

**Geochemical and Petrographic Investigation of Copper Mineralization in the Kohistan Island Arc: Insights into Subduction Zone Magmatism and Ore Genesis**

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Copper mineralization in the Kohistan Island Arc (KIA), located in Upper Dir, Pakistan, which is positioned in northwest Himalayas. Field observations, petrographic analysis, and geochemical data helped in understanding copper mineralization and the effects with subduction-induced magmatic events through SiO<sub>2</sub> vs. FeOt/MgO plot. Petrographic analyzes gave evidence of porphyritic texture with phenocrysts of quartz and plagioclase encased into iron oxide (e.g., limonite and hematite) and secondary copper minerals such as malachite and azurite. These features indicate the hydrothermal activity at the later stages of volcanic systems related to subduction. XRF and atomic absorption spectroscopy determined a mafic composition based on SiO<sub>2</sub> ranging from 42.01 to 46.53%; Al<sub>2</sub>O<sub>3</sub> from 15.82 to 20.02%; and CuO from 10.89 to 14.92%. Other noteworthy constituents are: Fe<sub>2</sub>O<sub>3</sub> 4.98–7.28%, K<sub>2</sub>O (~3.5%), Na<sub>2</sub>O (~2.5%), and 5.23%–5.13% loss on ignition, signifying the involvement of volatiles in mineralization. The ternary (10P<sub>2</sub>O<sub>5</sub>-TiO<sub>2</sub>-10MnO) diagrams suggested also a geochemical association with alkali basalts from oceanic islands. Total Alkali-Silica (TAS) diagrams identified most samples in the tephrite-basanite category, with a small percentage in the trachy-basalt field, showing a wide range of subduction-related magmatic processes. The latter, particularly the triangular (10Mn-TiO<sub>2</sub>-10P<sub>2</sub>O<sub>5</sub>) and the R1-R2 plots provide evidence for an oceanic island-arc like source consistent with a late-orogenic magmatic phase. Samples plotted in the SiO<sub>2</sub> vs. FeOt/MgO diagram demonstrated a tholeiitic trend consistent with the character of mantle-derived mafic magmas generated in a subduction-zone environment. These discoveries give a perspective on the tectonic and magmatic relations resulting in copper mineralization in island arc systems, and present a template for future exploration in such settings.

**Keywords:** Petrography; Upper Dir; mafic magmas; geochemistry