Supplementary material

Origin and evolution of the slab fluids since subduction inception in the Izu-Bonin-Mariana: A comparison with the southern Mariana fore-arc rift

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Assessing the effects of alteration and magma degassing

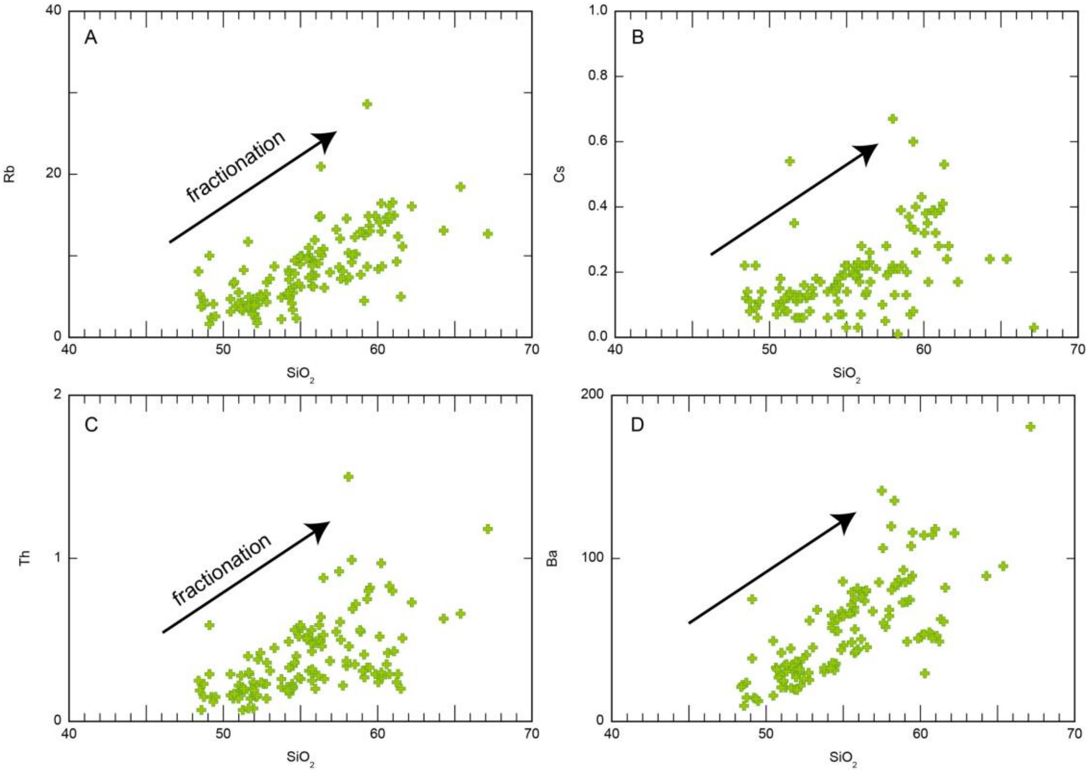

Fig. S1: Cs, Rb, Ba, Th vs. SiO_2 of the IBM infant arc magmas (bulk rocks) that formed in Eocene time. The fractionation trends are mostly preserved, indicating that the elements of interests are little affected by alteration processes. These elements can thus be further used to track the composition of the slab fluids that infiltrated the mantle source of the magmas. However, the scattering indicates that some samples could be affected by seawater alteration, especially for Cs and Rb which are very sensitive to seawater alteration. Thus, samples will be carefully scrutinized to minimize secondary effects.

To ensure tracking the slab-fluid proxies and mantle composition, we use fresh glass shards and olivine-hosted melt inclusions measured by *in situ* micro-analytical techniques reported in the literature, whenever they are available, to ensure freshness and minimize the effects of alteration. Quenched glass shards from pillow rims and olivine-hosted melt inclusions have preserved a better record of the melt prior its eruption on the seafloor than their host rocks (Schiano and Bourdon, 1999). Despite their freshness, glass shards and olivine-hosted melt inclusions can still be prone to secondary alteration processes upon their genesis or after being emplaced onto the seafloor (Kent et al., 1999). Secondary, alteration processes can modify the composition of the magmas, especially the incompatible, fluid-mobile elements (Rb, Ba, Cs) and water (Kent et al., 2002). However, the fact that the samples preserved their fractionation trends, especially for the elements of

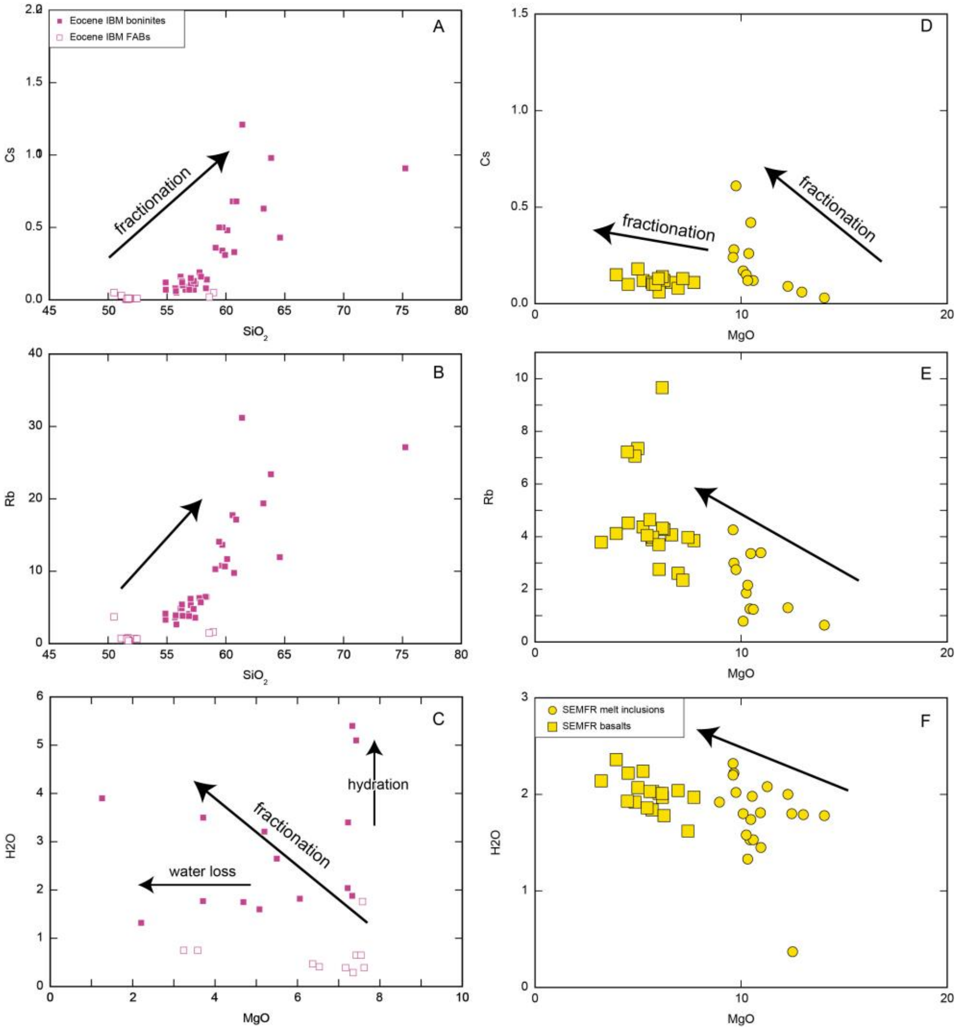

Fig. S2: Cs, Rb, H_2O vs. SiO_2 and MgO contents of the IBM proto-arc boninites and basalts (FABs) and SEMFR basalts showing the fractionation trends. Only glass shards were used to infer the water-rich slab fluids that infiltrated the IBM proto-arc mantle, as the bulk rocks are generally subject to alteration. Note that the SEMFR olivine-hosted melt inclusions (yellow circles) can have their own fractionation trend as compared to their associated glassy rinds (yellow squares). This reflects the fact that the melt inclusions underwent different petrogenetic processes during their formation.

interest here (Cs, Rb, Th) (Fig. S1-S2), further indicates that the basaltic magmas (filtered for oxide sum = 100 ± 2 wt% and $SiO_2 \leq 56$ wt%) retained their original composition without being much affected by alteration. This is especially true for the fresh glass shards and the olivine-hosted melt inclusions, as bulk rocks tend to be more prone to seawater alteration; and they thus display more scattered trends (Fig. S3). Only 2 glass shards from the IBM boninites, deviate from that fractionation trend (Fig. S2C). They show slightly higher content than expected from the fractionation trend, indicating that the glasses may have been enriched in seawater during or after magma eruption. Those two samples were thus filtered out to ensure tracking a reliable water content.

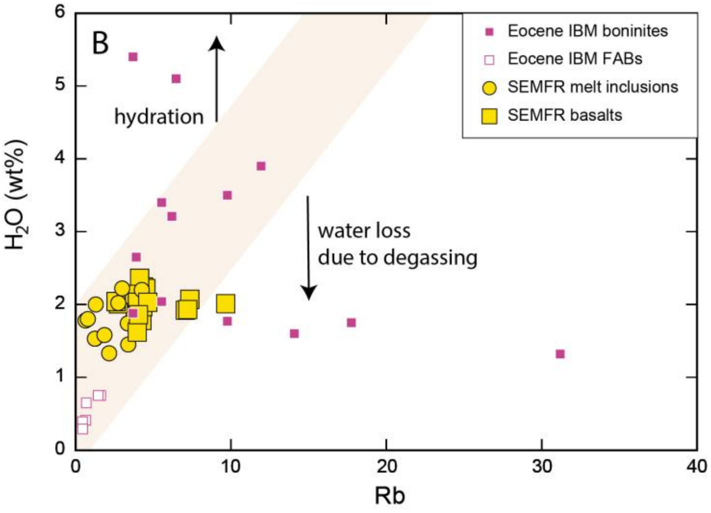

Fig. S3: Examining water degassing. H_2O vs. Rb diagram to examine water degassing. The correlation between H_2O and Rb indicate minimal water loss in the samples. Samples affected by secondary processes are filtered out

Magmas can degas upon their ascent or during eruption, and they can thus lose part of their water. Because S and CO_2 are believed to be less soluble than water in magmas (Dixon and Stolper, 1995), they tend to degas first. Hence, the effect of magma degassing can be evaluated by comparing the water, sulfur and CO_2 contents of the magmas. Fresh, primitive basalts were also filtered for minimally degassed volatile contents ($CO_2 > 50$ ppm and $S > 500$ ppm), when S and CO_2 contents of the glasses were available, to ensure that the samples display a reliable water content (Kelley et al., 2010; Ribeiro et al., 2015; Shaw et al., 2008). However, because S and CO_2 are not always measured in the samples, we compared the water content of the glass shards and olivine-hosted melt inclusions to another element that is similarly mobilized to the water-rich slab fluids, but is not affected by degassing (i.e., Rb in Fig. S3). The correlation between water and Rb indicates that the samples have minimally degassed and preserved their original water content.

Mixing calculations and slab-fluid composition

To assess the origin of the slab fluids, we conducted mixing calculations. The composition of the slab fluid end-members was assessed using the Pb-Sr radiogenic composition of subducted serpentinized mantle (Cannaò et al., 2015; Scambelluri et al., 2001), and the isotopic composition of the altered oceanic crust and the sediments drilled within the Pacific plate (Ishizuka et al., 2020; Plank and Langmuir, 1998). The trace element composition of the fluid C_f was assessed using the trace element content C_s of a composite for the Pacific crust (Kelley et al., 2003) and for the overlying sediments (Plank and Langmuir, 1998), combined to experimentally determined partition coefficients K_D (Johnson and Plank, 1999; Kessel et al., 2005), so that:

$$C_f = K_D \cdot C_s$$

This simple calculation provides an estimate of the slab fluid composition. The composition of fluid inclusions hosted in serpentinized mantle rock (Scambelluri et al., 2001) was also used to assess the trace element content of the serpentinite-derived fluid released from the subducted mantle. We used the composition of the mantle source assessed by Ribeiro et al. (2013b), using the composition of the Mariana back-arc basalt that have captured a minimal subduction input. Details regarding the end-members used for the mixing calculations can be found in Table S2.

Data compilation

We use a compiled dataset to further examine the processes that occur during near-trench spreading above a nascent and long-lived subduction. The dataset is reported in Table S1. Here, we report the literature from which the data were extracted from.

- **Southern Mariana convergent margin**: samples from the southern Mariana fore-arc rifts (SEMFR) were previously collected during several marine expeditions, which include Thomas Thompson TN273, and Yokosuka YK08-08, YK10-12 and YK13-08. Detailed descriptions of the glass shards and olivine-hosted melt inclusions, along with the analyses of their major, trace and volatile elements (including analytical techniques and precisions) were previously reported (Ribeiro et al., 2013a; Ribeiro et al., 2015; Ribeiro et al., 2013b; Ribeiro et al., 2017; Stern et al., 2014).

- **Mariana arc and back-arc**: We compiled a published dataset (Brounce et al., 2014; Gribble et al., 1996; Gribble et al., 1998; Hawkins et al., 1990; Ikeda et al., 1998; Kelley and Cottrell, 2009; Kelley et al., 2010; Kent et al., 2002; Pearce et al., 2005; Shaw et al., 2008; Stern et al., 2006; Volpe et al., 1990; Wade et al., 2005; Woodhead, 1989) for the Mariana arc and back-arc lavas. Compositions of the olivine-hosted melt inclusions corrected for post-entrapment crystallization are reported as published in the literature.

- **IBM proto-arc crust**: we compiled a published dataset (Coulthard et al., 2017; Coulthard et al., 2021; Dobson and O'Neil, 1987; Ishizuka et al., 2020; Kanayama et al., 2012; Li et al., 2019; Reagan et al., 2010; Shervais et al., 2019) for the Eocene IBM FABs and boninites, and for the infant arc.

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