

From Orogeny to Ore: Highly Enriched Lithium Pegmatites of Northwestern Pakistan

Kashif Shamsher¹, Tadeusz Przylibski¹, Norbert Zajzon²

¹Wrocław University of Science and Technology, Wrocław, Poland, ²Miskolc University, Miskolc, Hungary

Lithium-bearing granitic pegmatites are a major source of lithium for the global energy transition, yet large parts of the Himalayan orogenic belt remain poorly explored for critical metals. This study presents new petrographic and geochemical data from highly enriched lithium pegmatites in the northwestern Himalayas of Pakistan, focusing on their internal zonation, mineralogical characteristics, and geochemical signatures.

The studied pegmatites occur as lensoidal to tabular bodies intruding high-grade metamorphic rocks and granitoids of the Nanga Parbat–Haramosh Massif. Distinct internal zonation is observed. The pegmatite cores are dominated by aplitic to fine-grained textures and host the highest lithium concentrations. In contrast, the border and wall zones exhibit typical coarse-grained pegmatitic textures with quartz and feldspar, locally accompanied by radiating tourmaline crystals. Petrographic observations indicate that lithium mineralization is predominantly hosted by lepidolite within the fine-grained core zones, while spodumene occurs only as a minor phase. Trace amounts of topaz are also present in the core, suggesting a highly evolved and fluorine-rich system.

Whole-rock geochemistry indicates significant fluorine enrichment, with concentrations ranging from approximately 9 to 11 wt%. ICP-MS analyses reveal exceptionally high lithium concentrations of ~10,000 to 20,000 ppm. The samples also show enrichment in incompatible elements such as Rb, Cs, and Ta, reflecting advanced magmatic fractionation. Elevated fluorine contents suggest that volatile-rich melts and fluids played a key role in enhancing lithium solubility and stabilizing lepidolite during late-stage crystallization.

These characteristics are consistent with highly evolved peraluminous LCT-type (Li-Cs-Ta) pegmatite systems. This study highlights the significant but underrecognized potential of northwestern Pakistan for critical metal exploration and provides new insights into lithium enrichment processes in Himalayan collisional settings.