What are common geological settings for subduction initiation, and what tectonic events precede the development of self-sustaining subduction?

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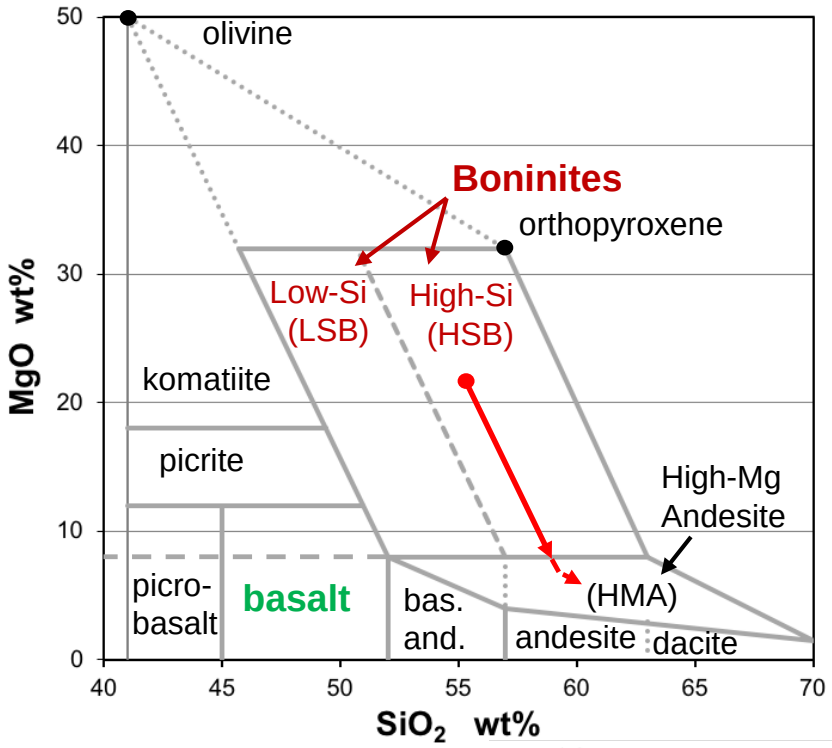
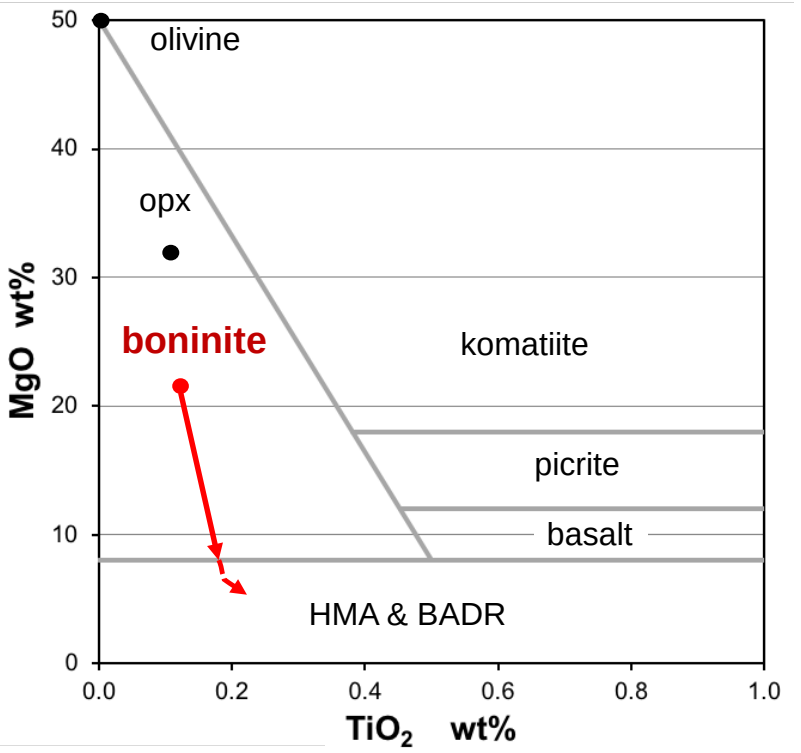
With thanks to: Julian Pearce and the IODP Expedition 352 Scientific team

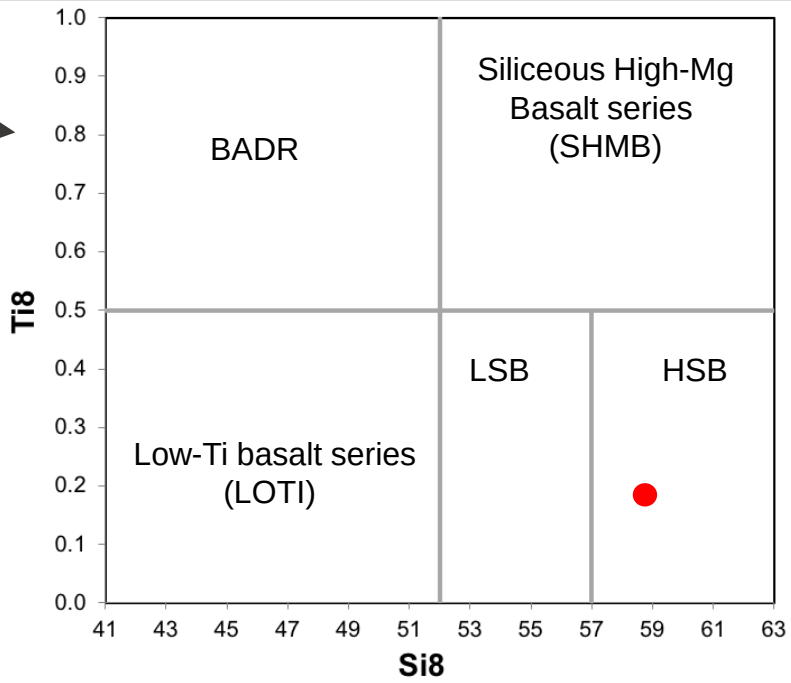
Outline

- Magmas in subduction initiation (SI) settings
  - FAB and boninite
- Examples of SI
  - Eocene: Izu-Bonin-Mariana (IBM)
  - Puysegur
  - Matthew & Hunter
- SI through geologic time
  - Boninites over Earth history
  - Implications for changes in dynamics of SI

Sheeted dike complex
Troodos Ophiolite, Cyprus

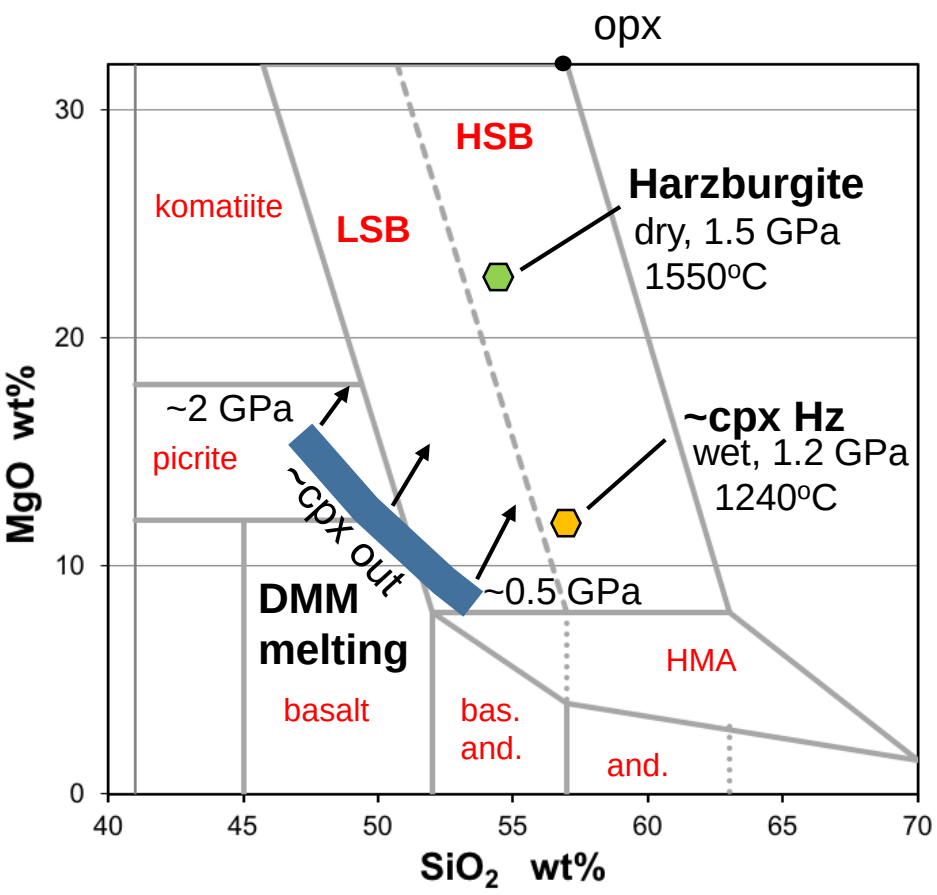


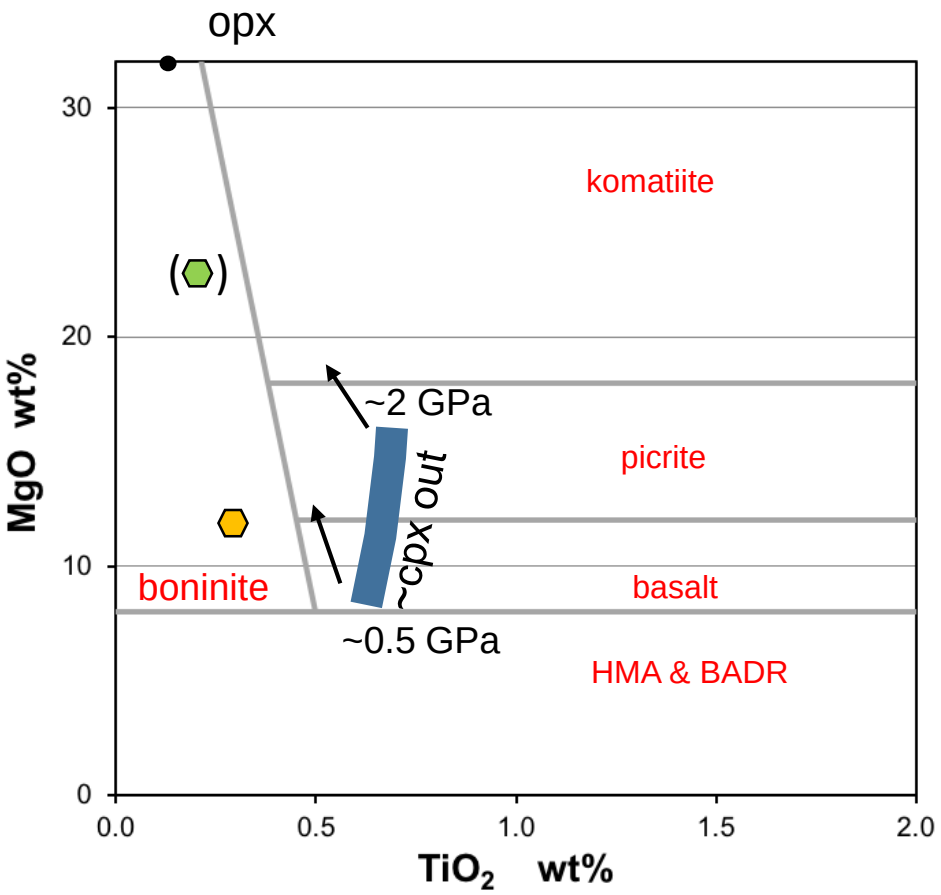




After: Pearce and Reagan
(submitted – ST2B-2)

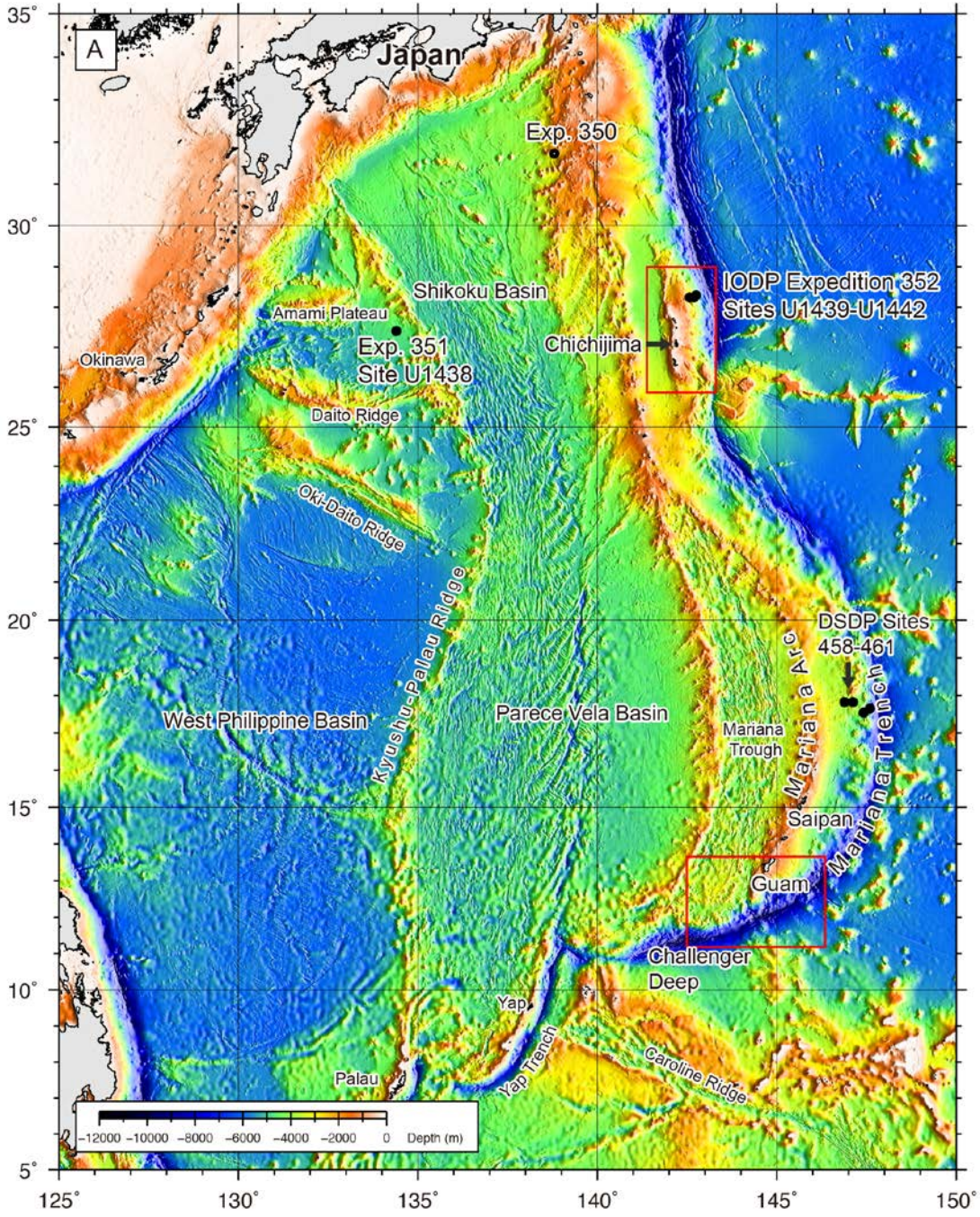
Mantle melting





Based primarily on equilibrium melting experiments by:
Hirose & Kawamoto (1995); Hirose & Kushiro (1998); Falloon & Danyushevsky (2000); Parman & Grove (2004); Wood & Turner (2009); Mitchell & Grove (2015)

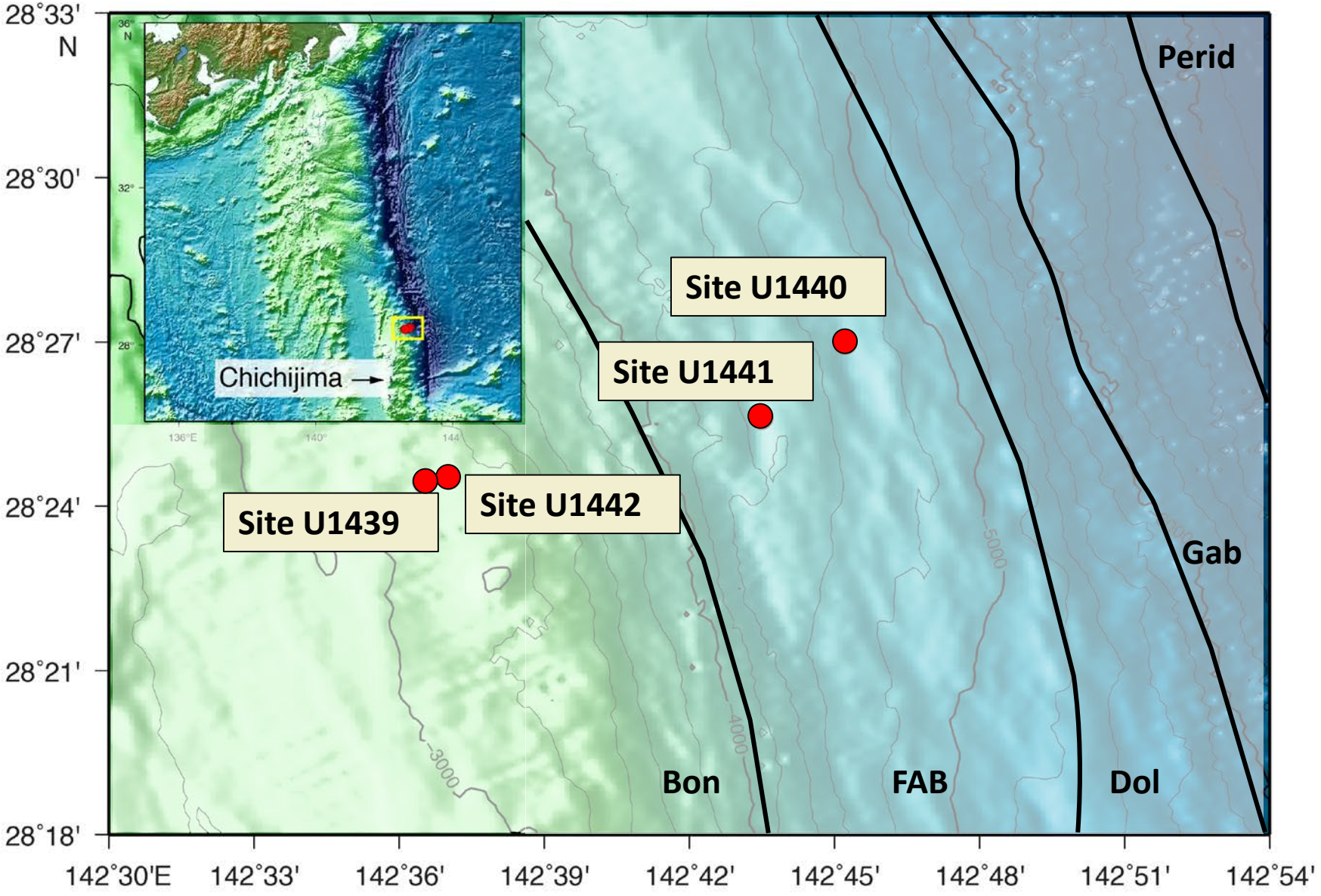
Izu-Bonin-Mariana (IBM) subduction system



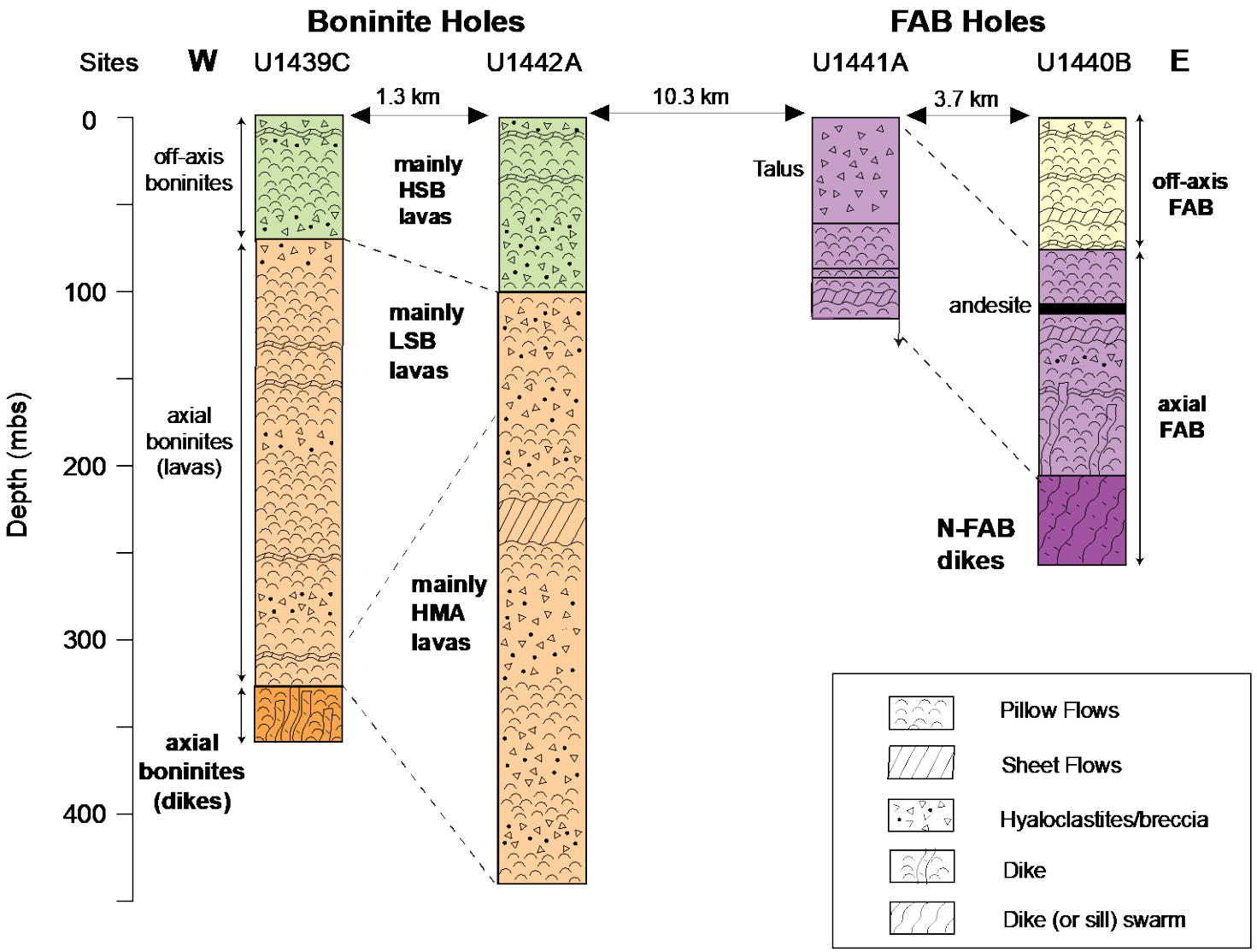
- IBM forearc recognized as early subduction terrane since ~ 1980
- Stern and Bloomer (1992) suggested boninites erupted at arc inception during near-trench rifting resulting from slab rollback
- Recent work has shown that the IBM forearc preserves an ophiolitic rock record attributed to a large scale, but short duration, subduction initiation event

Reagan et al. (2013)

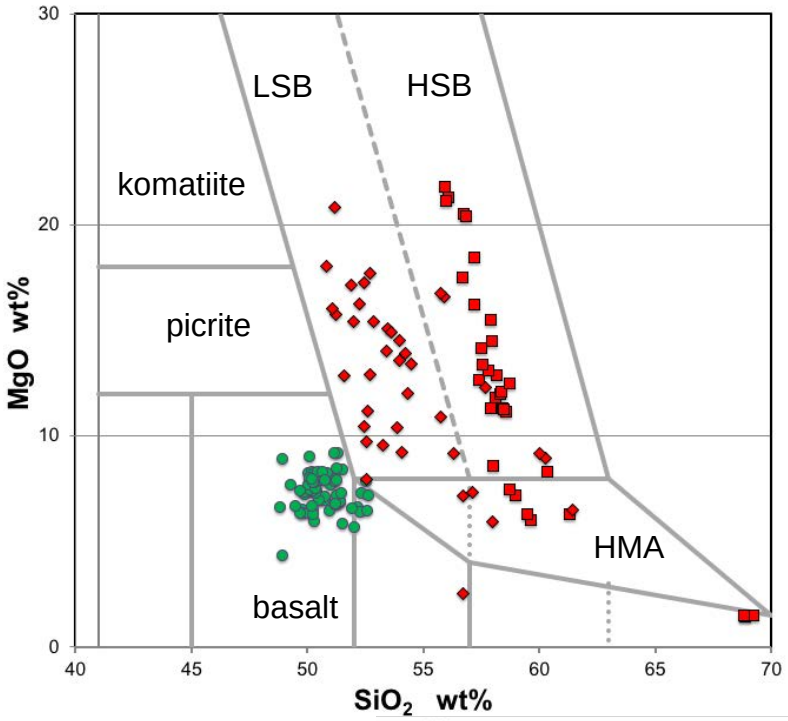
Drill Sites for IODP Expedition 352

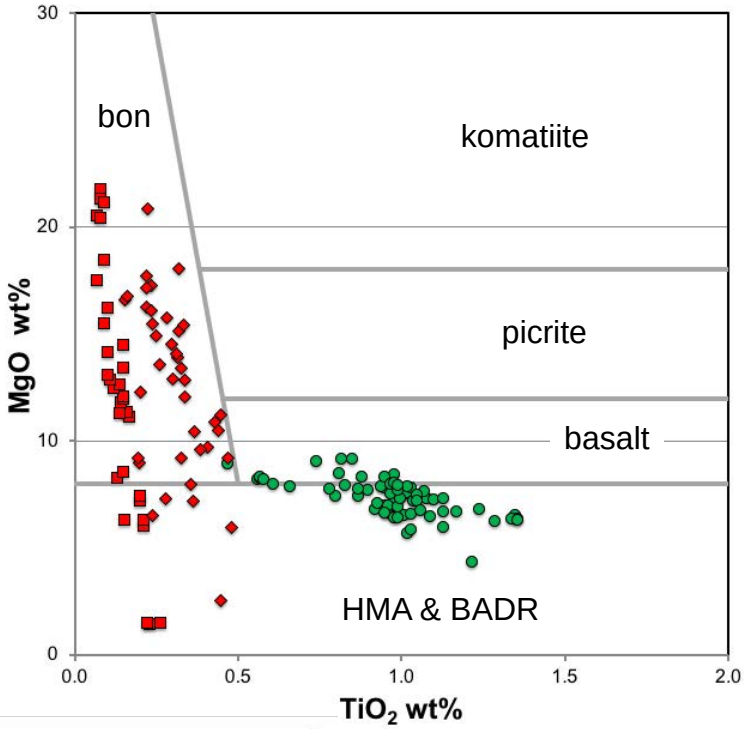


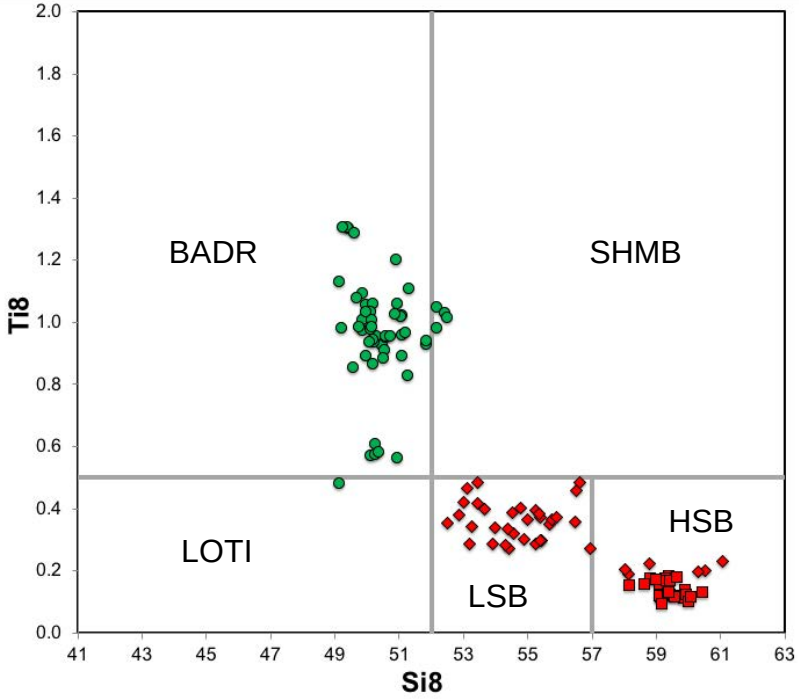
geology after Ishizuka et al. (2011)



(Reagan et al. 2017; Shervais et al. 2019; Li et al. submitted)





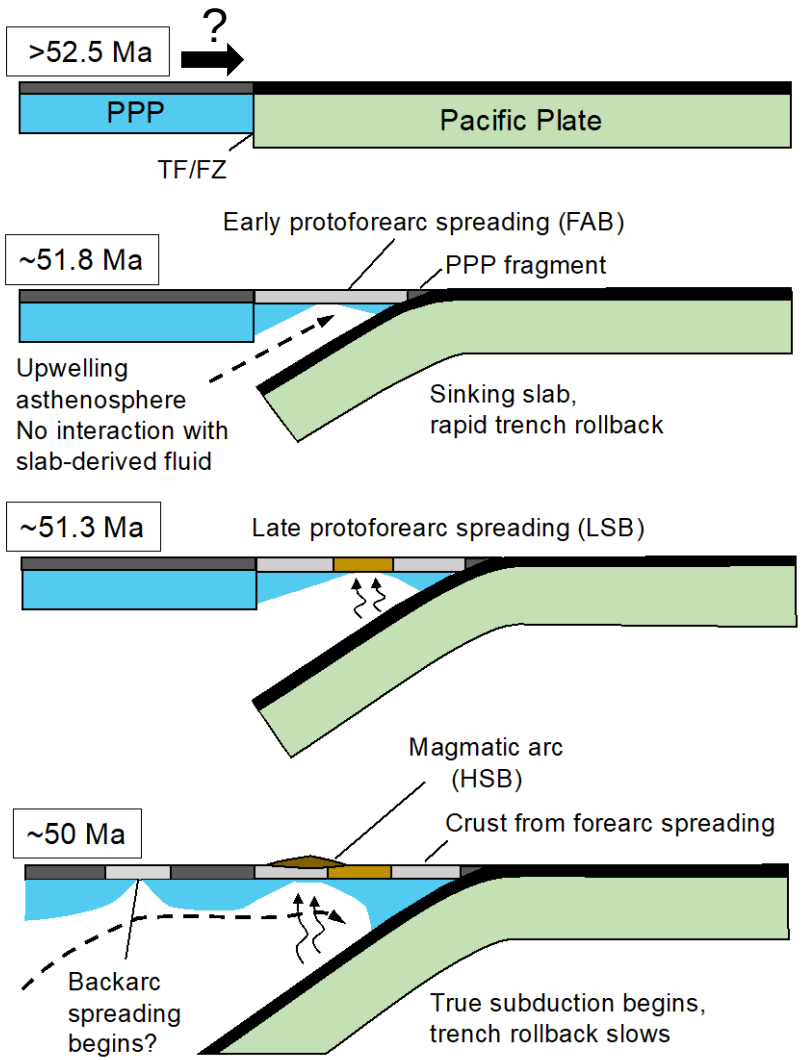


Chichijima Marubewan

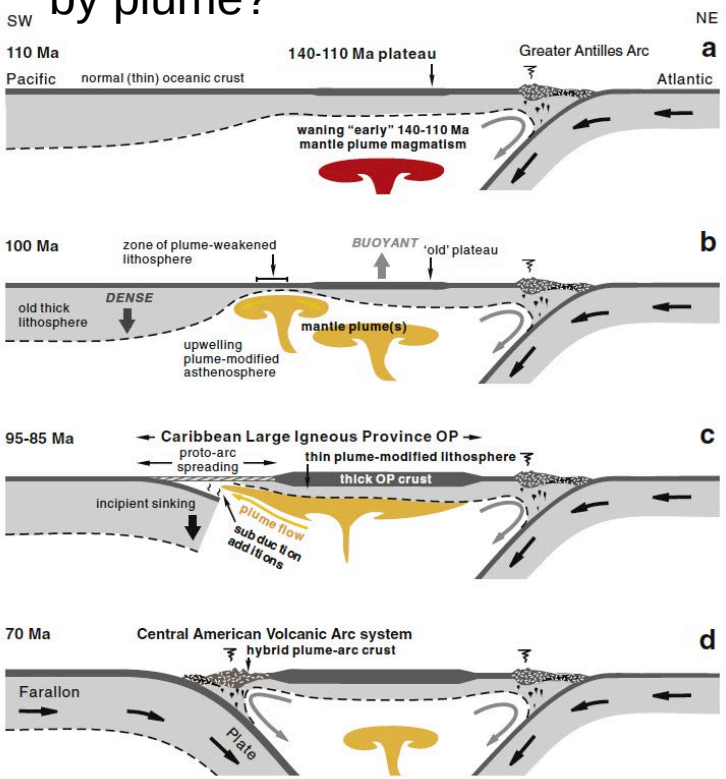
IODP Site U1439

IODP Sites U1440, U1441
FAB

Data sources: Taylor et al. (1994);
Shervais et al. (2019)
Godard et al. (in prep)



- Transform boundary before 52.5 Ma?
- Rapid, SI and near-trench sea floor spreading beginning at 52.0-52.5 Ma
- Flux melting and LSB to HSB generation begins within 1 m.y.
- Why?
  - Spontaneous? (e.g. Stern, 2004)
  - Induced by India-Asia collision? by plume?

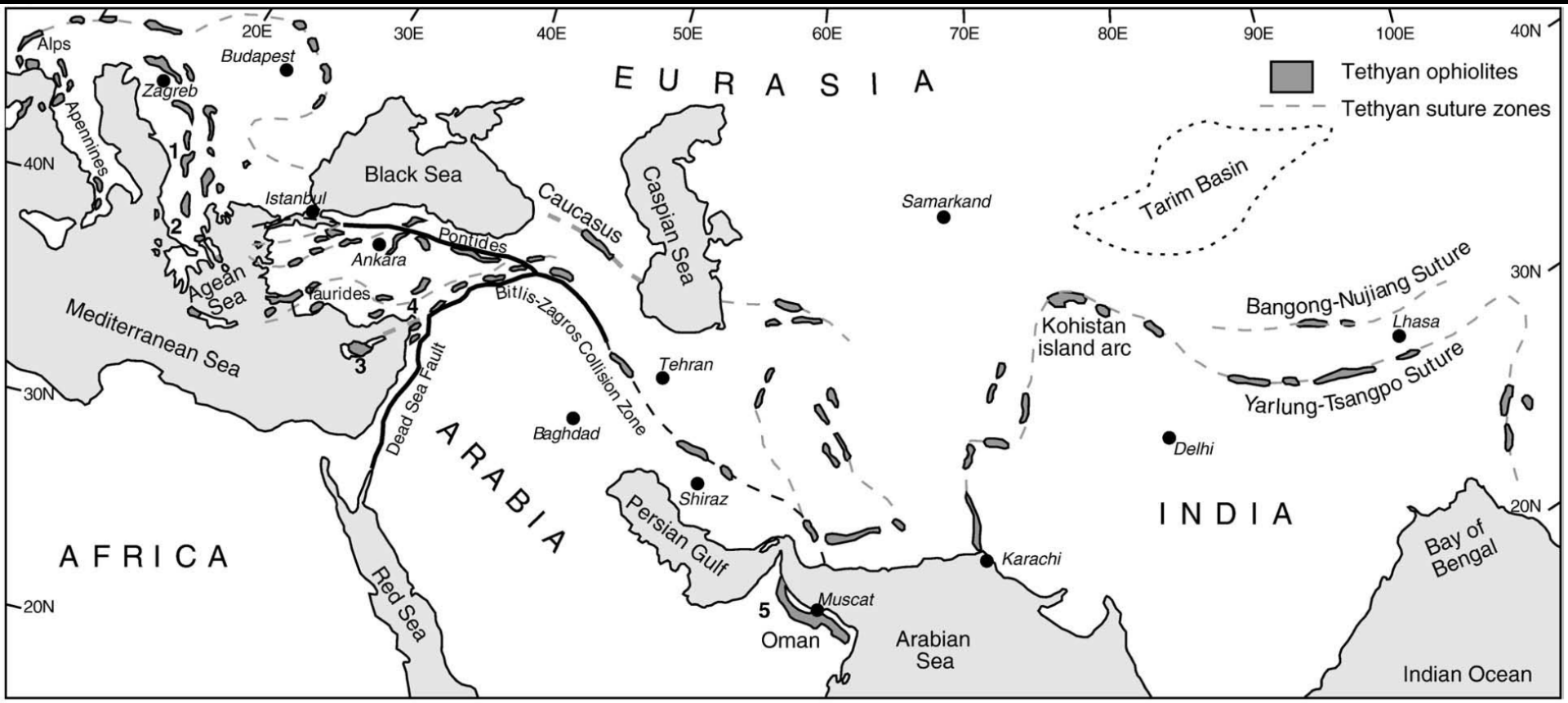


1st "normal" arc volcanism at 45-46 Ma

after Reagan et al. (2019)

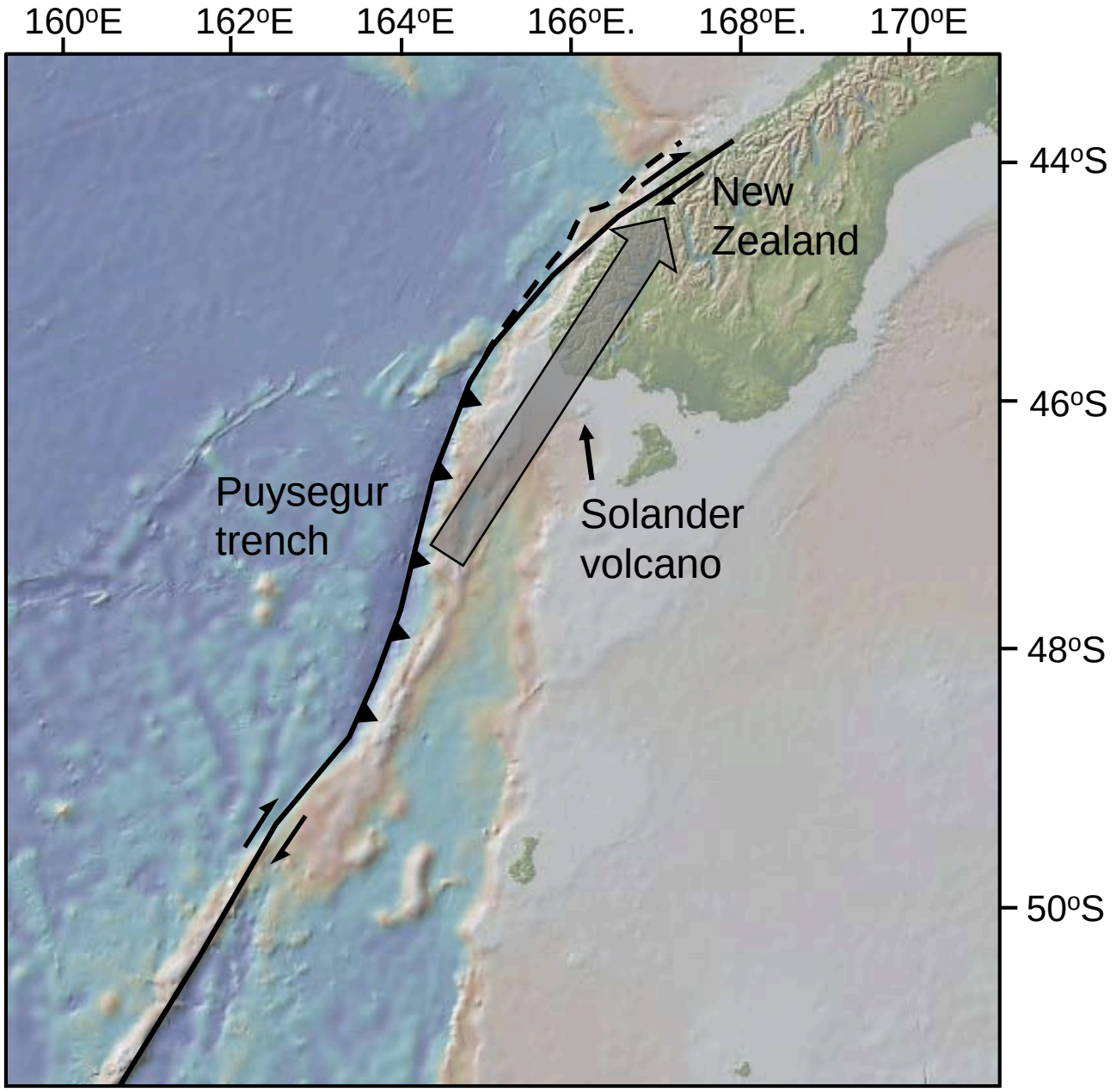
(Whattam and Stern 2015)

Early Eocene events



(from: Dilek and Furnes, 2009)

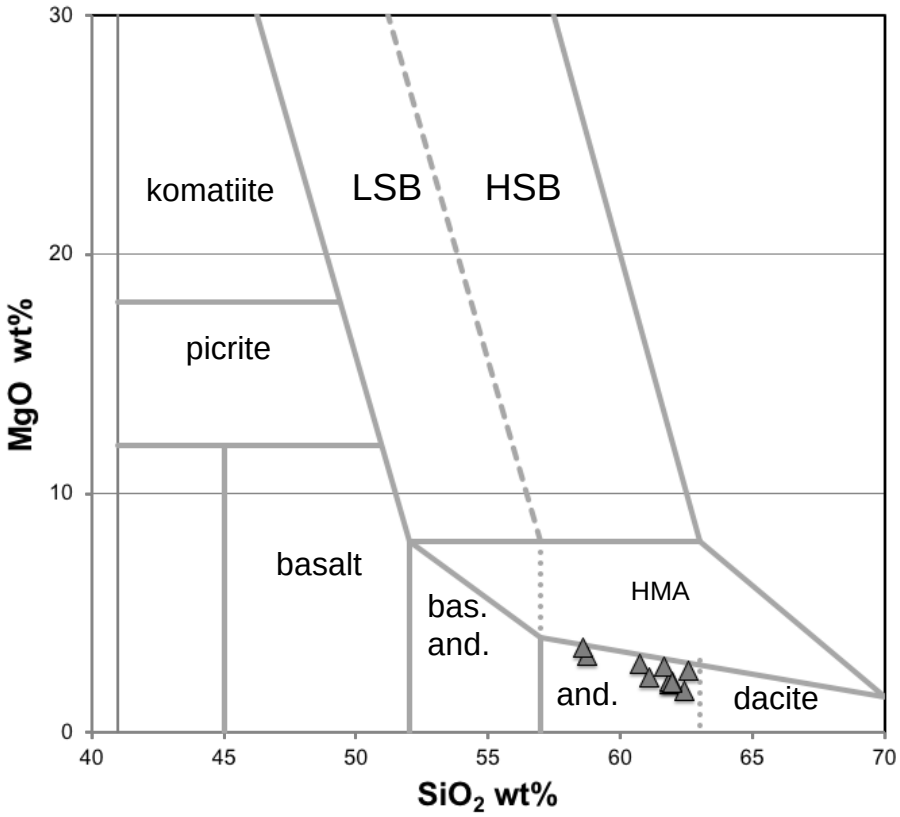
Ongoing subduction initiation I

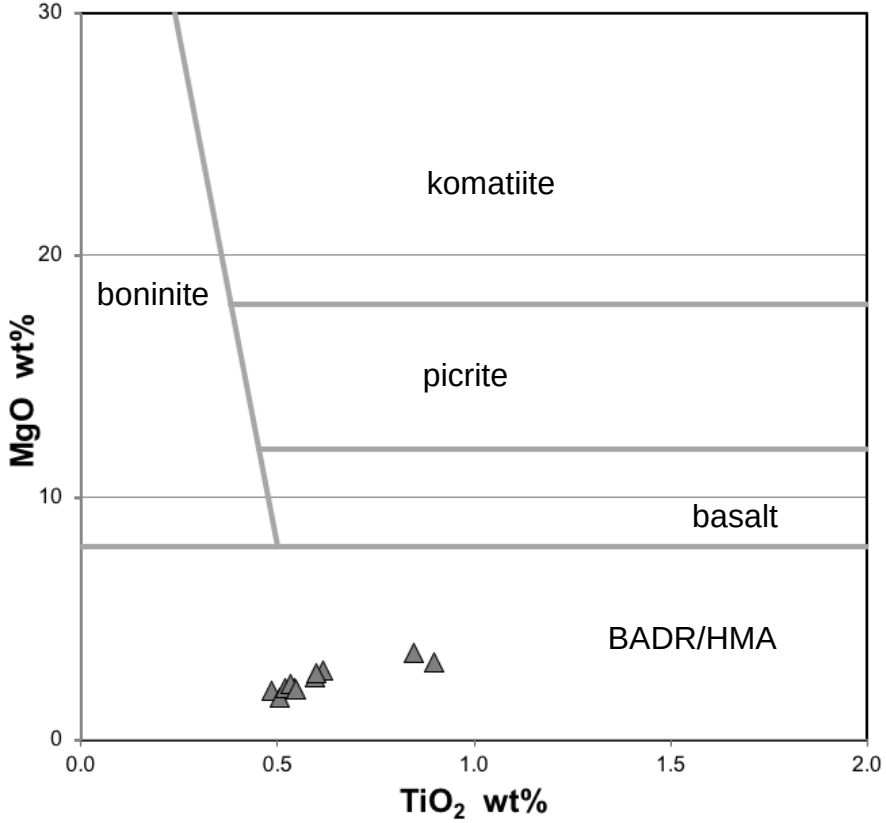


Map base: GeoMapApp geology: Sutherland et al. (2006)

Puysegur arc

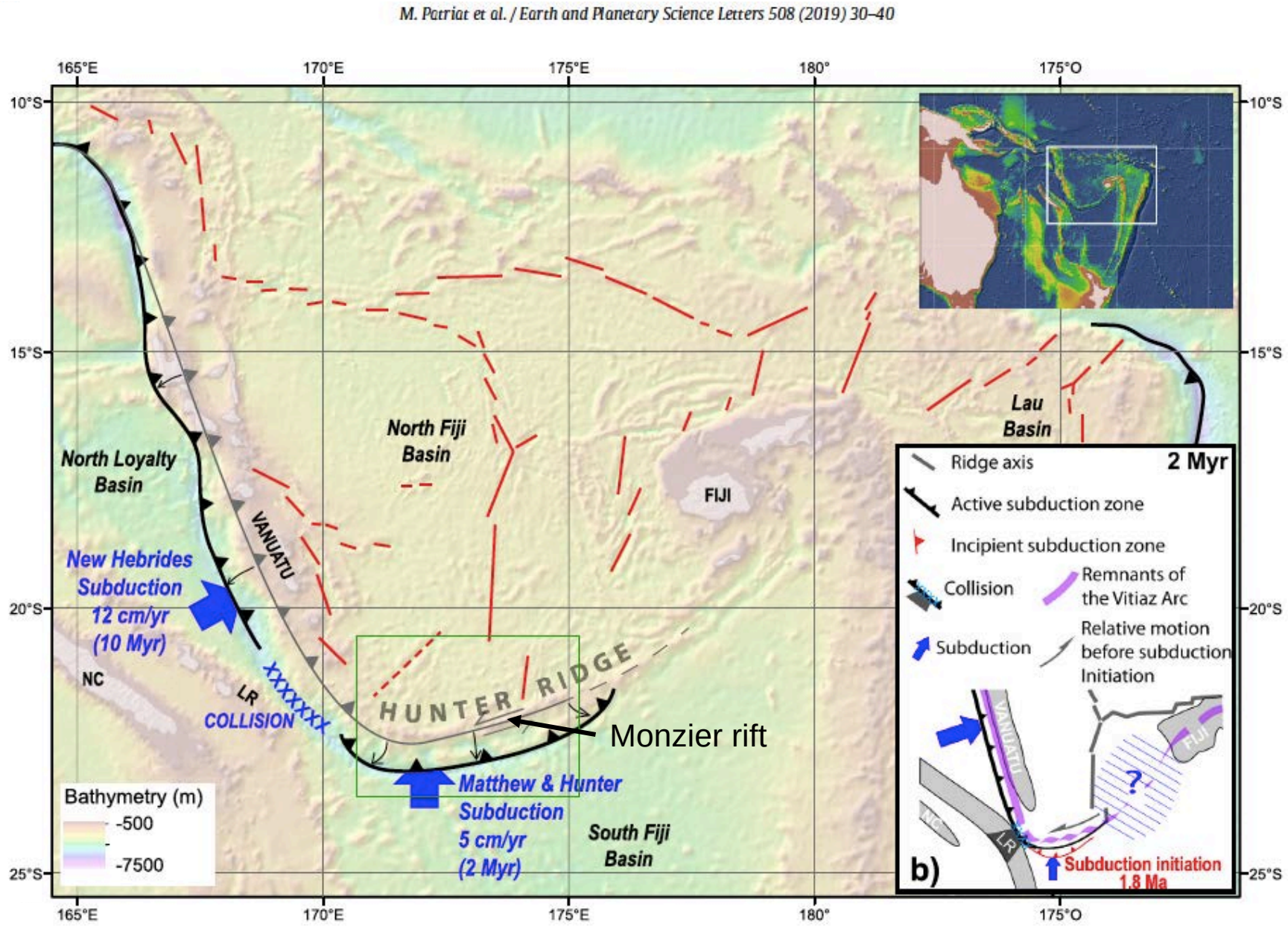
Solander volcano





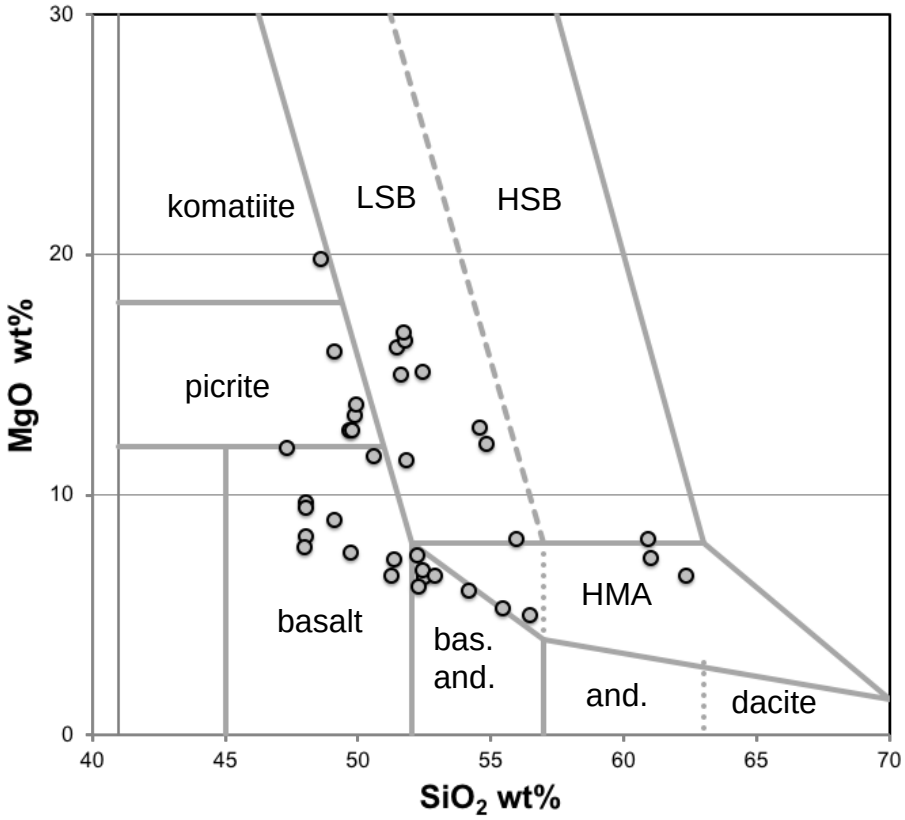
Data: Foley et al. (2013)

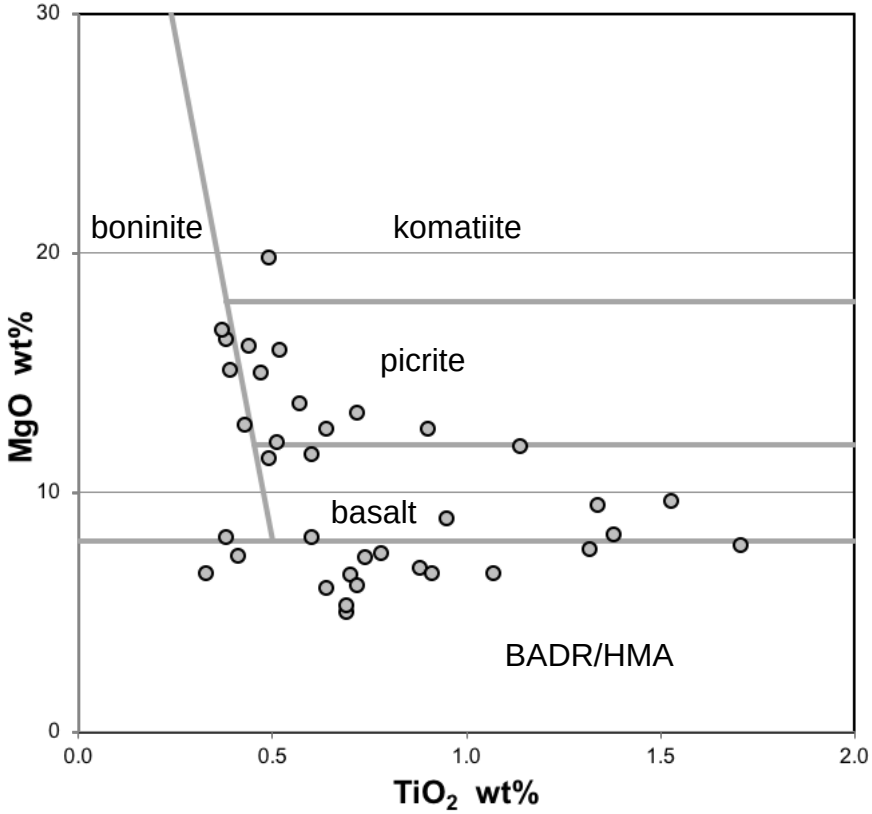
Ongoing subduction initiation II



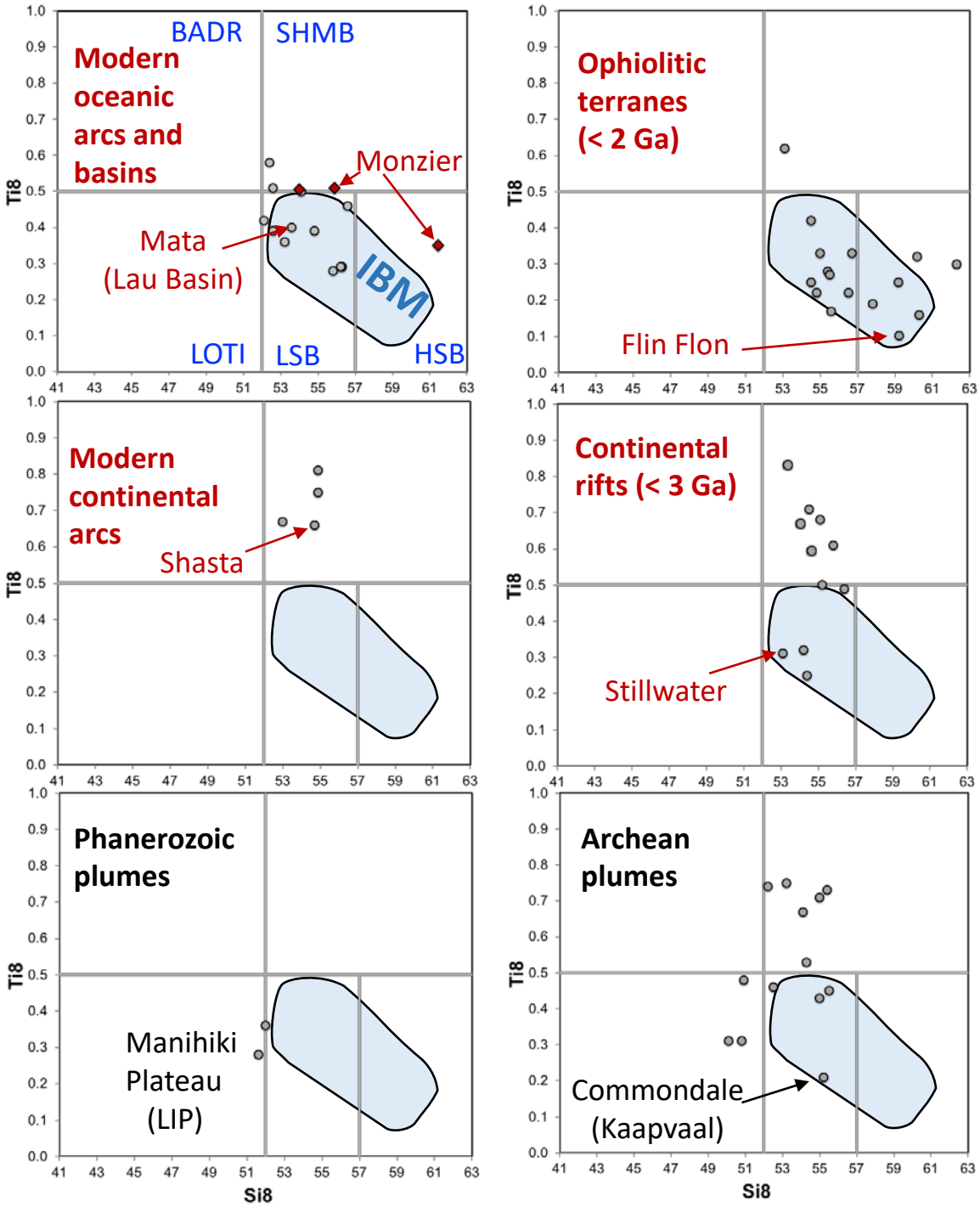
Matthew-Hunter subduction system

Monzier rift





Data: Patriat et al. (2019)

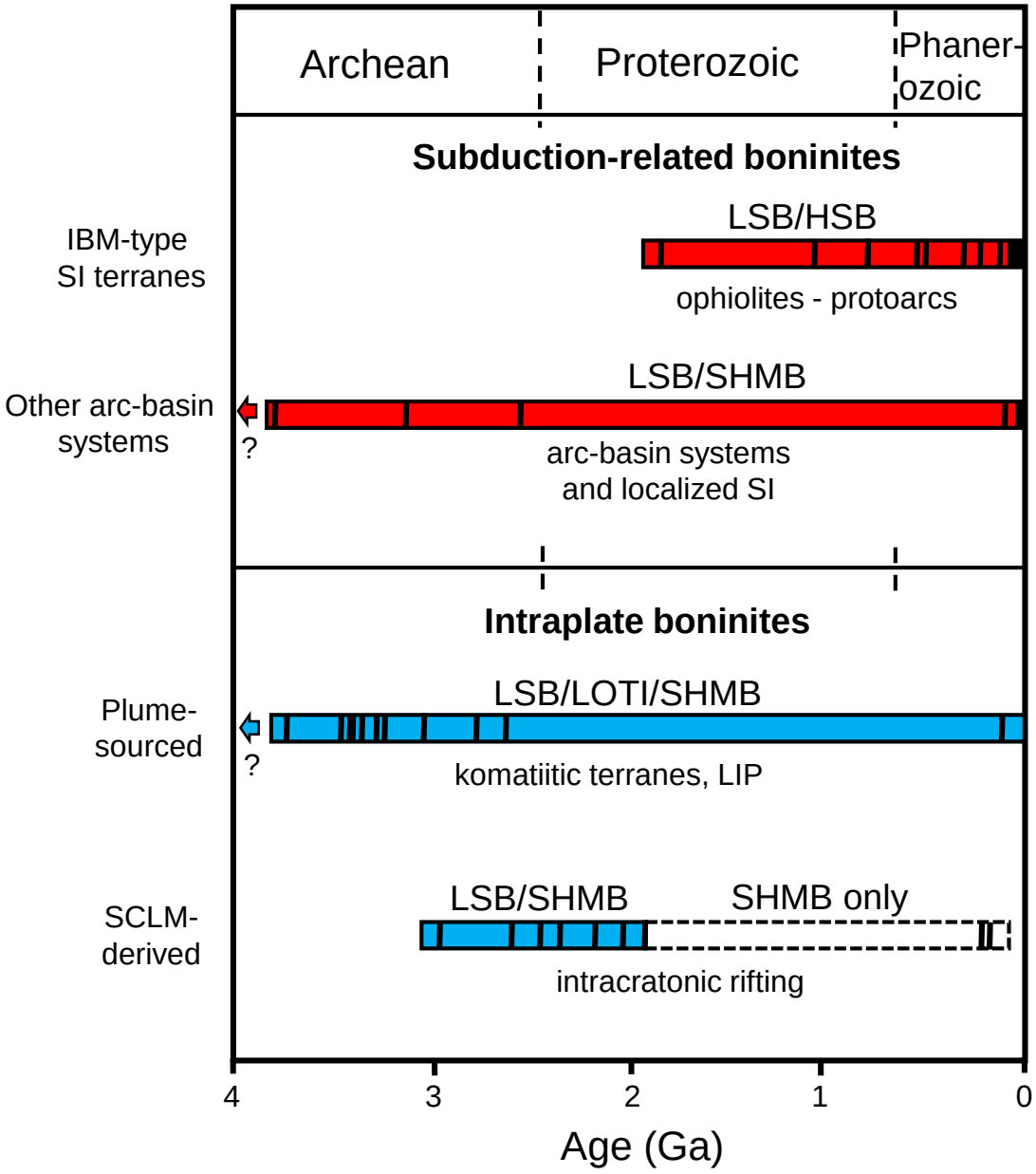


"Boninitic" magmas through time

Red lettering – arc-like trace element abundance patterns

Black lettering – MORB/OIB-like trace element abundance patterns

After Pearce and Reagan (submitted)



after Pearce and Reagan (submitted)

Conclusions

- Organized FAB to LSB to HSB volcanism in IBM related to a large-scale SI event that resulted near-trench sea-floor spreading associated with slab rollback and extreme mantle depletion before establishment of the volcanic arc.
- In IBM, FAB to HSB transition took ~ 1 Myr beginning about 52 Ma. “Normal” arc volcanism began at 46 Ma.
- SI in W. Pacific was a relatively rare significant tectonic and magmatic event; approximately synchronous with India-Asia collision and initiation of Manus plume; preceded bend in Hawaii-Emperor seamount chain by ~ 2 Myr.
- Recent SI events (Puysegur and Matthew-Hunter) have localized causes and effects. Similar events may be common.
- Evidence for subduction goes back to >3.8 Ga, modern strong plate SI could be <2 Ga.