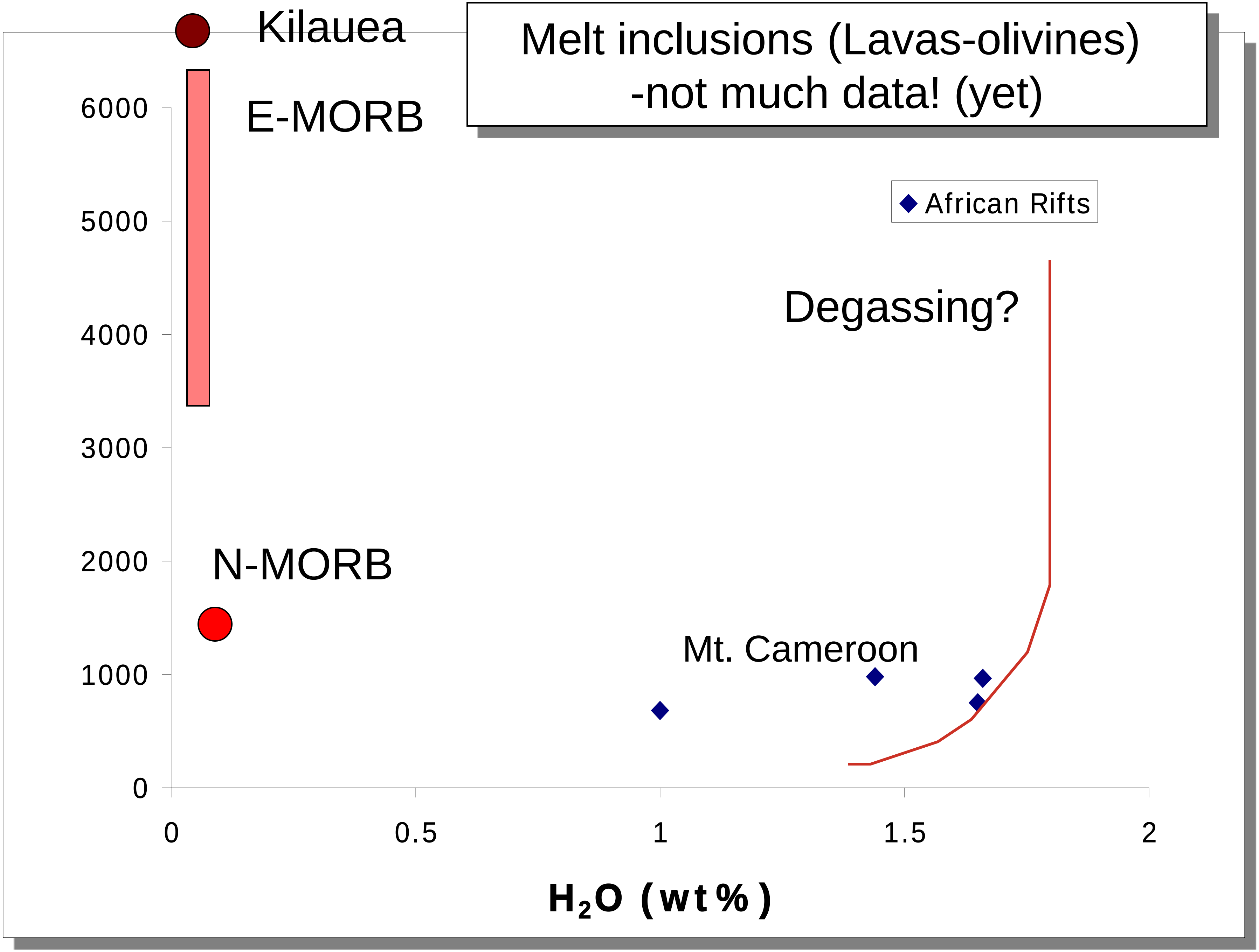
From: Hirschman's MARGINS talk
WHOI 2006

CO_2 also enhances melting….



Dasgupta & Hirschmann (2006) - Nature

From: Hirschman's MARGINS talk
WHOI 2006



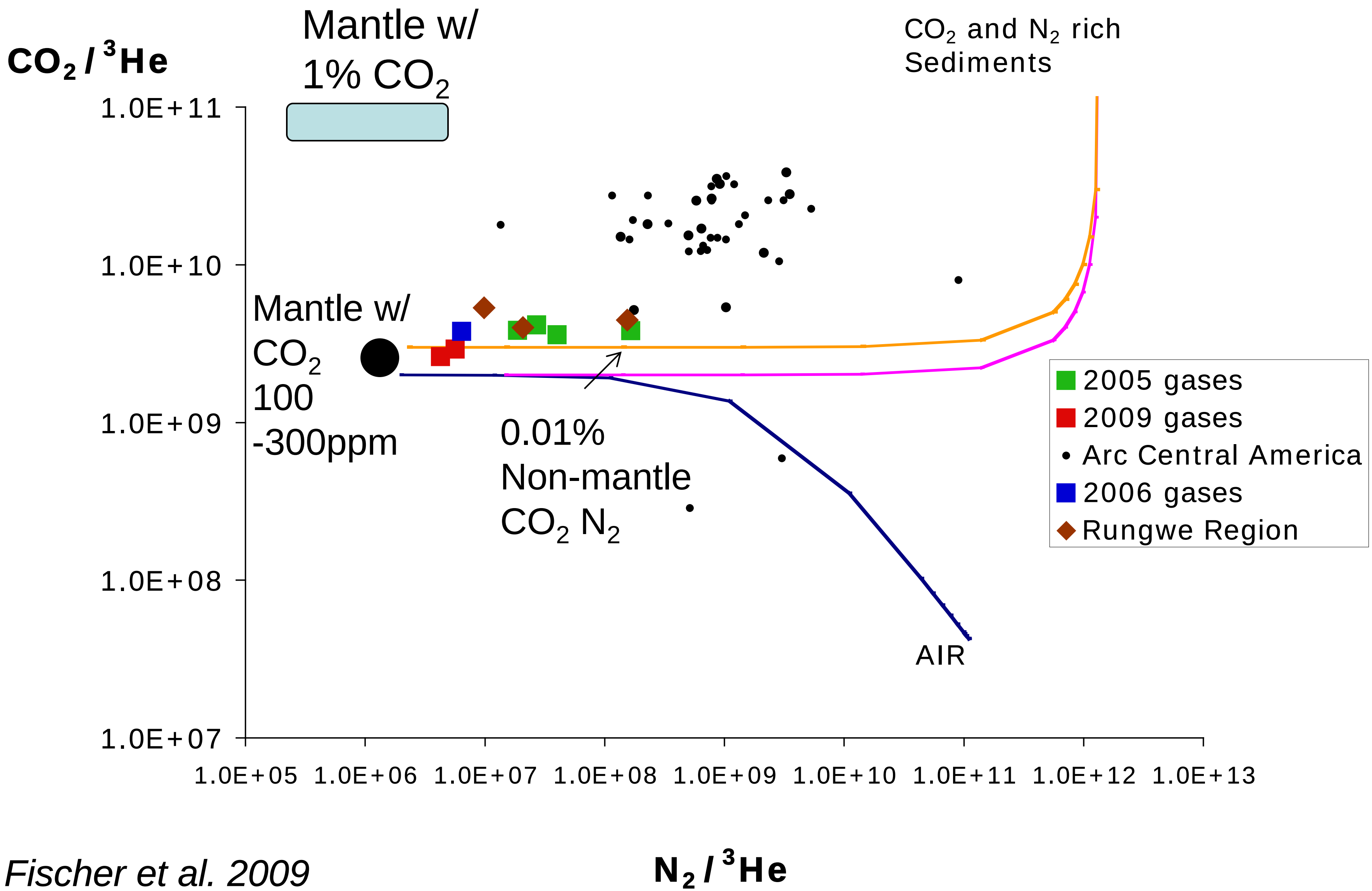
Suh, 2008 *'fields' from Wallace, 2005*

Georoc MI data-base (last update 2010)

Rungwe-region, Southern Tanzania

Gas sampling
(fumaroles; springs;cold, pure CO_2 vents)

CO_2 (and Nitrogen) in Gas Emissions (Lengai and Rungwe)



Fischer et al. 2009
and Barry, Hilton et al., 2009 AGU

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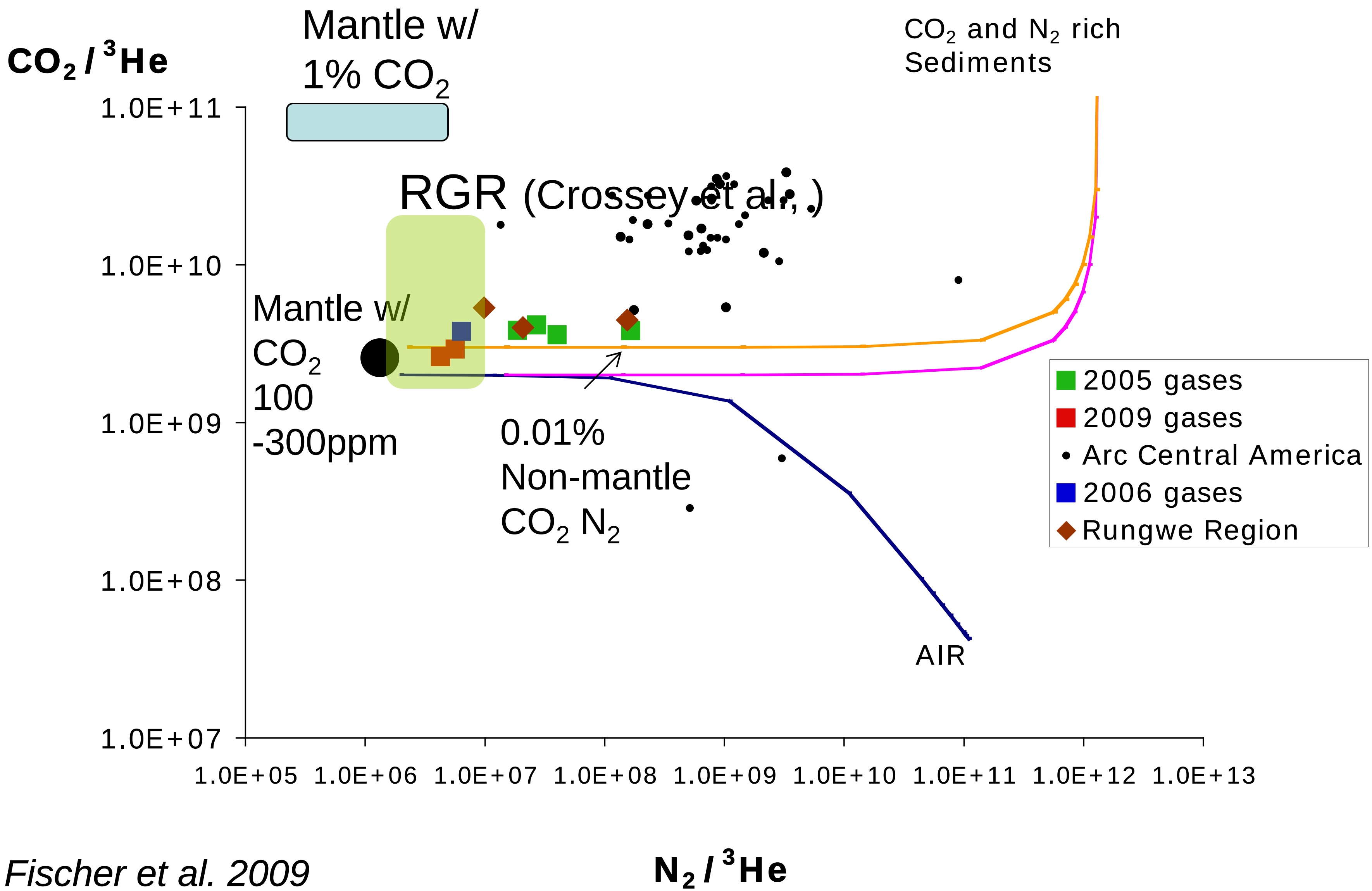

Fischer et al. 2009
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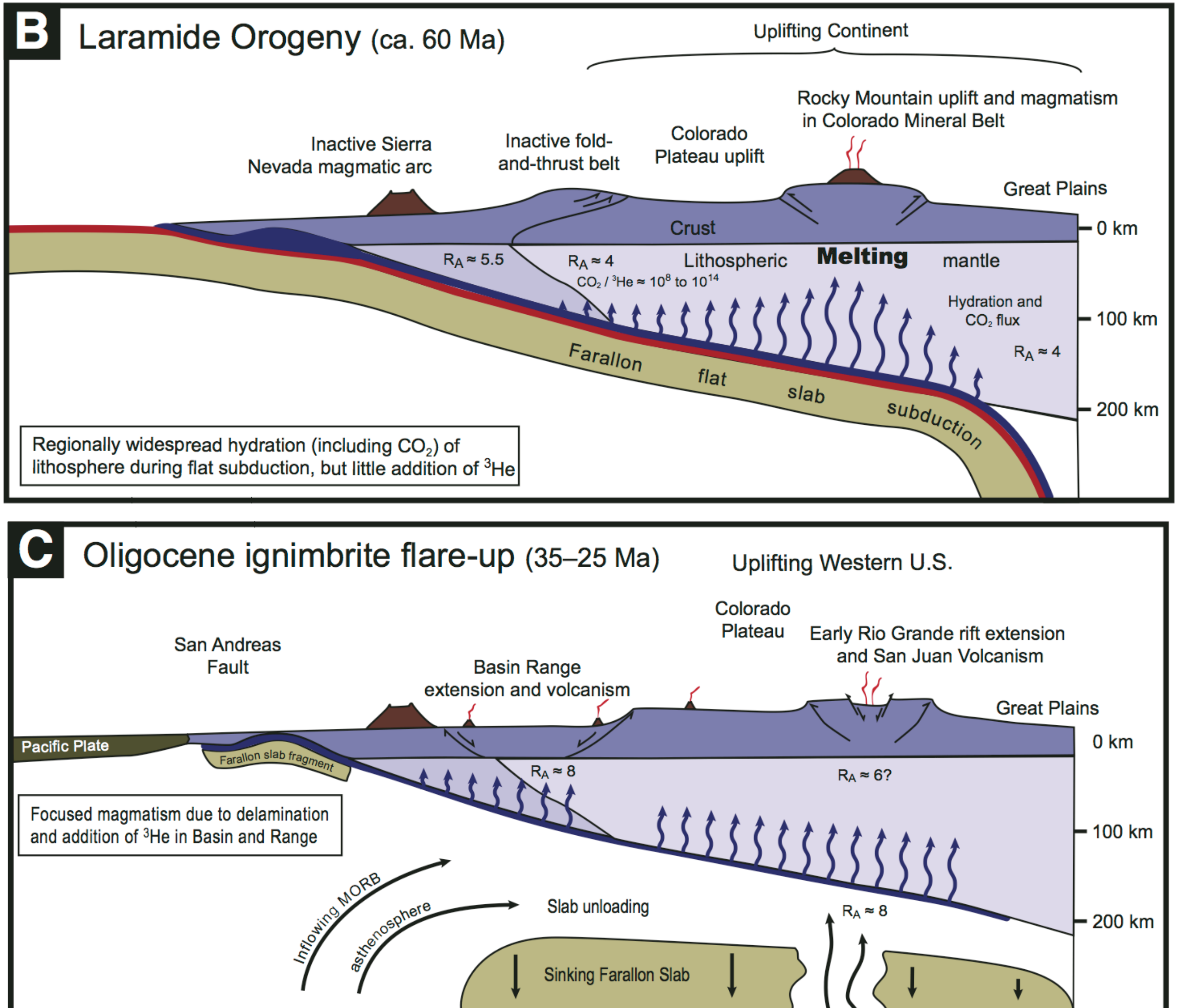
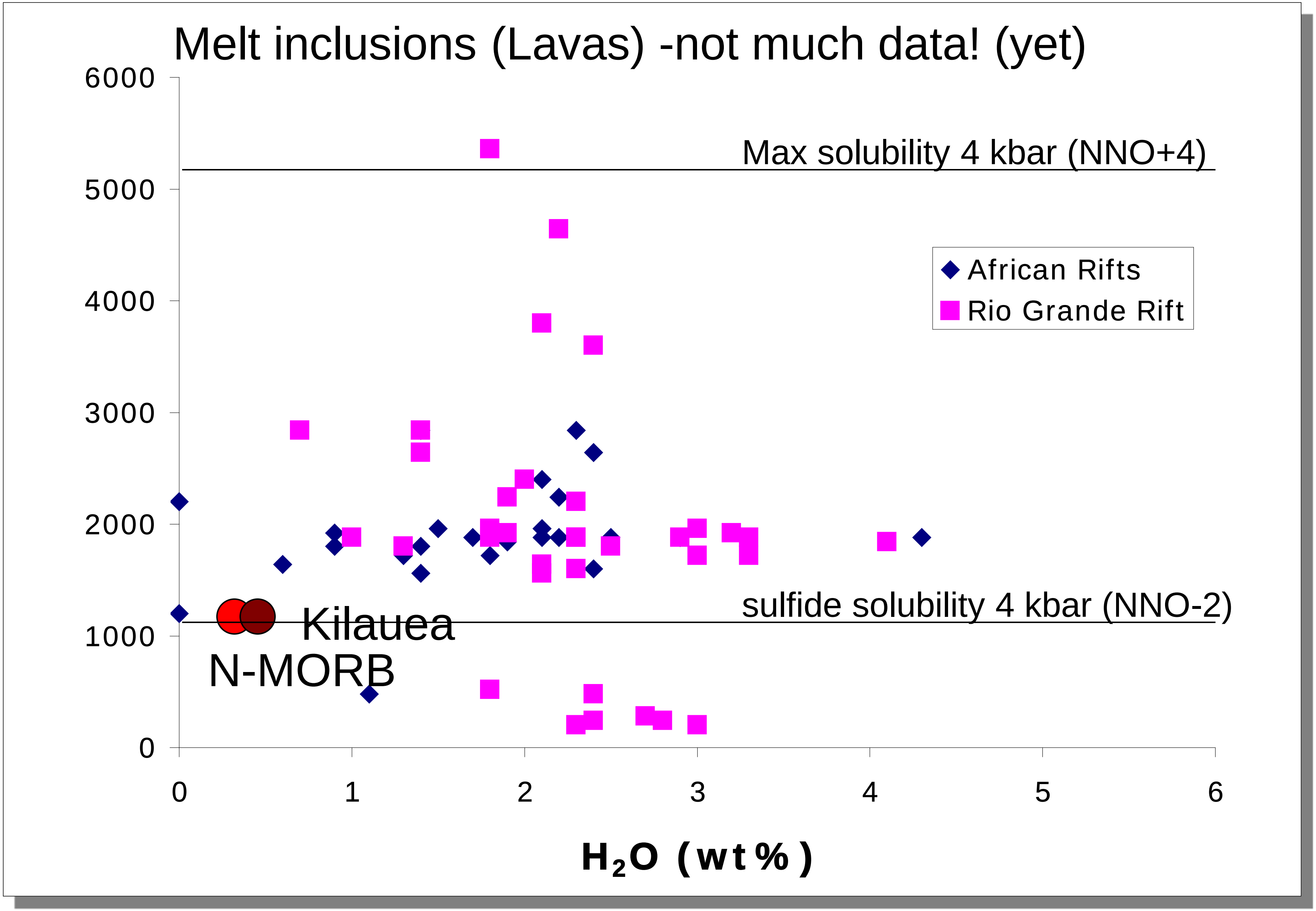
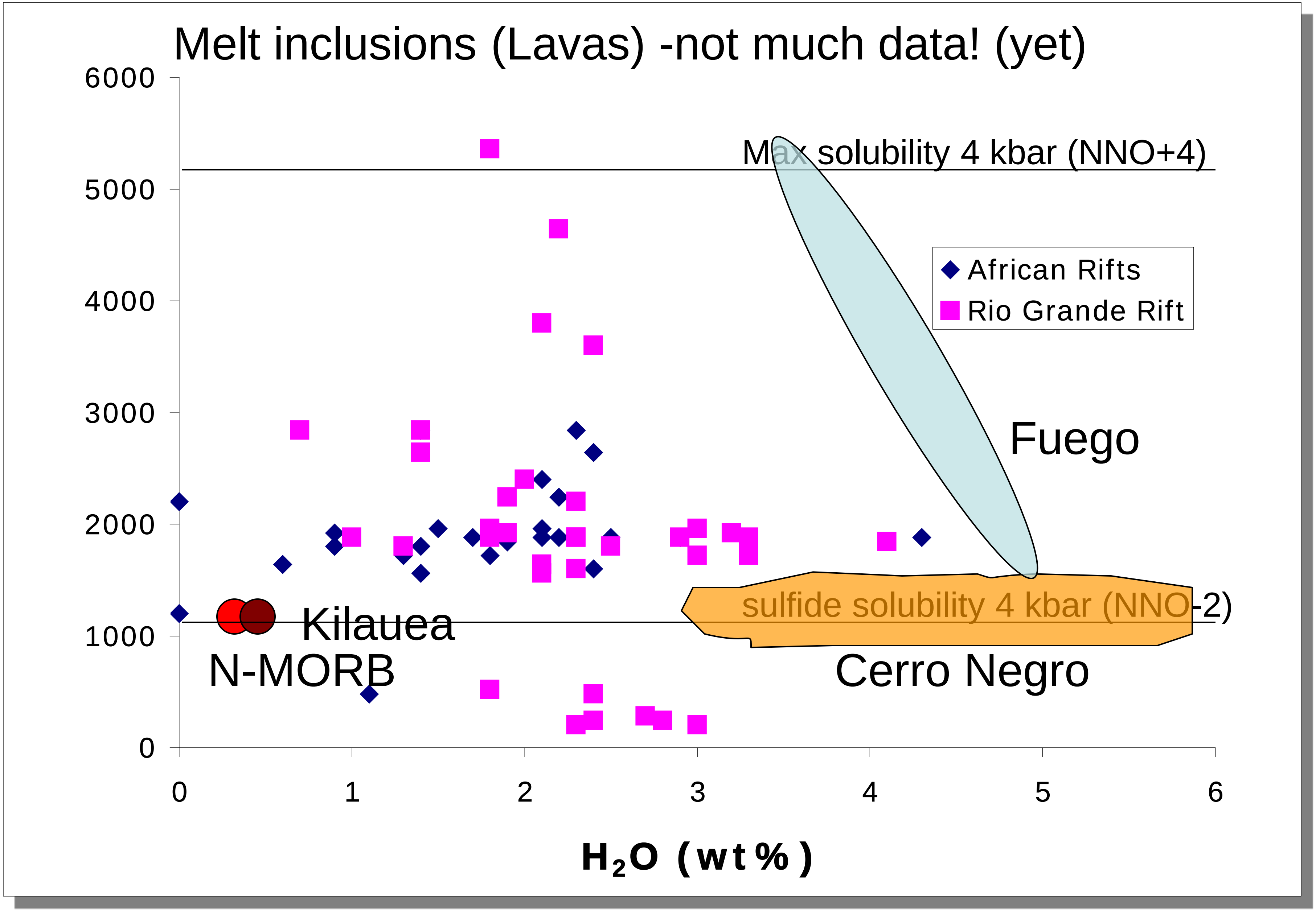
Rio Grande Rift



Crossey et al., 2010



Suh, 2008; Wilding, 1993; Lowenstern, 1997 DUNBAR N. W.(1992)



Suh, 2008; Wilding, 1993; Lowenstern, 1997

DUNBAR N. W. (1992)

Oldoinyo Lengai Gas

	OLD 1	OLD 2
H_2O	85.35	76.84
CO_2	14.13	22.80
Stotal	0.128	0.104
SO_2	0.060	0.039
H_2S	0.068	0.066
HCl	0.068	0.044
HF	n.m.	n.m.
He	0.0004	0.0001
H_2	0.2299	0.1633
Ar	0.0014	0.0003
O_2	0.0009	n.d.
N_2	0.0687	0.0276
CH_4	0.0002	0.0001
CO	0.0242	0.0169

in mol % total gas

Oldoinyo Lengai Rocks

Volatiles analyzed by SIMS (DTM)
July 4 2005 Carbonatite Lava flow

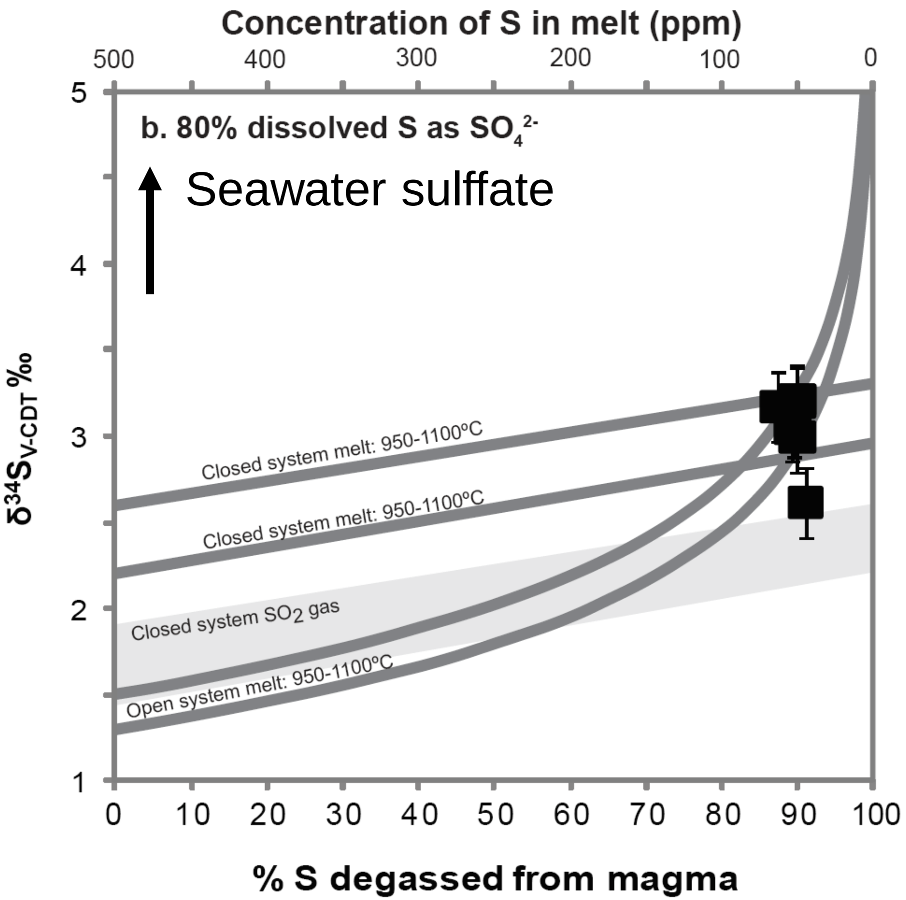
	wt% H_2O	CO_2 (wt%)	S (ppm)	Cl (ppm)	F (ppm)
OLD.	0.022376	> 9.69	8376	9909	4495
	0.103099	>11.75	2242	5647	640
	0.016047	>10.34	2255	5791	664
N- MORB	0.1-0.5	0.01-0.03	800-1500	<100	
Arcs	3.1-6.1	0 - 0.21	to 6000	to 4100	

OLD Nephelinite 2009: up to 0.8 wt% in glass and MI

Fischer et al., 2006
de Moor et al., AGU 2009

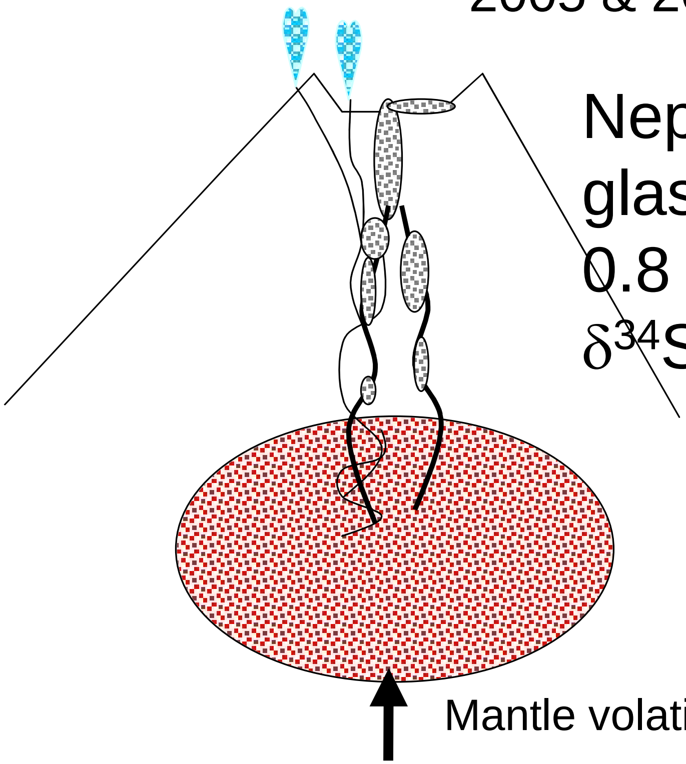
MORB glasses and arc melt inclusions from Wallace, 2005

Sulfur Degassing Model -> estimate S content and $\delta^{34}S$ in source



Lengai

2005 & 2009



Nepheline glass/MI
0.8 wt% S
$\delta^{34}S$ -0.7 ‰

de Moor et al. 2010 for Anatahan, Marianas

Fischer et al., AGU 2009
de Moor et al., AGU 2009

Some Issues related to Volcanoes and the Mantle

- Connection between mantle volatiles (H_2O, CO_2, S) and melt production/composition/location in rifts
- Volatile fluxes into and out of rifts not constrained
- Is ‘big mantle plume’ below Afar expressed in volatile/fluid composition at surface (*beyond* Helium)?
- Role of mantle CO_2 (experiments vs. observations)
- Role of mantle sulfur in melt generation
- Nature and role of metasomatism in melt generation