Application of alteration facies and infrared spectroscopy (IRS) in structural geology analyses

Alteration features can provide important clues to decipher the sense and amount of displacement in a fault during ore emplacement, and thereby optimize exploration strategies to target structurally favourable zones. This contribution emphasizes the use of infrared spectroscopy (IRS), and specifically point analyses of outcrops and mine exposures to incorporate invisible alteration information in the analysis of structural controls on epithermal mineralization.

In a practical sense, hydrothermal alteration form two groups:

1. Visible alteration features currently require expert identification of diagnostic facies in outcrop, drill core, or mine exposures. In the epithermal environment they include features such as paleosurface indicators, paleowater table, and steam heated silicification facies. The recognition of contrasting visibly recognizable paleodepth alteration indicators on opposite sides of a fault can provide an estimate of fault displacement magnitudes.

2. Invisible alteration features include a wide variety of data obtained through ground or remote sensing analytical methods such as IRS, geochemical analyses, and various geophysical techniques. These alteration data can be more efficiently digested by a data scientist than by a field geoscientist, if sound geological concepts and models are incorporated into the data sampling program.

Neither of the two groups provides a flawless methodology that can be applied to all epithermal deposits and prospects. Instead, the most robust input into structural geology analyses rests in a combination of visible and invisible alteration features.

Whereas the most widespread use of point IRS analyses consists of the identification of mineral species, the greatest value to structural geologists lies in batch extractions of semi-quantitative and qualitative spectral parameters that are independent of mineral identifications. Specifically, high sericite and to a lesser degree, high kaolinite crystallinity indices highlight faults that were active during hydrothermal events, albeit these faults may only be mineralized along segments that constitute structural or chemical traps. The presence of ammonium in spectra, regardless of its host mineral, is known to represent barren paleosurface alteration, yet where the ammonium is structurally trapped, it highlights high permeability zones. In certain cases, the juxtaposition of incompatible spectral features on opposite sides of a fault can provide information on post-mineralization displacement sense and magnitude.

Despite yielding semi-quantitative data, field-based point IRS data collection has important practical advantages over quantitative methods such as portable XRF. Namely, IRS instruments do not pose health hazards, and therefore lack transport and use restrictions. Relative to remote sensed ASTER or Worldview-2/3 data, point IRS has the advantages of providing higher spectral resolution data and not impacted by the atmosphere. Additionally, the method has low sensitivity to cross-sample contamination, and requires no sample preparation.

One of the main limitations of IRS lies on the arduous labour required to distinguish hydrothermal from metamorphic alteration features, rendering IRS application more arduous in older mineralized belts, where post-mineral orogenesis may have imbricated phyllosilicates of different origins.

To illustrate the method, I contrast successful and unsuccessful structural geology applications of ground-based visible alteration and point data IRS in epithermal deposits that underwent significantly different tectonic evolutions. Cenozoic deposits of the Mexican backbone emplaced after the Laramide/Sevier compression are contrasted to Permian deposits of the Angren District of Uzbekistan, which were affected by the Mesozoic deformation that assembled the Central Asian Orogenic Belt.