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Crustal Structure Variation Along the Lesser Antilles Arc Inferred from Seismology and Petrology

David Schlaphorst (1), Elena Melekhova (1), J-Michael Kendall (1), Jon Blundy (1), Brian J Baptie (2), and Joan L Latchman (3)

(1) School of Earth Sciences, University of Bristol, Bristol, United Kingdom (david.schlaphorst@bristol.ac.uk), (2) British Geological Survey, Edinburgh, UK, (3) Seismic Research Centre, The University of the West Indies, Trinidad & Tobago

Details of crustal structure in subduction environments have the potential to provide insights into continental crust formation processes. Here we investigate the crustal structure along the Lesser Antilles island arc using a grid-search inversion approach that combines seismic receiver functions and petrology.

The island arc system is built by the relatively slow subduction ($\sim$2cm/yr) of the North and South American plates beneath the Caribbean plate. It is interesting due to its wide range of parameters such as the amount of subducted water and sediments, as well as the type of subduction and its slab dip. Furthermore, analyses of cumulate samples from the different arc islands show a variation in dominant magma types along-strike.

We adopt a four-layer model that uses petrology of natural rocks and high-pressure experiments to provide constraints on the v_P/v_S ratio of plausible lithologies. With that approach, we are able to determine best-fit thicknesses and v_P of two magmatic crustal layers, separated by a mid-crustal discontinuity (MCD), overlying the Moho and underlying a 5 km upper layer of volcaniclastics and sediments. The mid-crustal layer comprises solidified magmas of the types exposed at the surface, whereas the lower crustal layer comprises complementary cumulate residues, whose mineralogy is consistent with experimental petrology and xenoliths. Our approach holds several advantages over conventional H–κ stacking, especially in arc settings where seismic stations are subject to significant noise.

Along the Lesser Antilles arc we see variations in the depth and strength of both Moho and MCD on length-scales of tens of km. Moho depth varies from 25 to 45 km; MCD depth varies from 10 and 25 km. Both discontinuities are located at greater depths in the northern arc. The results further show that the Moho is weakened and thus not the dominant discontinuity beneath some of the islands caused by changing mineral composition due to different temperatures and water content. We ascribe along-arc variability in crustal structure to variation in the composition and flux of mantle-derived parent magmas and the maturity of the magmatic system. A key interpretation is that the thermal and water conditions are laterally variable along the arc on short length scales. The water content of a lower crustal cumulate layer plays an important role in the regulation of the seismic strength of the Moho. A water content as little as 2.4 wt% is needed to weaken the Moho so that the MCD becomes seismically dominant.