SF	Collaborative Research: Magma Generation and Tectonics in the Early Mariana Arc System Revisited	
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Lavas from the fore-arc islands of Guam, Rota, and Saipan, and DSDP sites 458 and 459 (Fig. 1) have been analyzed for major element and trace element concentrations, as well as Sr, Nd, Pb, and Hf isotopic compositions, to investigate the evolution of volcanism in the Mariana arc from the initiation of subduction of the Pacific plate beneath the Philippine plate in the Eocene through the Miocene. The oldest "protoarc" (Pearce *et al*., 1999) lavas in the Mariana fore-arc region are ca. 48 Ma tholeiite to boninite sequence from DSDP sites 458 and 459. These tholeiites have NMORB-like REE, HFSE, and Th concentrations, but are enriched in LIL elements, Pb, and U. The capping boninite-series glasses have similar slab-derived trace element abundance patterns, but lower and flatter REE contents (1-2 x PUM). $^{40}Ar/^{39}Ar$ ages obtained on boninite series lavas from Guam stretch back to 44Ma. These lavas have U-shaped REE patterns and HREE concentrations about 3-8 x PUM. La/Nb decreases with increasing Ba/La for both the DSDP and Guam lavas (Fig. 2). Pb isotope values plot within fields defined by Pacific plate lavas and volcanogenic sediments (Fig. 3; Meijer, 1976; Pearce *et al*., 1999). Hf isotopic compositions display weak correlations with Zr/Sm ratios for lavas from the DSDP sites, but not for those from Guam (Fig. 4). Taken as a whole, these data suggest that the variations in La/Nb and Zr/Sm ratios are related to changes in the residual mantle source mineralogy, with progressive melting, rather than a flux of HFSE from a subducting plate. Therefore, the source for the DSDP site lavas apparently was a transitional Pacific-Indian Ocean MORB-source. Fluxed melting at high-P generated the tholeiites. Boninites were generated at low-P by continued fluxed melting. The mantle source for the boninite-series lavas from Guam was less depleted. Progressive fluxed melting here apparently occurred with less mantle upwelling. In both locations, Pb in slab fluids was from Pacific volcanogenic sediments.

Rhyolites erupted on Saipan at 45- 46 Ma are unusually high in silica for an oceanic island arc setting. These lavas are enigmatic in that they have trace element and isotopic compositions similar to those of Oligocene (36-32 Ma) "First arc" (Gill *et al*., 1994) andesites and dacites from forearc sites. Pb isotope values for the Saipan rhyolites and first arc volcanics plot along a trend that stretches from the NHRL toward Pacific siliceous sediments, with the rhyolites plotting at the least radiogenic end of the array. Basalt dikes with ages of ca. 41 Ma cut the boninite series lavas in Guam. These basalts have trace element patterns of typical arc tholeiites, and mark the first appearance of relatively normal mafic arc lavas in this system. Pb isotope compositions for these samples indicate that siliceous sediment also makes its first appearance at this time. "Second arc" (Gill *et al*., 1994) volcanism began on Guam and Saipan at about 14 Ma, after spreading in the Parece Vela Basin ceased. These lavas have incompatible trace element and isotopic ratios that are remarkably similar to those of the modern Mariana arc.

The convergence required to trigger the initiation of subduction of the Pacific plate (Hall *et al*., 2003) may have been due to migration of Indian Ocean type mantle northeast beneath the West Philippine basin. Protoarc lavas from DSDP sites 458 and 459 were apparently generated from upwelling mantle that rushed in behind the newly subducting

Pacific lithosphere (see Stern and Bloomer, 1992). The transition from an upwelling mantle wedge to relatively normal mantle counterflow and P-T distributions in the mantle wedge apparently required about 6 million years of subduction and cooling of the corner of the mantle wedge. The compositions of the subducted components (volcaniclastic to silicic sediment) changed with the mantle convection regime. Processes and sources generating today's lavas are identical to those that generated the second arc lavas, which erupted before the opening of the Mariana Trough.

Figures and Captions

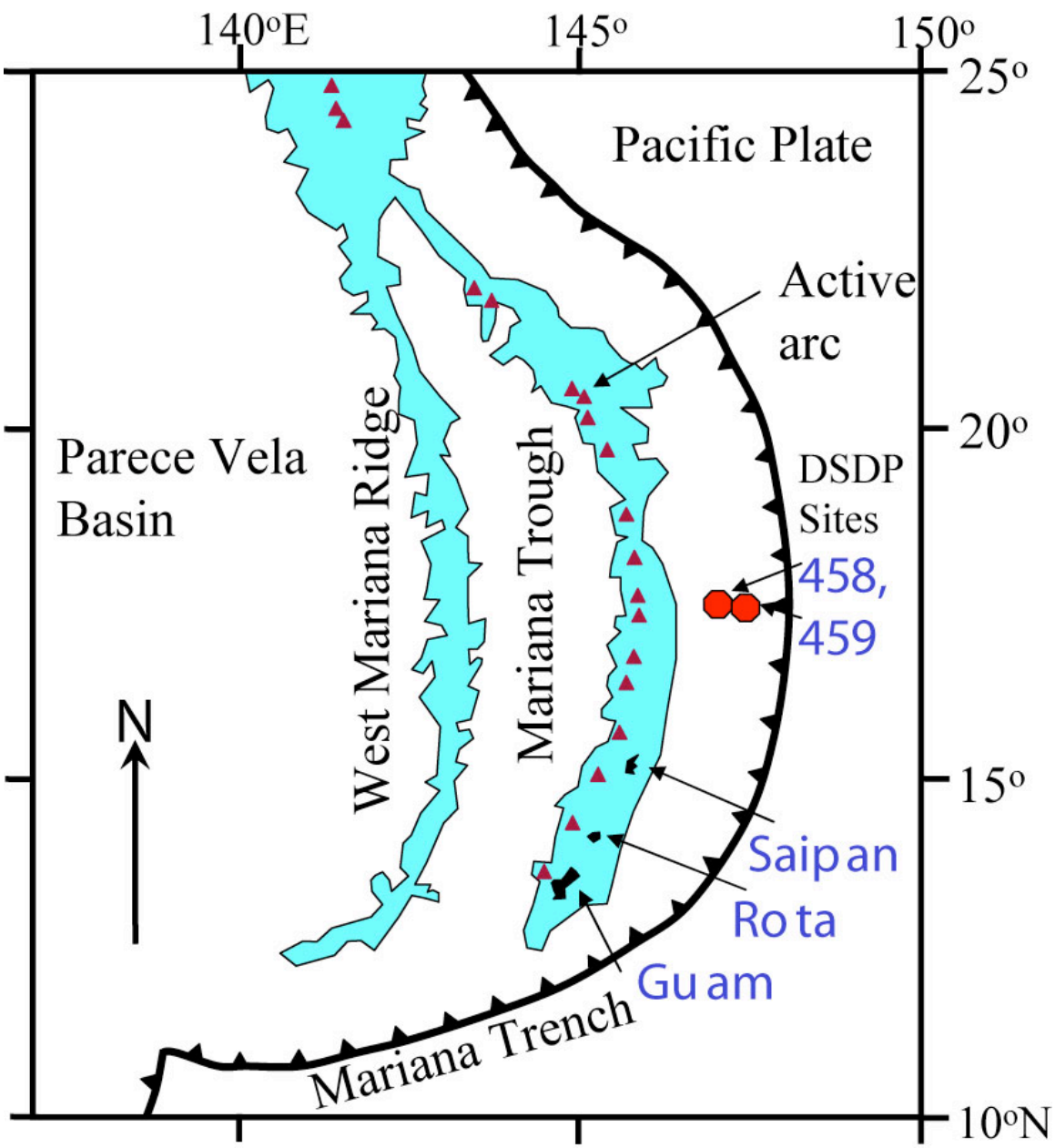

Figure 1: Location map for forearc sites in the Marianas island arc system.

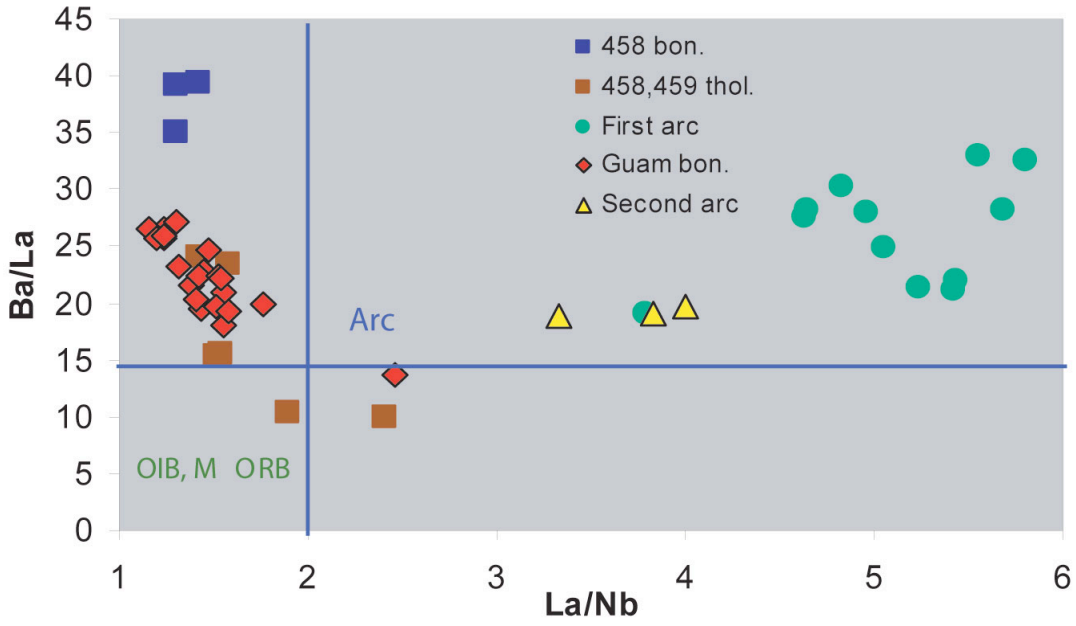

Figure 2: Plot of Ba/La against La/Nb for Mariana forearc lavas are characterized by Ba/La>15 and La/Nb<2. Most OIB and MORB have Ba/La<15 and La/Nb<2. The negative correlation on this plot for protoarc lavas indicates that the Nb anomaly that characterizes most arc lavas disappears at the extreme degree of melting required for boninite genesis.

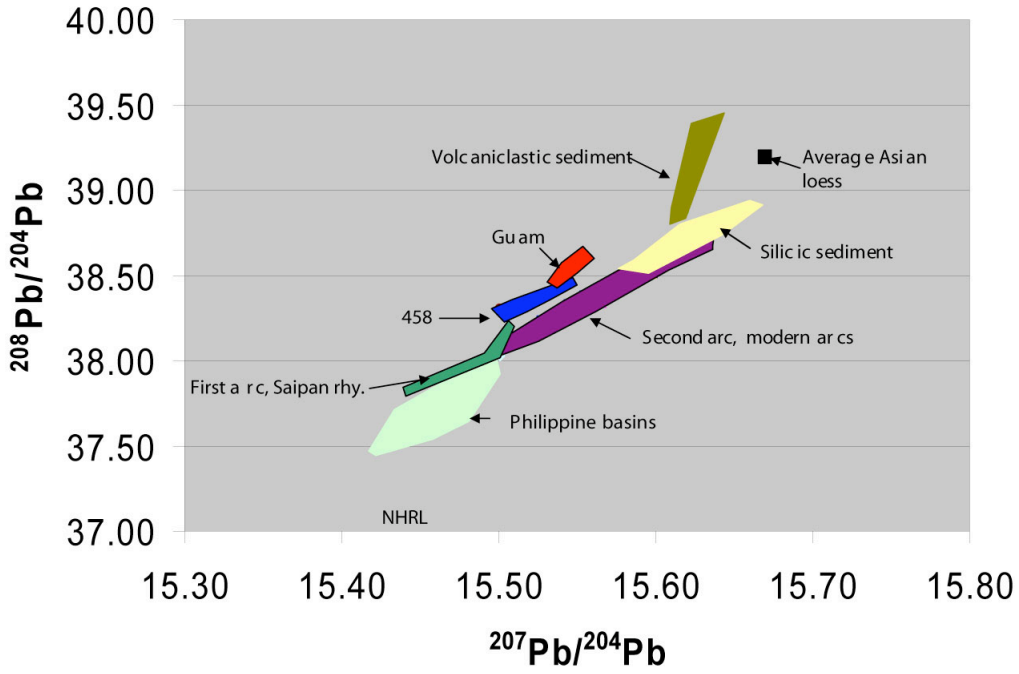

Figure 3: Plot of $^{208}Pb/^{204}Pb$ against $^{207}Pb/^{204}Pb$ for Mariana lavas and potential sources for Pb. Protoarc lavas have Pb only from mantle or basaltic sources. First arc and later lavas have Pb derived from subducted silicic sediment [Data sources: This study; Meijer (1976); Hickey-Vargas and Reagan (1987); Hickey-Vargas (1989), Elliott *et al*. (1997); Hickey-Vargas (1998); Pearce *et al*. (1999); Pettke *et al*. (2000); Woodhead *et al*.

(2001)].

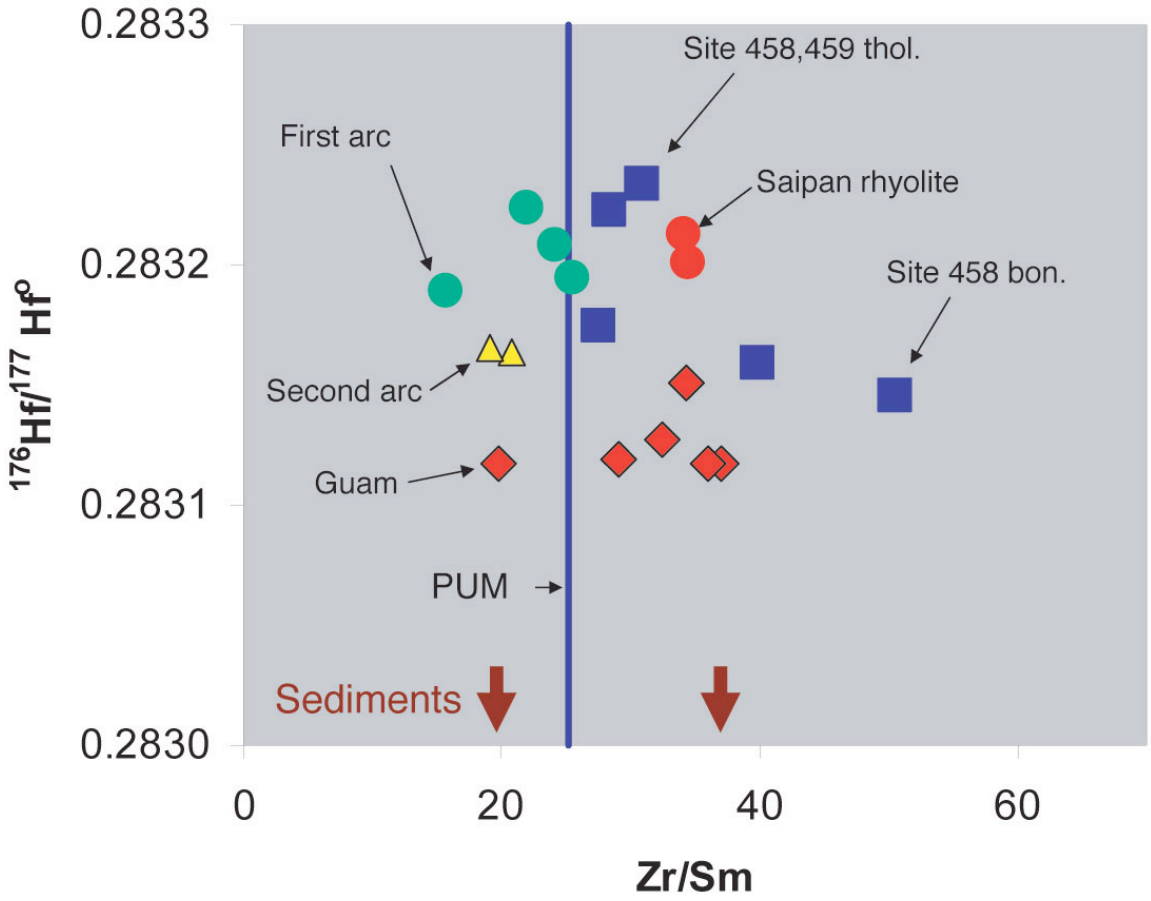

Figure 4: Plot of age corrected Hf isotopes against Nr/Sm for Mariana forearc lavas. Sources for sediment compositions: Pearce *et al*. (1999). Although site 458 and 459 lavas display a weak negative correlation on this plot, those from Guam do not, suggesting that the positive Zr and Hf anomalies of boninite lavas do not result from the addition of Zr and Hf in a slab fluid.

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