

Geochemistry and isotopic characterization of volcanic gases for source, degassing, and MTI studies

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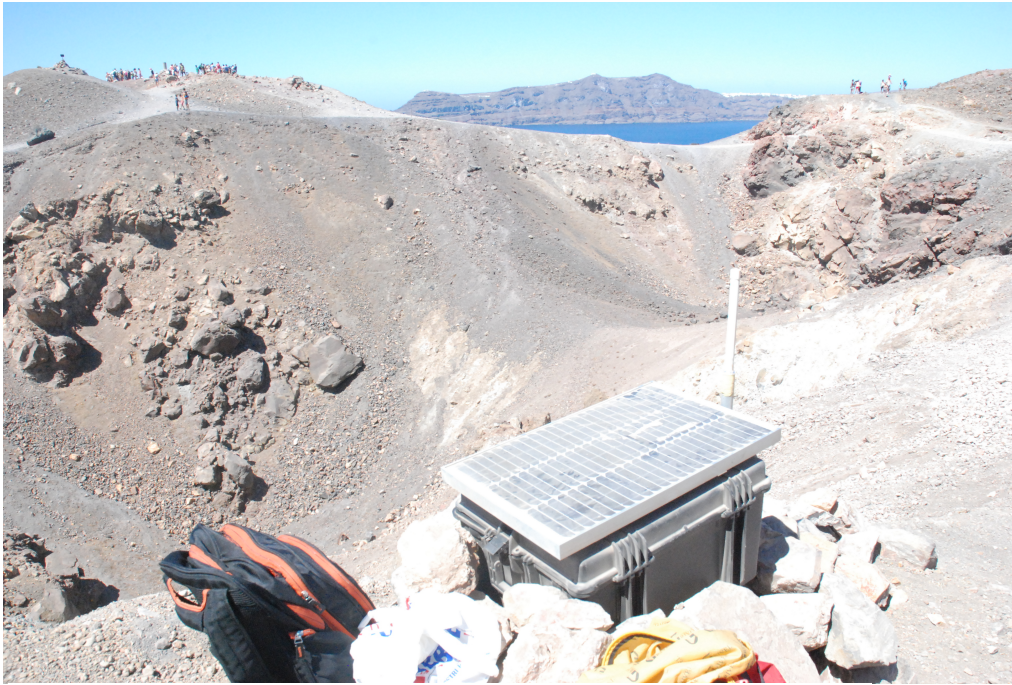
Typical High Temp (920°C) volcanic gas from arc volcano (mol %)

Direct gas sampling:

H_2O	95	N_2	0.025
CO_2	1.6		
SO_2	1.3	He	0.00014
H_2S	0.4	H_2	0.77
HCl	0.7	O_2	<0.0005
HF	0.01	CH_4	0.00005
		CO	0.0008

C, N, S, H, O, noble gas isotopes

... and many trace elements (PGE, Na, K, Sr, Rb, B, Be...) at ppm, ppb levels



MultiGAS (i.e. Aiuppa)

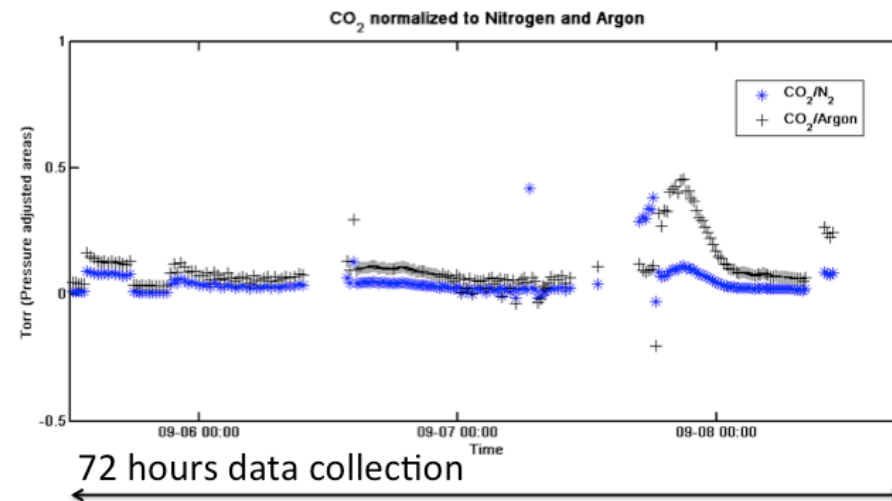
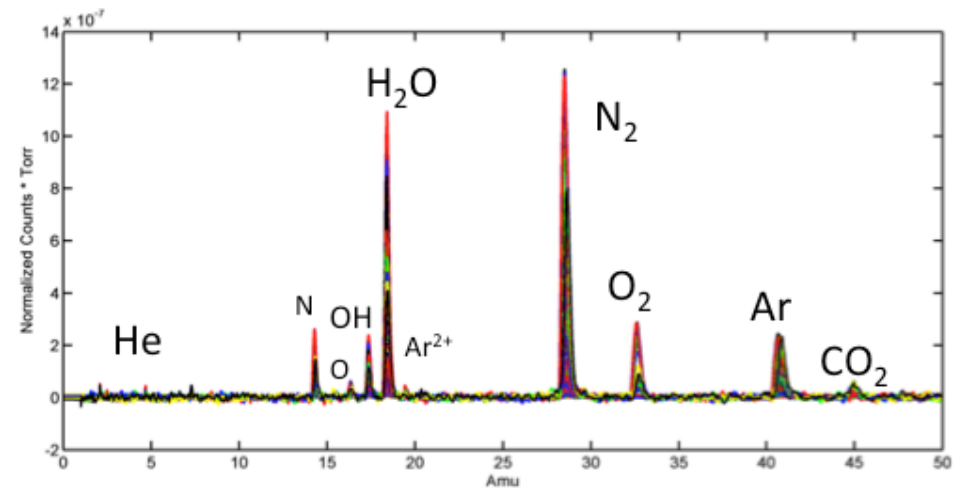
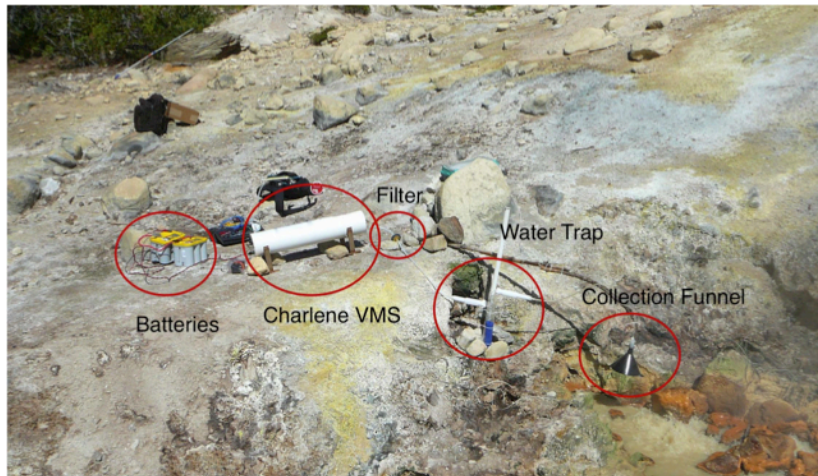
SO_2 , H_2S , CO_2 (H_2O , H_2)



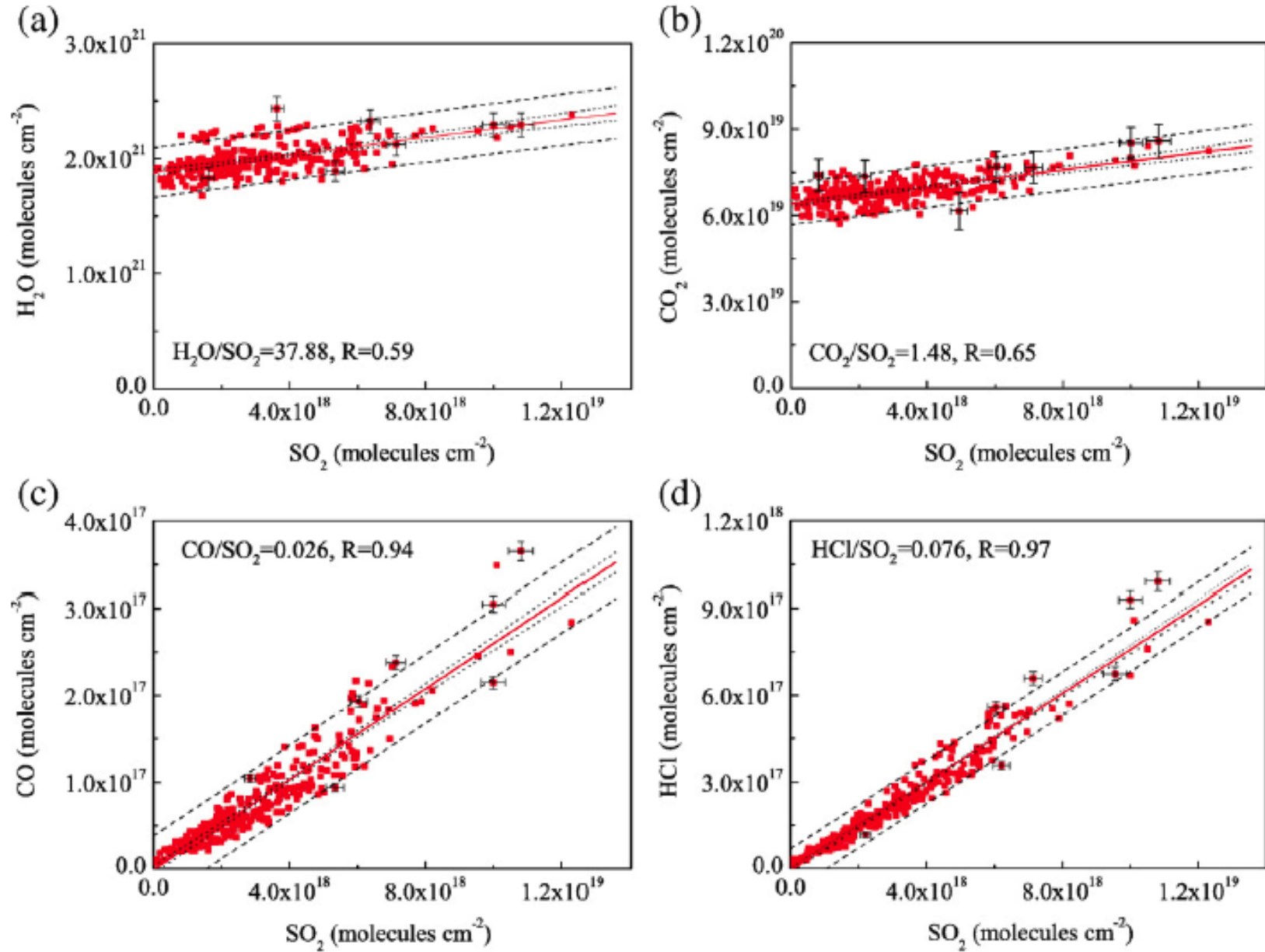
FTIR (i.e. Oppenheimer)

SO_2 , H_2S , CO_2 , CO , HCl

Volcano Mass Spectrometer



multiGAS and FTIR: lots of data, remote sensing/sampling







GIGGENBACH
BOTTLES

SCIENTIFIC GLASSCRAFT

NEW ZEALAND

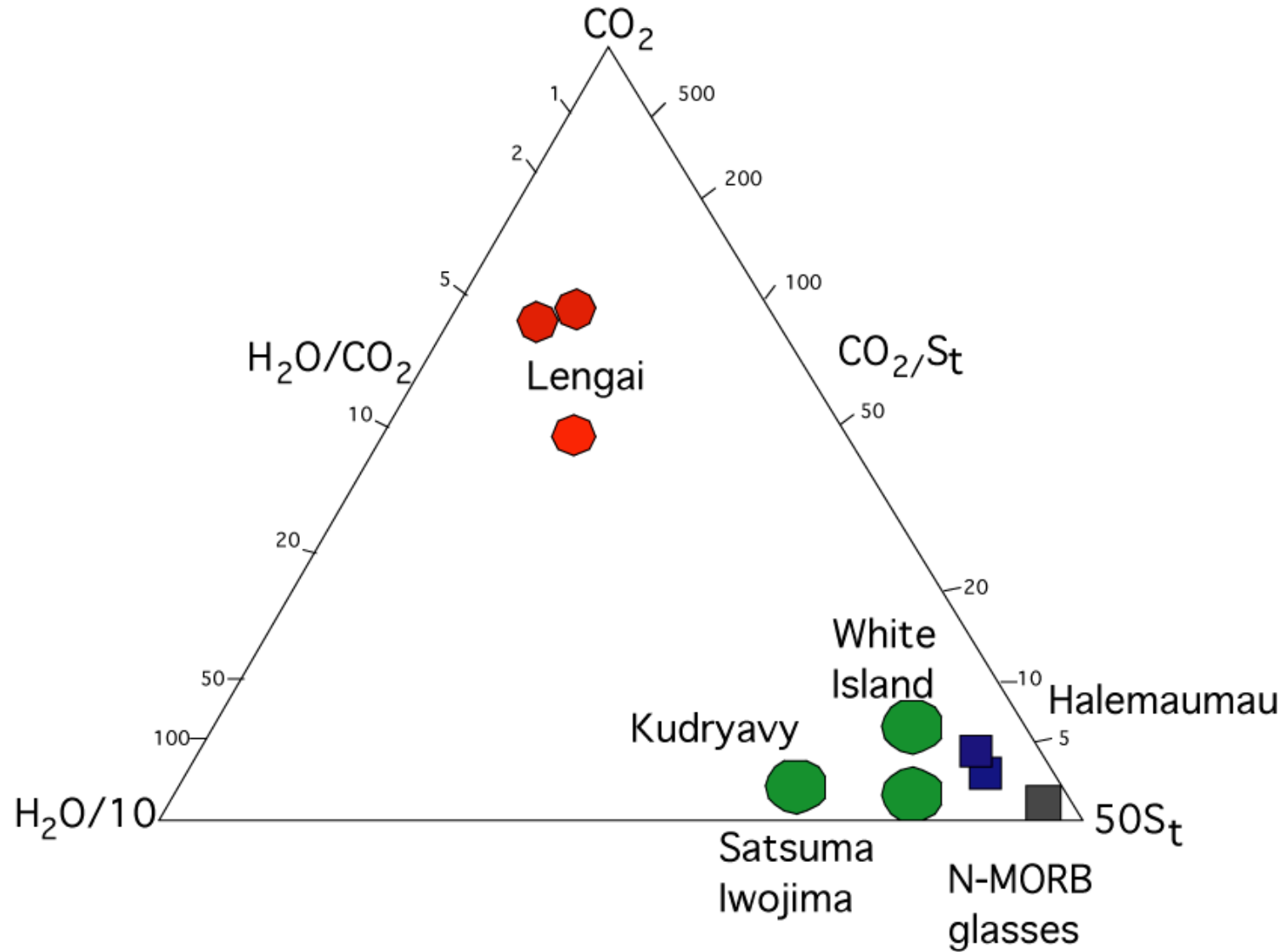
FAX

+04 4 586 1591

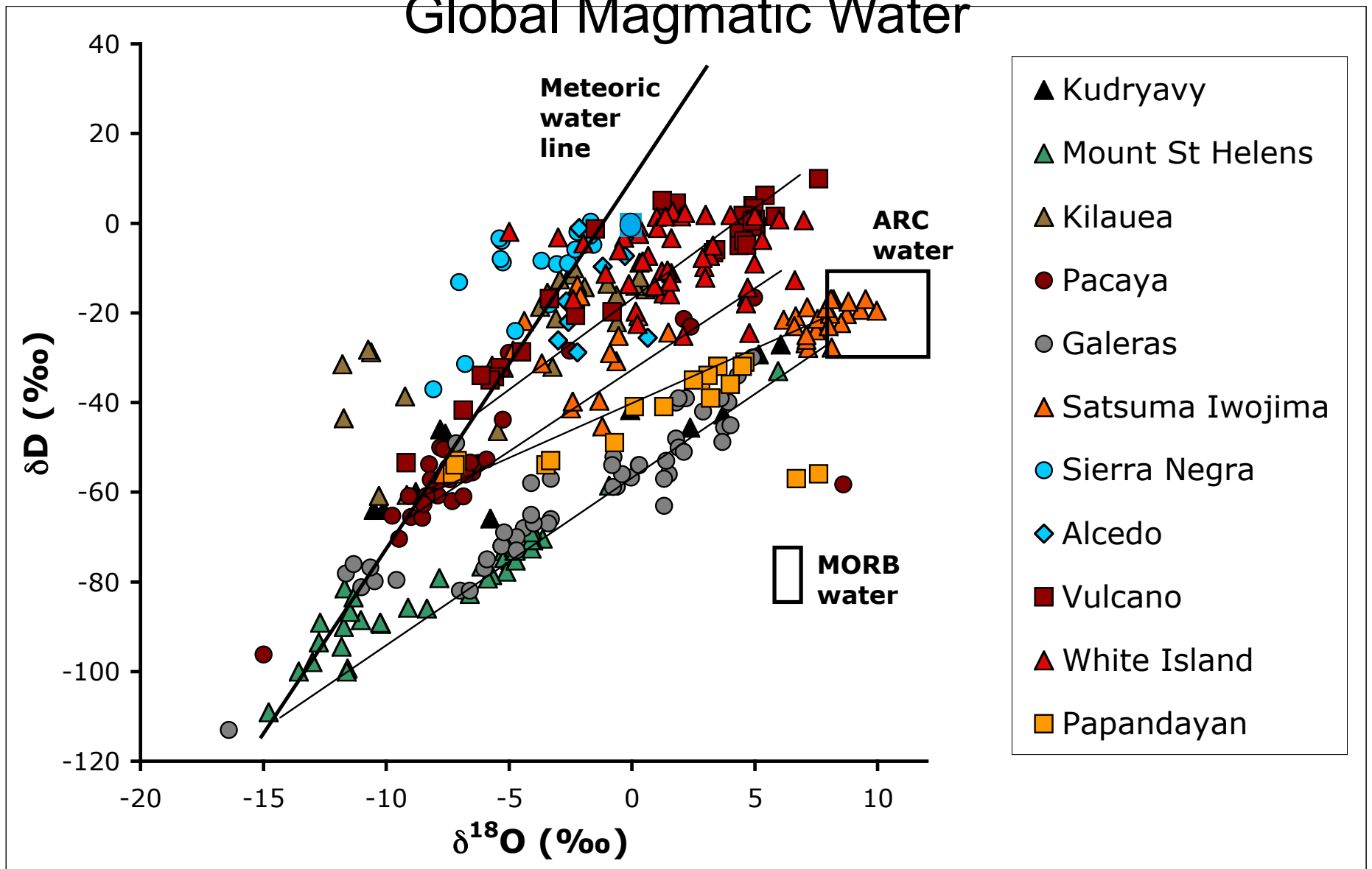
LTD

1-1AM

Global Compositions: gas samples



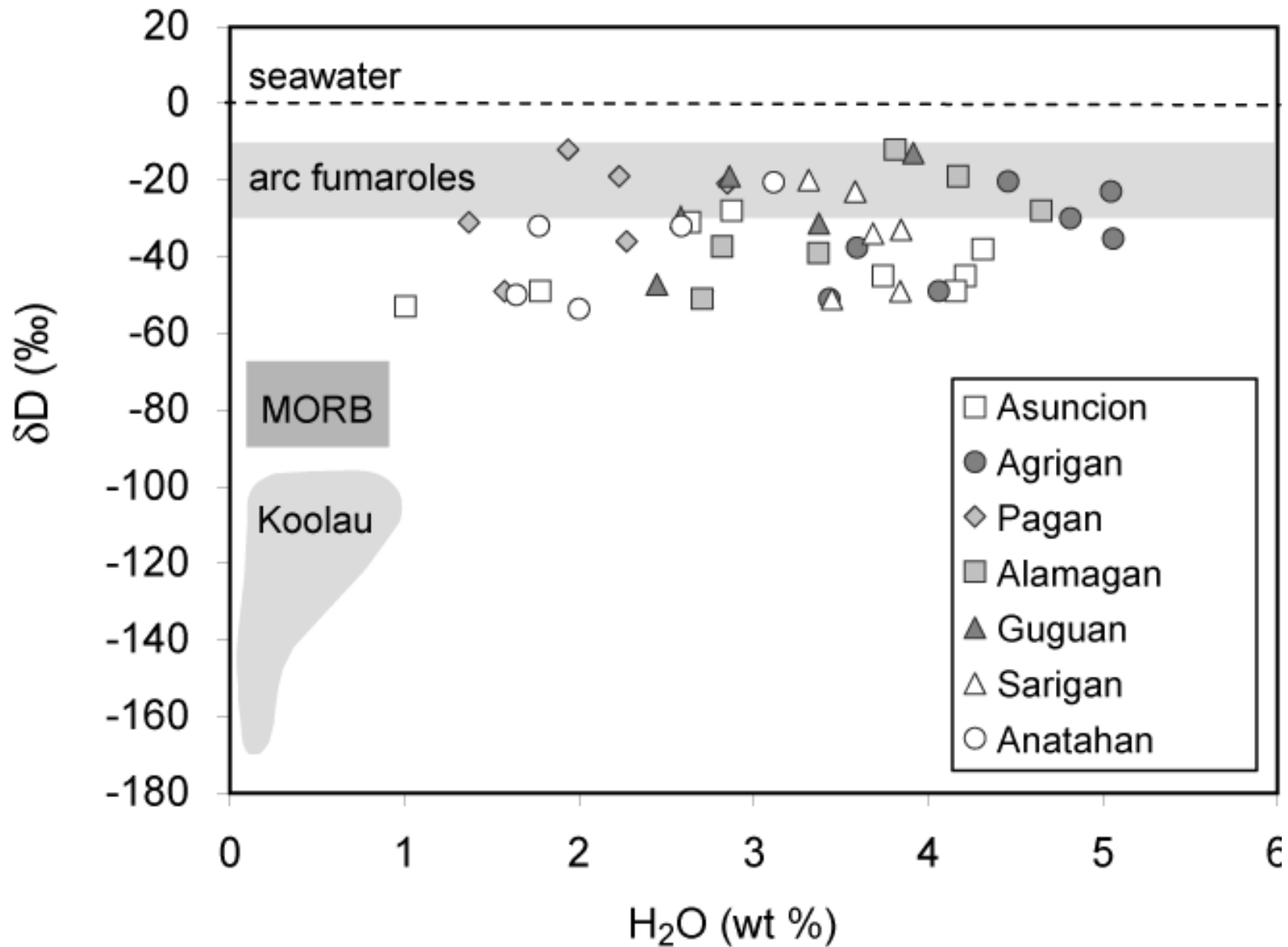
Global Magmatic Water

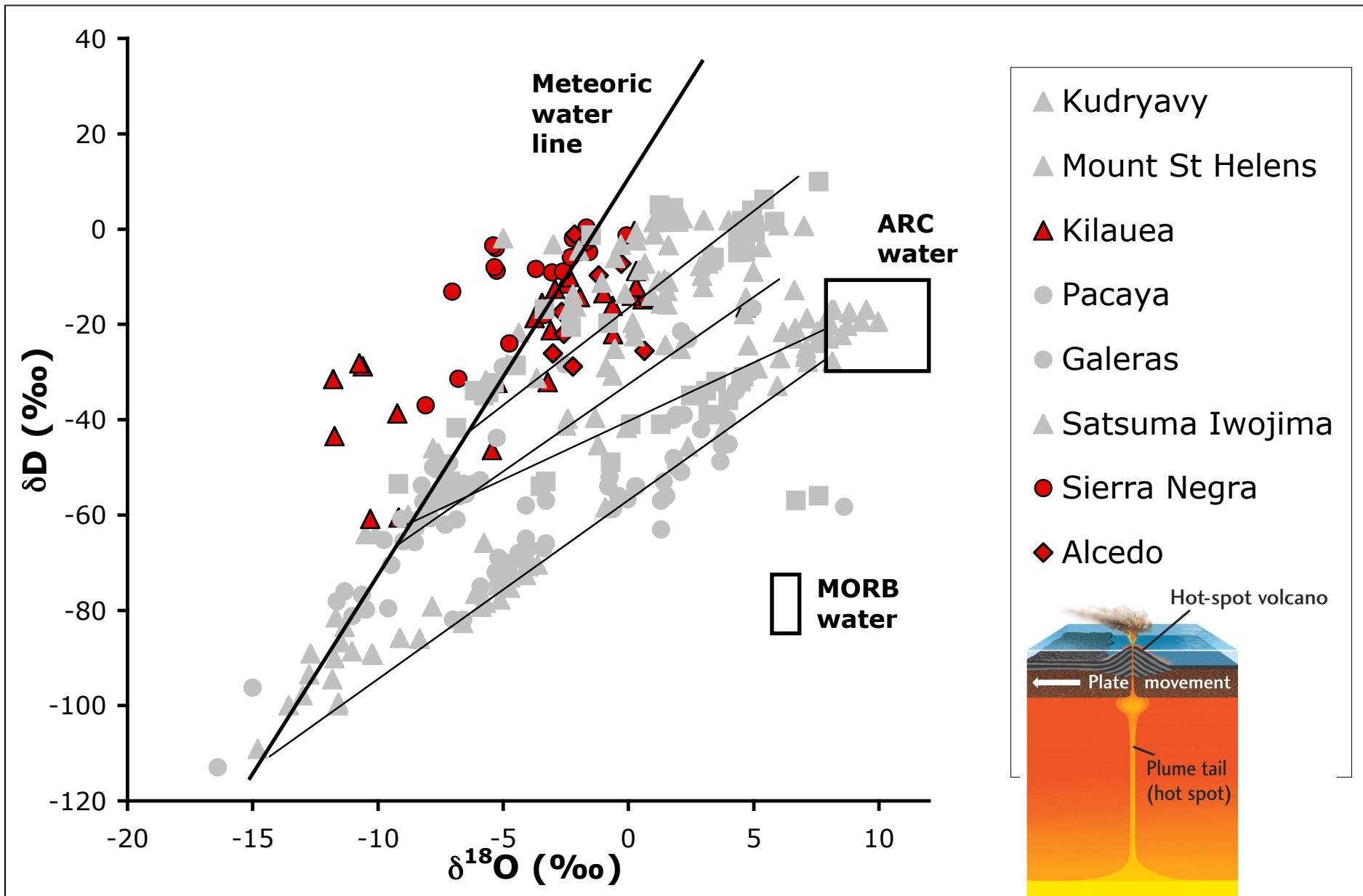


After Giggenbach 1992 and Taran 1992

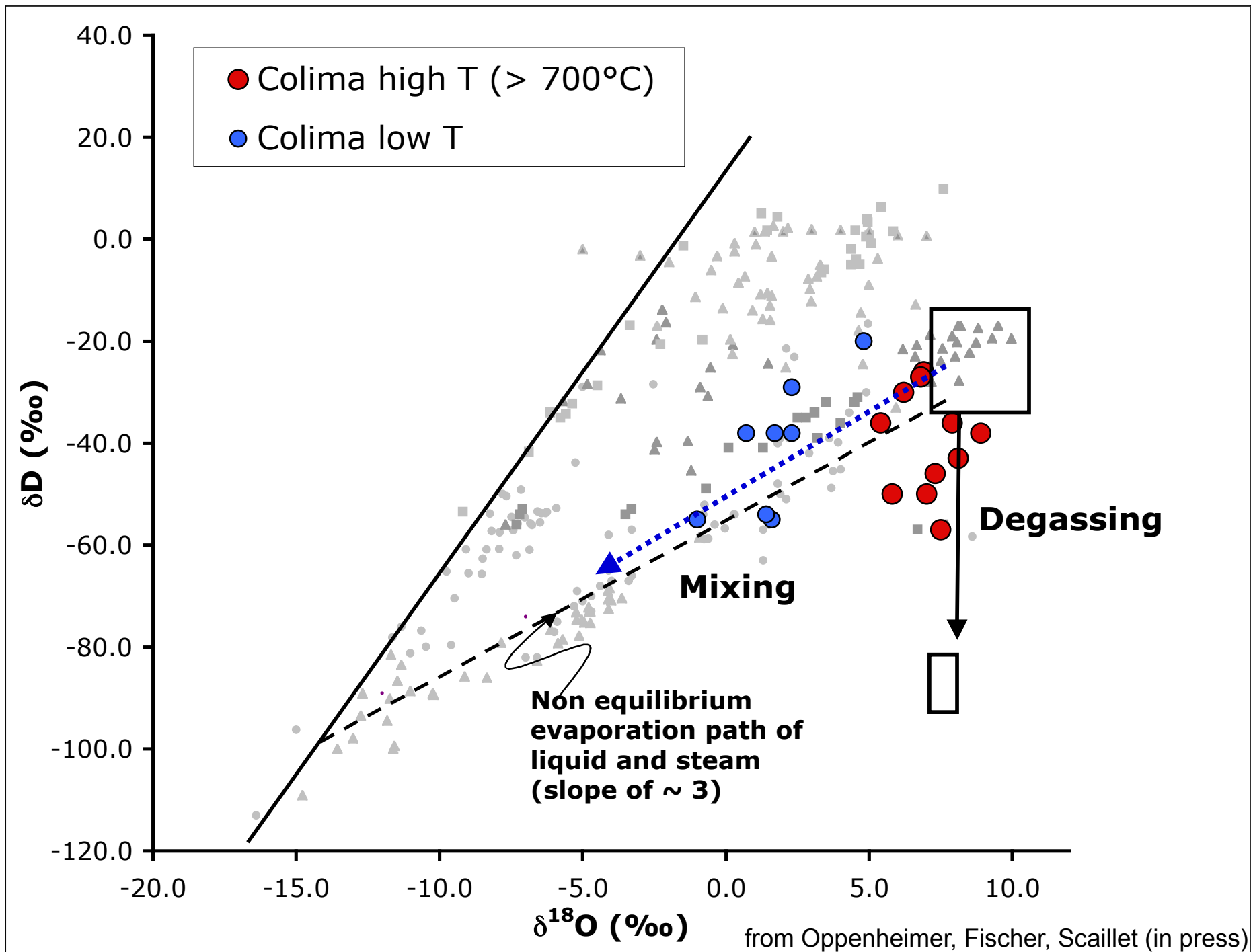
from Oppenheimer, Fischer, Scaillet (in press)

Melt inclusions: Marianas



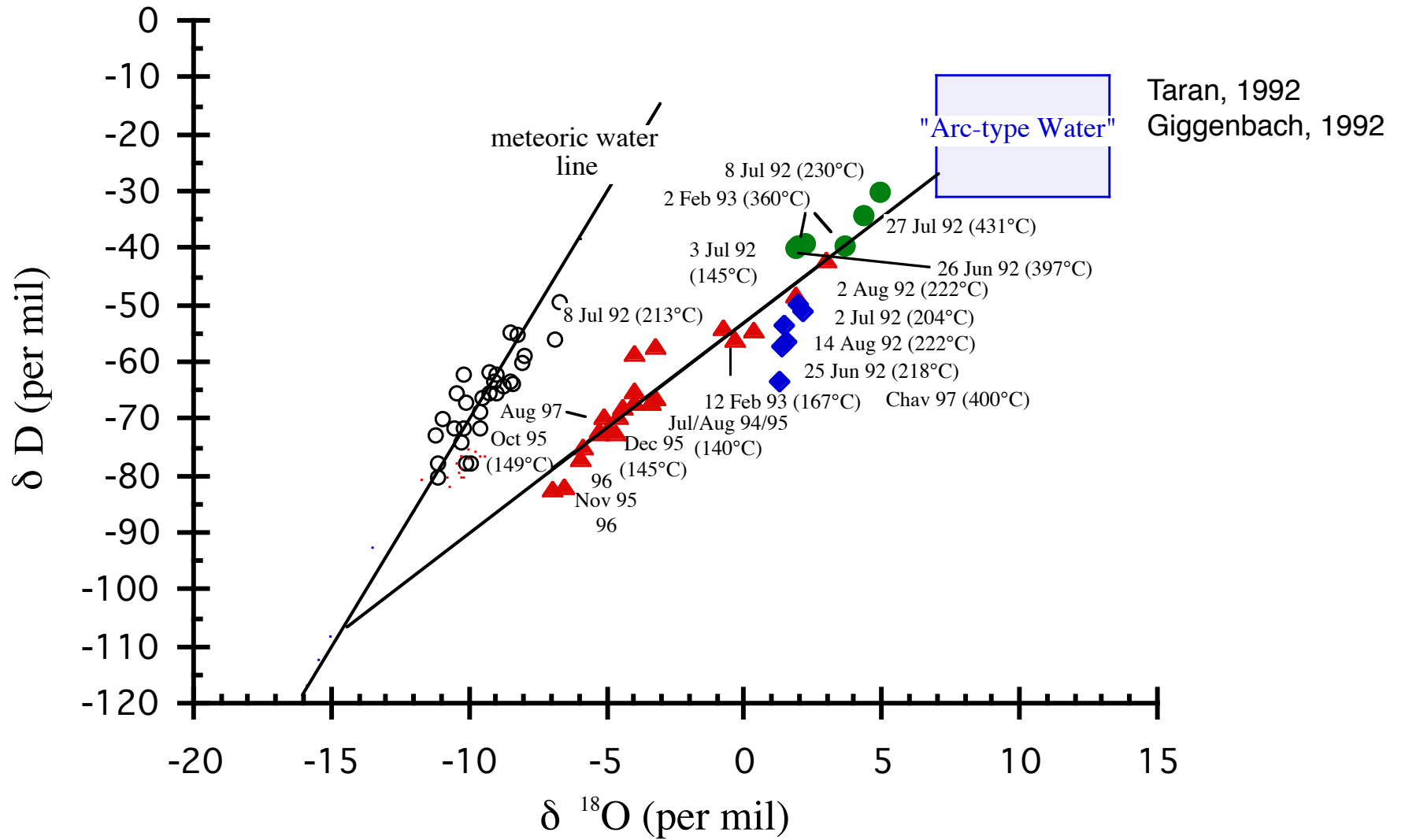


from Oppenheimer, Fischer, Scaillet (in press)

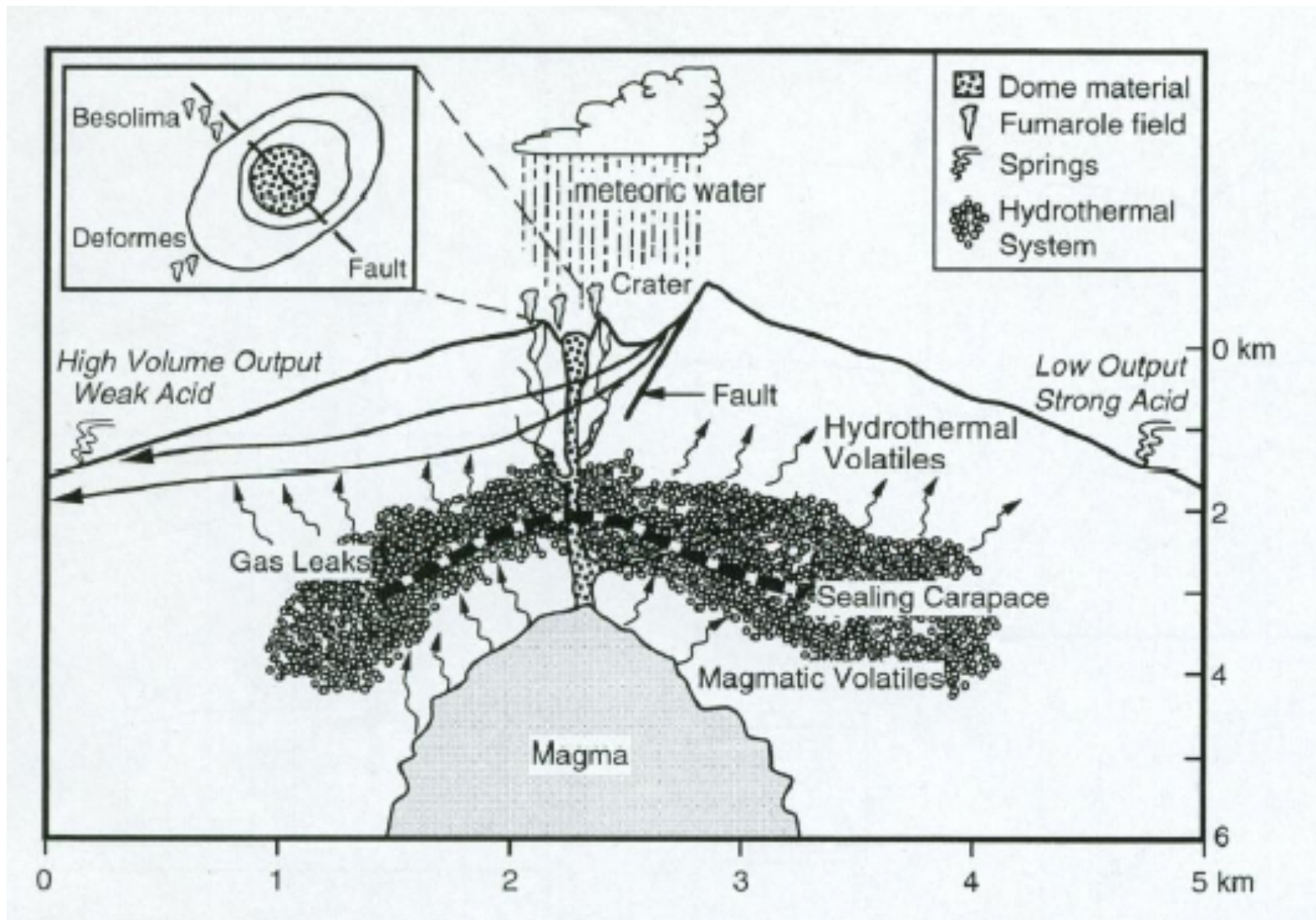


Galeras Volcano, Colombia: Oxygen and Hydrogen isotope variations of steam

- ▲— Deformes
- Besolima
- ◆ Chavas
- Hot Spring

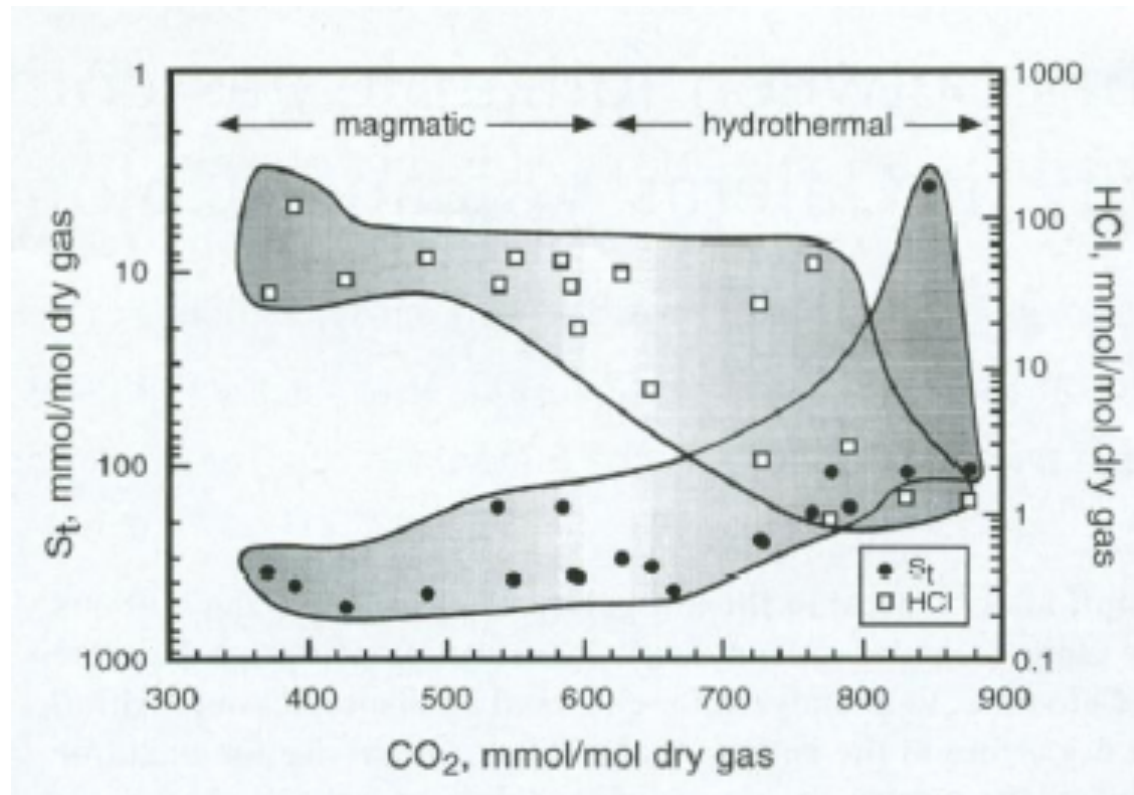


Fischer et al., 1997



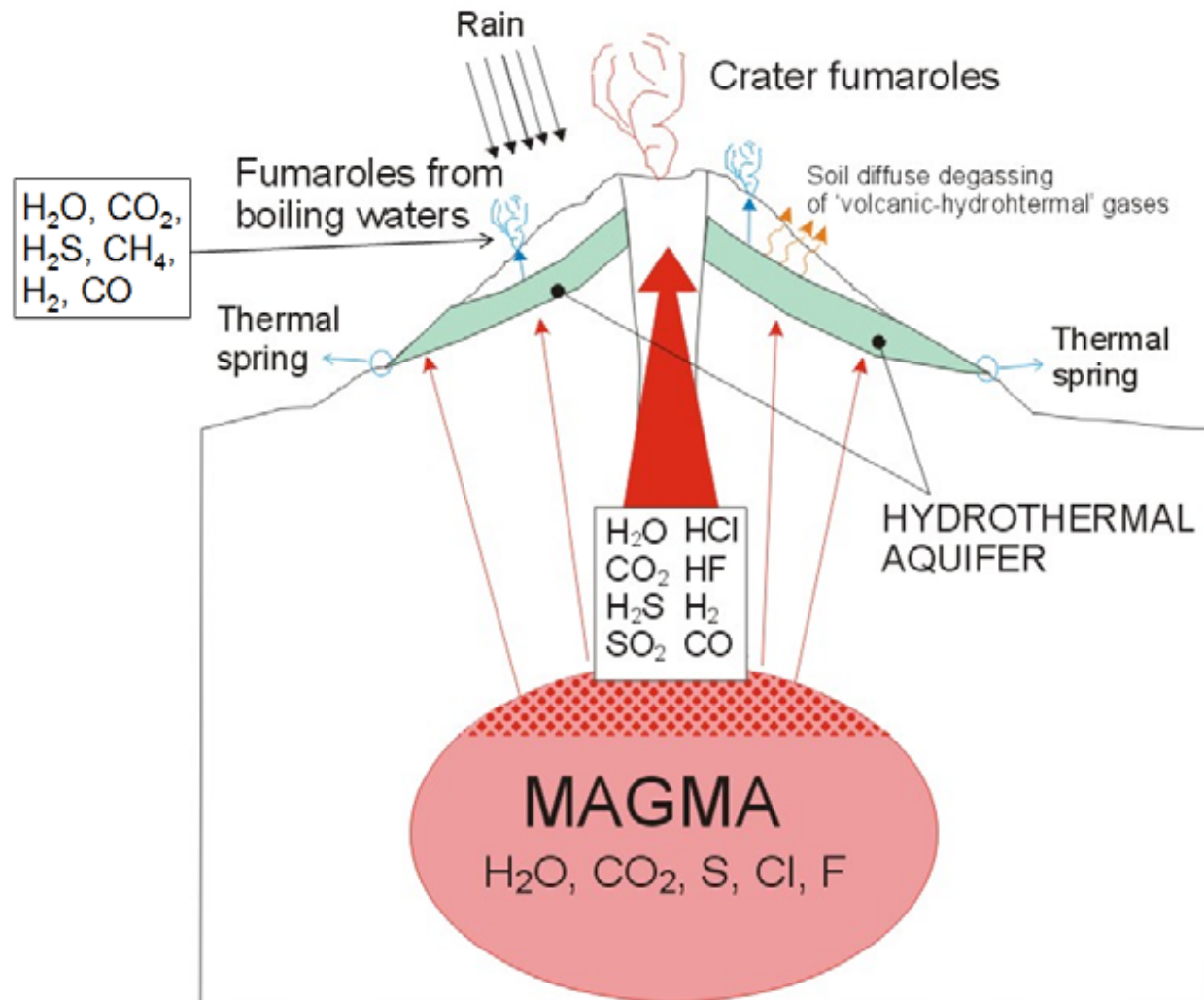
Fischer et al., 1996

Magmatic vs hydrothermal

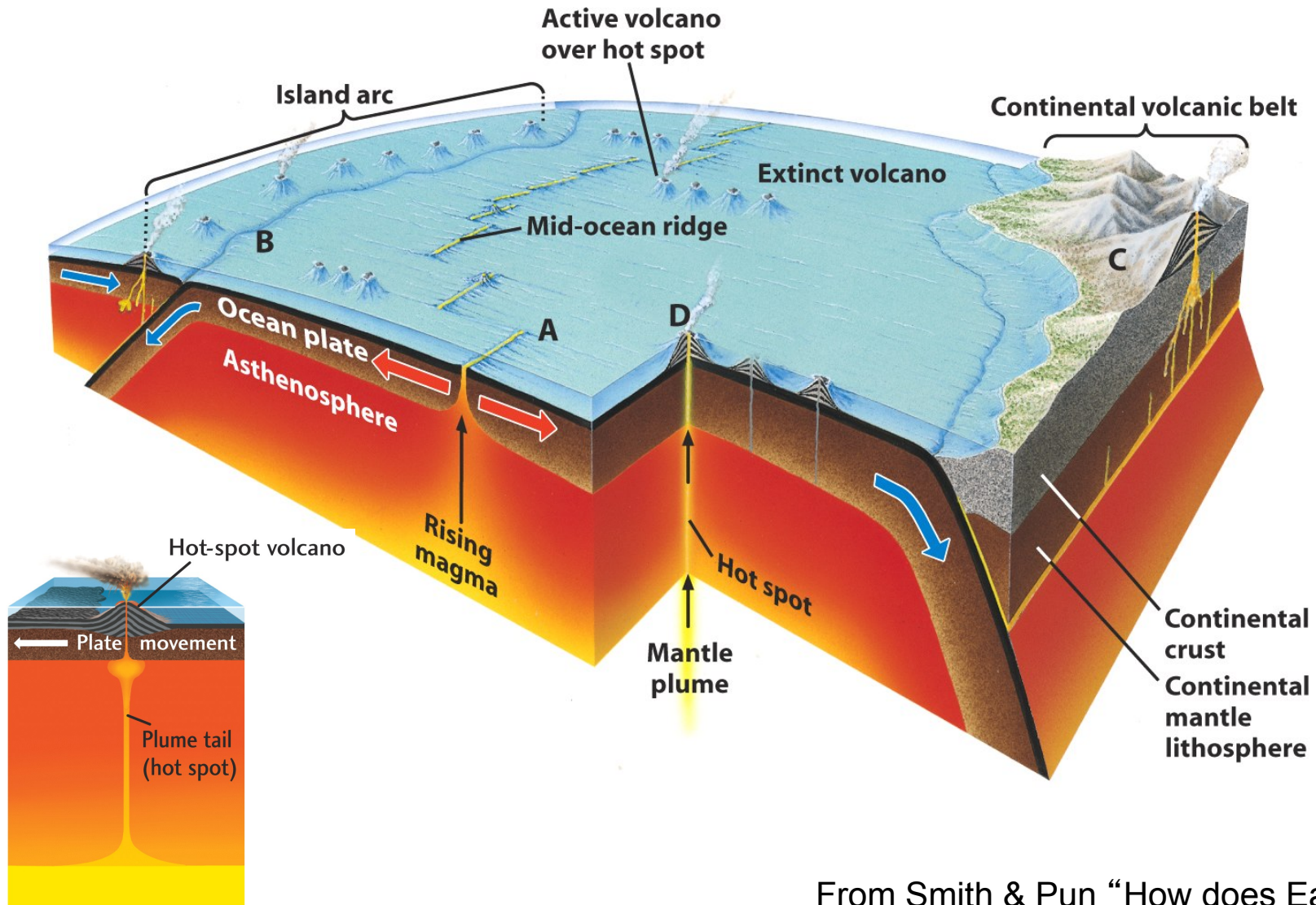


Fischer et al., 1996

Volcano from gas geochemist's perspective (from Chiodini, pers. communication, 2013)



Volatile sources: the bigger picture

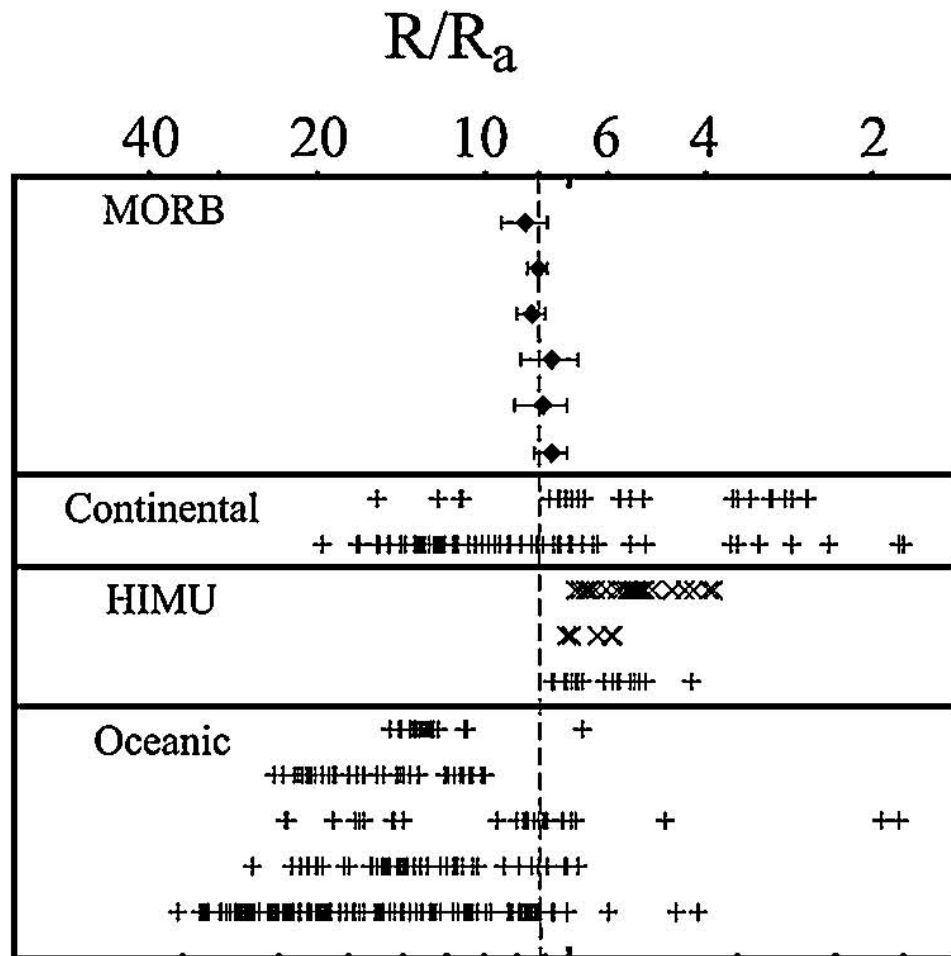


From Smith & Pun "How does Earth Work?"

Helium

- East Pacific Rise
- Juan de Fuca
- Central Indian and Carlsberg Ridges
- South West Indian Ridge
- North Atlantic
- South Atlantic
- Yellowstone & Columbia River Basalt Group
- Afar
- Cameroon line continental
- Cameroon line oceanic
- St Helena, Mangaia and Tubuai
- Reunion
- Samoa
- Galapagos
- Iceland
- Hawaii

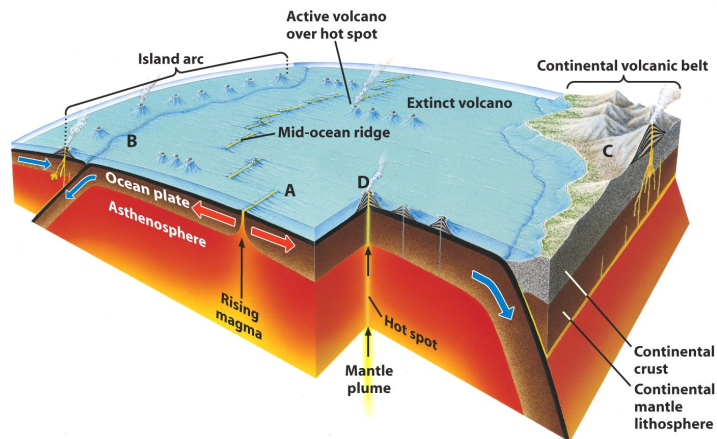
OIBs



10,000

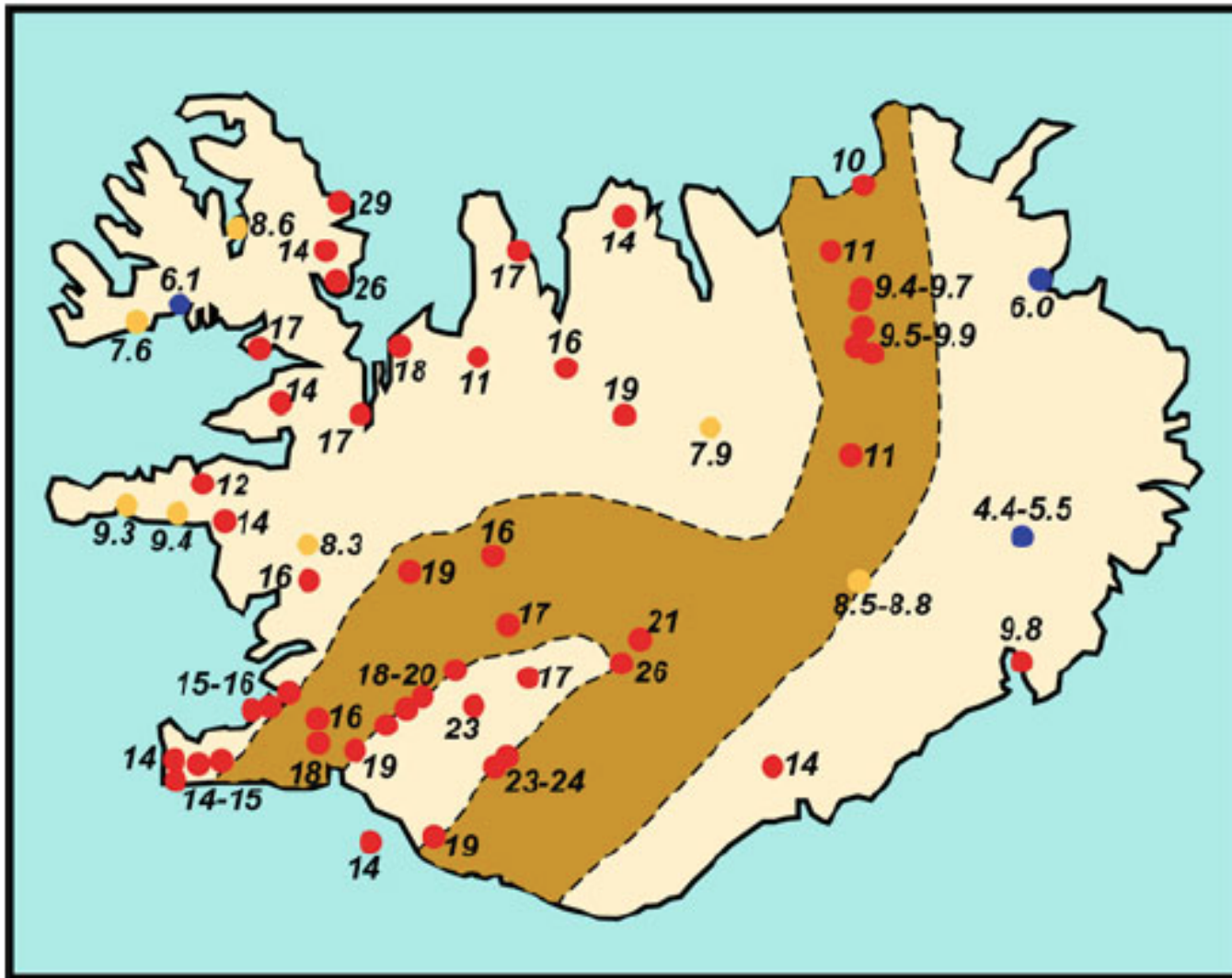
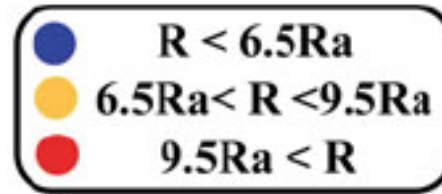
100,000

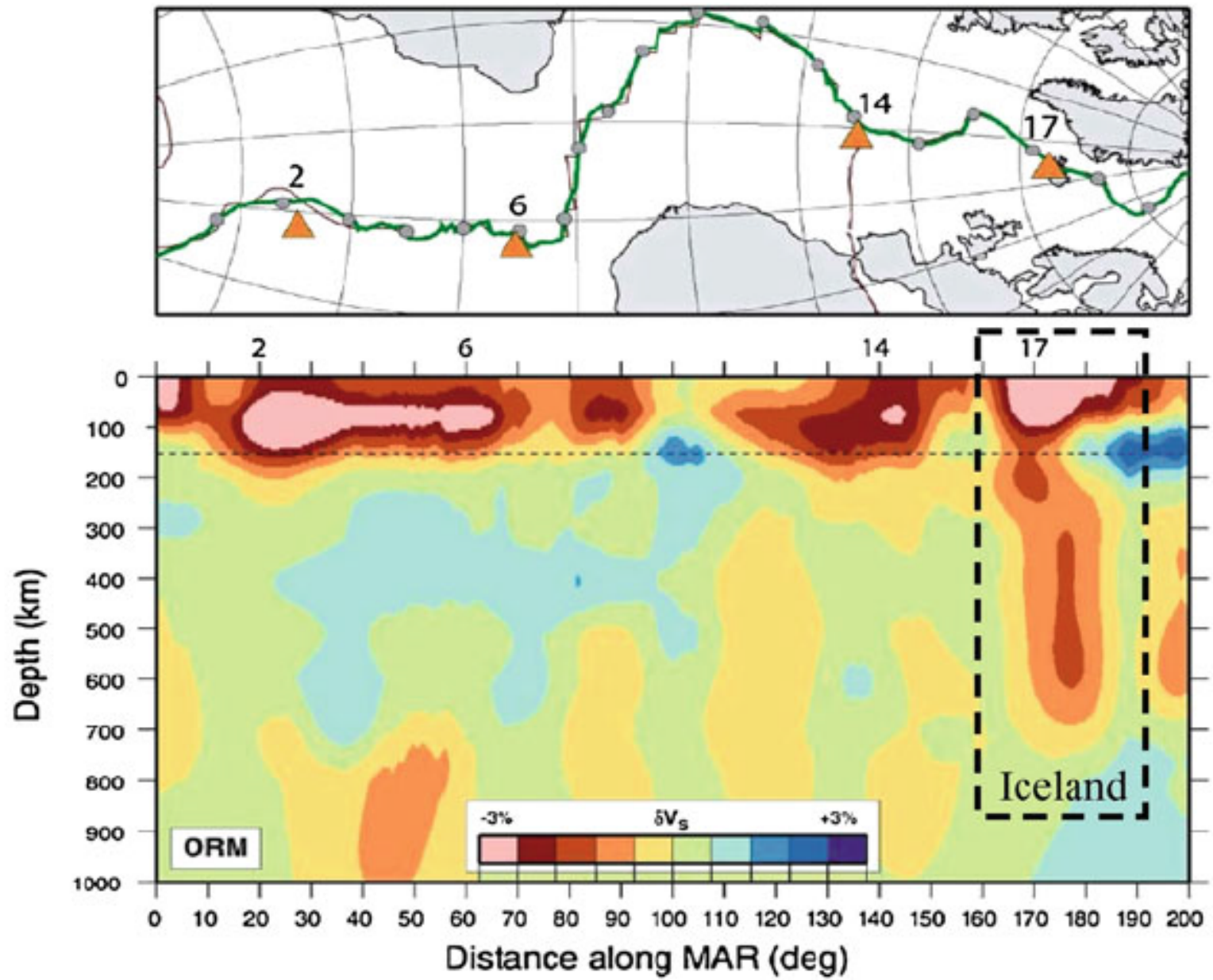
$^4\text{He}/^3\text{He}$

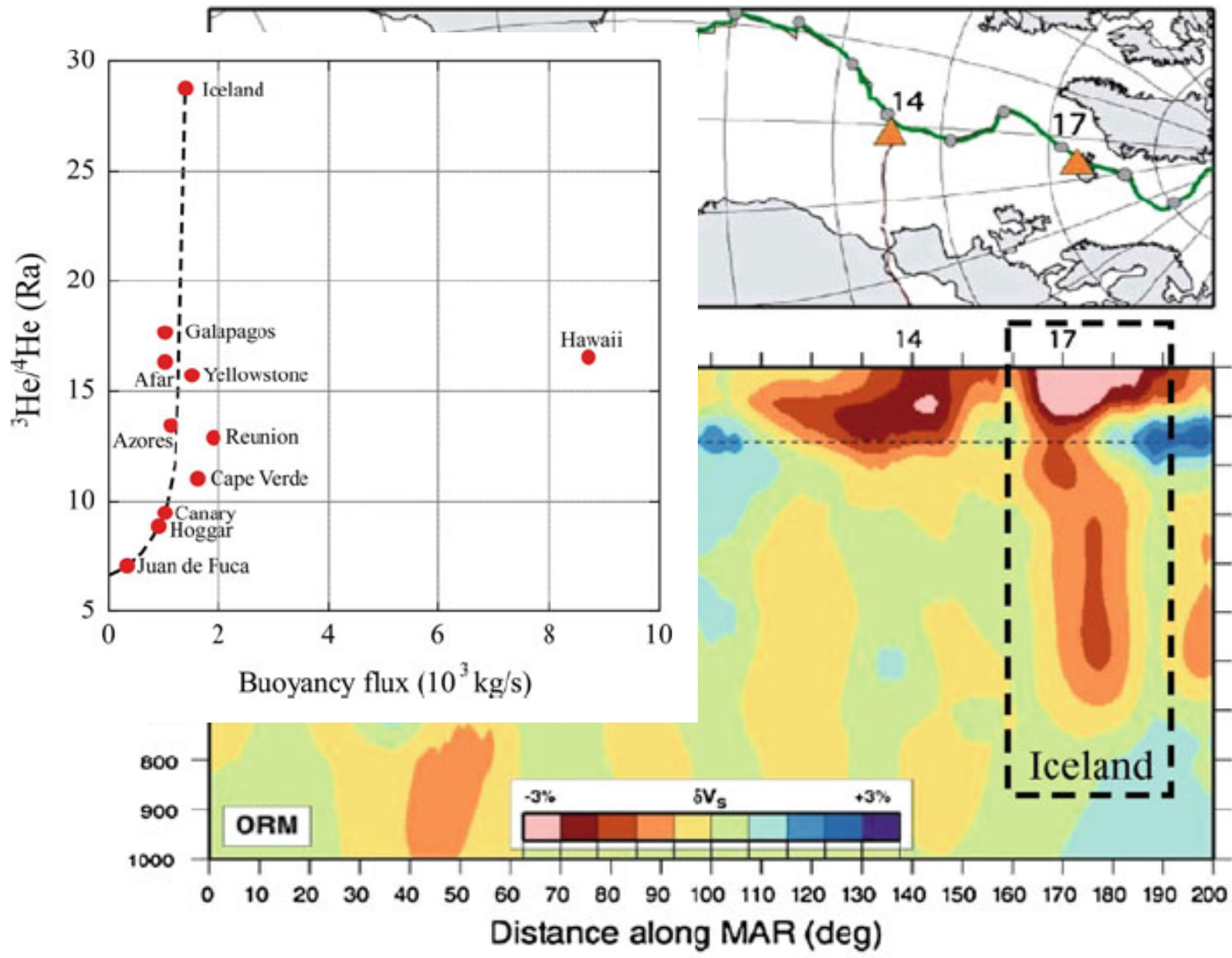


Van Keken et al., 2002

Iceland Fluids

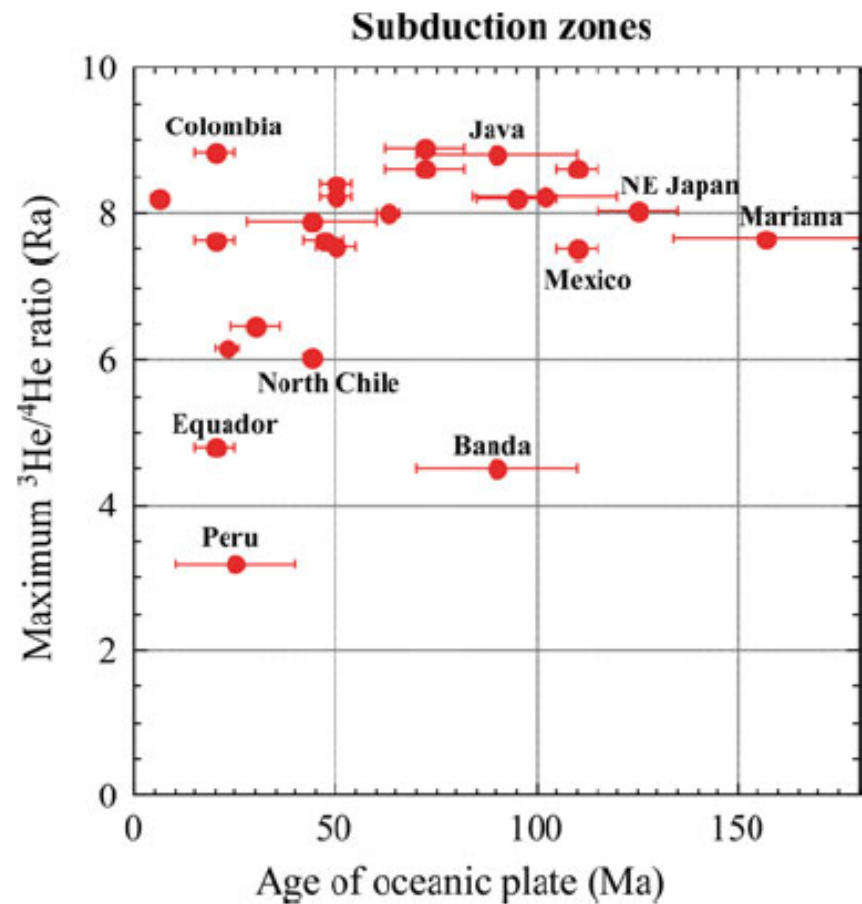
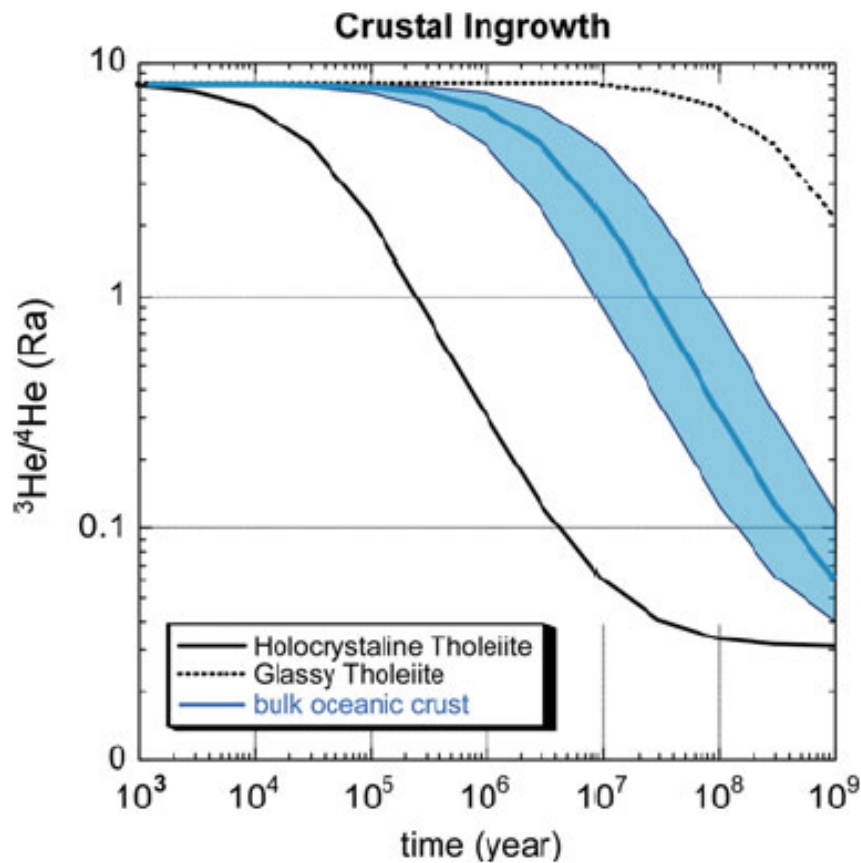


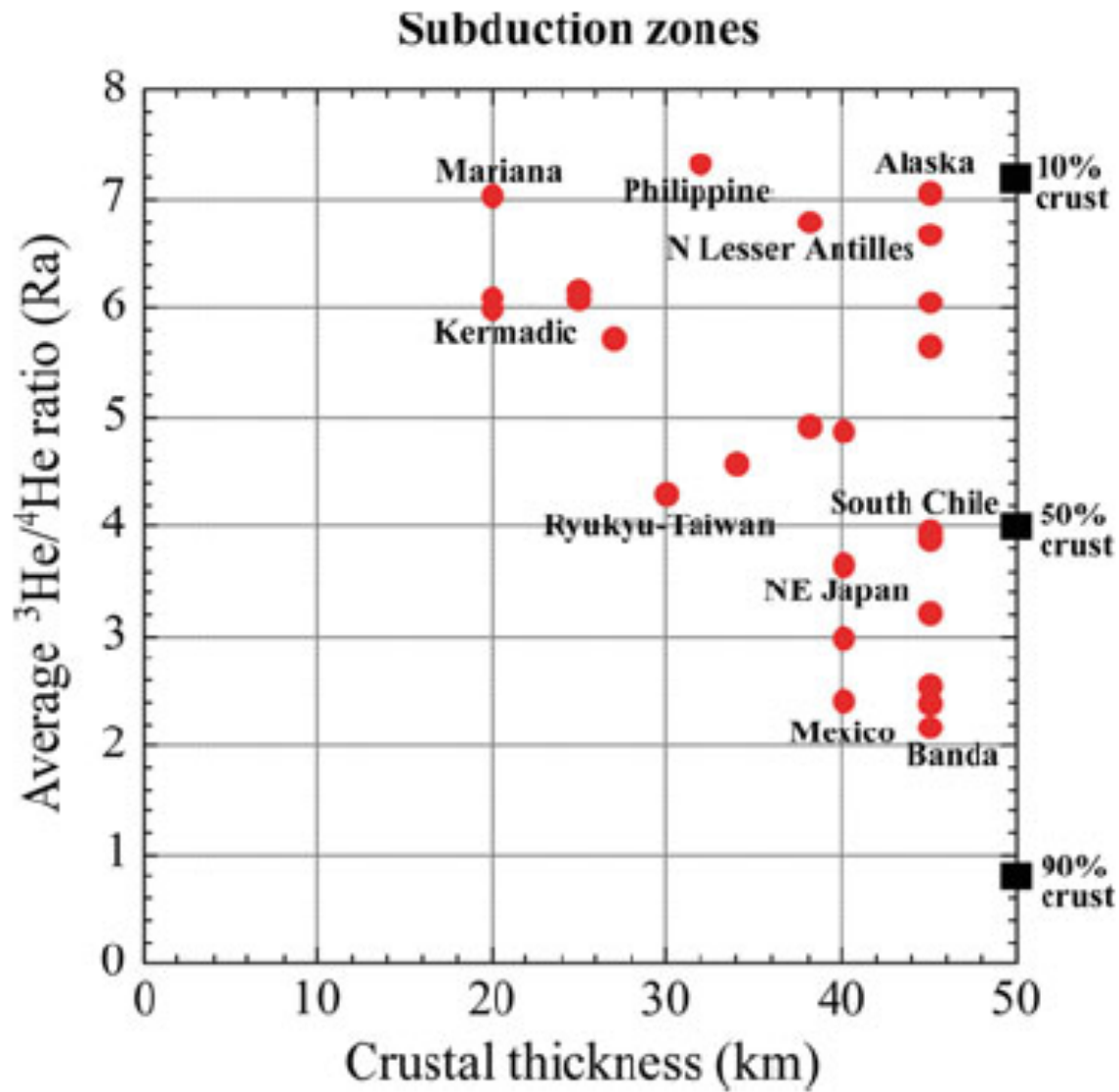


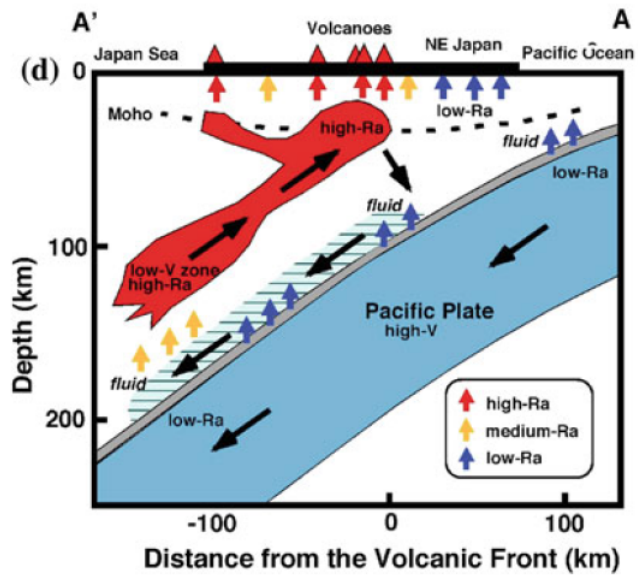
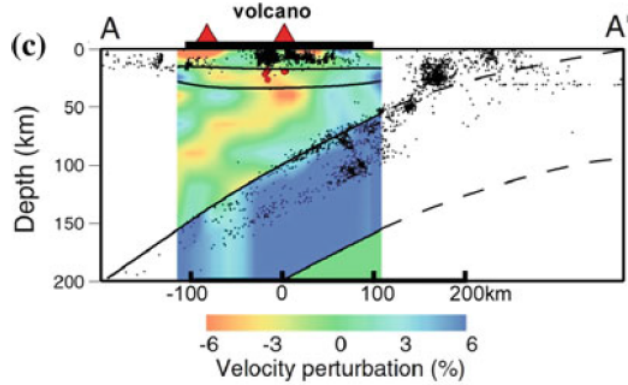
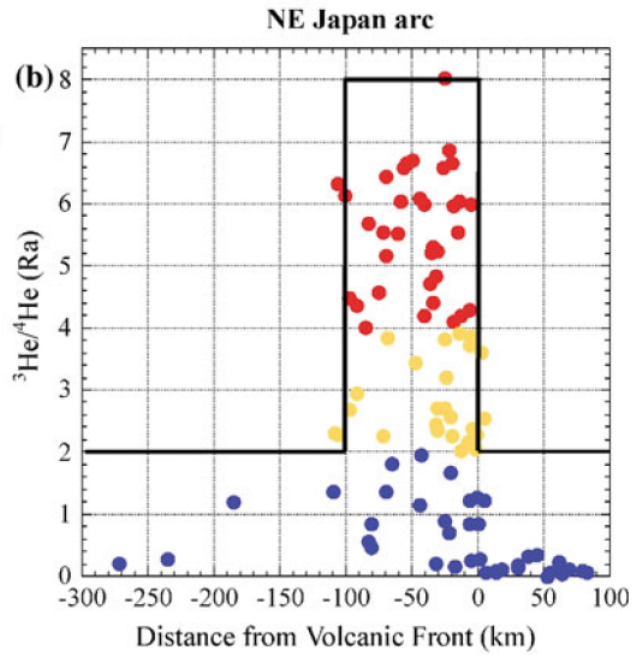
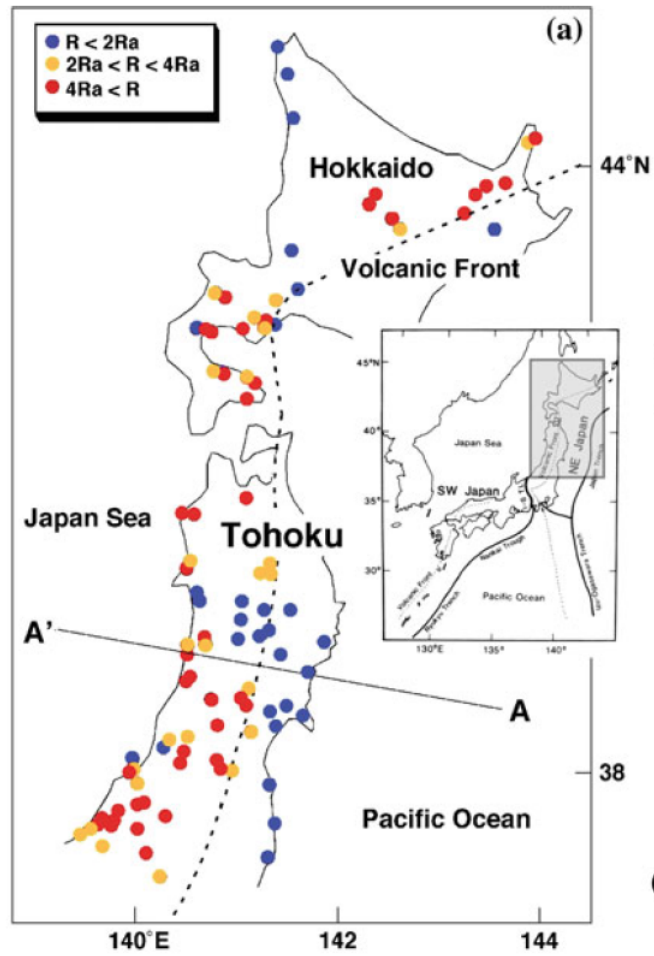


Sano and Fischer, 2013

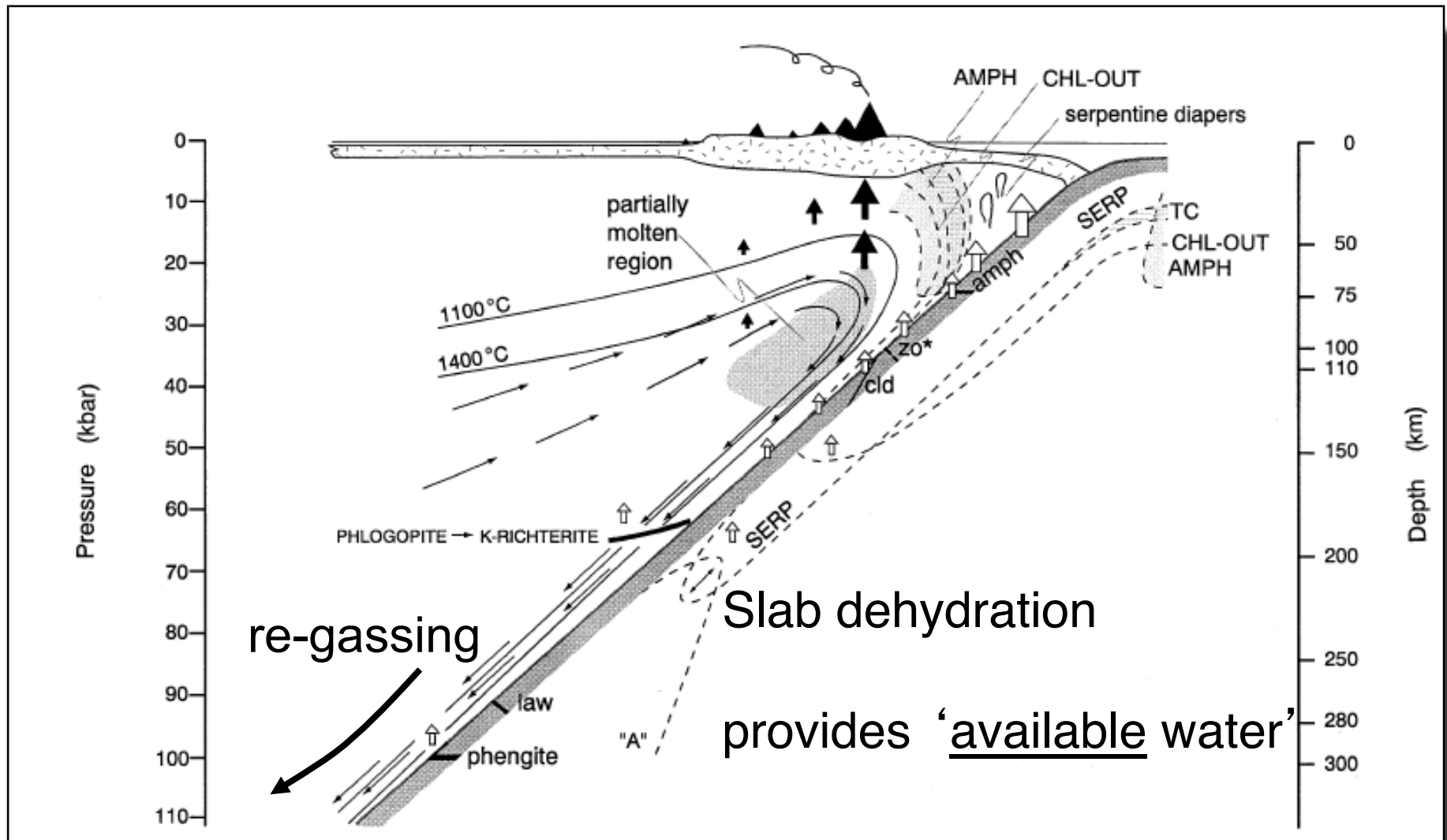
Subduction Zones: Helium isotopes in fluids



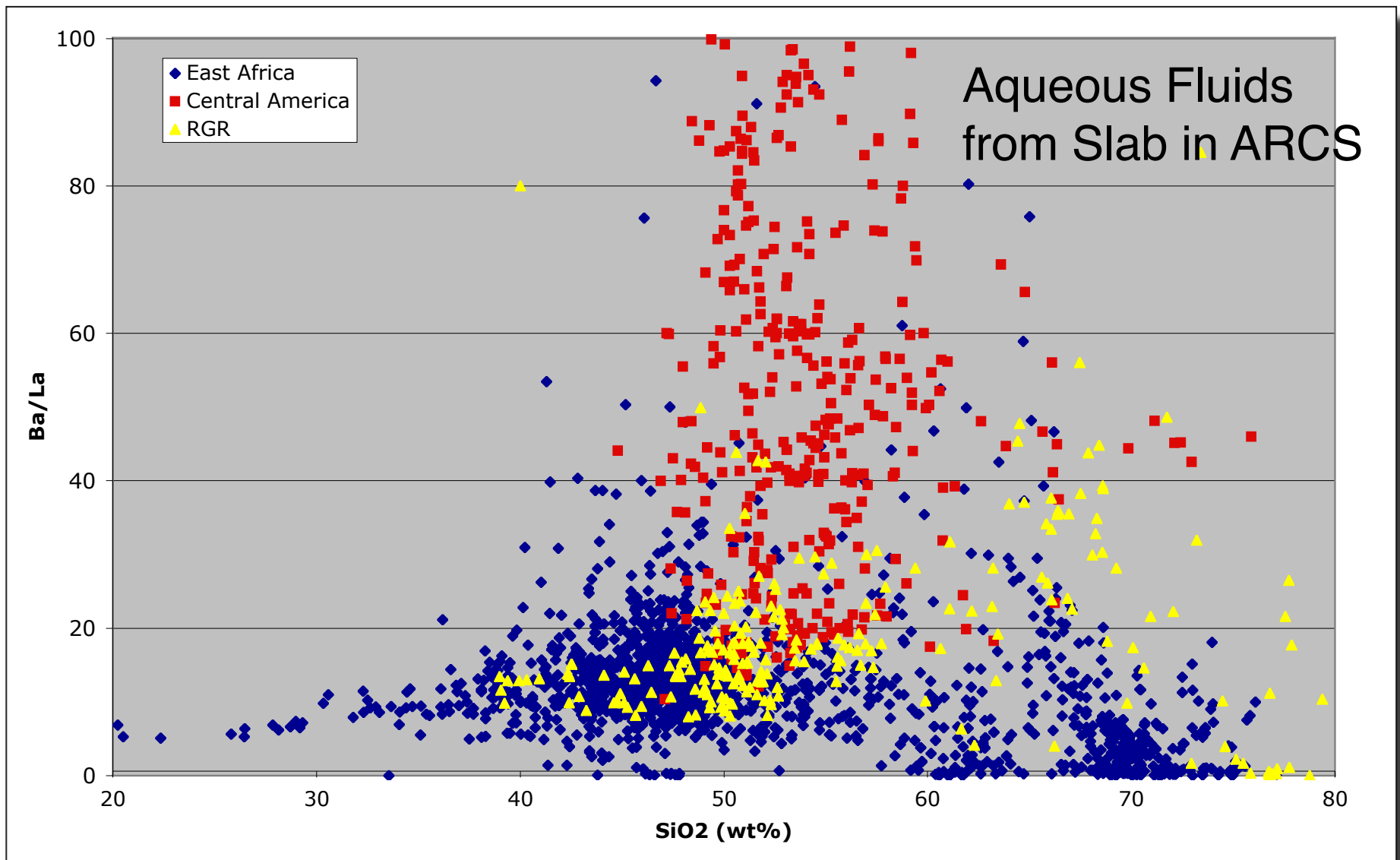




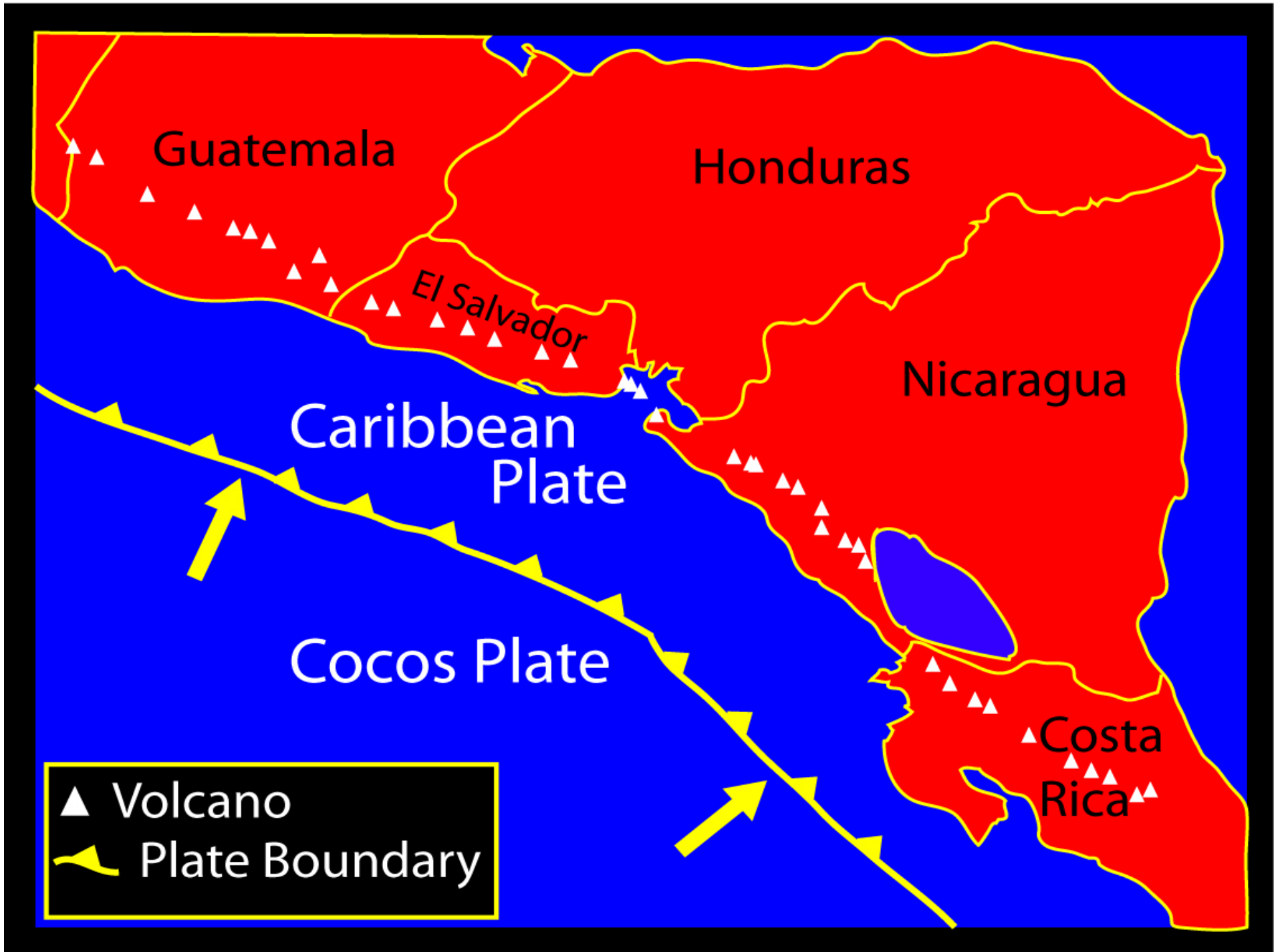
In Arcs fluids come from the slab



Schmidt+Poli, 1998



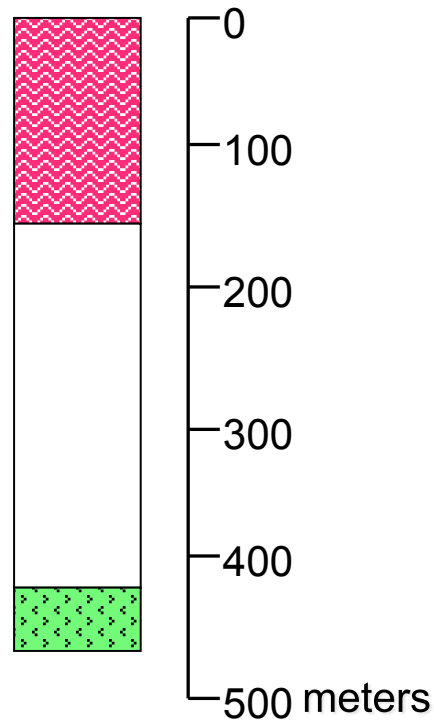
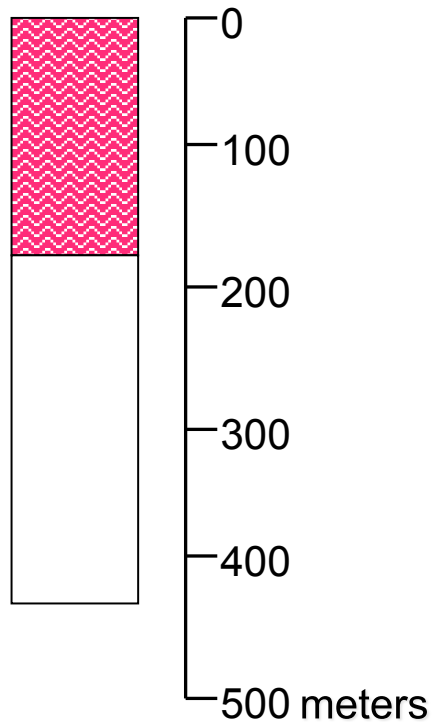
Georoc database and Mike Carr's data base



Sediment lithology:

★ Site 495
Guatemala

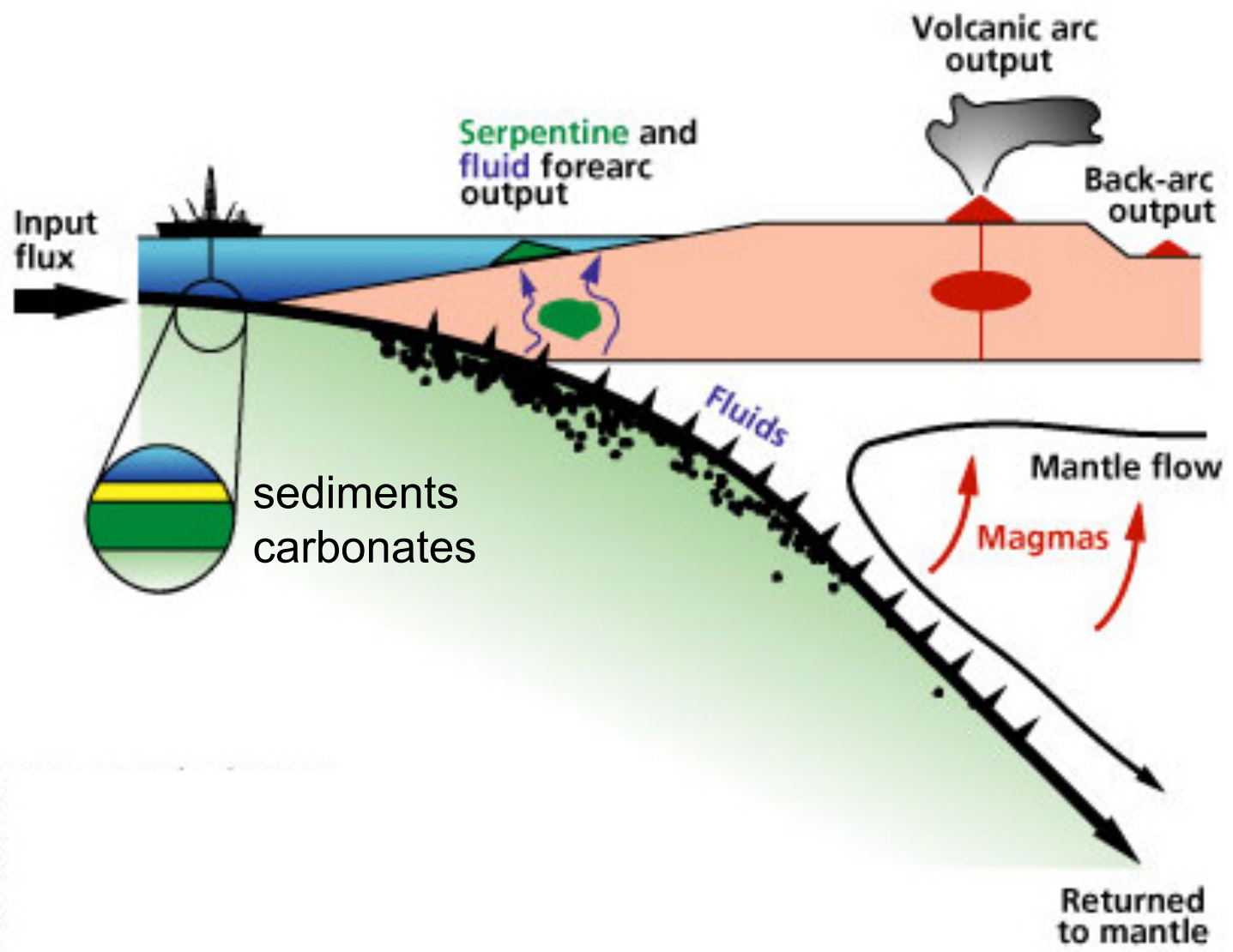
★ Site 1039
Costa Rica



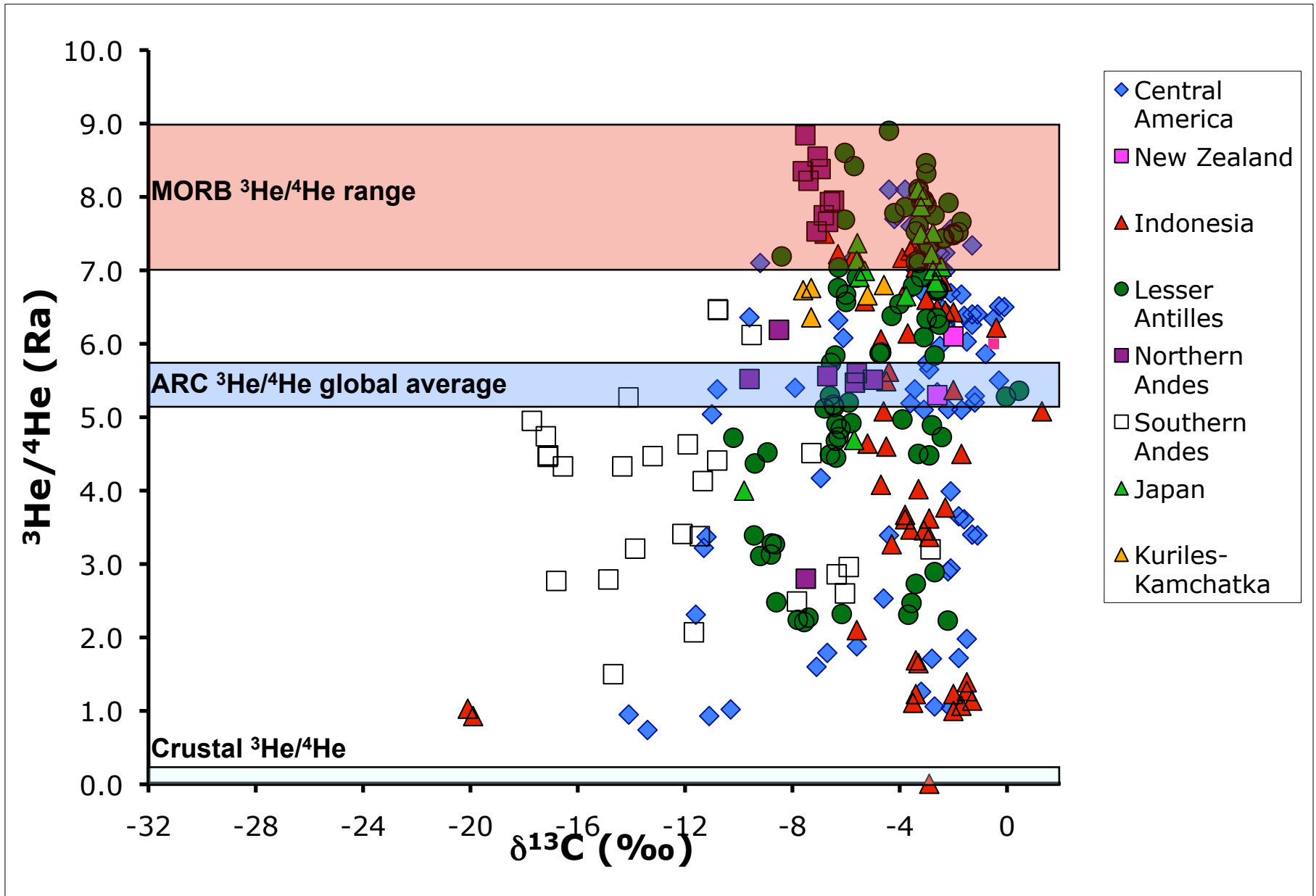
Hemi-pelagic
diatom-rich mud

Pelagic
Carbonates

Pyroxene Gabbro

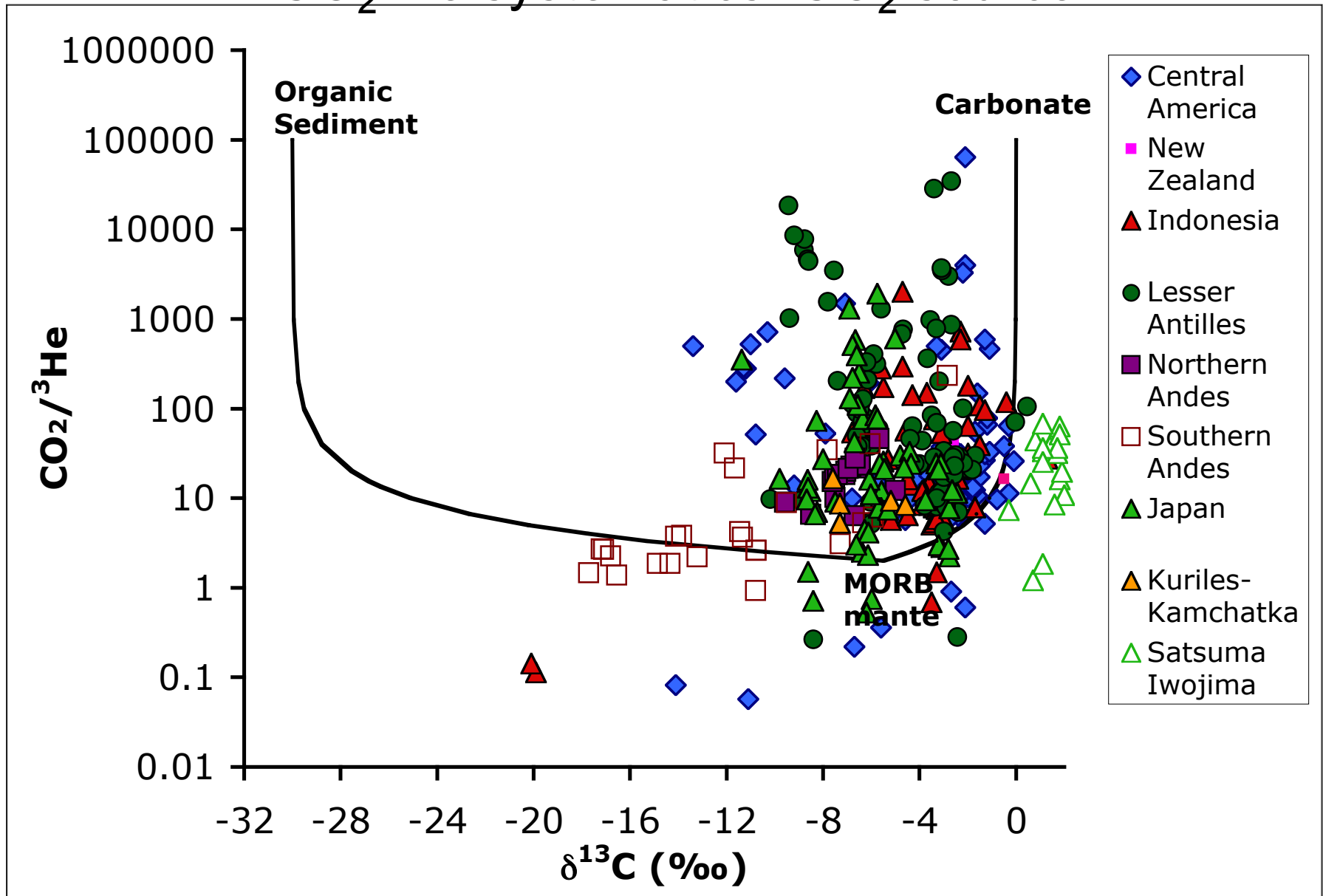


Arcs: Helium and Carbon isotopes (CO_2) in gases



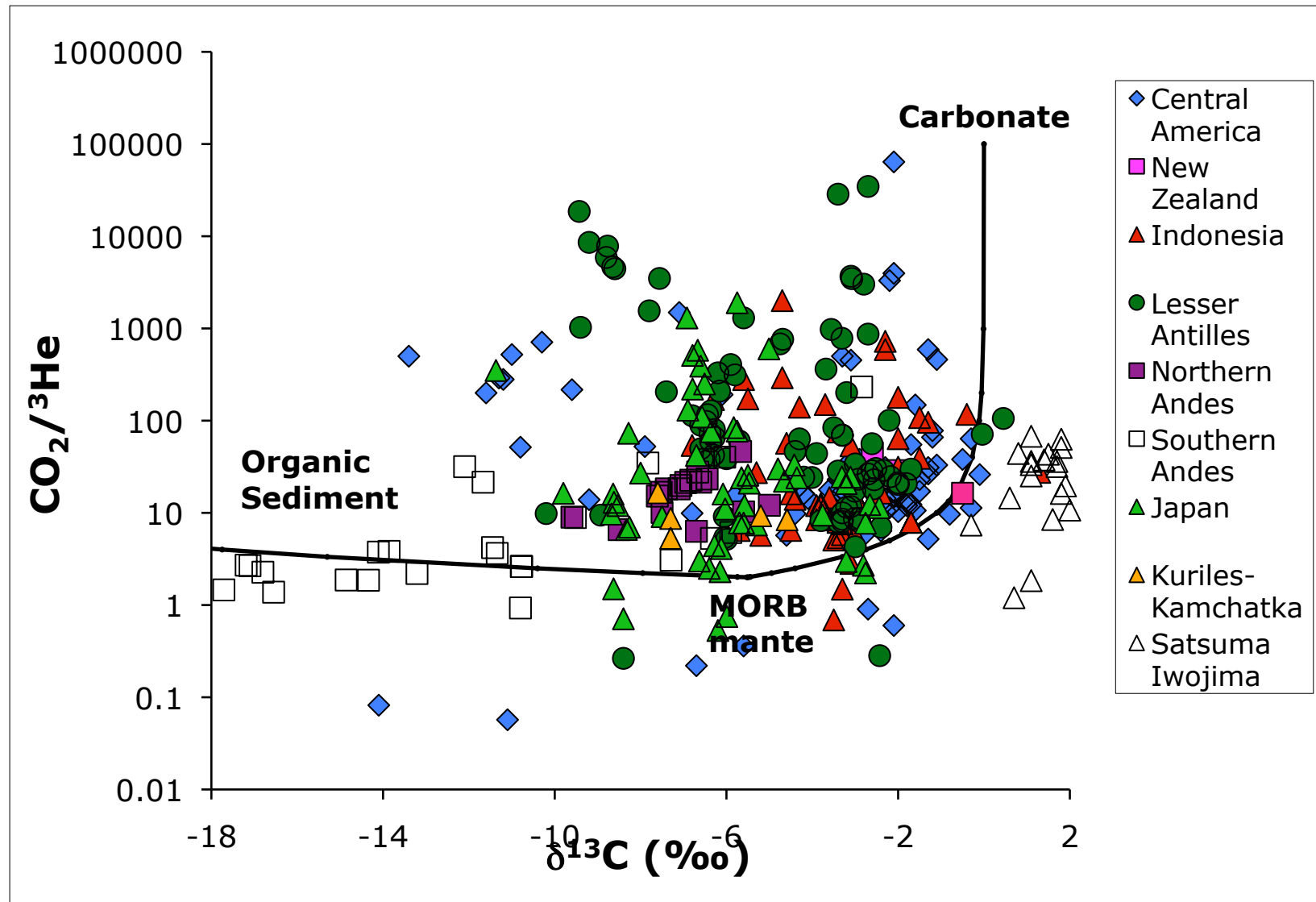
from Oppenheimer, Fischer, Scaillet (ToG in press)

CO₂-He systematics: CO₂ source



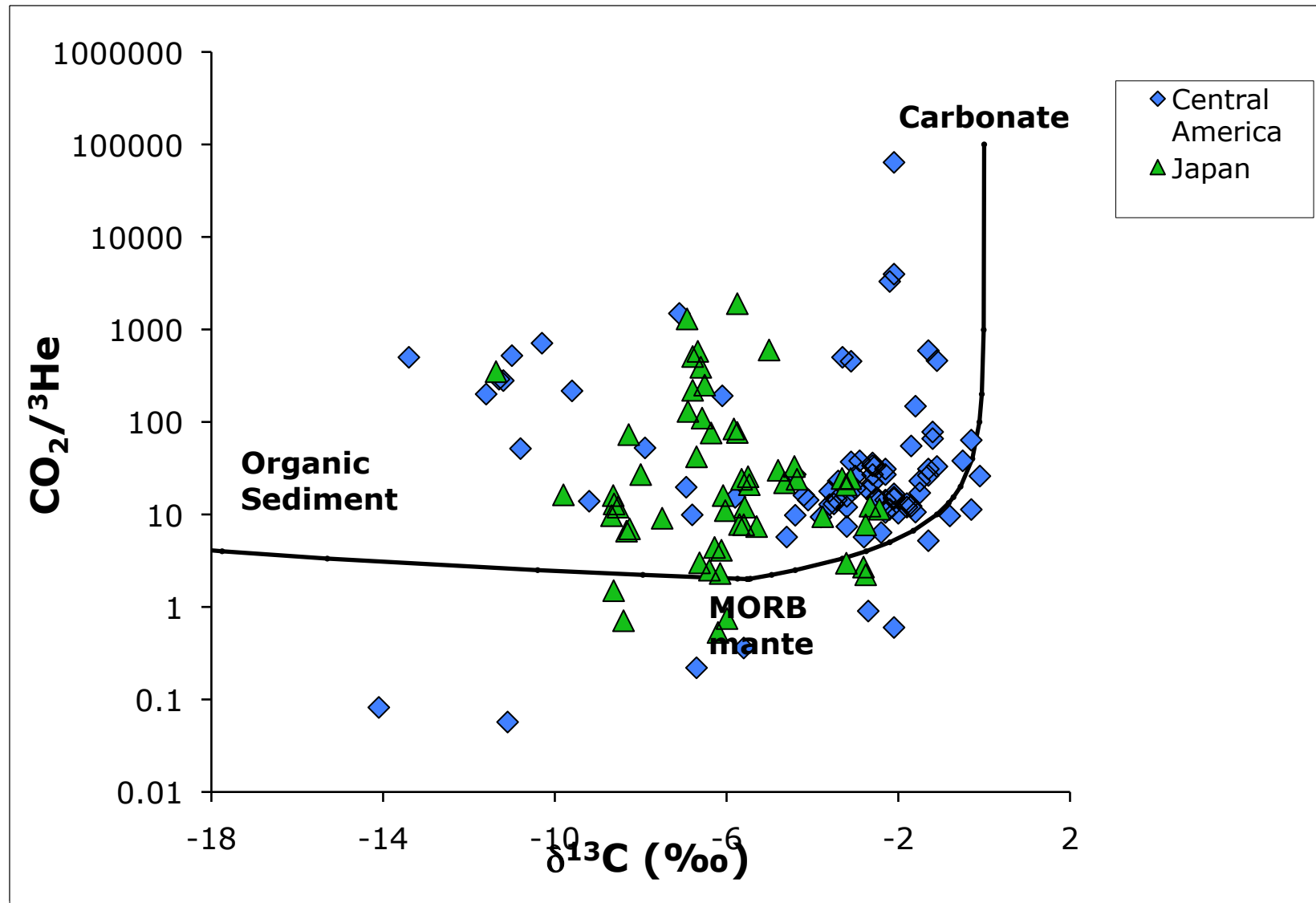
after Sano and Marty (1995); from Oppenheimer, Fischer, Scaillet (ToG in press)

CO₂-He systematics: CO₂ source



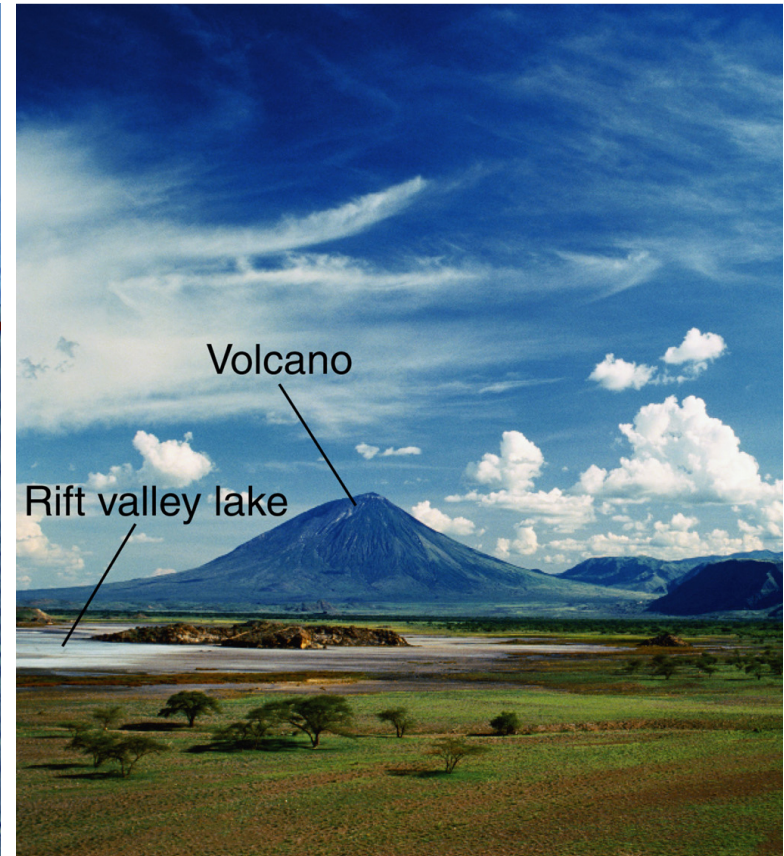
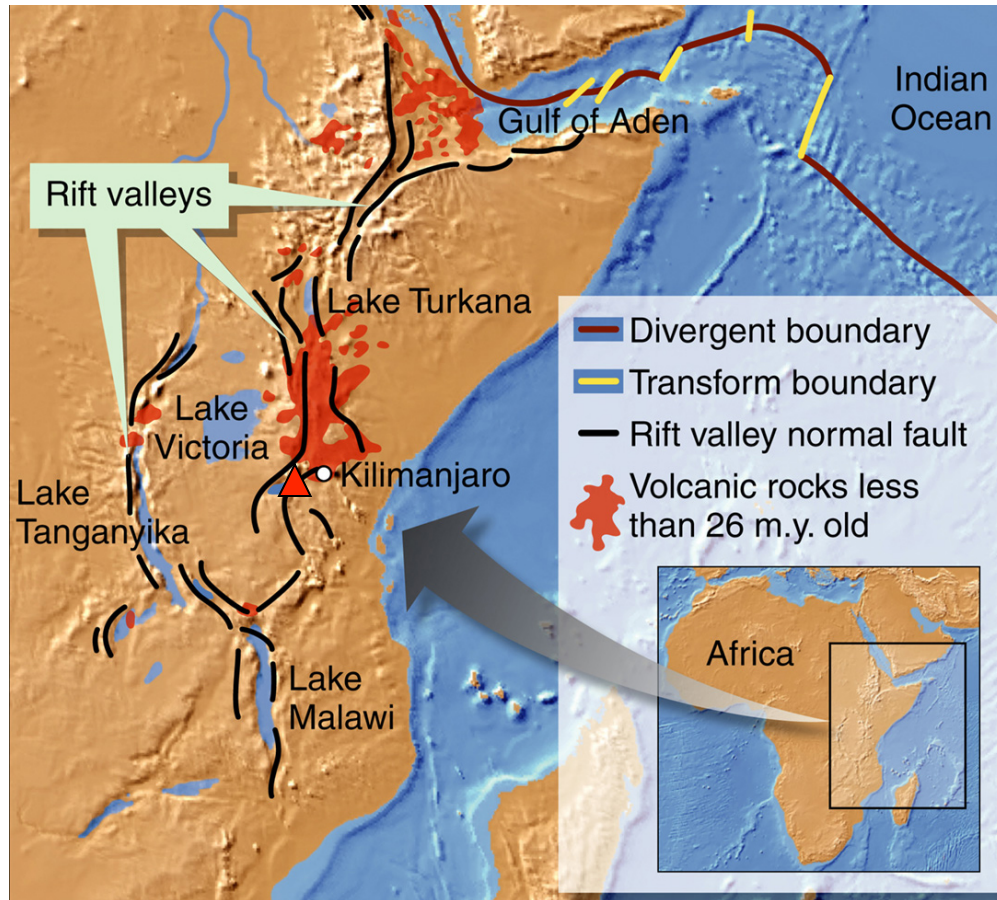
after Sano and Marty (1995); from Oppenheimer, Fischer, Scaillet (ToG in press)

CO₂-He systematics: CO₂ source



after Sano and Marty (1995); from Oppenheimer, Fischer, Scaillet (ToG in press)

Upper mantle gases away from Subduction Zones: Oldoinyo Lengai



Oldoinyo Lengai:
World's only active carbonatite
Volcano

Ol Doinyo Lengai Gases:

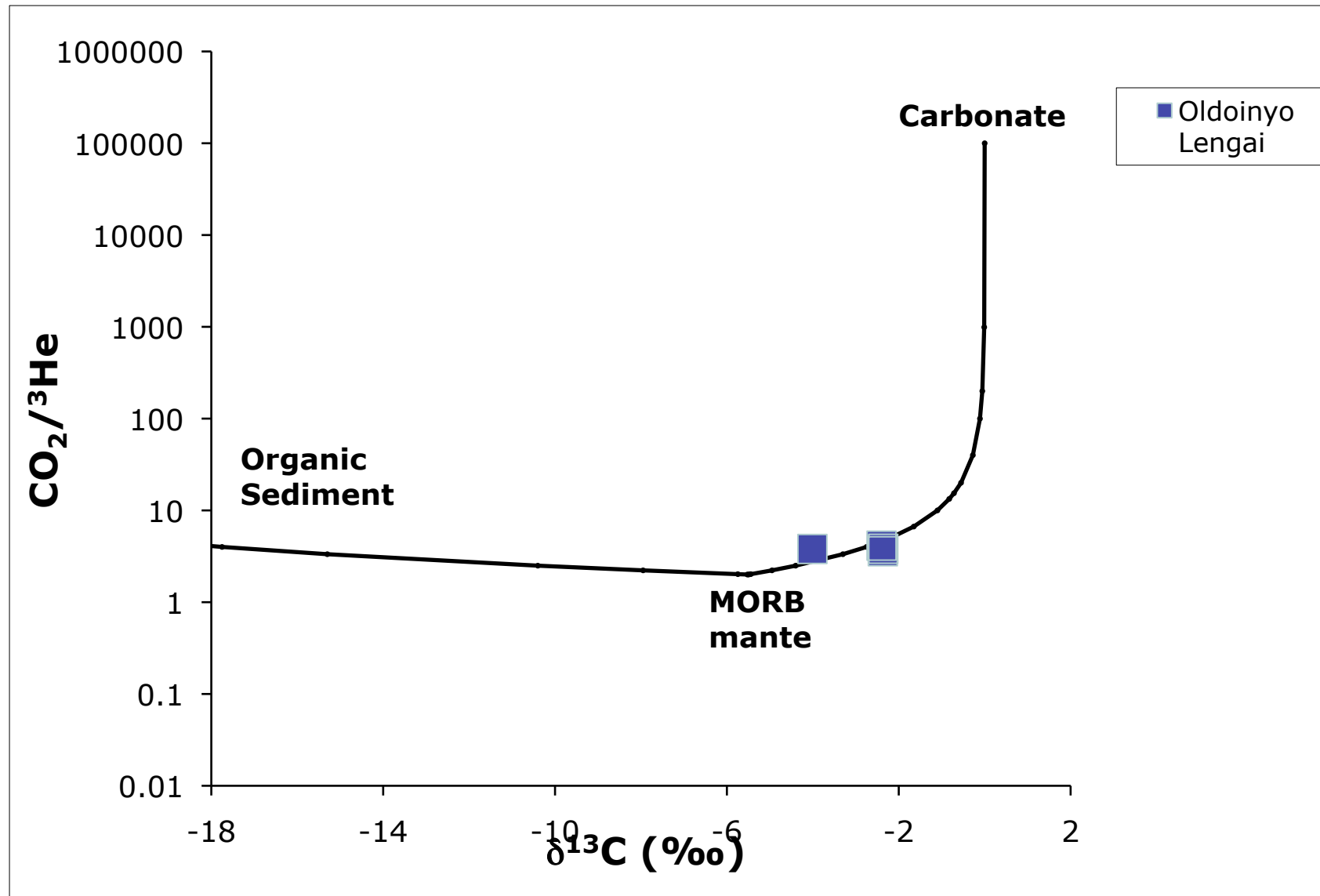
$^3\text{He}/^4\text{He}$: $6.86 \pm 0.03 R_A$

(Fischer et al., 2009)



July 2005

CO₂-He systematics: CO₂ source

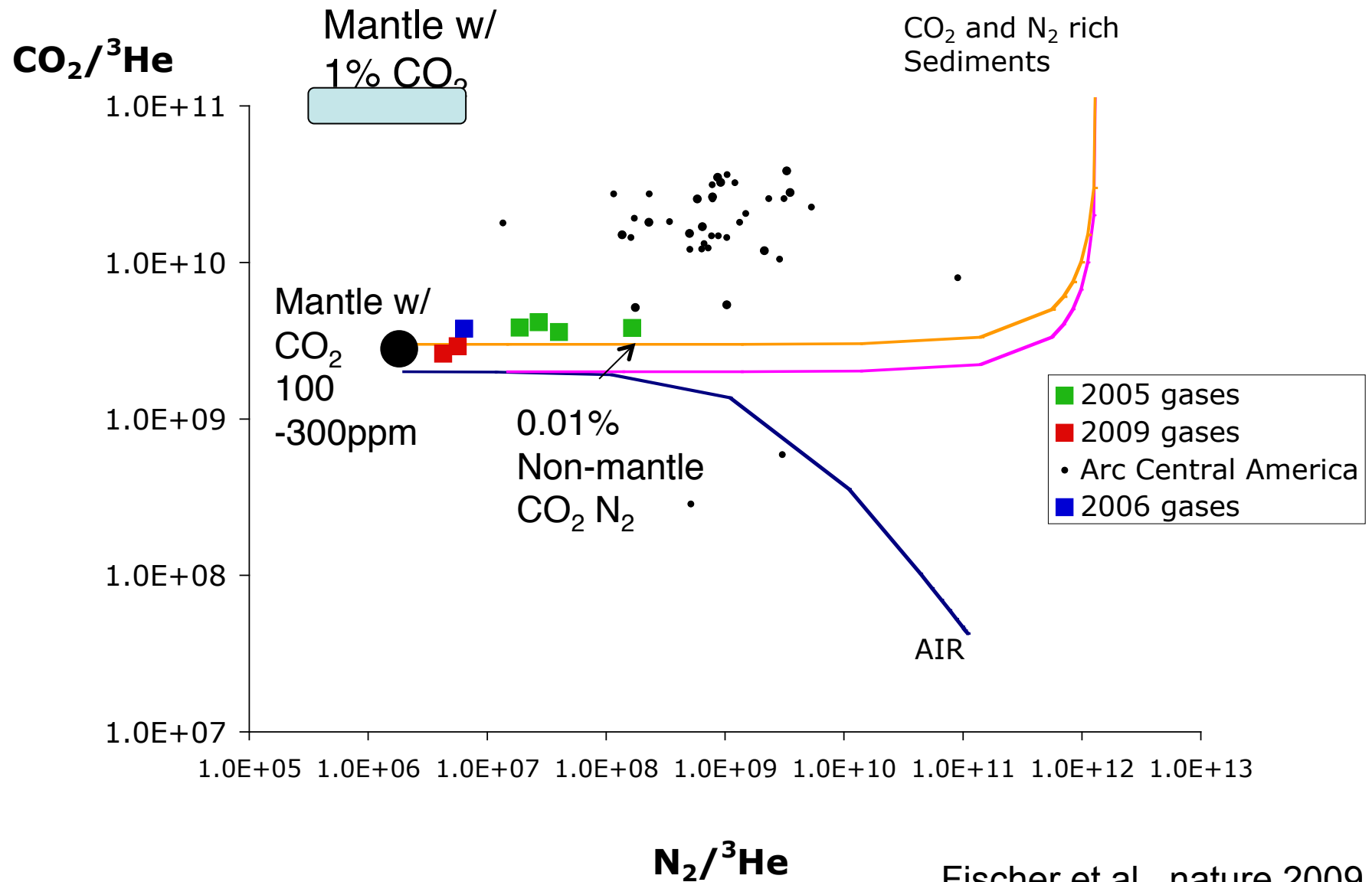


after Sano and Marty (1995); Fischer et al., nature 2009

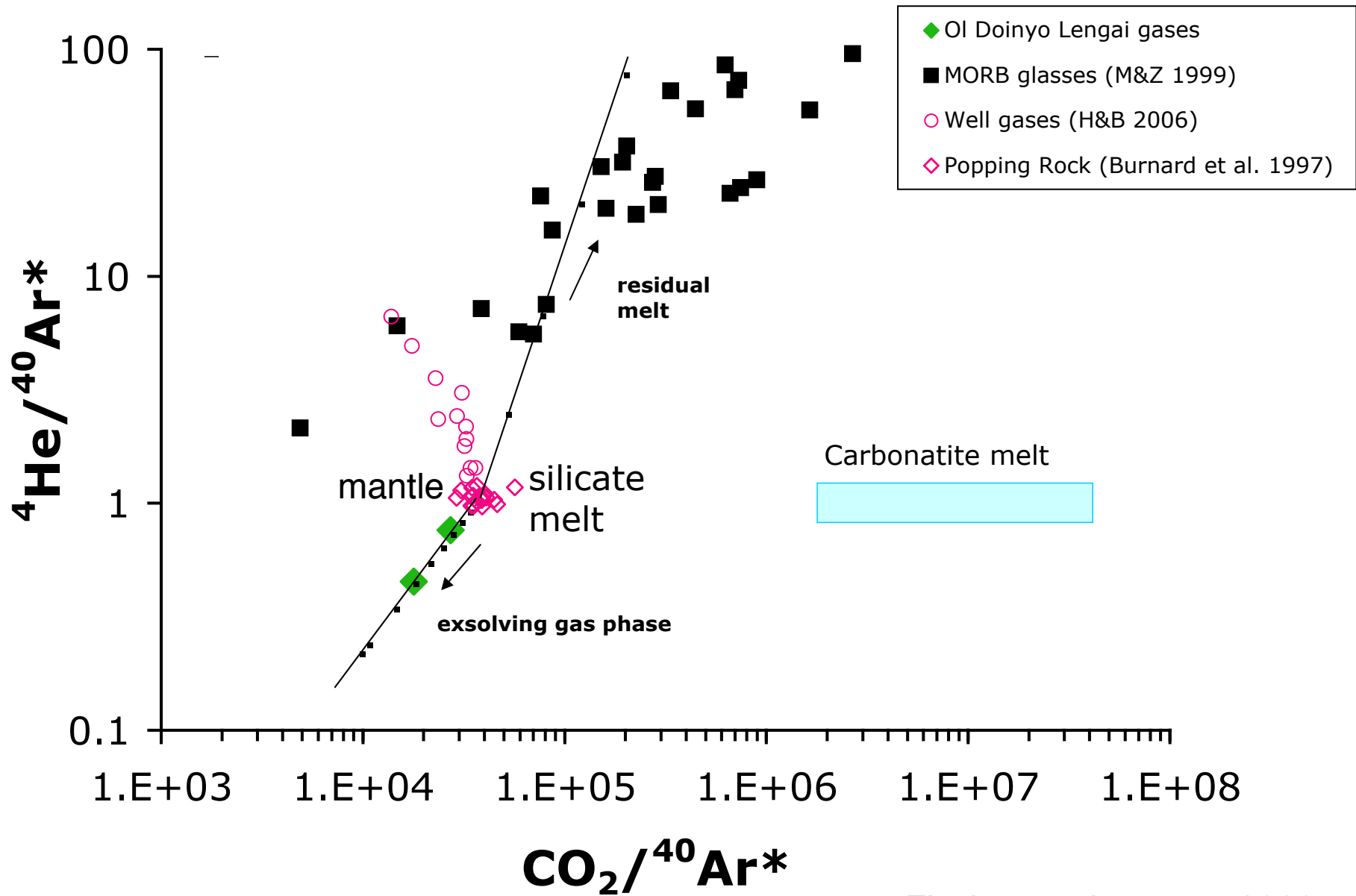
CO₂, Nitrogen, Chlorine in Magma Source

Year	³ He/ ⁴ He R _c / R _A	CO ₂ / ³ He (*10 ⁹)	δ ¹³ C (‰)	δ ¹⁵ N (‰)	δ ³⁷ Cl (‰)
2005	6.77 ± 0.16	2.60	-2.43 ± 0.02	-3.5 ± 0.4	0.0 ± 0.3
2009	6.88 ± 0.20	2.91	-2.77 ± 0.04	-1.5 ± 0.4	
MORB	8 ± 1	2.5 to 3.0	-5 to -2.5	-5 ± 3	0 ± 0.5

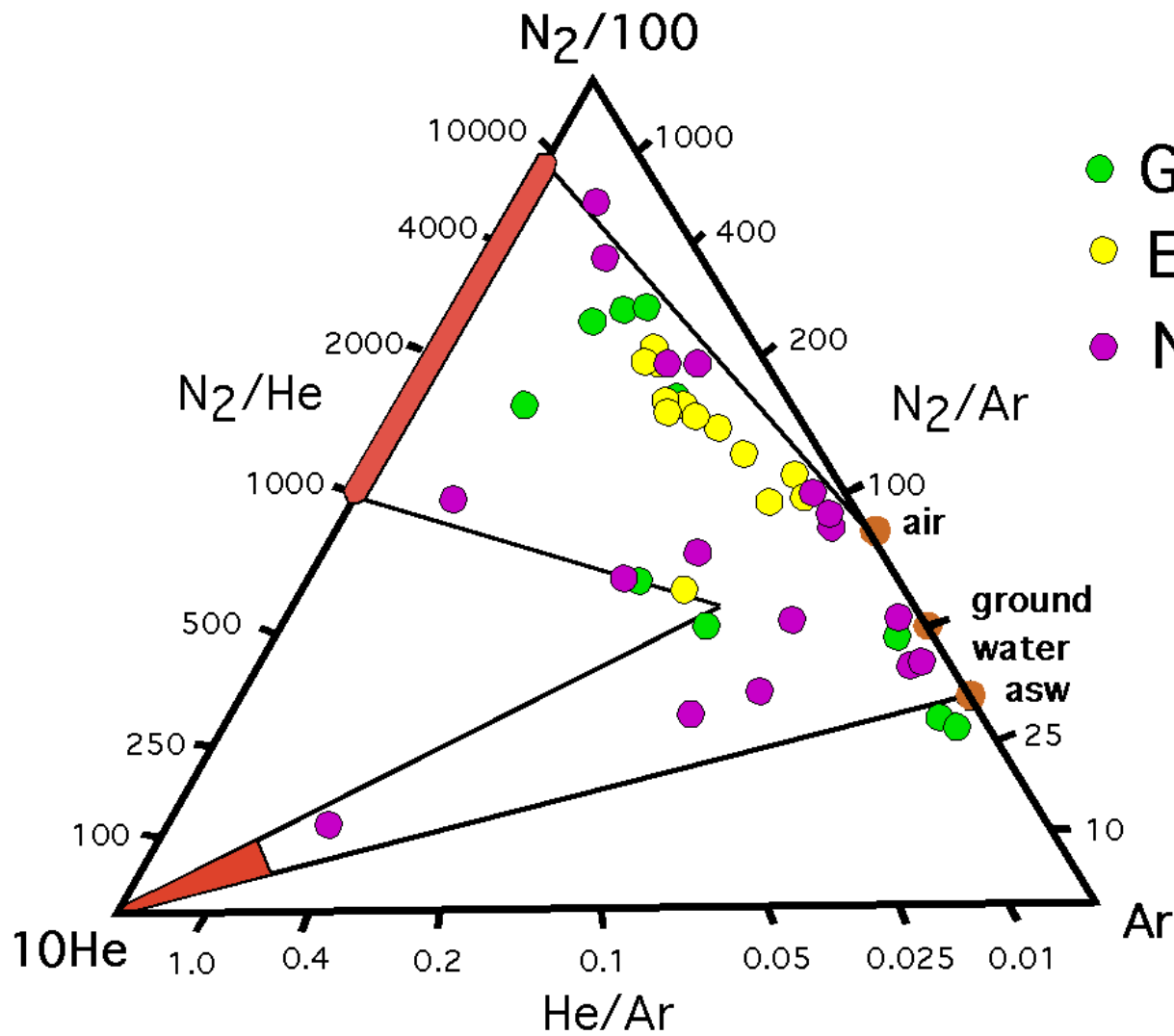
CO₂ in Magma Source Region



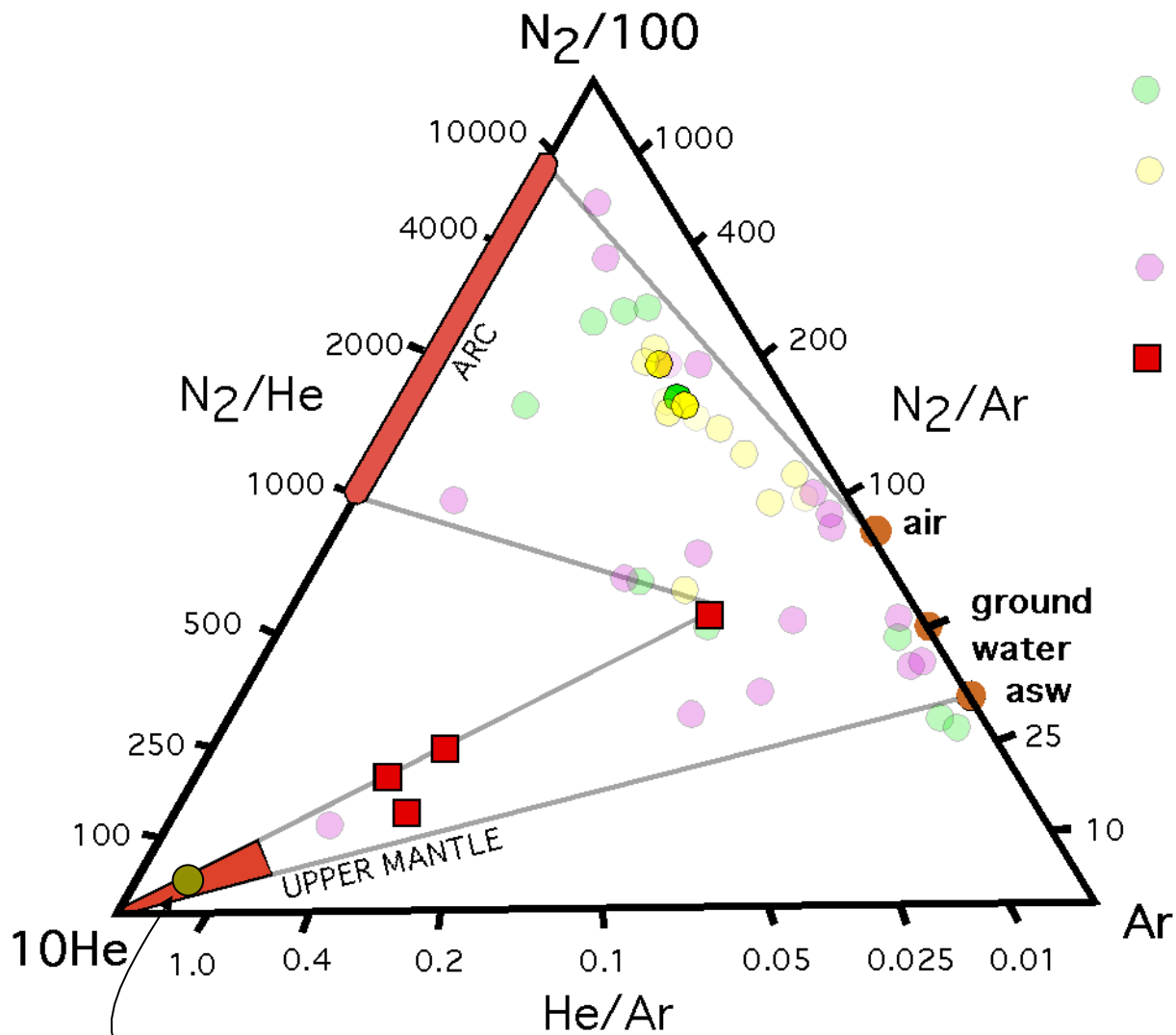
CO₂-He-Ar systematics: mantle-derived silicate melt degassing



Gas Samples

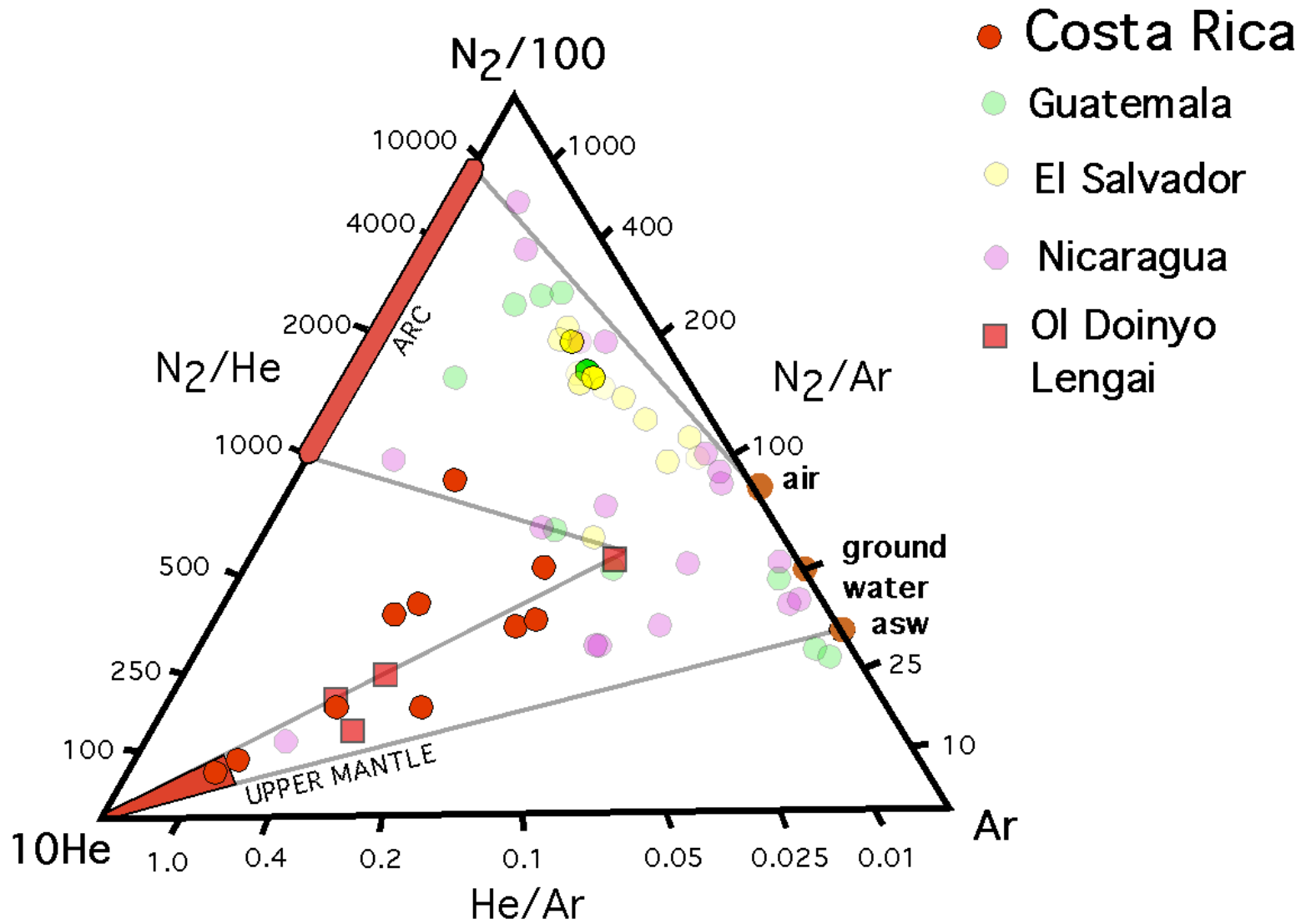


Zimmer, Fischer, et al. G3, 2004; Fischer unpubl.

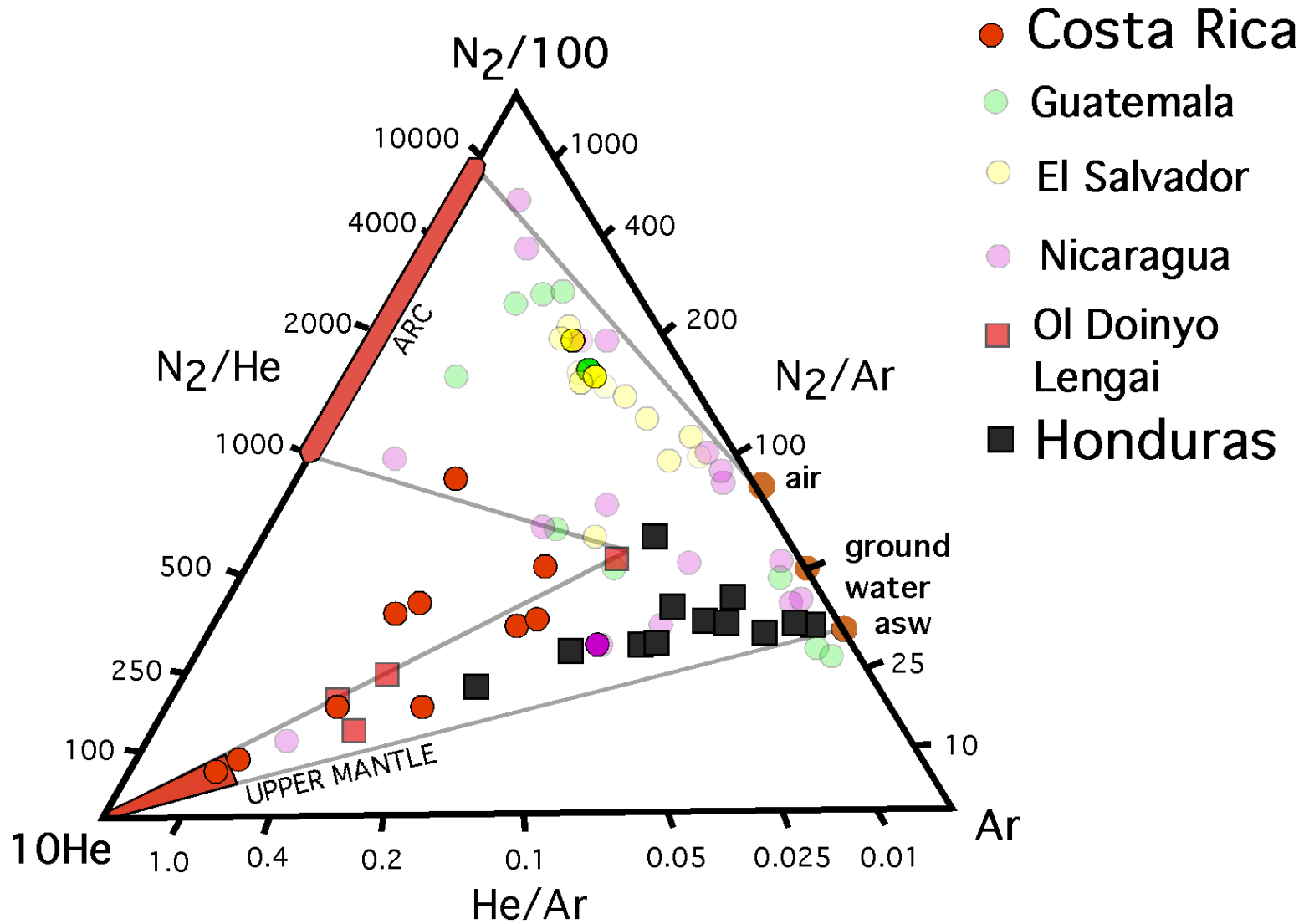


- Guatemala
- El Salvador
- Nicaragua
- Ol Doinyo Lengai

Mid-Atlantic Popping Rocks
(Javoy & Pineau, '91)



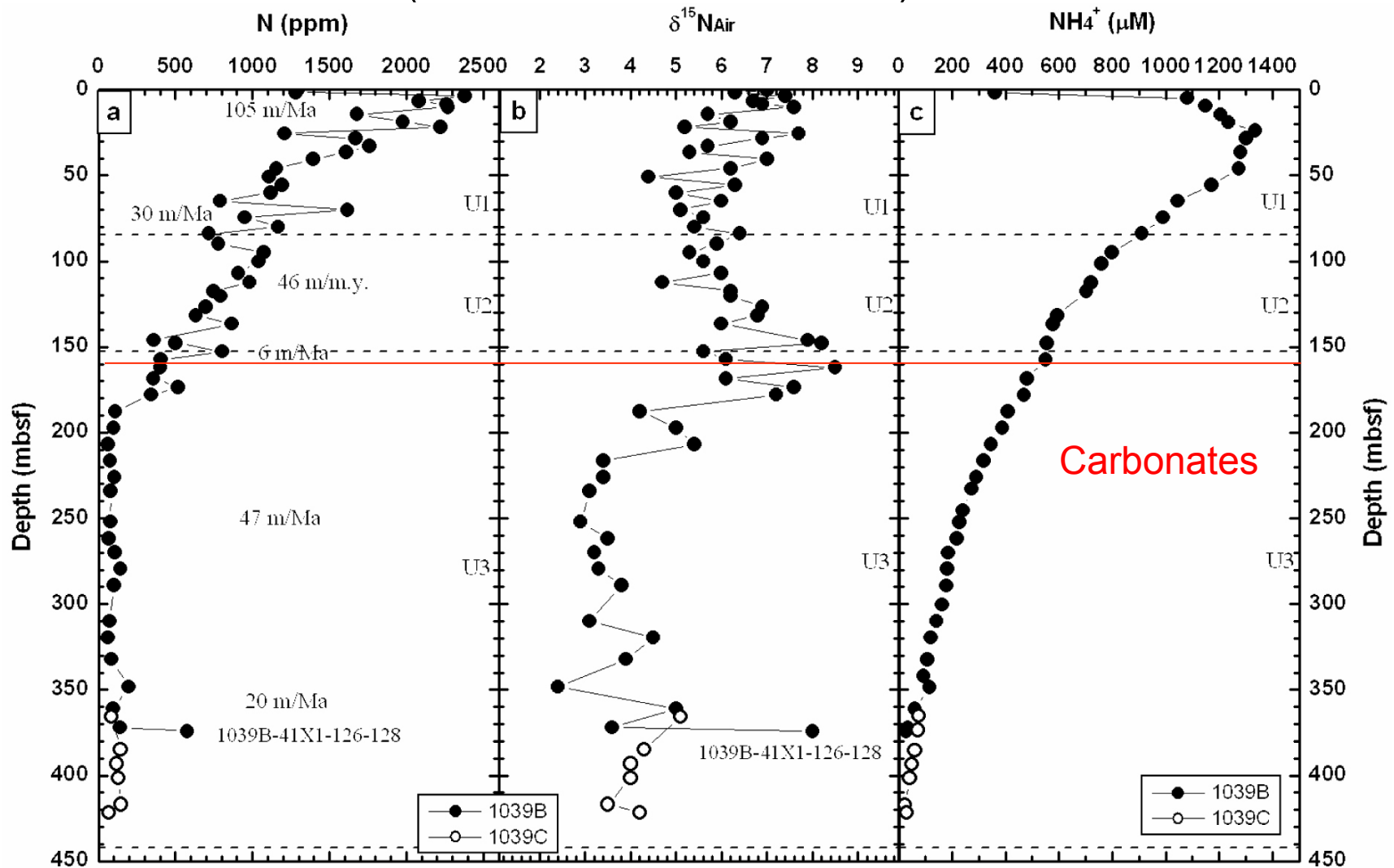
Zimmer, Fischer, et al. G3, 2004; Fischer unpubl.
 Fischer et al., nature 2009

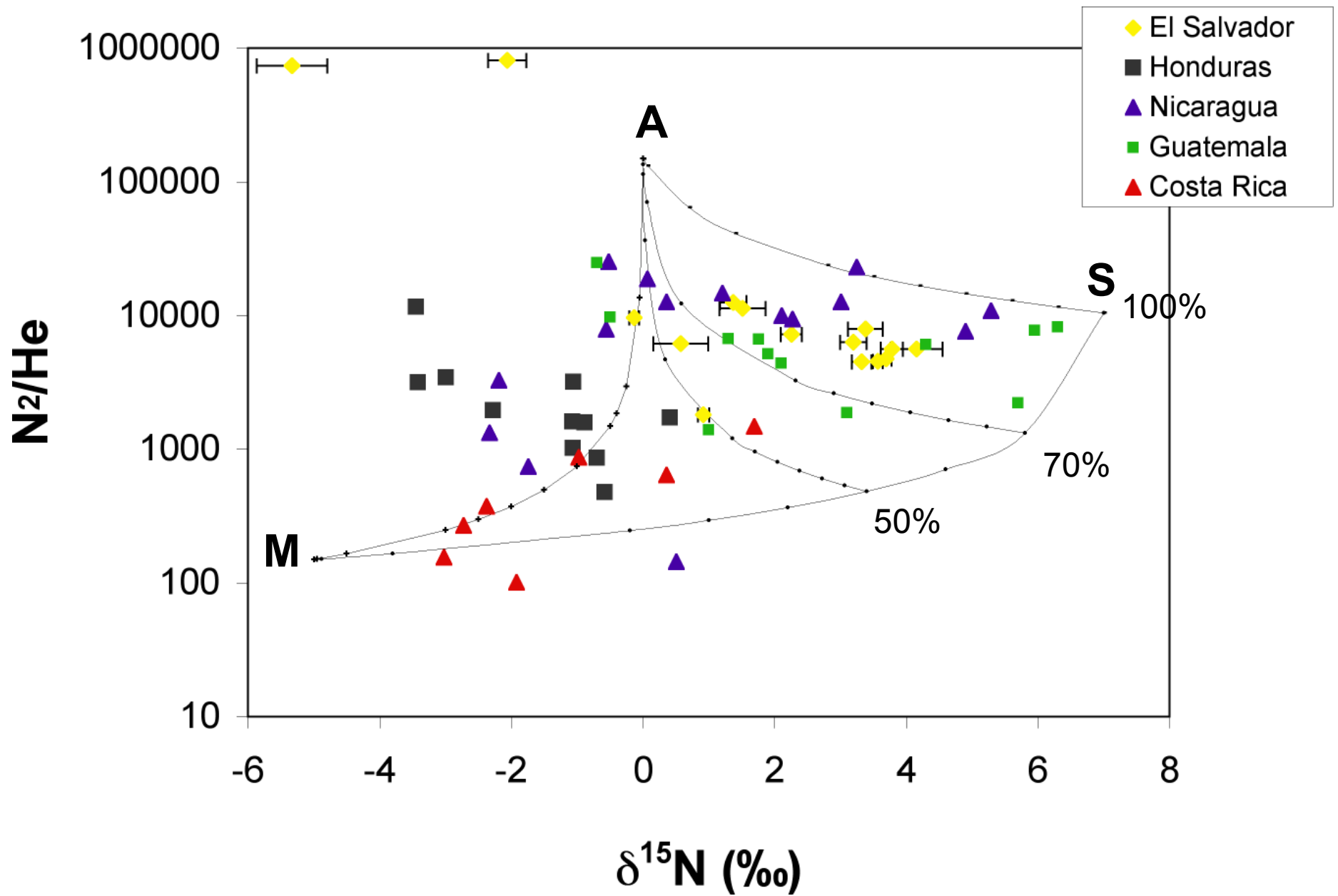


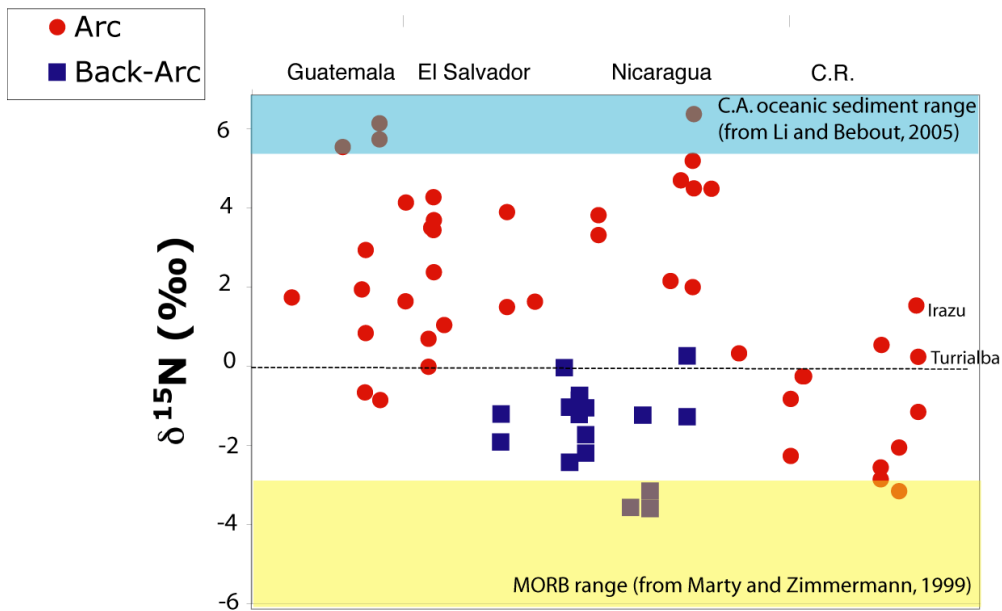
Zimmer, Fischer, et al. G3, 2004; Fischer unpubl.
 Fischer et al., nature 2009

Nitrogen in Sediments of Site 1039: Off Costa Rica

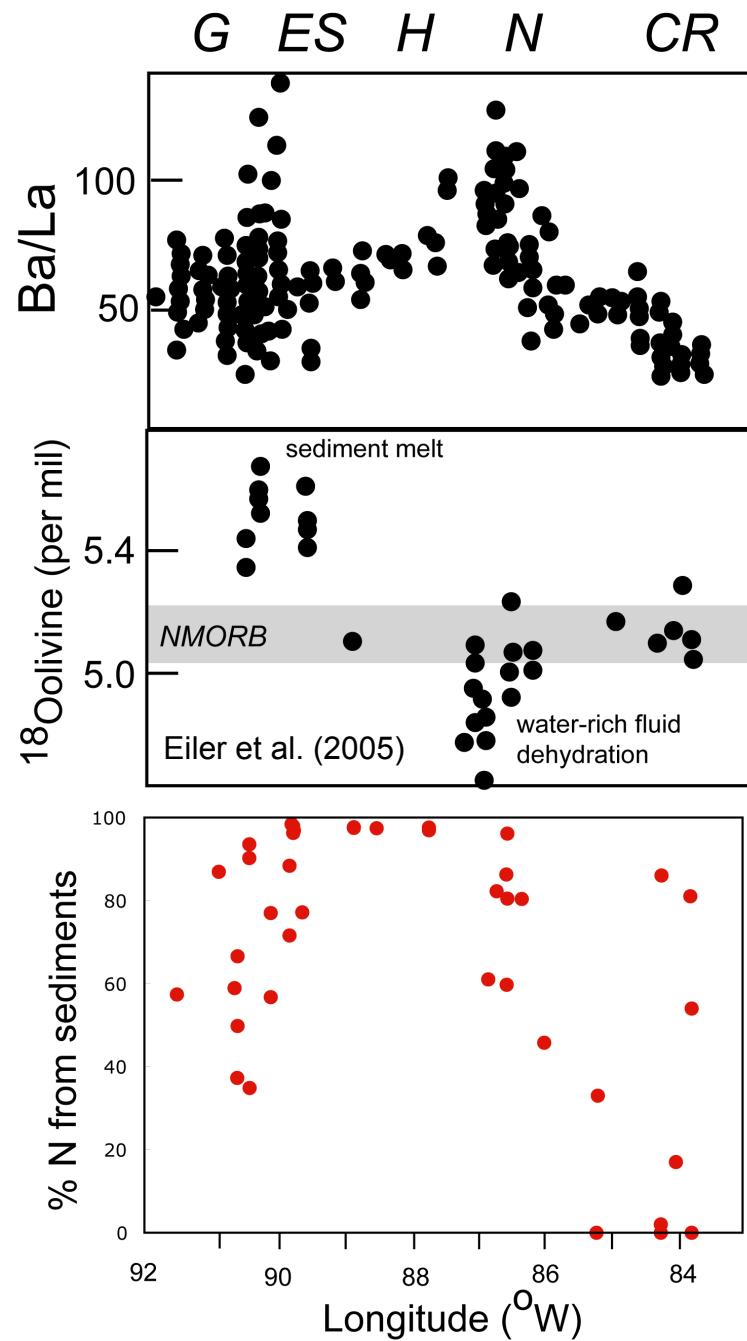
(Li and Bebout, JGR 2005)







Use end-members to calculate



Elkins et al. (2006), Fischer et al. (2002),
 Zimmer et al. (2004), M. Carr's online database

Suggestions for beginning gas/ geochemical monitoring and research

- Start technically simple: alkaline solutions, Giggenbach bottle, multiGAS
- Establish baselines of S/Cl and S/CO₂
 - > do your own analyses
- Collaborate for noble gas and stable isotopes
 - > technology transfer
- Build chemistry lab in central place
- Work up to other techniques: Picarro C, O, H