Advanced Mineralogical, Spectral, and Geochemical Tools for Locating Upflow Zones and Mineralization in the Lithocap Environment

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Lithocaps are extensive domains of hypogene silicic, advanced argillic, and argillic altered rocks that develop between the paleosurface and shallow crustal intrusive complexes. They may host high sulfidation mineralization in breccias, veins, or as disseminations in silicic and advanced argillic alteration zones above porphyry intrusions. These high sulfidation mineralization can also be superimposed on earlier-formed porphyries in regions affected by rapid uplift and exhumation. However, their large volumes, complex mineralogy, and poorly defined alteration zonation make exploration particularly challenging.

Previous research (e.g., Chang et al., 2011) developed geological and geochemical vectoring tools based on field geology, whole-rock geochemistry, alunite spectral features, and alunite chemistry, to assist in identifying upflow zones and/or mineralized centers. Despite these advances, significant challenges remain in tracing hydrothermal fluid pathways and estimating the depth to underlying porphyry intrusions.

Recent work, using a combination of high-resolution short-wave infrared (SWIR) spectroscopy, scanning electron microscopy (SEM), cathodoluminescence (CL), and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) mineral chemistry, distinct mineralogical assemblages and textural features, we have identified, documented, and characterized upflow zones in several deposits worldwide. These zones are characterized by high-temperature advanced argillic alteration assemblages, containing abundant zunyite, topaz, diaspore, pyrophyllite, white mica, aluminium-phosphate-sulfate (APS) minerals, and rutile. Their mineralogical zoning, textures, and mineral chemistry provide key insights into fluid directionality and proximity to porphyry centers, and have proven to be reliable indicators of hydrothermal fluid feeder zones. By integrating these datasets, we have developed and refined new exploration tools that enable the identification and prioritization of epithermal and porphyry targets both within and beneath lithocaps. These tools offer a more predictive framework for mineral exploration in complex terrains and improve the likelihood of discovering concealed porphyry mineralization.