Geochemistry of Southern Pagan Island Lavas, Mariana Arc: Role of Subduction Zone Processes

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Pagan Island consists of two dormant volcanoes, Mt. Pagan (last active 2009) and South Pagan (last confirmed eruption 1864 A.D.), connected by a Central Volcanic Region (CVR) of pre-Holocene age. Two erupted stages are identified for South Pagan: pre-caldera (780-9.4 ka) and post-caldera (<9.4 ka; Trusdell, 2009). The eruptive history of the older CVR is poorly constrained. New $^{40}Ar/^{39}Ar$ ages were obtained for two lavas; 12 ± 15 ka from South Pagan and 286±56 ka for CVR. Major and trace element abundances, and Pb, Sr, and Nd isotopic ratios were determined for lavas collected in 2006 from South Pagan and the CVR to investigate the mantle source (i.e. slab components) and melting dynamics for the Mariana island arc. South Pagan and CVR lavas are subalkaline, medium-K basalts to high-silica andesites (48-62 wt. % SiO_2) with low to moderate MgO contents (2.0-6.3 wt. % MgO; Fig. 3), which is typical of Mariana arc lavas (e.g. Woodhead 1989). Petrography (rocks are crystal-rich, ~15-40 vol. %, with complexly zoned and sieved plagioclase phenocrysts) and compositional trends (decreasing CaO and FeO*; Figure 3) indicated that crystal fractionation and magma mixing were important crustal processes for lavas from South Pagan and CVR. Partly digested gabbroic xenoliths (< 5 cm) in some South Pagan post-caldera lavas reflect some crustal assimilation. Normalized trace element patterns for South Pagan and CVR lavas relative to average normal mid-oceanic ridge basalt (N-MORB; Hofmann 1988) are similar to other Mariana arc lavas. South Pagan and CVR lavas are enriched in Th, U, Pb, and large ion lithophile elements (LILE: Rb, Ba, K, Sr), and depleted in high field strength elements (HFSE: Nb, Ta, Hf, Zr) with respect to N-MORB. South Pagan and CVR lavas are slightly enriched in most of the light rare-earth elements (LREE: La, Ce, Pr, Nd) compared to N-MORB, but have relatively constant or slightly decreasing abundances of the middle (MREE: Sm, Eu, Gd, Tb, Dy, Ho, Er) to heavy (HREE: Tm, Yb, Lu) rare-earth elements, which are slightly more depleted than N-MORB. The REE abundances of CVR and South Pagan lavas normalized to N-MORB or some other Pagan lavas (e.g. CVR sample TM-06-217) produce saucer-shaped REE patterns. No crustal amphibole interaction or fractionation is required to depress the middle REE abundances of these Mariana lavas.

Compositional and isotopic variations in lavas from the three Pagan volcanic complexes indicate: 1. Lavas from each volcano were derived from compositionally distinct parental magmas; 2. These parental magmas represent small contributions (1-2%) of slab components (sediment-fluid component is not quantified); 3. Slab material was added to the melts from moderate amounts (3-7%) of partial melting of the underlying mantle wedge. Pb and Nd isotopic ratio variations indicate the average sediment is 2.1% for CVR, 1.8% for South Pagan and 1.4% for Mt. Pagan lavas. These slab contribution estimates are typical of Mariana Arc volcanoes, which range from 1.3% (Guguan) to 2.0% (Agrigan) (~2.0%). The degree of mantle partial melting for Pagan volcanoes (3-7%), and for Agrigan (2-5%), Guguan (9-15%) lavas correlates with indicators of fluid addition (e.g. Ba/Th). This relationship suggests that the fluid flux to the mantle wedge is the dominant control on the extent of partial melting beneath Mariana arc volcanoes. A decrease in the amount of fluid addition (lower Ba/Th) and extent of melting (higher Sm/Yb), and an increase in the sediment contribution (higher Th/Nb, La/Sm, and Pb isotopic ratios) from Mt. Pagan to South Pagan could reflect systematic cross-arc or irregular along-arc melting variations. These observations indicate that the length scale of compositional heterogeneity in the mantle wedge beneath Mariana arc volcanoes is small (~10 km). Melt modeling demonstrates that the saucer-shaped normalized rare-earth element (REE) patterns observed in Pagan lavas can arise from partial melting of a mixed source of depleted mantle and enriched sediment.