High water contents in Tonga arc magmas

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The Tonga arc-Lau back-arc basin system is one of the best regions in the world to study the role of slab fluids in driving melting at increasing distances above the slab, where the arc and back-arc together overlie slab depths of 85-270 km. To test these relationships, we focus here on the volatile content of Tonga arc magmas, to complement the relatively well-studied Lau back-arc magmas. We provide here the first H_2O measurements in magmas from the recent Tonga volcanic front (Tofua arc).

Samples were dredged from Tonga arc submarine volcanoes on the Tonga-Eastern Lau Vents Expedition (TELVE) in 2003, and the Northern Tonga Vents Expedition (NoToVE) in 2004. These submarine volcanoes lie among the Tonga arc islands, and cover the entire extent of volcanism from this arc system. Most dredges recovered fresh material from which we studied both glassy rinds and melt inclusions trapped in olivine, plagioclase and pyroxene phenocrysts. While the dredged samples include similar magma types to the subaerial volcanoes (i.e., basaltic andesite to rhyolite compositions), they contain more abundant olivine, which is rare from the islands.

We have measured volatile contents by SIMS ion microprobe in melt inclusions from 7 submarine volcanoes along the length of the Tonga arc (from 23 – 16°S), finding the highest H_2O concentrations (3 – 5 wt%) in basaltic to basaltic andesite melt inclusions in the most primitive phenocrysts ($Fo_{85–91}$ olvine and An_{89-90} plagioclase), with the highest S contents (800-2000 ppm). These H_2O contents are higher than any back-arc samples, and lead to a smooth trend of decreasing magmatic H_2O with increasing depth of the slab, possibly reflecting progressive slab dehydration with depth.

The arc volcano with the highest H_2O content (> 4.9 wt%) occurs in the middle of the arc (21°S) and also records the highest Ba/La (125 ppm), a classic tracer of slab fluids. H_2O concentrations in the arc melt inclusions (all with 51 – 55% SiO2) correlate inversely with Y concentrations (from 12 – 22 ppm), consistent with H_2O driving higher extents of mantle melting and diluting the concentration of incompatible, yet non-slab-derived, trace elements like Y. The H_2O-Y trend for the Tonga arc is similar to that for the Central American arc and clearly demonstrates the high degrees of H_2O-fluxed melting at volcanic arcs, up to 30% melting for the lowest Y Tonga arc sample (Y at Fo_{90} = 10 ppm).