Geophysical Research Abstracts,
Vol. 10, EGU2008-A-06606, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-06606
EGU General Assembly 2008

Insights on genesis and thermal evolution of rhyolitic magmas beneath Lipari Island (Aeolian Islands, Italy) by ion microprobe U/Th dating and trace element analysis of zircons

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The Aeolian Volcanic Arc (Southern Italy) is a complex of seven islands and eight seamounts, which have generally been linked to Ionian plate subduction. Volcanism over most of the 1 Ma history of the Aeolian Arc has been dominated by mafic to intermediate rocks but appreciable volumes of more evolved rocks (rhyolites) also occur, particularly within the central sector of the arc (Lipari, Vulcano, Salina). The origin of Aeolian rhyolites remains controversial. They are thought to originate by either anatexis of Calabrian basement that extends beneath the central sector of the arc or by fractionation from parental trachytes. A related issue that also bears on volcanic hazard potential is whether rhyolite has been stored beneath the Aeolian Islands for long periods of time (10^3 to $> 10^4$ yr). We have thus initiated work on the rhyolites to address these fundamental petrogenetic and time scale issues using age (U/Th) and trace element information from zircon. Our initial reconnaissance has focused on only two samples from the island of Lipari, where rhyolite-dominated volcanism commenced at 42 ka, and produced lava domes and flows and pyroclastic deposits that are exposed mainly in the southern and eastern parts of the island.

Zircon U/Th ages and trace element data were obtained by SHRIMP-RG at Stanford University on a crystal-poor (<3% crystals) juvenile obsidian clast from pyroclastic deposits associated with the eruption of Monte La Guardia (MG; K/Ar age of 22 ka) and the nearly aphyric obsidian ($<$1% crystals) of Rocche Rosse (RR; eruption age of ca.700 AD). Cathodoluminescence imaging of zircons reveals distinct differences between the two samples. Most zircons from MG show oscillatory zoning at the edges of crystals and have dark cores. Sector zoning is also common. Zircons from RR are less euhedral, have larger domains showing oscillatory zoning and fewer clear dark cores. Sector zoning is absent.

Zircons from MG yielded a U-Th isochron of 44.8$\pm$5.3 ka; MSWD = 1.7), whereas sample RR failed to give a statistically meaningful isochron, although a majority of the zircons lie approximately along a 7 ka minimum isochron. Several zircons from RR are clearly outliers and have distinctly older ages (model ages between about 13 and 66 ka), but the most striking feature of the zircon age data so far is that all zircons plot well away from the equiline.

Zircon crystallization temperatures using Ti-in-zircon thermometry (a_{TiO2}= 0.6) for MG range from 670–740˚C but temperature differences of up to 50˚C are observed between dark and light sectors. All zircons have chondrite-normalized REE patterns typical of igneous rocks. Th and U are generally higher (Th 4000; U 6000; all concentration data in ppm) in the dark cores and sectors than in the light cores and sectors (Th 1000; U 2000) but Hf concentration is similar in cores and rims and fairly high (ca. 12000). Ce/Ce* decreases (300–2), Eu/Eu* is constant and low (ca. 0.03), and Yb/Gd increases (11–21) with decreasing temperature. Zircon crystallization temperatures in RR range from 720–800 ˚C and like sample MG, Th and U are higher and more variable in the dark cores (Th 1000 – 3300; U 1000 – 300) than in lighter rims (Th 300, U 600) and Hf concentrations show little variation (ca. 8600) between cores and rims. Ce/Ce* and Eu/Eu* are quite variable (170 -17, and 0.04 to 0.13 respectively), whereas cores and rims show different Yb/Gd ratios (12 and 8, respectively).

Although these data are preliminary we tentatively draw the following conclusions: (1) zircons from both samples grew primarily in rhyolite melt and are not inherited from Calabrian basement; (2) most zircon crystallization preceded eruption (a minimum of ca. 5-6 ka in case of RR), and the eruptions recycled zircons formed in earlier magmatic pulses that invaded the crust beneath Lipari over several tens of ka (in MG no zircons having ages close to the K/Ar age were found); (3) differences in Ti concentration between sectors in sector-zoned zircons are well outside analytical errors and cannot be explained by differences in temperature; instead they are more likely related to variations in crystal-growth kinetics for Ti during crystallization of zircon; (4) the overall lower zircon temperatures and higher concentrations of Th, U, and Hf and lower Eu/Eu* for MG zircons compared to RR zircons suggests that each eruption tapped chemically distinct batches of rhyolite rather than a single, long-lived, rhyolite reservoir.