Insights into the Spatial and Temporal Geometry of Subaxial Magma Reservoirs and Diking Processes from Individual Volcanic Eruptions along Mid-Ocean Ridges

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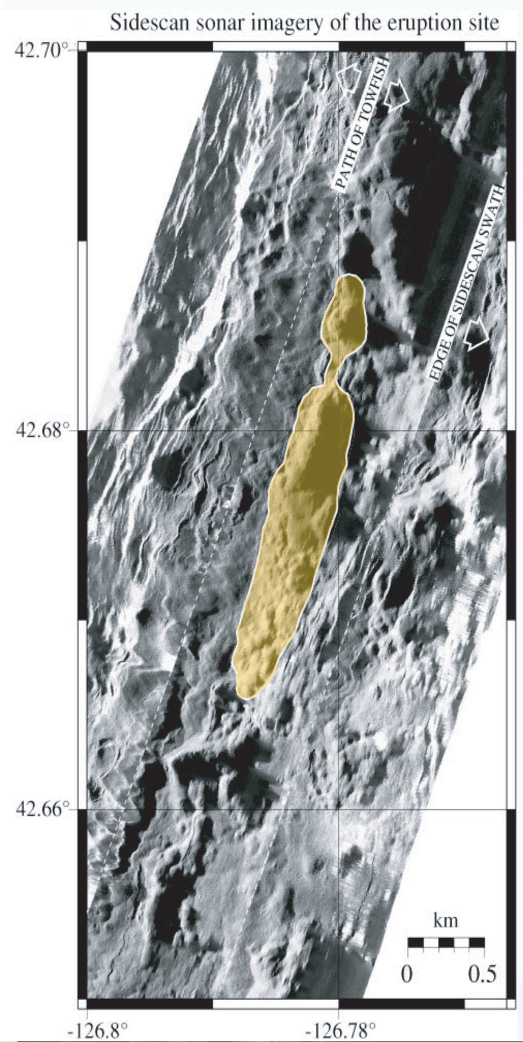
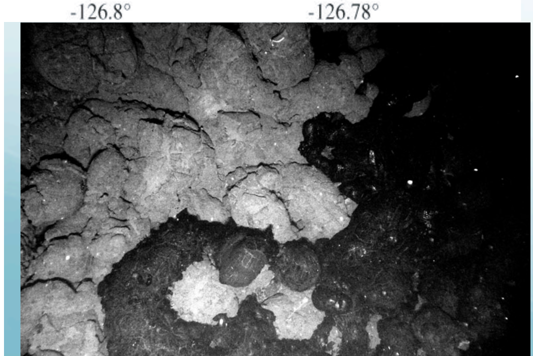
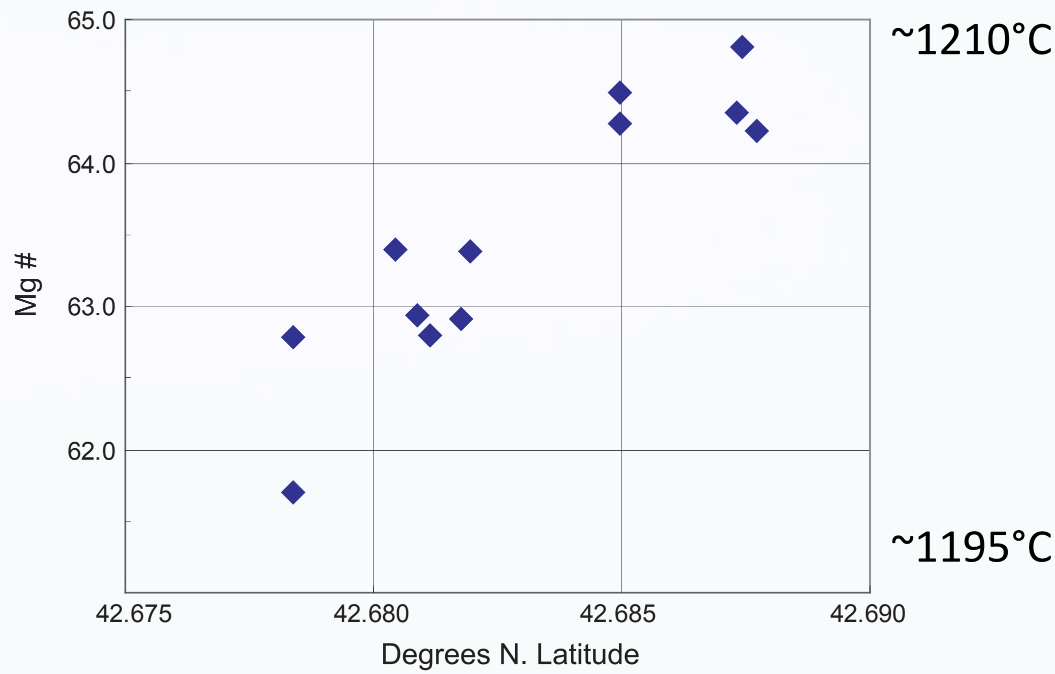
- Compositional variations in lava flow fields reflect variations in magma systems at depth
- This observation has implications for the geometry of magmatic plumbing beneath and within magma reservoirs
- and for how reservoirs are tapped during eruptions





1996 North Gorda Ridge

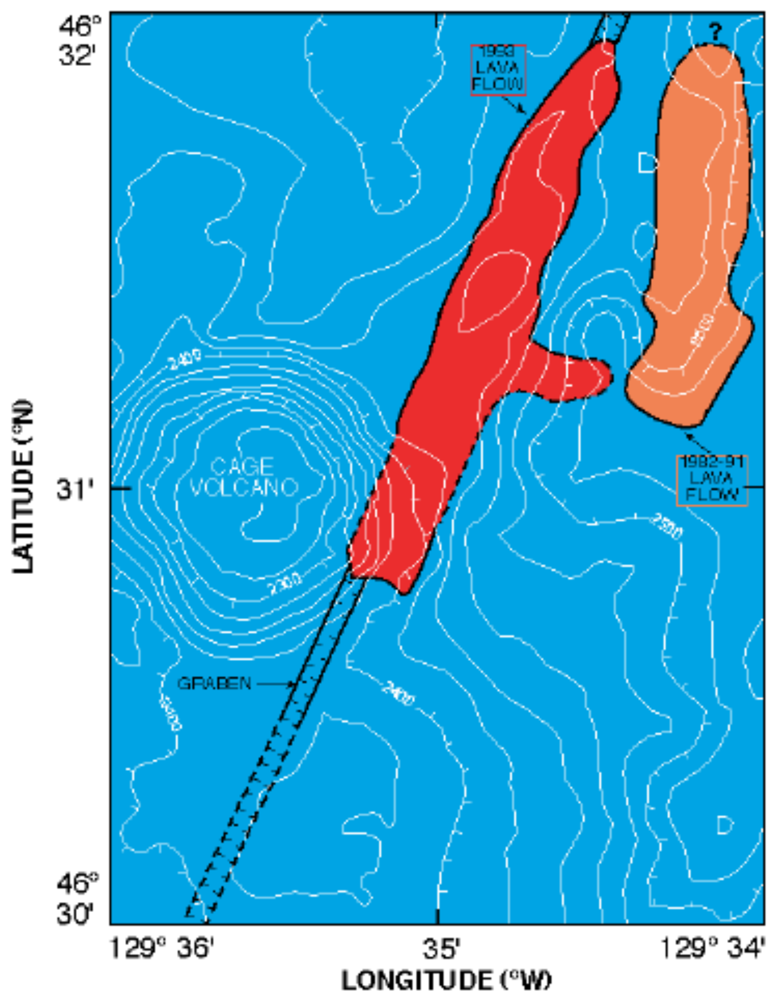


Systematic variation with sample location

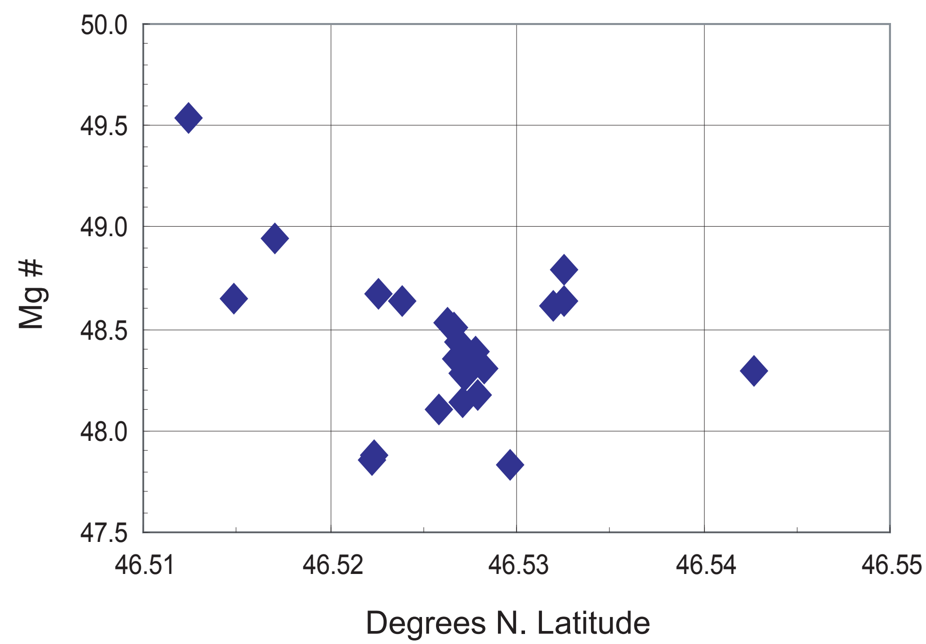
- most likely reflects a gradient in chemistry and temperature in the underlying magma reservoir that is preserved in the erupted lava flow field

- this observation suggests vertical diking and little mixing en route to the surface or on the surface after eruption

Seismo-acoustically detected 1993 Co-Axial eruption Juan de Fuca Ridge

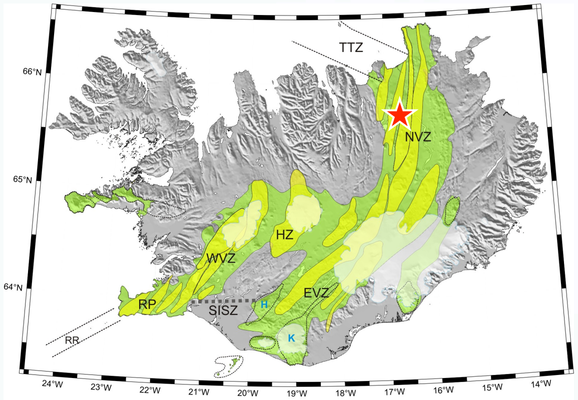


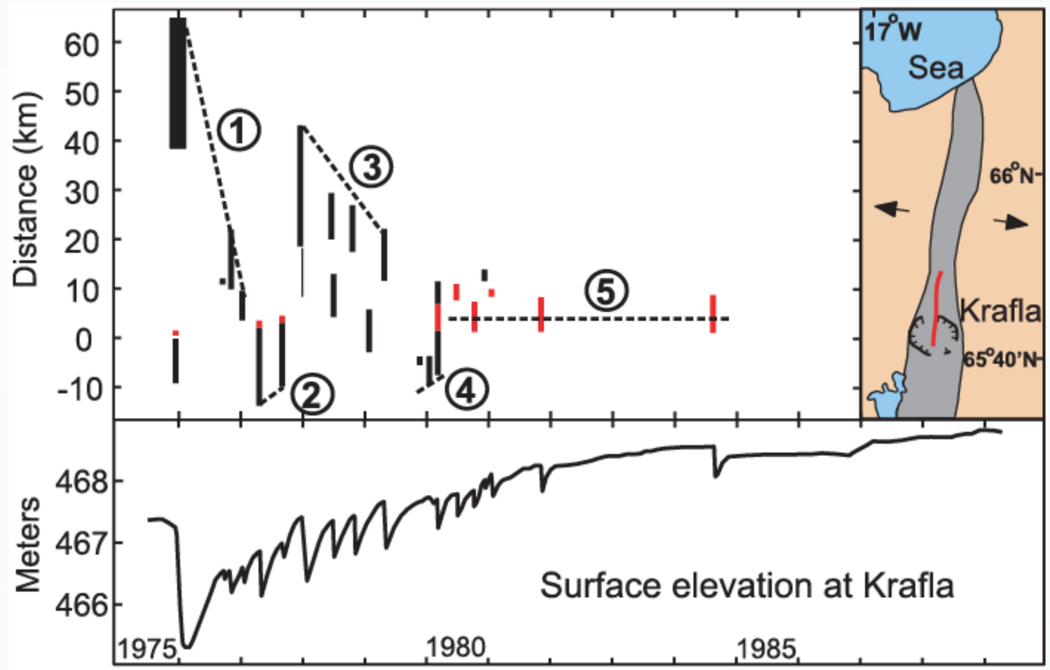
Well-documented, along-axis northward propagation of EQ epicenters during the early part of the eruption (Dziak et al., 2007]



Chemical variations are difficult, but not impossible, to explain by lateral dike transport

1975-1984 Krafla Rifting Episode, N. Iceland





Buck et al. (Adapted from Einarsson, 1991)

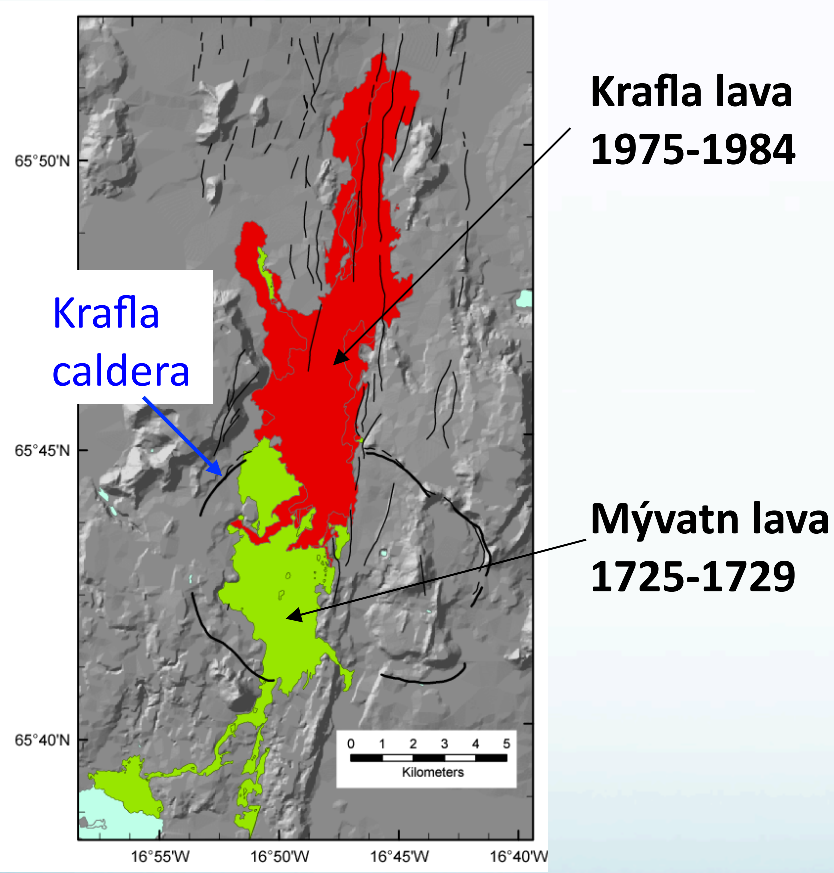
20 events; 9 eruptions; total erupted volume ~0.25 km^2

Erupted volume increased in each successive eruption; last one by far the largest

Erupted lava volume ~1/4 that determined to have moved through the magma system based on deformation modeling (~1 km^3)

1975-1984 Krafla Rifting Episode

Caldera lava basically the same as the Mývatn lava erupted 250 yrs earlier

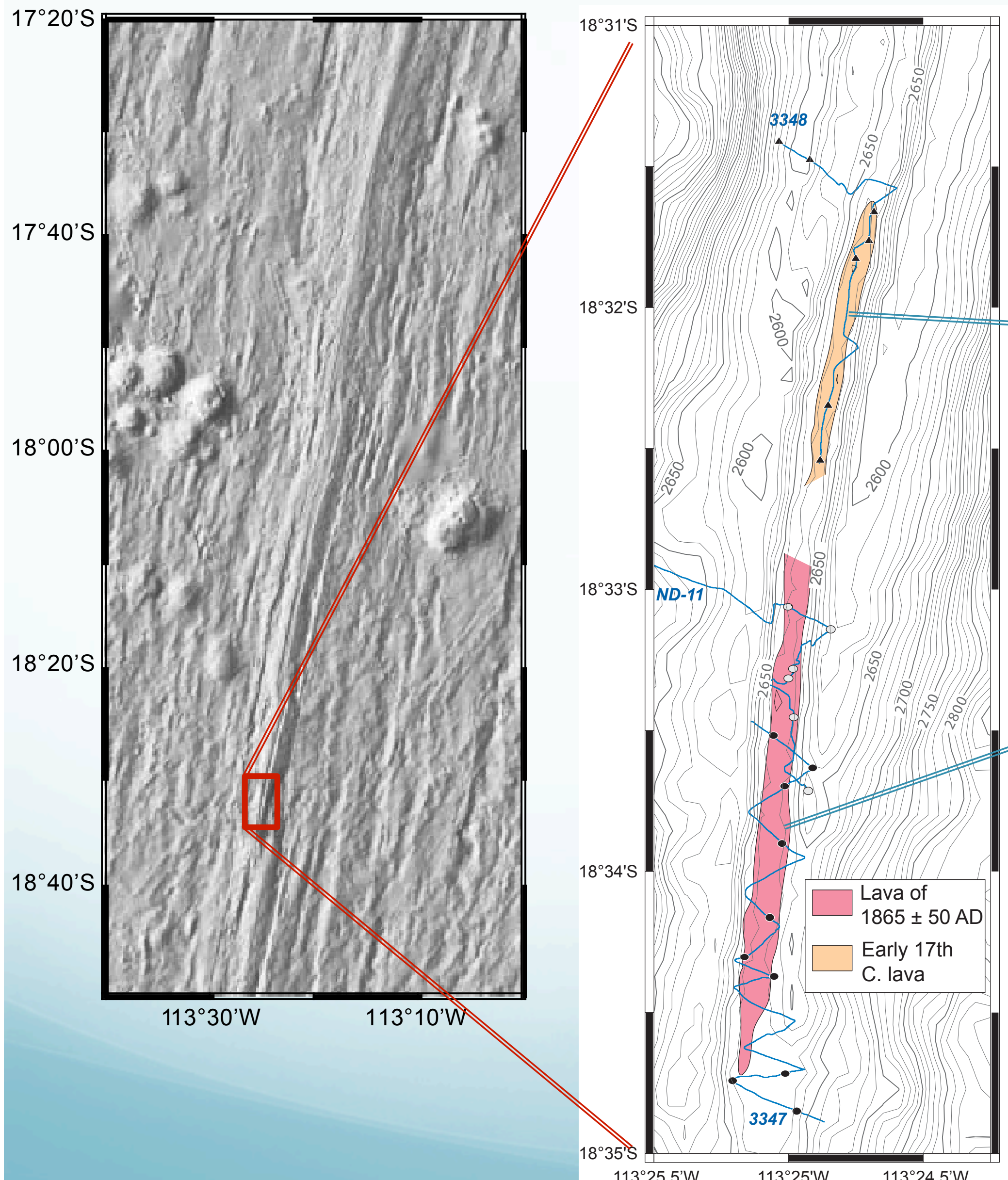


Why is the low-MgO, high $^{206}Pb/^{204}Pb$ (Mývatn) magma not erupted beyond the caldera boundary?

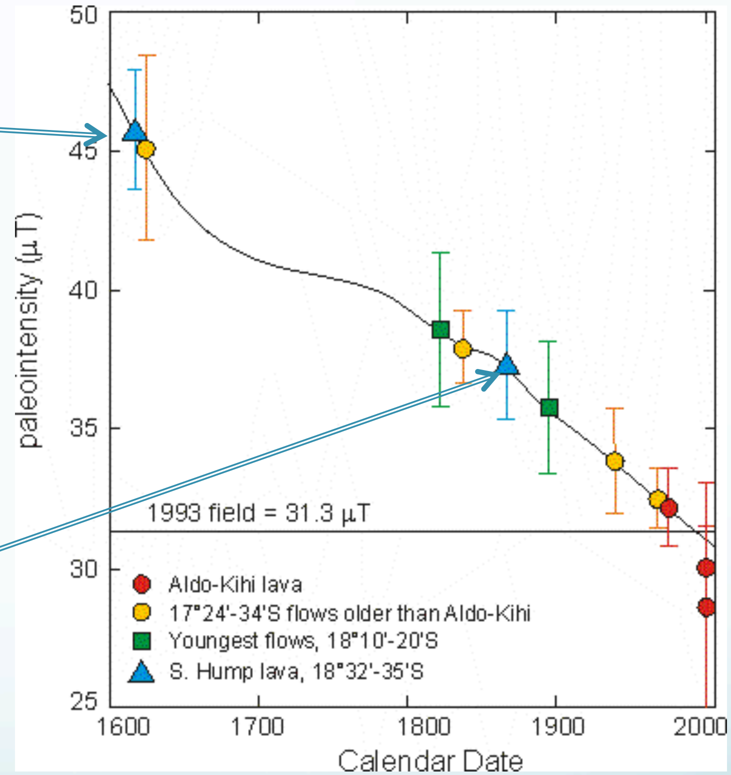
Can vertical transport of Mývatn magma to the surface be reconciled with the localized deformation in the caldera region?

Photo by S. Thorarinsson

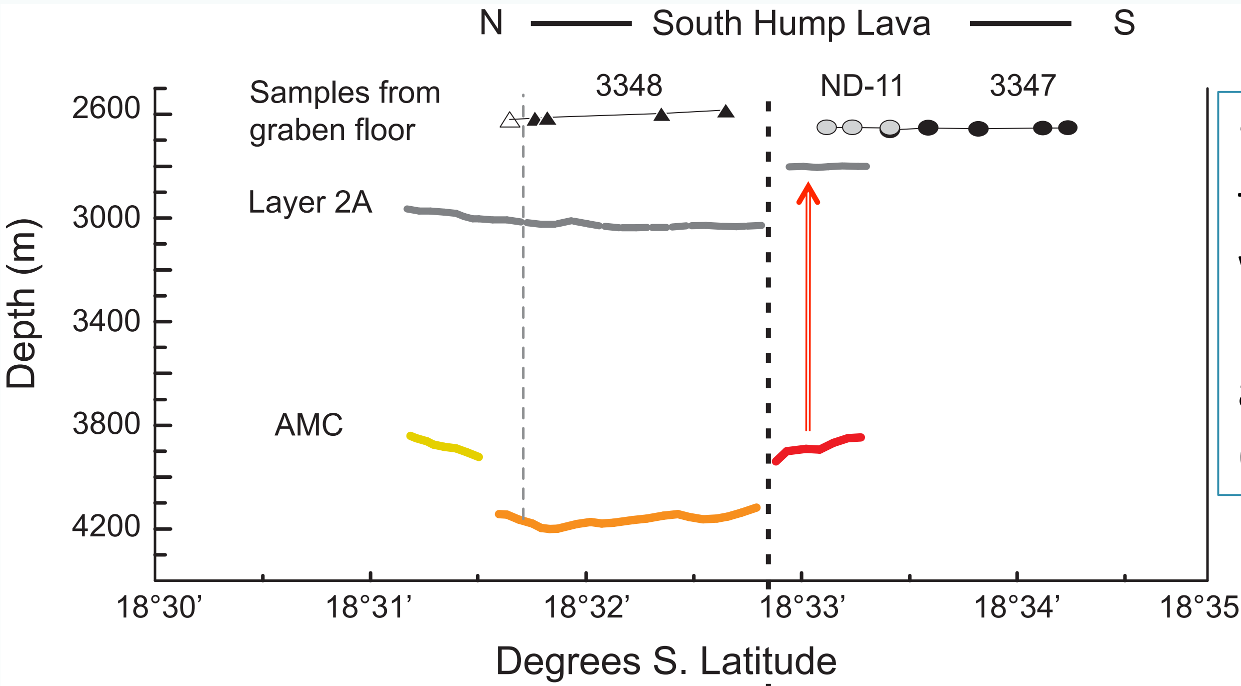
Fast-spreading Southern East Pacific Rise, 18°32’ S



Two graben-filling lava flows, erupted ~200 yrs apart

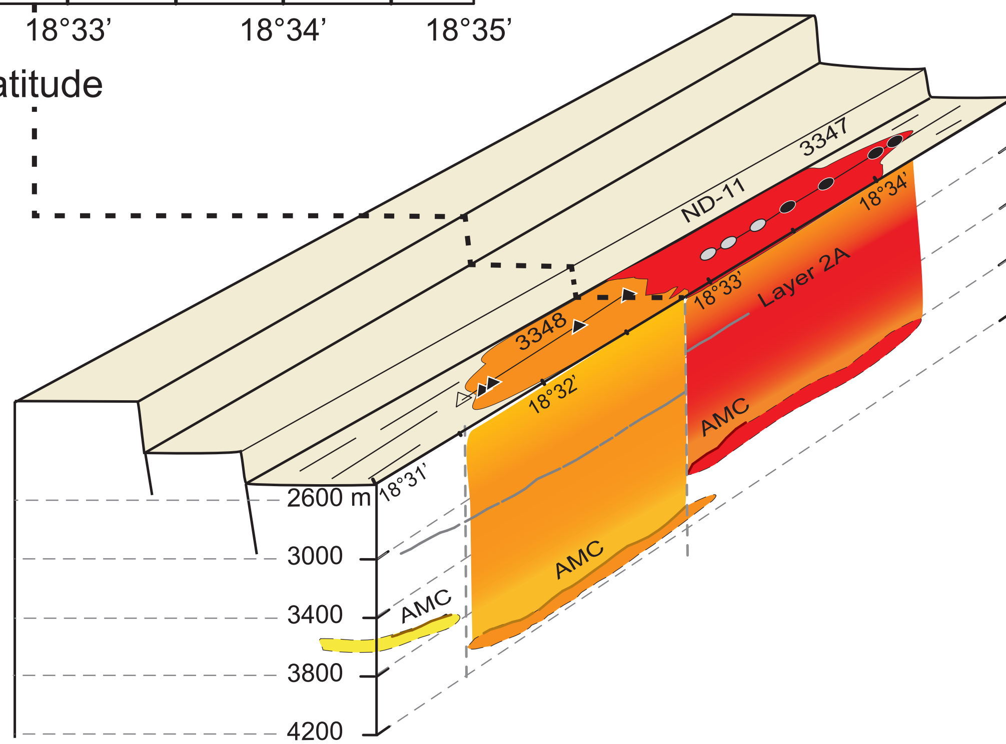


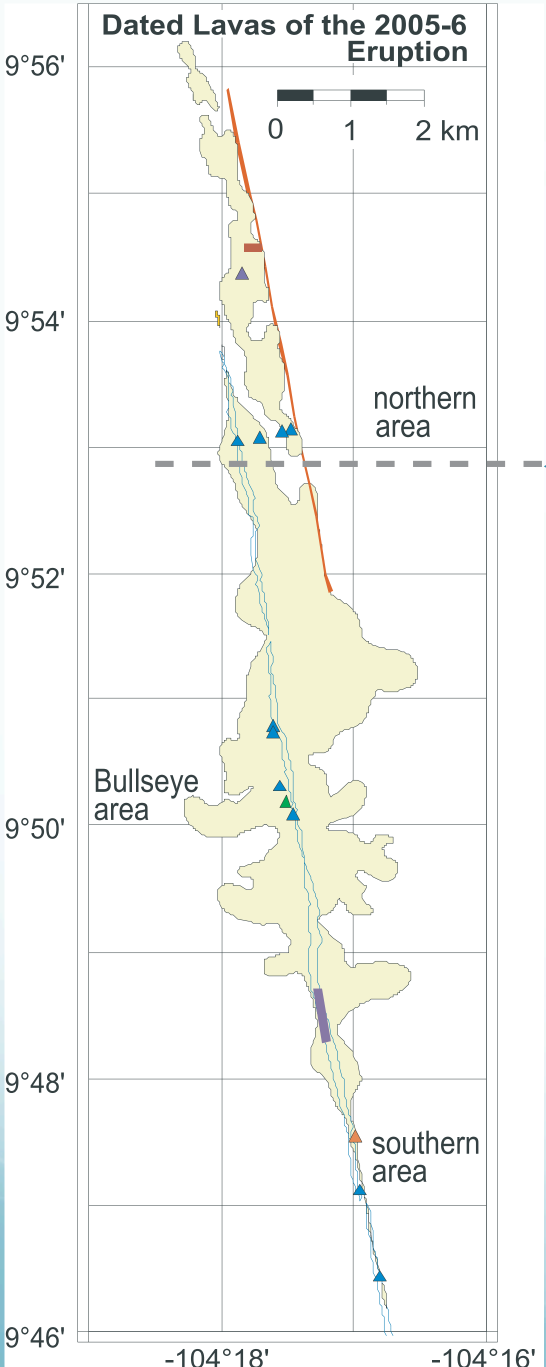
Magnetic paleointensity data from Bowles et al., 2006



"Boundary" between the two lava flows coincides with discontinuity in underlying AMC reflector and layer 2A structure (data of Hooft et al.)

Coincidence of flow boundaries with the AMC discontinuity requires (?) near-vertical (<1 km lateral) transport of lava from the AMC to the surface, at least for the younger lava eruption

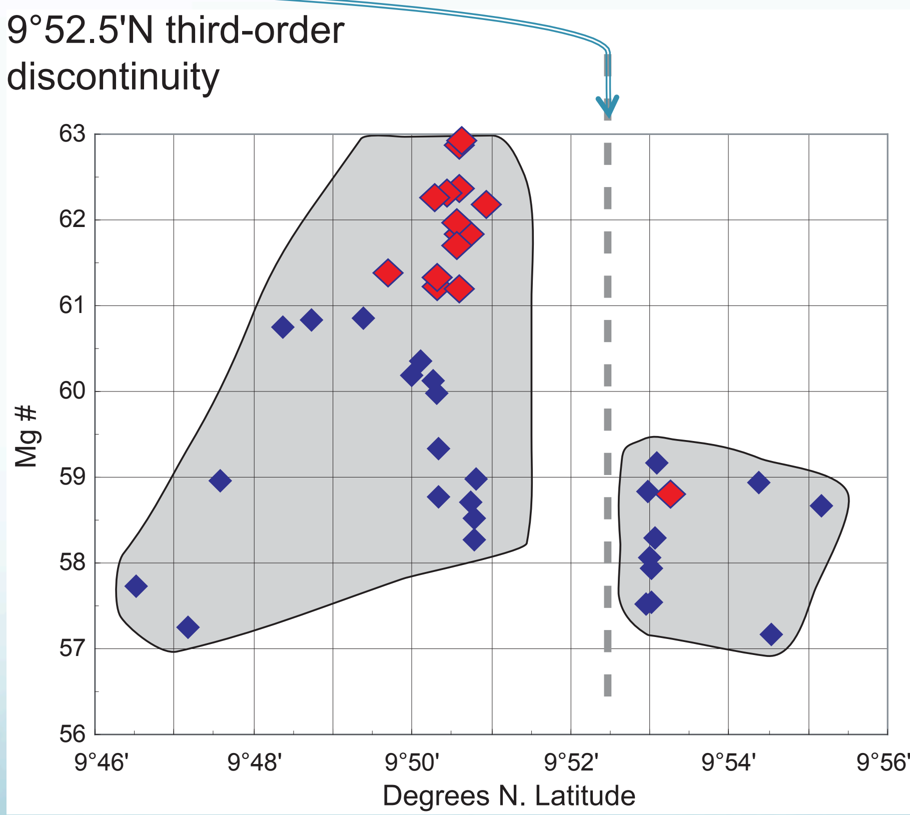




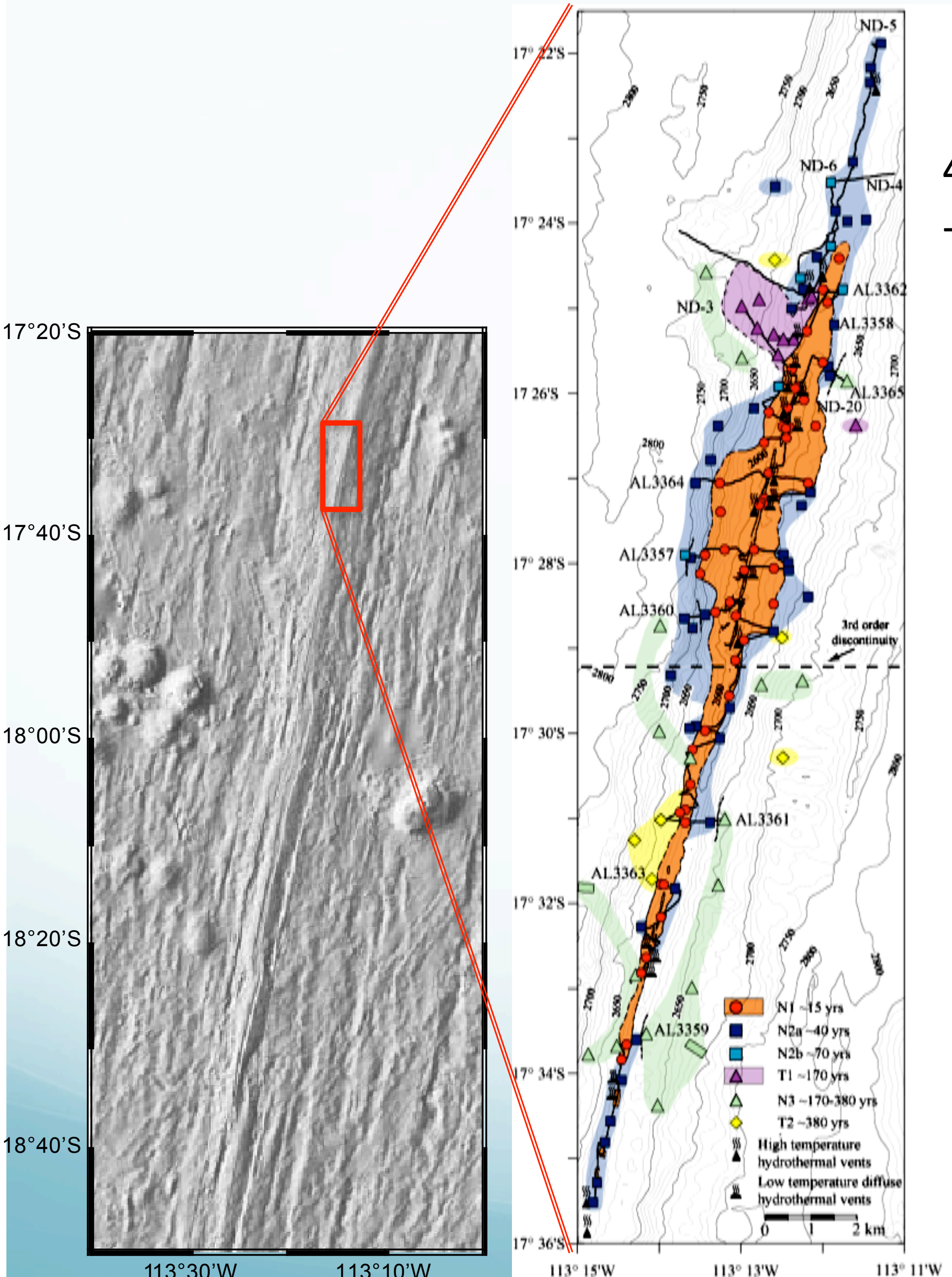
1991-2 and 2005-6 eruptions, EPR near 9°50'N

Note:

- Significant along-axis compositional variation, and
- change in Mg# across the tiny 9°52.5'N axial discontinuity for both eruptions

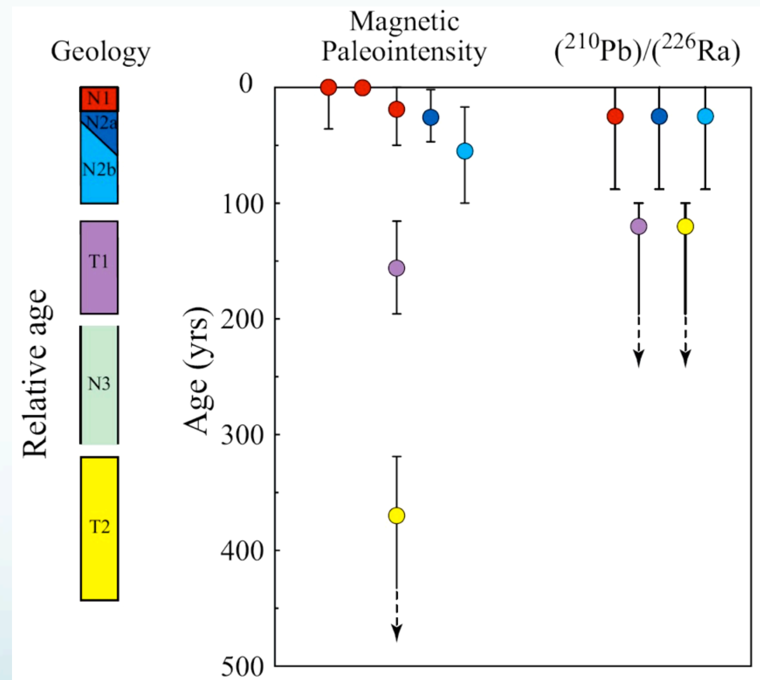


Flow field map from Soule et al. [2007]; chemical data from Ruben et al., 1991 and Goss et al., 2009]

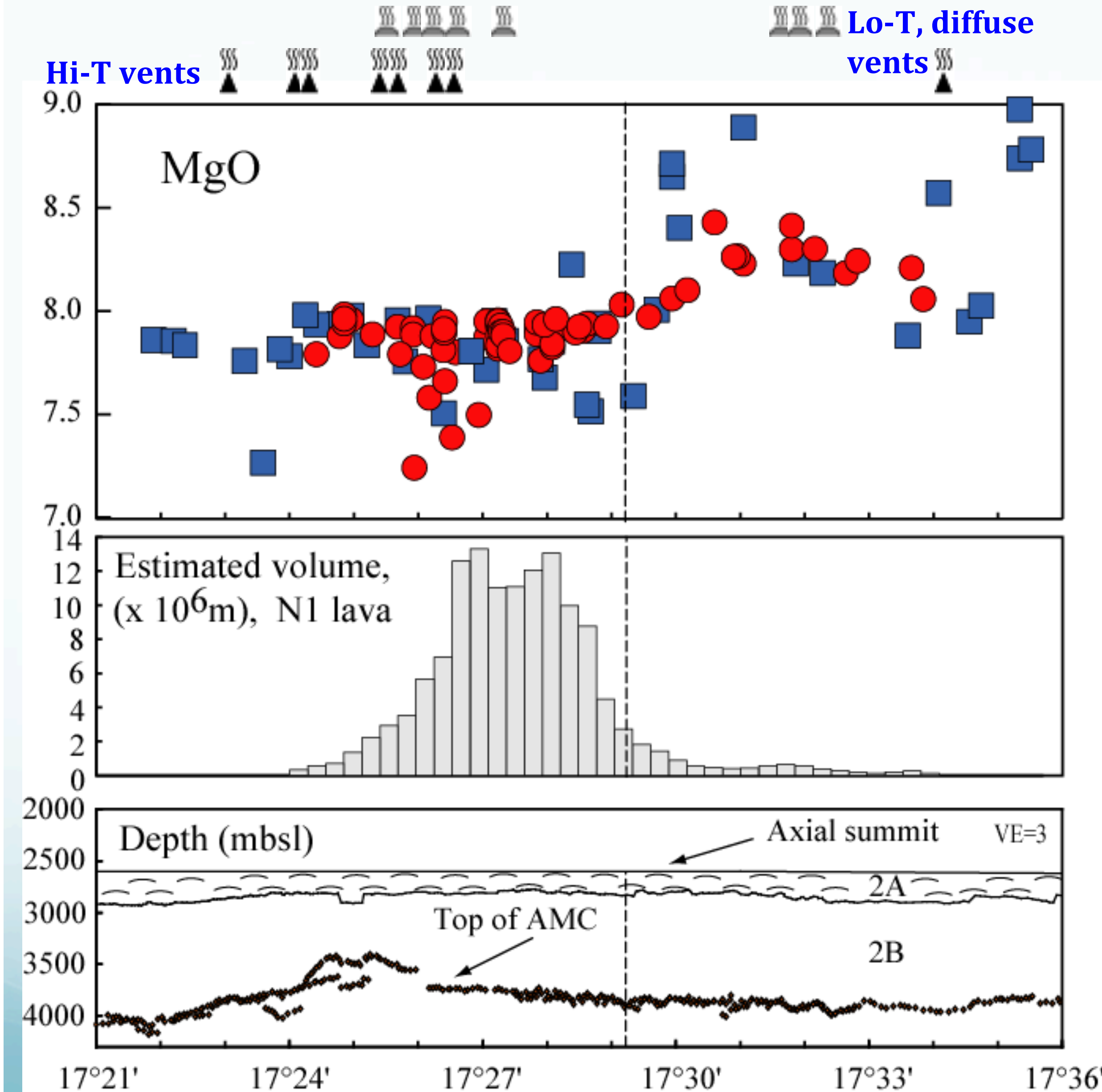


EPR near 17°30' S

4-5 eruptive episodes in last ~500 yrs
-Last one in late 80's to early 90's
  ~25 km-long fissure eruption
  ~ 0.25 km^3 of lava erupted



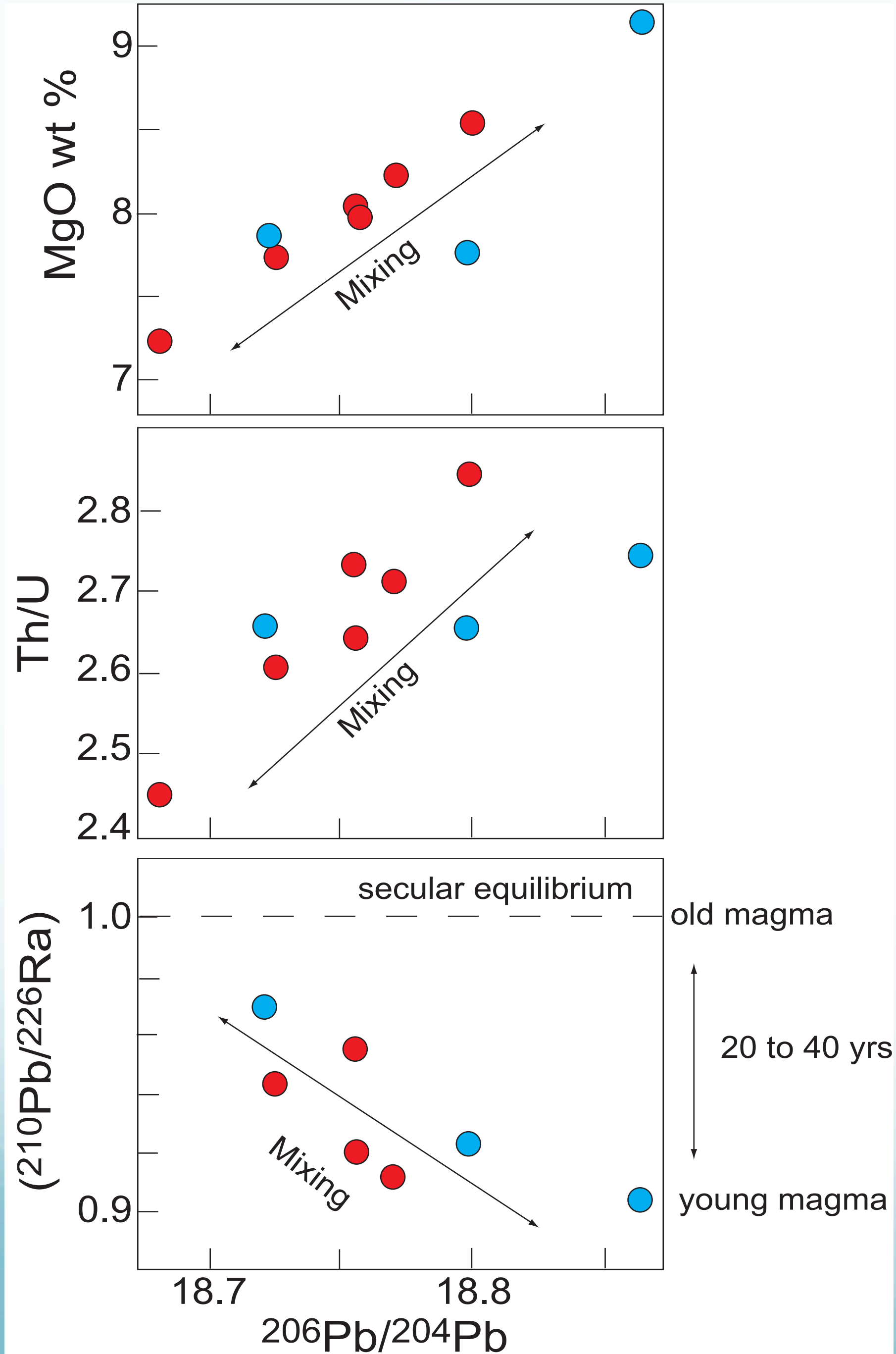
Bergmanis et al., 2007



After Bergmanis et al., 2007

For last two eruptions:

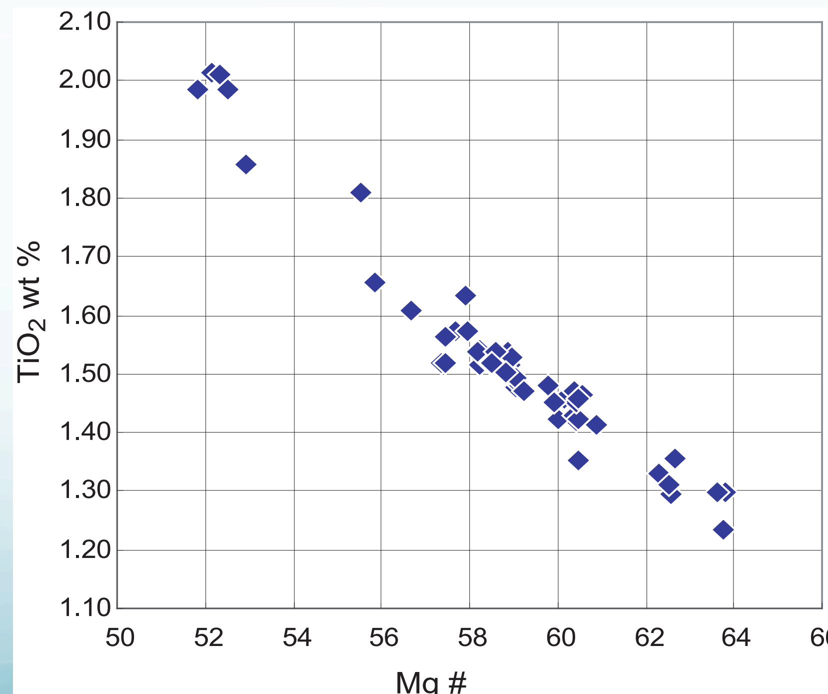
- Center of eruptive activity where the magma lens is shallow and relatively low temperature; not at the hottest part of the magma lens
- MgO and magma temperature generally correlate with AMC depth



Chemical variations within the <u>two youngest lavas</u> are dominated by mixing

-a low-MgO, low-$^{206}Pb/^{204}Pb$ magma residing in the magma reservoir, and

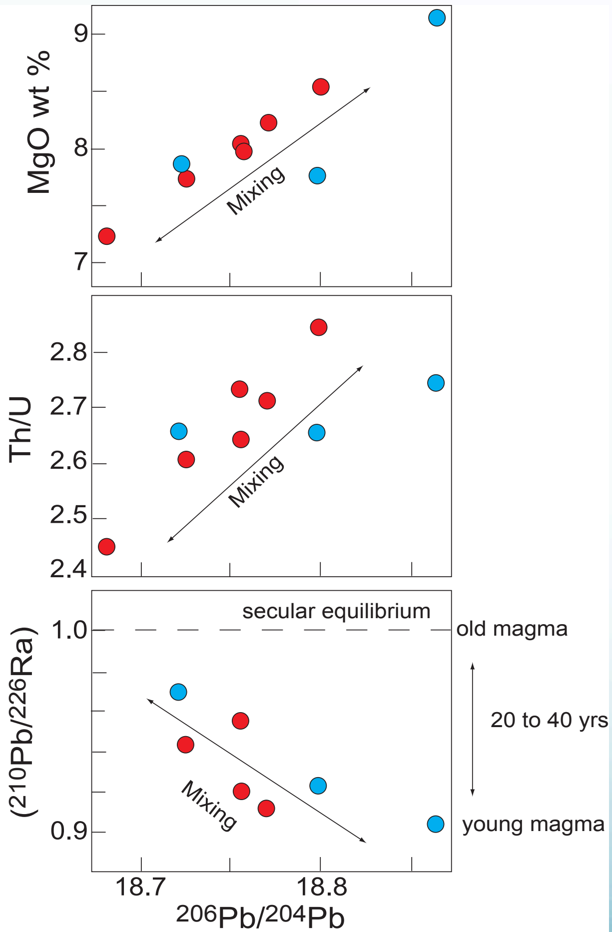
- magma with high MgO and $^{206}Pb/^{204}Pb$ that was injected within 20 years prior to 1993 (collection date).

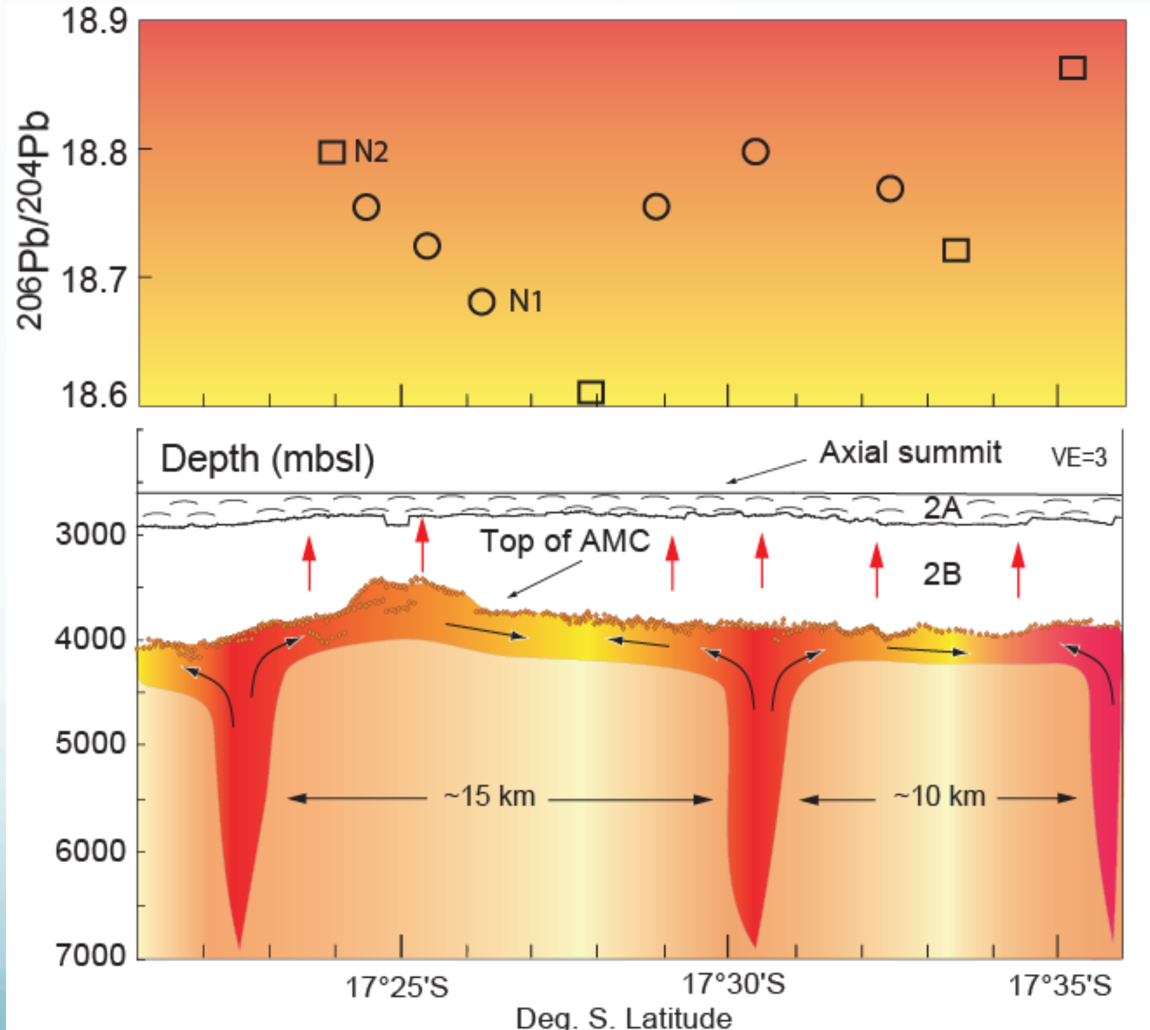


pattern of isotopic variation along axis

-Variation in amount of newly arrived, high $^{206}Pb/^{204}Pb$ magma that is progressively mixed with resident low-$^{206}Pb/^{204}Pb$ magma in the shallow melt lens.

- in this interpretation, the high $^{206}Pb/^{204}Pb$ regions represent locations (concentrations) of recent magma injection to the shallow lens





Chemically heterogeneous lava flow fields (from isolated eruptive episodes) likely reflect variations in underlying magma reservoirs

Incomplete mixing and homogenization promoted by

- long, flat shape of melt lenses,
- limited mixing in crystal-rich mush zones
- frequency of recharge exceeds the time scales for mixing

Three types of heterogeneous lava flow fields

1. Along-axis variations in magma temperature and chemistry

   gradients in reservoir chemistry and temperature not disturbed during emplacement

   Examples: EPR 17.5°S; 9°52’N; N. Gorda, Co-Axial

2. Correlations of along-axis chemical variations with ridge axial discontinuities or other structures, e.g. caldera boundary

   Axial discontinuities reflect deeper level variations in magma chamber or thermal structure preserved in lava flow fields

   Examples: EPR 17.5°S; 9°50’N; Krafla

3. Along-axis chemical variations coincident with AMC discontinuities or mid-crustal injection centers

   Requires vertical rise of magma to the surface with limited along-axis mixing, either within dikes or in surface lava after eruption

   Examples: EPR 17.5°S, S. Hump

Not all lava flow fields are chemically heterogeneous

Not all events lead to eruption

Eruptions typically associated with “short” rifting events after considerable stress released during prior events

Can chemical evidence for vertical transport of magma to the surface be reconciled with rapid deflation over injection centers at the onset of (some) eruptions?