



## VOLCANIC OUTPUTS AT THE IBM

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### *1. Introduction*

Lavas erupted at the IBM front show a rich variety of compositions. The absence of underlying continental crust enable these variations to be largely attributable to mantle processes within the subduction zone, and can thus help place important constraints on its functioning.

The IBM is traditionally carved up on a geographical basis and few studies provide a consistent data set across the whole ~2000km of arc. As a result of this legacy from the literature, the arc will be discussed in three sections (Central and Southern Marianas, Northern Mariana seamounts and Southern Volcano islands, Northern Volcano and Izu islands) before attempting to synthesis the observations.

### *2a. Central and Southern Marianas*

The sub-aerial Mariana islands, or Central Island Province, have been extensively studied. The more limited data on the active submarine seamounts to the south seem in keeping with the trends of the islands. Geochemical variability is dominantly inter-island, and the historic eruptions of any given island tend to be compositionally rather limited. Moreover, there are no systematic along-arc variations. Lavas show two clear endmember geochemical signatures. One component has low  $^{143}\text{Nd}/^{144}\text{Nd}$  but high  $\text{La}/\text{Sm}$ ,  $\text{Th}/\text{Nb}$  together with marked negative cerium anomalies, and is associated with elevated concentrations of all incompatible element contents. The other component is dominantly characterised by specific enrichments in divalent cations e.g.  $\text{Pb}$ ,  $\text{Ba}$ ,  $\text{Sr}$  resulting in extreme  $\text{Ba}/\text{Th}$ ,  $^{226}\text{Ra}/^{230}\text{Th}$  for example and also shows marked  $^{238}\text{U}/^{230}\text{Th}$  excesses (see Figure 1). The second component is most evident in lavas which display a small contribution of the first component, resulting in the positive correlation in Figure 1. As a whole, the lavas thus form a trend between the two components, neither of which resemble compositions found in non-subduction related settings.

The role for two subduction components is thus clear, and it has been proposed that the components represent contributions from the sediment and altered mafic oceanic crust respectively. However, simple addition of these components to the mantle wedge does not adequately account for the variations and it is further inferred that different transport processes also shape the composition of the added components, e.g. melt vs aqueous fluid transport (e.g. Elliott et al 1997)

The mantle protolith to which the subduction components have been added has been much discussed, with candidates ranging from back-arc melt depleted MORB-type mantle of either Indian or Pacific flavour to and OIB type mantle. To some extent this confusion results from the dominance of the subducted contribution to the arc lava signature. Maybe the role of the mantle is most clearly evident in the Li isotopic signature of the lavas, which are ubiquitously indistinguishable from

MORB (and OIB?), despite the heavy isotope composition of the subducted assemblage.

### *2b. Northern Mariana Seamounts and Southern Volcano Islands*

The striking features of the lavas from this dominantly submarine section of the arc are the systematic along arc variations culminating in enriched, alkalic (so called 'shoshonites') around 24°N. This is associated mineralogically with the early appearance of hydrous phases such as biotite and hornblende on the liquid line of descent. In terms of the more frequently used trace element and isotopic tools, the trend of enrichment in these lavas appears to be an extension to more extreme compositions of the 'sediment' component observed in the Mariana Islands, notably showing lower  $^{143}\text{Nd}/^{144}\text{Nd}$ , higher La/Sm, Th/Nb and also negative cerium anomalies. A further key observation is that the Nb/Ta ratios of the lavas become super-chondritic, a feature rarely observed in any terrestrial lavas, but potentially consistent with the contribution of a melt produced in the presence of residual rutile (e.g. Stolz et al 1996). However, some authors have proposed that the signatures of the lavas reflect essentially an OIB source that has experienced unusual trace element fractionations during melting as a result of slab additions.

### *2c. Northern Volcano and Izu Islands*

The anomalously enriched signature of the Southern Volcano islands has disappeared by ~27°N. To the north of this, Nishinoshima and the Izu arc lavas are notable for lying at the end of the Plank and Langmuir (1988) melting array. These lavas have the lowest fractionation corrected Na contents and so are inferred to represent the largest degrees of melting in global terms. All lavas are very depleted, both in incompatible element contents, ratios and Nd isotope ratios. The most depleted Mariana island samples, approach the composition of the Izu lavas. The trend of certain Mariana islands towards an enriched sedimentary component is not evident in the Izu lavas. Instead, the dominant trend of chemical variation exhibited is in the northernmost islands of Miyakejima and Oshima. These islands show extreme relative enrichments in Ba. Interestingly it is these relatively Ba enriched samples that appear an extension of the depleted Mariana lavas, rather than the bulk of Izu lavas that are noted for their relative Ba deficit (e.g. Plank and Langmuir 1993) at given degree of enrichment.

*(Illustration to be added)*

Figure 1. *Illustrative geochemical plot to show the different effects of sediment and 'fluid' addition to a depleted upper mantle source. It is proposed that variable proportions of these two slab additions are the principal causes of geochemical variation in the erupted IBM lavas. The breakdown of IBM into different sections highlights the dominance of different processes along different segments of the arc.*

### *3. Key Points to Explain*

Geochemical enrichment ~23°N  
Island-island variability in Marianas  
Extreme depletion of Izu arc  
Regional Izu barium gradient

### *4. Interim synthesis*

Within the Marianas it appears that the role of variable sediment addition generates the dominant geochemical variability. The apparent coherence of the Northern seamounts and S. Volcano islands

with the geochemical trends of the Marianas also implicates an increasing contribution of sediment to generate this regional enrichment. The intersection of seamounts chains (Magellan and Marcus-Wake) with the subduction zone between 21-25°N suggests this load of volcanics and volcanoclastic debris may account for the additional 'sedimentary' addition. This may also readily explain the modified OIB-like nature of this component.

Within the Marianas itself, the cause for island-island variability is less clear. Collection of sediment poor and sediment rich zones within the subducting plate may result from development of a horst-graben structure. In a restricted time-window, different islands may sample differentially horst or graben portions of the plate, which may result in non-systematic along arc variability. Alternatively, the presence or absence of seamounts in different portions of the down-going plate may lead to different 'sediment' fluxes to the overlying islands.

More puzzling is the extreme depletion in the Izu arc lavas, which was a driving force behind quantifying the sediment flux into the arc, accomplished in ODP leg 185. Neither a sedimentary component (e.g. low La/Sm), nor altered oceanic crustal component (e.g. low Ba contents) appear to be effectively incorporated into the arc front lavas. The gradient within the Izu arc to higher Ba contents in the north appears to reflect a return to more Mariana-like conditions. The most obvious physical differences between Mariana and Izu islands is the abundance of back arc volcanoes behind the Izu islands and the proximity of back-rifting to the frontal Izu islands. It is tentatively suggested that these features may prevent input of subducted material into the arc front lavas. If so this places interesting constraints on the mechanism by which material is transported from slab to arc front.