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Contrasting estimates on the depth of magma storage zones in volcanic systems from mineral barometry and phase equilibrium experiments: a case study from Mount Merapi, Indonesia

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Mount Merapi, located in central Java, erupts on average every 5-10 years by discharging block-and-ash flows that pose local, but spatially restricted hazards. In 2010, however, the volcano erupted with a force that has been unprecedented in over 100 years. Its proximity to the metropolis of Yogyakarta with a population of >4 million makes short- and long-term eruption forecasting a task of vital importance. Critical to the appraisal of the volcano's hazard potential are tight constraints on its upper-crustal magma plumbing system and particularly on the location of its pre-eruptive reservoir. Previous petrological studies have estimated on the basis of amphibole and clinopyroxene barometry that the main magma storage zone below Merapi is located at depths of >10-15 km, while geophysical surveys have inferred significant magma storage zones at depths of ∼5.5-9 km. We have carried out phase equilibrium experiments on basaltic andesite erupted in 2010, which indicate that the main pre-eruptive reservoir is located at a depth of ∼7-8 km (∼200 MPa). Our results thus corroborate the findings of earlier geophysical surveys and highlight the extreme uncertainty of mineral-based pressure estimates for volcanic magma systems. We point out that the commonly employed amphibole barometric calibrations of Ridolfi et al. (2010) and Ridolfi & Renzulli (2012) calculate low crystallization pressure for amphibole crystallized from felsic melt and high crystallization pressure for amphibole crystallized from mafic melt, and that the calculated pressure is thus largely unrelated to true values. Commonly employed clinopyroxene barometers (e.g., those of Nimis 1999; Putirka 2008) are also of limited use for estimating the location of crustal magma reservoirs, because the methods have large standard errors and are extremely temperature-sensitive. As a result, the calculated crystallization pressures inevitably indicate crystallization over a large range of depths, often from deep- to upper-crustal levels. We emphasise the limited use of such estimates and their bias to generate method-driven models of crustal magma systems, which should not influence the assessment of hazards at individual volcanoes or our image of the character of crustal magma plumbing systems.