Phreatomagmatic Ash as a Natural Drill Core: Unraveling Subvolcanic Hydrothermal Systems in Active Arc Volcanoes

Muhammad Andriansyah Gurusinga[1,2,4], Tsukasa Ohba[2], Takashi Hoshide[2], Wildan Nur Hamzah[2], Gabriela Nogo Retnaningtyas Bunga Naen[1], Indranova Suhendro[5,6], Dini Nurfiani[3], Aoi Hirata[2]
[1]Center for Regional Revitalization in Research and Education, Akita University, Japan, [2]Department of Earth Resource Science, Akita University, Japan, [3]Research Center for Geological Disaster, National Research and Innovation Agency of the Republic of Indonesia (BRIN), Indonesia, [4]Department of Geological Engineering, Faculty of Mineral Technology, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Indonesia, [5]Department of Environmental Geography, Faculty of Geography, Universitas Gadjah Mada, Indonesia, [6]Center for Disaster Studies (PSBA), Universitas Gadjah Mada, Indonesia

Active arc volcanoes host dynamic hydrothermal systems that exhibit alteration processes similar to those in porphyry-epithermal ore environments. Phreatomagmatic eruptions—driven by magma-water interaction—can excavate material from depths reaching hundreds of meters to ~2 km, in contrast to the shallower origins of phreatic eruptions. These events eject lithic fragments from active alteration zones, providing a unique opportunity to investigate subvolcanic hydrothermal processes and fluid-rock interactions. This study analyzes altered lithic fragments from Bromo and Ciremai volcanoes (Indonesia), supplemented by comparative data from the Akita Yakeyama and Chokai volcanoes (Japan). The samples are characterized using petrography, componentry, SEM-EDS, and X-ray diffraction (XRD) to identify and characterize the alteration textures and assemblages.

The results reveal three distinct alteration regimes: [1] Ciremai samples are dominated by alunite (SO_3 ~45 wt%), silicate-rich (SiO2 ~ 97.7 wt%) assemblages, kaolinite-group minerals, irregular to laminated pyrite, and rare copper oxide grains observed (30.85% in isolated particles). The Akita Yakeyama 1997 samples exhibit similar quartz-alunite-kaolinite associations. Both indicate high-sulfidation conditions under acidic, steam-heated regimes. [2] Chokai samples are characterized by smectite and pyrophyllite dominance, reflecting intermediate argillic alteration at near-neutral pH conditions. [3] Bromo samples feature Mg-Fe phyllosilicates (chlorite with MgO ~23.4 wt%, illite with K_2O ~5.45 wt%), Fe-Ti oxides (magnetite, ilmenite with TiO_2 ~70.5 wt%), and Zinc enrichment (ZnO ~ 2.8 wt%). This assemblage suggests higher-temperature alteration compared to the acidic systems in Ciremai and Akita Yakeyama.

The distinct alteration assemblages on Ciremai - Akita Yakeyama, Chokai, and Bromo indicate different hydrothermal conditions beneath these arc volcanoes. Ongoing investigations on additional Indonesian (Marapi, Lewotobi, and Ruang) and Japanese (Aso) volcanoes will integrate altered/juvenile particle ratios, mineralogical fingerprints, and host magma characteristics to advance our understanding of how modern hydrothermal systems develop in arc settings, with implications for both volcanic hazards and the fundamental ore-forming systems.