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Identifying volcanoes with increased likelihood of large magnitude eruptions from the geochemical record

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Large magnitude eruptions, classified with VEI-7 (Volcanic Explosivity Index), recur on average once or twice every millennium, therefore posing a significant global catastrophic risk. However, with over 1400 potentially active volcanoes worldwide, identifying those systems capable of producing cataclysmic events in the future remains a major challenge. Geophysical tomography has revealed ubiquitous anomalies in the crustal roots of volcanoes, but mostly comprised of non-eruptible magma. While this could mean that there is at present low risk from a large magnitude eruption, petrological evidence suggests that melts may amalgamate and mobilise over short timescales, challenging long-term eruption forecasting using geophysical imaging. Nevertheless, short-term unrest signals such as increased seismicity can be expected to herald large eruptions, which requires to concentrate monitoring efforts at selected volcanoes with increased likelihood of such events.

In this presentation I will show that the geochemical diversity of arc volcanoes reflects the likelihood of large magnitude eruptions. Bulk-rock compositions have been compiled and analysed for 54 volcanic systems in convergent margin settings with well constrained eruptive history. To quantify the compositional spread of each volcano, the 95th percentile range (R95) of the bulk-rock SiO_2 (wt.%) distribution was calculated. Independent of sample size, spatial extent of sampling, and volcano lifespan, caldera volcanoes show greater diversity in erupted compositions (R95 of SiO_2 = 17-28 wt.%) compared to stratovolcanoes (R95 of SiO_2 = 5-20 wt.% SiO_2) with 90% confidence interval. These differences cannot be attributed to stress field changes during caldera-formation, as high magma diversity is already observed in the pre-caldera stage for five out of six systems. Thermobarometry and thermal modelling of stochastic magma injection shows that differences in crustal magma flux result in a dependency between compositional variability and magmatic systems size that is consistent with the observations. This suggests that the geochemical diversity of erupted rocks should be included as a criterion to assess volcanic disaster risk, allowing to identify volcanoes with increased likelihood of producing large magnitude eruptions that have previously not been recognized.