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The 2011 El Hierro eruption supports models of multi-stage magma ascent at ocean island volcanoes: linking the geophysical and petrological records

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A number of recent studies have investigated magma plumbing systems of La Palma and El Hierro (Canary Islands), Madeira, and Fogo (Cape Verde Islands), by applying clinopyroxene-melt geobarometry and microthermometry of CO_2-rich fluid inclusions. The data for each volcano as well as the combined data set indicate a remarkable bimodality of retrieved pressures, reflecting a multi-stage magma ascent. Most clinopyroxene phenocrysts last equilibrated with the host melt at 430-800 MPa (about 16-30 km depth), within the uppermost mantle. These depths are interpreted as the levels of major magma reservoir systems where crystals are fractionated prior to eruption. In contrast, most fluid inclusions in phenocrysts and xenoliths recorded significantly lower pressures of 200-580 MPa (about 8-20 km depth), within the lower crust to upper mantle. The crustal depths are interpreted as major intrusion levels where ascending magmas stagnate or move laterally before their eruption. The bimodality is attributed to fluid inclusions re-equilibrating to changing ambient pressures much faster than clinopyroxenes. The petrological data show that temporary stalling of magmas within the crust beneath Atlantic ocean islands is the rule rather than the exception.

This model is corroborated by seismic data from the submarine eruption of El Hierro that began on Oct. 10th, 2011 (data courtesy of Instituto Geográfico Nacional, Madrid, Spain). The eruption was preceded by three months of ground deformation and seismic unrest with most hypocenters being located beneath the island at 7-15 km depth. Three weeks before eruption the seismic foci migrated southward and increased in depth and magnitude. The data are best explained by emplacement of sills and filling-up of a lower crustal storage system, corresponding to the intrusion level reflected by fluid inclusions. Immediately after the eruption had begun, the seismic foci shifted to beneath the north of the island at 15-25 km depth, within the upper mantle. The cessation of crustal seismicity indicates that a stable magma pathway with lateral transport within the lower crust had been established. The subsequent strong seismicity in the mantle was most likely related to magma withdrawal from a reservoir system, and/or concomitant recharge from depth. This inferred reservoir system is consistent with data indicated by clinopyroxene-melt barometry. The observed seismicity at El Hierro thus confirms the suitability of geobarometric methods for the investigation of magma plumbing systems, and demonstrates the value of phenocrysts as recorders of pre- and syn-eruptive processes.