

Initiation and maturation of island arcs

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Island arcs are defining features of a geodynamically active and habitable planet, which have contributed to the formation of continents. They result from the dynamic interplay between mantle convection and dehydration of the downgoing plate that occurs within the deep interior of the Earth. However, how island arcs evolve into mature, thicker intra-oceanic arcs has remained an open question. Part of the problem resides in the fact that modern intra-oceanic arcs are associated with long-lived subduction zones; and the early processes that are associated with arc initiation are thus concealed.

Here, we examine of the Mariana arc magmas along a S-N transect to better comprehend the processes that occurred during island arc initiation and maturation. The southern Mariana arc is an incipient island arc that has recently emplaced (< 5 Ma) onto newly spread oceanic crust. The southern Mariana arc is thus composed of submarine volcanoes that are less developed (arc crust ≤ 10 km thick) and irregularly distributed to the south, as compared to northern volcanoes. To the north, the arc volcanoes have developed a ~ 20 to 40 km thick crust with gabbroic to tonalitic middle crust for the past 41 Ma. The juvenile, southern Mariana arc thus progressively evolves into stable, thicker-crust stratovolcanoes to the north. We find that stabilization and retreat of the volcanic arc front in mature, long-lived island arcs is modulated by the growth of the serpentized fore-arc mantle since subduction inception. Deepening and stabilization of the depth of arc magma generation enable, in return, the deeply-sourced, slab fluids to infiltrate the sub-arc mantle wedge, conferring to the magmas a typical arc geochemical fingerprint. Melt focusing along magmatic conduits further promotes magma fractionation and crustal assimilation, which result in thickening and differentiation of the arc crust in the mature volcanic edifices. We further propose that transient and disorganized arc magmatic activity may also develop during subduction initiation, as observed today in the southern Mariana arc.