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Lateral Variation in Crustal Structure along the Lesser Antilles Arc from Petrology of Crustal Xenoliths and Seismic Receiver Functions

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We reconstruct crustal structure along the Lesser Antilles island arc using an inversion approach combining constraints from petrology of magmatic crustal xenoliths and seismic receiver functions. Xenoliths show considerable island-to-island variation in xenolith petrology from plagioclase-free ultramafic lithologies to gabbros and gabbronorites with variable proportions of amphibole, indicative of changing magma differentiation depths. Xenoliths represent predominantly cumulate compositions with equilibration depths in the range 5 to 40 km. We use xenolith mineral modes and compositions to calculate seismic velocities (vP, vS) and density at the estimated equilibration depths. We create a five-layer model of crustal structure for testing against receiver functions (RF) from island seismic stations along the arc. Lowermost layer (5) comprises peridotite with physical characteristics of mantle xenoliths from Grenada. Uppermost layer (1) consists of 5 km of volcaniclastics and sediments, whose physical properties are determined via a grid inversion routine. The three middle layers (2) to (4) comprise igneous arc crust with compositions corresponding to the xenoliths sampled at each island. By inversion we obtain a petrological best-fit for the RF on each island to establish the nature and thicknesses of layers (2) to (4).

Along the arc we see variations in the depth and strength of both Moho and mid-crustal discontinuity (MCD) on length-scales of tens of km. Moho depths vary from 25 to 37 km; MCD from 11 and 25 km. Both discontinuities are located at greater depths in the northern arc. The Moho is the dominant discontinuity beneath some islands (St. Kitts, Guadeloupe, Martinique, Grenada), whereas the MCD dominates beneath others (Saba, St. Eustatius). Along-arc variability in MCD depth and strength is consistent with variation in the inferred magmatic H_2O contents and differentiations depths that, in turn, influence xenolith lithologies. A striking feature is steep, along-arc gradients in vP similar to those observed at other oceanic arcs. These gradients are reflected in abrupt changes in rates and processes of magma generation in the underlying crust and mantle. We find no evidence for large, interconnected bodies of partial melt beneath the Lesser Antilles. Instead, the crustal velocity structure is consistent with magma differentiation in vertically-extensive, crystal mush-dominated reservoirs. Along-arc variation in crustal structure may reflect heterogeneous upwelling within the mantle wedge, itself driven by variation in slab-derived H_2O fluxes.