A temporal perspective on arc crustal growth from the Mariana island arc

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Different models of crustal growth result in divergent predictions for the geochemical evolution of volcanic arcs. Here we test such models with major and trace element abundances and Sr-Nd-Pb-Hf isotope ratios for fallout tephra recording the last 34 million years of Mariana Arc evolution with high temporal resolution (0.8±1.1 myr) and precision. The Mariana Arc is well-known for secular changes in K_2O pointing to increasing melt differentiation in the gradually thickening arc crust. However, our data link K_2O increase to collision with the Cretaceous Western Pacific Seamount Province (WPSP) in the late Miocene. Nd-Hf isotope and trace element systematics demonstrate MORB-type crust covered by pelagic clay and biogenic sediment was subducting prior to 11 Ma. The sediment had high Nd/Hf = 33-36 producing arc magmas with high $^{176}Hf/^{177}Hf$ =0.2832-33 at a broad range of $^{143}Nd/^{144}Nd$ =0.5127-31, defining an end-member in the global spectrum of arc compositions. After 11 Ma, the Nd-Hf isotope ratios of the arc magmas shifted along the mantle array as a result of subduction of enriched crust and volcaniclastics of the WPSP with low Nd/Hf =4-6. The change in the composition of the subducting slab is confirmed by a simultaneous shift towards the higher $^{206}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ of the WPSP relative to MORB.

Temporal variations in isotope and source-sensitive trace element ratios denote four periods of arc formation (52-34, 34-24 , 22-11, and 10-0 Ma) each of which is characterized by a distinctive melee of source materials. Abrupt changes between these periods, the lack of time-dependent variations of the crust-forming major elements oxides, and the bimodality of mafic and silicic melt through time contrast with models of time-progressive andesite crust formation by ingestion of older crustal basement. Rather, our data suggest steady crustal growth by addition of mafic and silicic melts that form simultaneously within time intervals commensurate to elemental recycling from trench to arc.