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Unravelling complex fluid-rock interactions at elevated pressure and temperature using a novel flow-through hydrothermal reactor

JAMIE I. FARQUHARSON[1], KYOKO S. KATAOKA[1] AND TAKUMI IMURA[2]

[1]Niigata University
[2]Yamagata University

Fluid-rock interactions are ubiquitous in volcanic systems and can contribute to numerous geohazards, including edifice destabilisation, pressurisation, and explosive eruptive activity. Adatarayama volcano in Fukushima Prefecture (Japan) is home to multiple complex hydrothermal processes, broadly divided across four alteration zones. Operative reactive processes include pyrite alteration, the formation of clays, silica redistribution, and precipitation of sulfates and other minerals. Intriguingly, evidence for low-temperature hydrothermal alteration is found in direct contact with zones of extreme high-temperature alteration, highlighting that the reaction conditions (pressure-temperature-composition: PTX) are highly spatially and temporally variable. Through a series of batch reaction experiments and hydrothermal flow-through experiments at elevated temperatures (up to ~150 °C) and pressures (up to 70 MPa), we can "reverse engineer" some of the diverse alteration textures observed in the field. In turn, this allows us to map out the PTX parameter space dominating the different alteration zones, and gives insight into volcanic hazards at Adatarayama—a volcano characterised by cycles of phreatic and magmatic explosive activity, but not by extensive collapse events akin to the neighbouring Bandai volcano. The novel flow-through apparatus designed for this research comprises a pressure vessel encased in a custom-fabricated heating mantle. A combination of precision fluid pumps allows the delivery of hydrothermal fluids (e.g. sulfuric acid) through nominally pristine volcanic materials. Ultrasonic sensors allow us to track flowrate and permeability changes over time, providing insight into pressure generation or dissipation mechanisms in the volcanic setting as a function of geochemical processes. In concert with extensive geochemical characterisation, field surveying, and reactive modelling, these experiments form part of a larger effort to understand the nature of the hydrothermal system at Adatarayama, and fluid–rock interactions more generally.