Magma-crust interaction at Merapi volcano, Indonesia: geochemical insights into volcano behaviour

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Indonesian volcano Merapi, one of the most active volcanoes of the planet, is characterised by periods of dome growth and intermitted explosive events. Merapi currently degasses continuously through high temperature fumaroles (>500°C) and its recent eruptive activity is restricted to crystal-rich basaltic andesite lavas that carry a large range of igneous and meta-sedimentary xenoliths. To evaluate mechanisms that trigger intermitted explosive eruptions, we collected a large set of lava and xenolith samples, plus gas samples from active fumaroles.

Recent Merapi lava contains abundant complexly zoned plagioclase crystals. Crystals show variations in An content between 40 and 95 mol% across resorption surfaces. There appears to be a negative correlation between An content and other indicators of magmatic fractionation, such as MgO and FeO. In-situ Sr isotope analyses show Sr ratios of discrete zones in plagioclase that range from 0.70568 to 0.70627 (± 1). This range notably exceeds that seen in the recent host lavas (< 0.705737). Often, zones with the highest An content also have the highest radiogenic Sr values, and low MgO, indicative of a Ca-rich, MgO-poor, high radiogenic Sr contaminant. Xenoliths of metamorphosed limestone, 0.70584 to 0.70786 (± 2), contain compositionally identical feldspar of up to An95. The presence of these inclusions coupled with the Sr ratios observed in feldspar crystal zones, indicates that magma crust interaction is far more significant than previously thought. Moreover, high carbon isotope ratios of fumarole gases, coupled with low He isotope ratios, are consistent with a late-stage crustal volatile component in addition to purely mantle and slab-derived volatile sources, arguing in favour of extensive and ongoing magma-crust interaction beneath the volcano. This poses consequences for eruptive behaviour, volatile emission, mass-balance calculations, and hazard assessment at Merapi and similar island arc volcanic systems elsewhere, as such late volatile input could trigger explosive eruptions independently of magmatic recharge and fractionation by sudden over-pressurisation of the shallowest parts of the magma storage system.