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Petrological evidence of magma storage, ascent and extrusion at Merapi volcano, Java, Indonesia

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Merapi is one of the most persistently active volcanoes in the world, which, throughout history has displayed both explosive and effusive activity. Over the last century, however, activity has mainly been dominated by the extrusion and subsequent gravitational collapse of basaltic andesite domes, producing block-and-ash flows (BAFs), as observed during the 2006 eruptive episode. This eruption began in April 2006, with the extrusion of a new lava dome. The peak of activity occurred on 14th June when BAFs travelled 7 km in the Gendol valley, resulting in two fatalities. Subsequent flows were emplaced, producing at least eight overlapping BAF deposits. Lower rates of dome extrusion and minor rockfall activity continued into 2007, after which, activity returned to background levels. The deposits of the 2006 eruption have previously been mapped [1] allowing for collection of a well-constrained and extensive set of juvenile products, spanning the entire eruption, including samples taken from the dome in August 2008 during ‘background’ activity.

Although whole rock XRF analysis of the 2006-08 eruptive products shows a narrow bulk composition (~55-56 wt.% SiO2), chemical and petrographic examination of mineral phases reveals evidence of a dynamic system. For example, plagioclase crystals often display sieve textures, resorption surfaces and compositional zonation, providing evidence of magma mixing and crustal assimilation. Generally, feldspar microlites consist of cores of elevated anorthite contents compared to the rims. However, microlites with very high-anorthite cores or with orthoclase-rich rims have also been discovered. Amphiboles are magnesiohastingsite in composition, with phenocrysts and microphenocrysts usually surrounded by reaction rims. These rims either consist of intergrown plagioclase, pyroxene and oxide crystals, formed as amphibole becomes unstable during magma ascent, or they are solely composed of oxide crystals, inferred to be formed via late-stage oxidation. Some amphibole microphenocrysts are less altered and display minimal breakdown textures. Amphibole thermobarometry suggests the existence of a magma storage region at between 9- 18 km depth, possibly extending to 22 km depth. Micro-textural and CSD analysis reveal differences in crystal population density between different phases of the eruption. For example, samples collected from the dome in 2008 display higher microlite abundance than products from the peak of the eruption. Differences are inferred to be related to differing extrusion rates and dome residence times. Clinopyroxene-hosted melt inclusions range in composition between 64 and 69 wt.% SiO2 and yield low totals, suggestive of volatile contents between 0.6 and 4.5 wt.%.

Comparison of these findings with petrological analysis of products from the more explosive 2010 eruption will help to understand better the processes that enable persistent and long-lived (dome-forming) activity at Merapi and identify parameters that may drive relative abrupt changes from effusive to explosive behaviour (and vice versa) as observed during the 2010 events.

[1] Charbonnier & Gertisser (2008) J. Volcanol. Geotherm. Res. 177, 971-982