Micro- to arc-scale geochemical evaluation of plutonic-volcanic records across the Sunda-Banda Arc

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‘We use **micro- to macro-scale geochemistry** and **geodynamics** to evaluate the **copper accumulation potential** of **Sunda-Banda Arc** by analyzing the **crystal cargo** and **matrix** of **porphyry deposits** vs. **active volcanoes**’

Introduction

Copper (Cu) is a critical metal with a wide range of applications in ‘green’ technology. Copper is a key component of solar panels, electric vehicles, and wind turbines. The high demand for Cu means there will be a **supply deficit of 30% by 2035** [1]. Declining ore grades alongside the high demands means we need to find **new targets for Cu exploration**.

The **Sunda-Banda arc (Fig. 1)** have a high potential to host **economic porphyry Cu deposits** [2,3]. However, the Sunda-Banda arc also host **83 active volcanoes** [4]. Factors that lead to Cu accumulation in porphyry deposits vs. volcanic eruptions are not well understood. Recent geophysical and geochemical evidence suggests **slab tearing** may yield **anomalous magmas** associated to Cu accumulation [5].

Here we aim to evaluate **the geochemical, petrological,** and **geodynamic factors** that contribute to the **Cu accumulation potential** of magmas along the arc.

Project Questions

1.What do the crystal cargo tell us about the magmatic processes occurring in porphyry Cu deposits vs. volcanoes?

2. How can we differentiate between the processes leading to anomalous geochemistry among volcanoes and porphyry Cu deposits?

Approach

We evaluate the Cu accumulation potential of the Sunda-Banda arc magmas by:

1. Evaluating arc-scale magmatic records e.g. crystals and matrix from active volcanoes vs. porphyry deposits along the arc.

2. New micro-scale analyses of matrix and crystal cargo e.g. pyroxene, plagioclase from depth of volcanoes along the arc and porphyry copper deposits.

3. Infer the chemical signatures and magmatic factors driving Cu accumulation in porphyry deposits vs. eruption triggers for volcanoes.

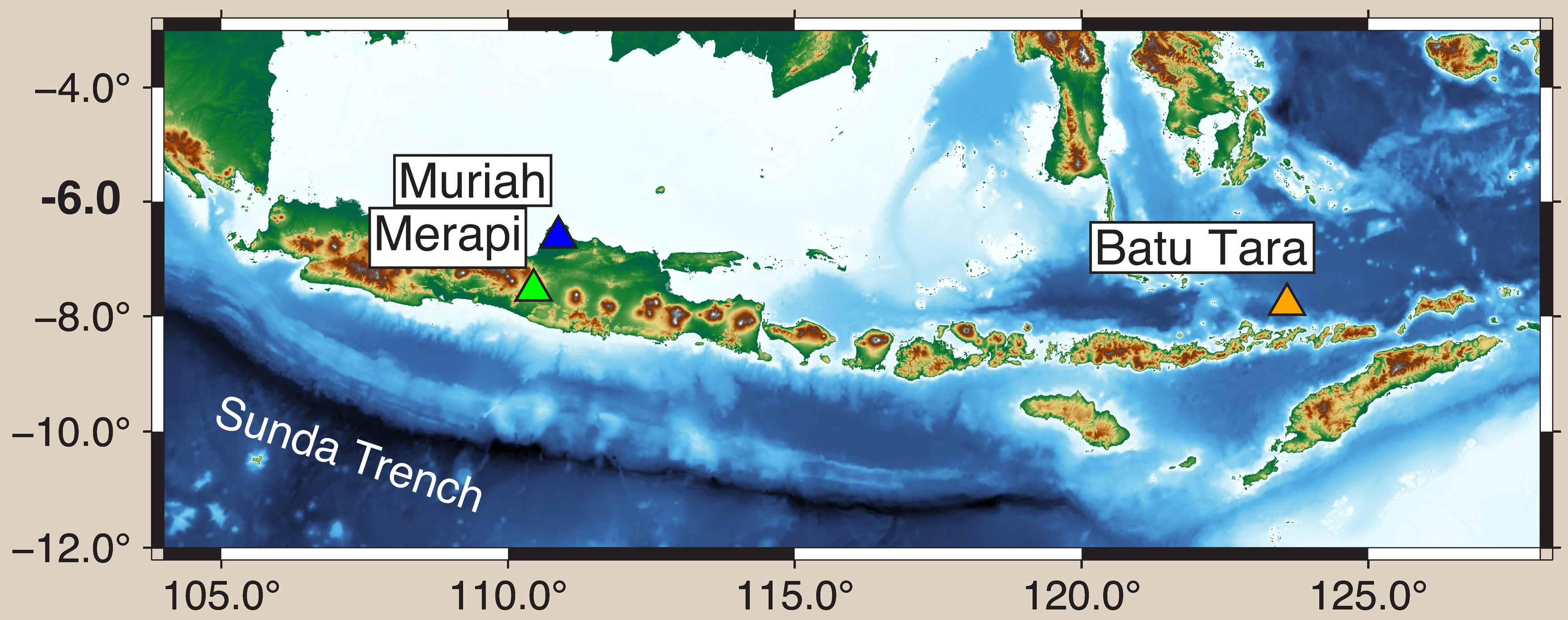

Figure 1: Map the Sunda-Banda arcs, with the volcanoes sampled in this study highlighted: Merapi (green), Muriah (blue), and Batu Tara (orange). Merapi is located in the main arc, whereas Muriah and Batu Tara are located above a deepening subducting slab.

1. Merapi, Muriah, and Batu Tara matrix chemistry

Here Muriah and Batu Tara represent the anomalous alkaline end-member volcanoes in the Sunda-Banda arc, whereas Merapi is their calc-alkaline counterpart.

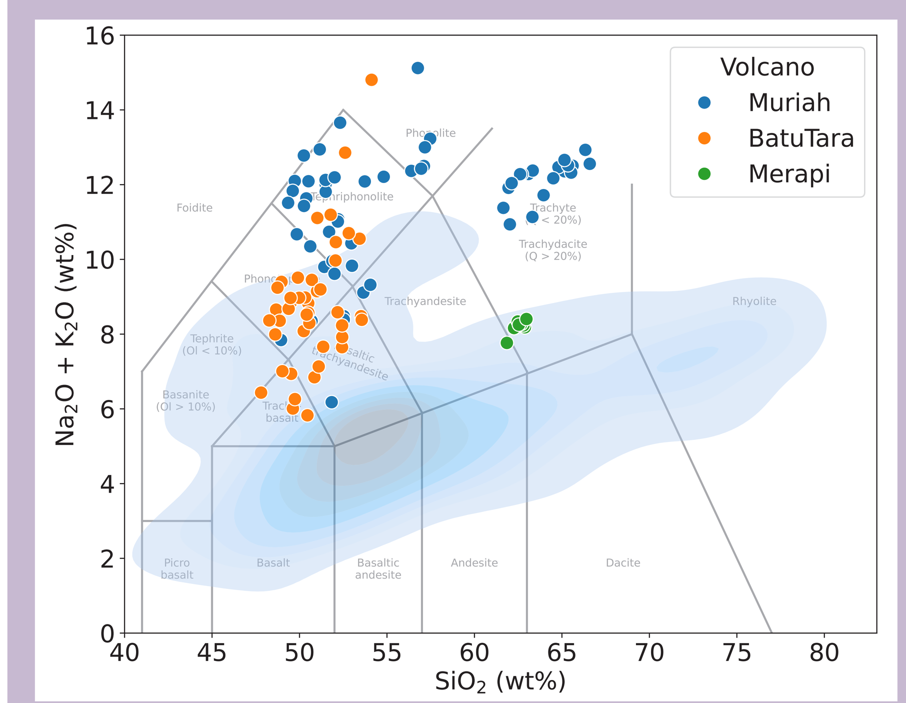

Figure 2: Silica vs. total alkali content of matrix compositions from Muriah [4], Batu Tara [5], and Merapi. The blue region represents the compiled and curated whole rock compositions taken from GEOROC [6].

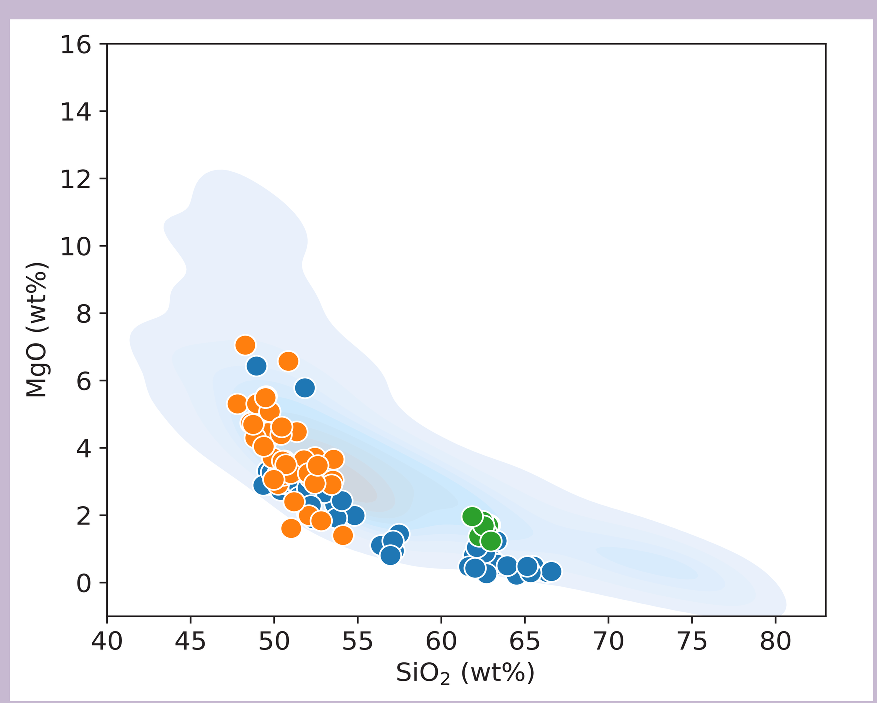

Figure 3: Silica vs. magnesium oxide content of matrix compositions from Muriah [4], Batu Tara [5], and Merapi. The blue region represents the compiled and curated whole rock compositions taken from GEOROC [6].

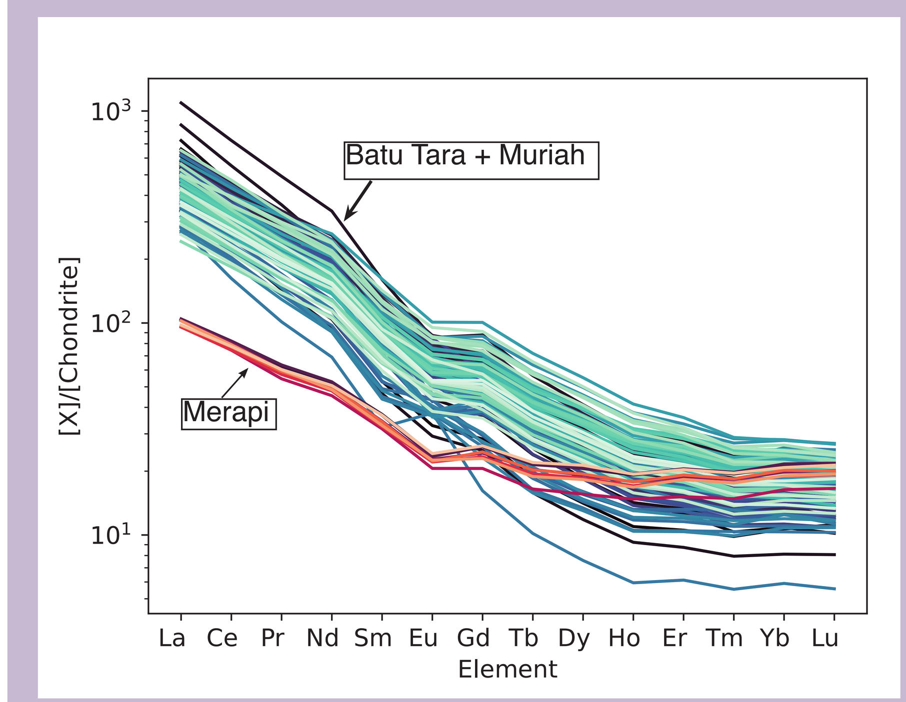

Figure 4: Chondrite-normalized Rare Earth Elements (REE) of matrix compositions from Muriah [4], Batu Tara [5], and Merapi, relative to the Indonesian arc. The chondrite composition are taken from McDonough and Sun (1995) [7].

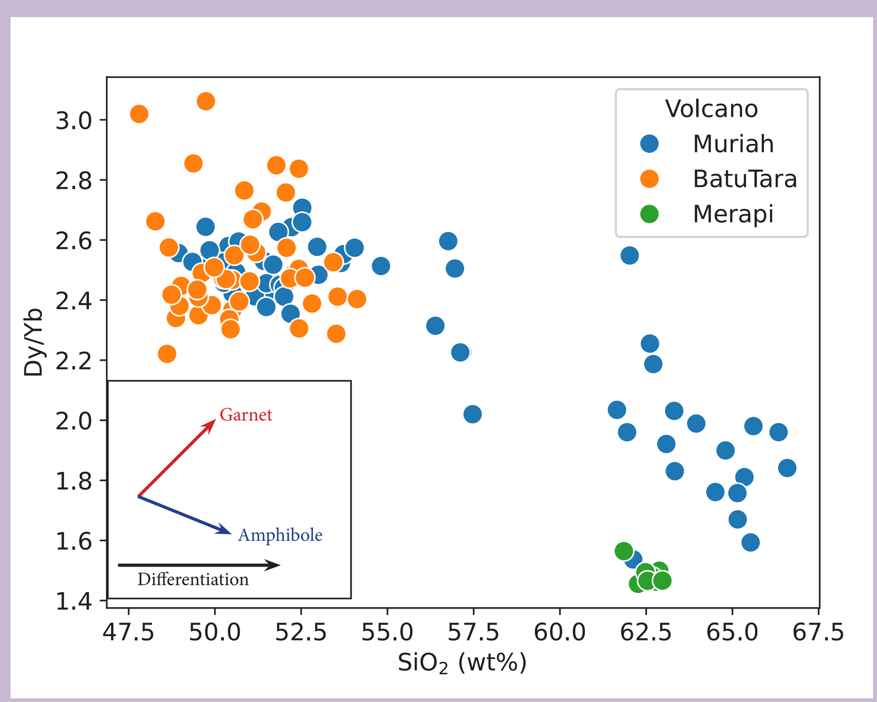

Figure 5: Silica content vs. Dy/Yb of matrix compositions from Muriah [4], Batu Tara [5], and Merapi. Inset shows the general trend corresponding to differentiation, amphibole fractionation, and garnet fractionation along according to Davidson et al. (2007) [8].

2. Along-arc magmatic variations based on matrix geochemistry

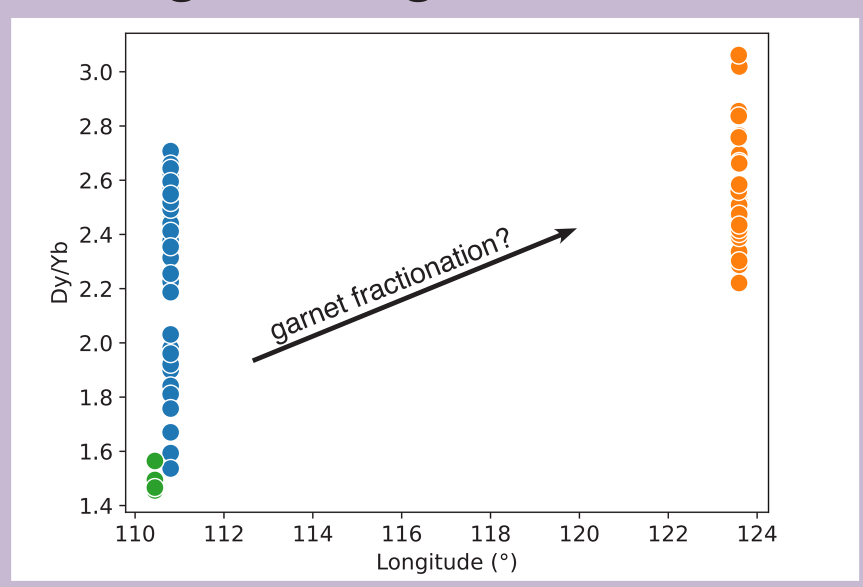

Figure 6: Longitude vs. Dy/Yb of matrix compositions from Muriah [4], Batu Tara [5], and Merapi, representing the indices of mineral fractionation from Davidson et al. (2007) [8].

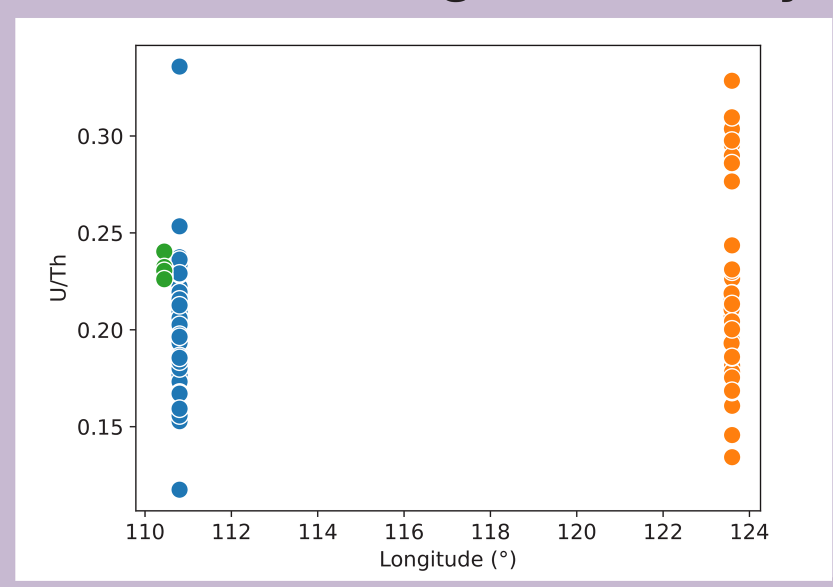

Figure 7: Longitude vs. U/Th of matrix compositions from Muriah [4], Batu Tara [5], and Merapi, representing the influence of fluids released from the downgoing slab.

3. Magma storage conditions under Merapi, Muriah, and Batu Tara

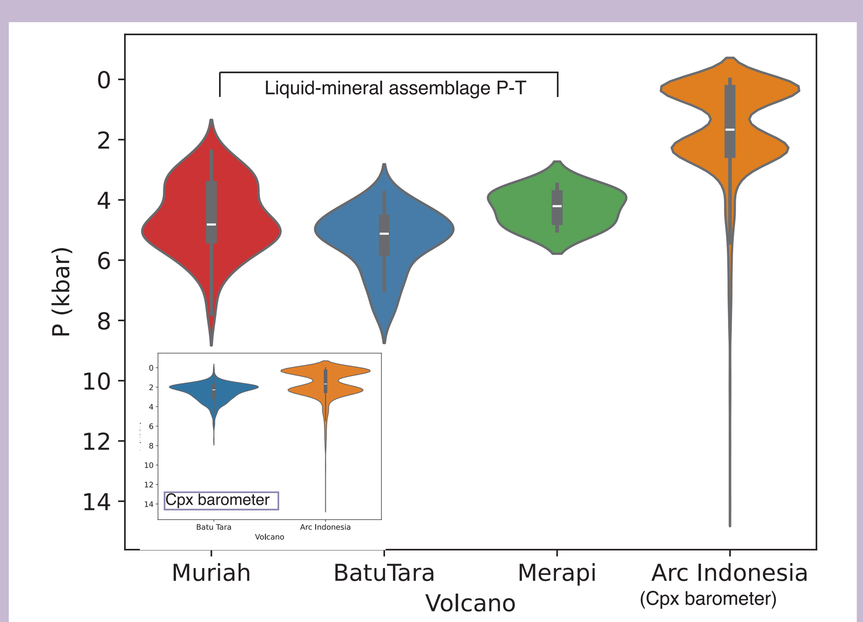

Figure 8: Violin plots of pressure estimates from Muriah [4], Batu Tara [5], and Merapi compared to the Indonesian arc. The storage pressures for Muriah, Batu Tara, and Merapi were estimated using the liquid - mineral assemblage thermobarometer by [9] (using experiments with at least 1 mineral in equilibrium with the liquid). Pressures from clinopyroxene were estimated using a machine learning clinopyroxene barometer [10].

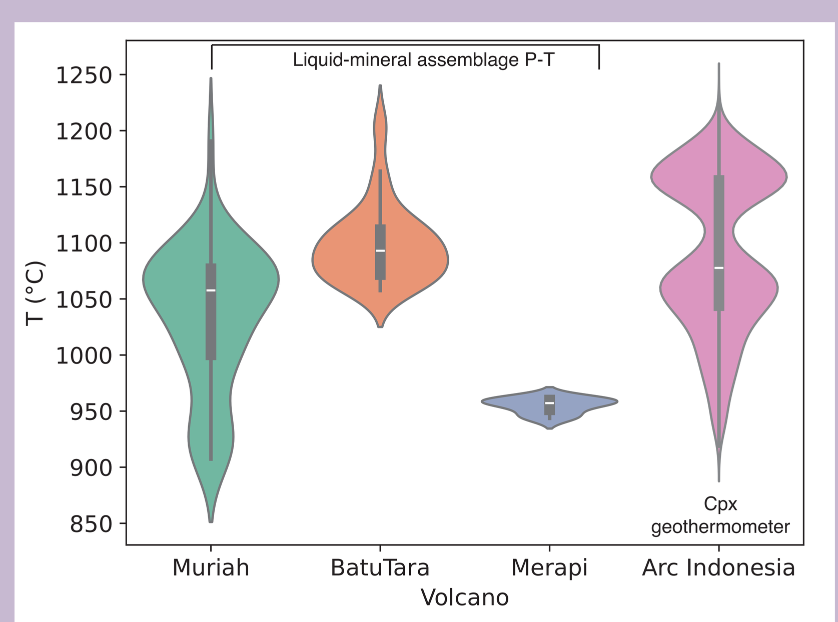

Figure 9: Violin plots of temperature estimates from Muriah [4], Batu Tara [5], and Merapi compared to the Indonesian arc. The temperatures for Muriah, Batu Tara, and Merapi were estimated using the liquid - mineral assemblage thermobarometer by [9] (using experiments with at least 1 mineral in equilibrium with the liquid). Temperatures from clinopyroxene were estimated using a machine learning clinopyroxene barometer [10].

4. Preliminary insights

Major element indicators show evidence of magma differentiation and increasing alkalinity (Figs. 2-3). The REE patterns of Merapi are distinct from both Batu Tara and Muriah, but all share the negative slope (Fig. 4). Elemental ratio Dy/Yb show garnet (Muriah + BT) and amphibole (Muriah + Merapi) fractionation (Fig. 5). Along-arc variations increase in Dy/Yb from Merapi/Muriah to Batu Tara, despite receiving comparable fluid input (Figs. 6-7). Storage conditions are comparable between the three volcanoes (Fig. 8). Temperatures for Muriah and Batu Tara are comparable, but overall indicate higher P-T of storage than Merapi (Fig. 9).

Next Steps

A sampling campaign is planned to visit Sangeang Api, Tambora, and poprhyry copper deposits around Sumbawa. This will complete our suite of samples for further analyses. We plan to use state-of-the-art micro-analytical techniques to characterize our samples, including LA-ICP-MS mapping of crystals and groundmass [11], geochemical and isotopic characterization with EPMA [12], and magma storage condition estimation of the new samples using the latest software e.g. Thermobar [13]. The aim is to distinguish the magmatic drivers of Cu accumulation vs. eruption triggers along the Sunda-Banda Arc.

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