Magmatic Plagioclase as a Porphyry Copper Fertility Indicator in Arc Systems

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Subduction zones host not only Earth's most hazardous volcanoes but also its largest porphyry copper deposits, which supply ~75% of global copper production. Both the formation of porphyry deposits and volcanic eruptions are linked to magmatic processes within the arc. However, it remains unclear why magma sometimes erupts, sometimes stalls and contributes to crustal growth, or in other cases drives the formation of economic mineralisation.

The Andes hosts some of the world's largest porphyry copper deposits, along with complex volcanic structures. Our study targets three key components of the Andean arc: porphyry Cu-Mo deposits (El Teniente), barren intrusions (within El Teniente district, Central Chile, and global datasets), and a diverse suite of Central Andean volcanoes (stratovolcanoes, cones, and volcanic fields). We analyse magmatic plagioclase—the most common mineral in arc magmas—using novel in-situ microanalytical techniques. We measured major and trace elements, as well as Sr isotopes, using electron microprobe and LA-ICP-MS (quadrupole and multicollector), and assessed textures with petrographic microscopy and X-ray Fluorescence Microscopy.

Our results reveal chemical and textural similarities between plagioclase from mineralised porphyries and volcanoes located in tectonically anomalous segments of the arc. Porphyry-related plagioclase displays dominant oligoclase–andesine compositions, sharp Sr increases with minor Fe variations, and a decoupled relationship between An and Sr. In contrast, crystals from barren intrusions and volcanoes along the main arc show dominant labradorite compositions, typical of arc settings, and Sr–Fe trends indicative of mafic magma recharge. These findings show that the magma sources and processes involved in porphyry formation—likely influenced by subduction geometry and crustal structure—share similarities with those in certain anomalous Andean volcanoes and may also be crucial in metal accumulation. This new approach highlights plagioclase as a key mineral for identifying fertile magmatic systems in active arcs, with direct applications in future mineral exploration.