

Integrated Hyperspectral Imaging and Geochemical Characterization of LCT Pegmatites Hosting Critical Mineral Deposits in Collision Orogen

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Pegmatites in Shigar Valley (Kohistan Island Arc–Eurasian Plate boundary) represent a significant but underexplored source of Li–Cs–Ta (LCT) mineralization in a collisional orogenic setting. Hosted within the Dassu Orthogneiss, these sub-horizontal bodies exhibit distinct internal zoning. Their coarse-grained core zones represent significant potential LCT mineralization.

A field campaign was conducted across Shigar Valley to investigate the occurrence and evolution of LCT-type mineralization. The pegmatites contain coarse crystals of quartz, feldspar, schorl, muscovite and lepidolite, while associated leucogranites contain quartz, tourmaline, biotite, muscovite, and albite feldspar. Laboratory hyperspectral imaging in the VNIR, SWIR, and LWIR ranges were used to identify mineral phases in hand samples. Lithological variations were mapped using PRISMA hyperspectral data and delineate pegmatite zones based on diagnostic absorption features near ~2190–2206 nm and ~2330–2340 nm associated with muscovite and lepidolite.

Geochemical results indicate progressive magmatic differentiation within the pegmatite system. Highly fractionated pegmatites show elevated Rb, Ta, Sn and Li (0.5–2.14 wt%) concentrations. Low Nb/Ta ratios (<0.5) and low K/Rb ratios (<30–100) indicate advanced fractionation consistent with rare-metal–fertile LCT pegmatites derived from syn-collisional granitic sources. Lepidolite is identified as the primary lithium-bearing mineral based on characteristic SWIR spectra, while tourmaline indicates boron-bearing magmatic fluids. Samples with elevated Ta but limited Li represent intermediate crystallization stages prior to lithium saturation, reflecting decoupled enrichment of Ta and Li during pegmatite evolution. Feldspar and clay minerals identified in hyperspectral spectra indicate subsolidus hydrothermal alteration caused by late-stage low-temperature fluids.

Hyperspectral mapping shows pegmatites are concentrated north of the Main Karakoram Thrust, whereas hydrothermal alteration and metallic mineralization are more prominent south of the valley. This approach demonstrates that integrated hyperspectral and geochemical analysis is a powerful tool for mapping rare-metal fertile pegmatite systems and constraining their magmatic–hydrothermal evolution in complex orogenic settings.