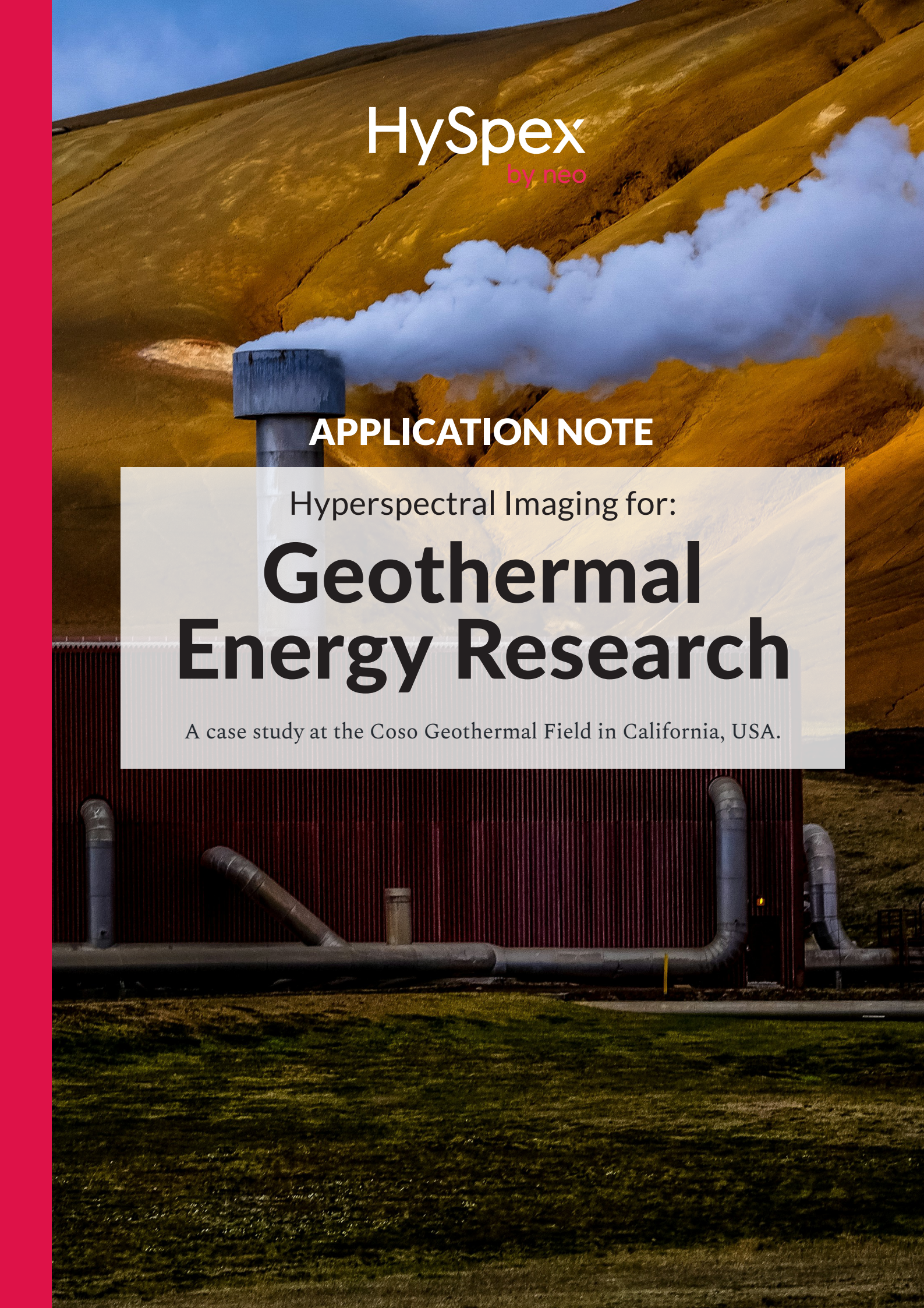




HySpex
by neo

APPLICATION NOTE

Hyperspectral Imaging for:

Geothermal Energy Research

A case study at the Coso Geothermal Field in California, USA.



Geothermal energy represents a sustainable and low-emission alternative to fossil fuels, but its development hinges on accurately mapping subsurface geological features.

Advanced hyperspectral imaging in the short-wave infrared (SWIR) wavelength can be used to identify alteration minerals in geothermal systems, providing actionable insights for exploration and development.

Revealing the Subsurface Through Hyperspectral Imaging

Hyperspectral imaging, which captures detailed spectral data across a wide range of wavelengths, has proven particularly effective in geothermal studies. In the SWIR range (1300–2500 nm), the technology can identify key alteration minerals such as smectite, illite, chlorite, and other clays that serve as indicators of thermal gradients and fluid pathways. These minerals are critical for understanding subsurface temperature distribution and permeability, both essential factors in assessing geothermal potential.

A recent study at the Coso Geothermal Field in California was carried out within the Center to Advance the Science of Exploration to Reclamation in Mining (CASERM) at Colorado School of Mines, which is supported by the Industry-University Cooperative Research Centers program of the National Science Foundation. The study highlighted the power of SWIR hyperspectral imaging in geothermal exploration.

The Coso Geothermal Field, one of the largest geothermal power sources in the United States, has a history of volcanic activity that has left a complex geological footprint.

A HySpex hyperspectral SWIR-384 camera was used to analyze drill chips from five drill holes, generating a detailed downhole map of alteration mineralogy and thermal gradients (Al-Attar, 2024).



Figure 1: A HySpex Classic SWIR-384 camera.

Mapping Alteration Zones and Thermal Gradients

Alteration minerals form as hot geothermal fluids interact with surrounding rocks, leaving behind distinct mineral assemblages that vary with temperature and fluid chemistry. Smectite, for example, is stable at temperatures up to 180°C, whereas illite forms at higher temperatures, often exceeding 225°C.

By identifying the spatial distribution of these minerals, hyperspectral imaging provides a proxy for subsurface temperature gradients. At the Coso Geothermal Field, this approach revealed a complex distributions of alteration minerals, suggesting multiple hydrothermal events and offering clues about the system's thermal history.

Enhancing Geothermal Exploration Efficiency

For geothermal companies, hyperspectral imaging delivers several advantages. The SWIR range excels at detecting molecular bonds (e.g., OH, H₂O, AlOH, MgOH) that define many alteration minerals (Figure 2). This capability enables rapid, accurate mineral identification,

even in mixed assemblages. In the Coso study, researchers used a HySpex SWIR-384 scanner with Prediktera Breeze Geo software to scan and analyze drill chips (Figure 3). Mineral identification used the USGS PRISM MICA routines providing objective classification of SWIR-active alteration minerals (Kokaly, 2011; Kokaly et al., 2017).

This streamlined workflow enables operators to:

- ◆ Quickly identify alteration zones that indicate high-temperature reservoirs and upflow zones.
- ◆ Construct detailed thermal gradient models to target productive areas.
- ◆ Enhance subsurface modeling by pinpointing zones with high permeability and favorable thermal conditions.

Moreover, hyperspectral imaging enables a more extensive sampling approach, allowing for the analysis of full drill holes and adds value by supporting traditional sampling and geochemistry by providing a fast, reliable way to identify areas in the drill core for further sampling.

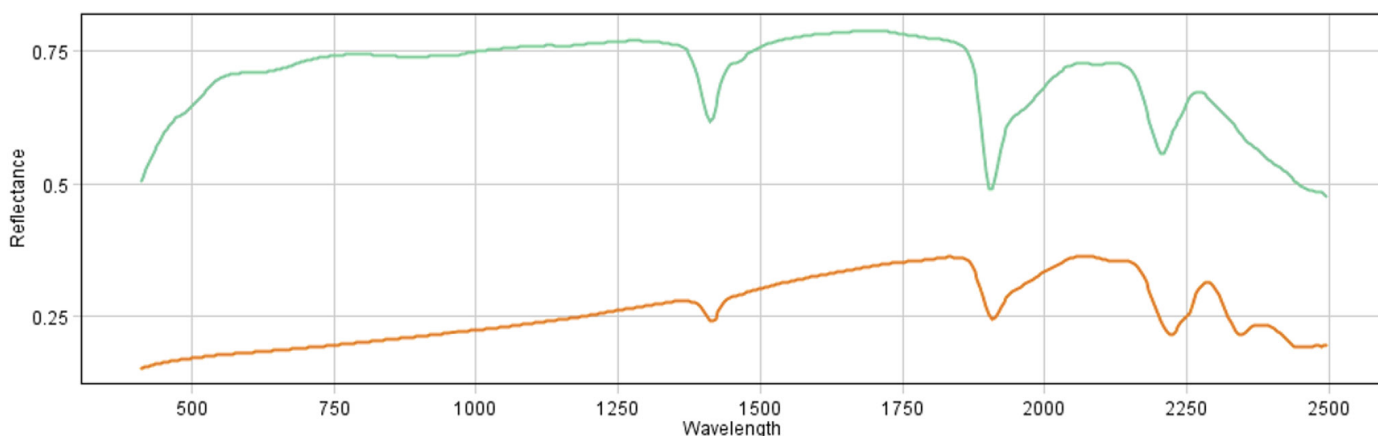


Figure 2: Montmorillonite (smectite, green) and illite (orange) spectra plotted within Breeze software. Wavelength in nanometers. Sample “Montmorillonite_Na_SWy-1” and “Illite GDS4 Marblehead” from USGS Spectral Library Version 7 (Kokaly et al., 2017).

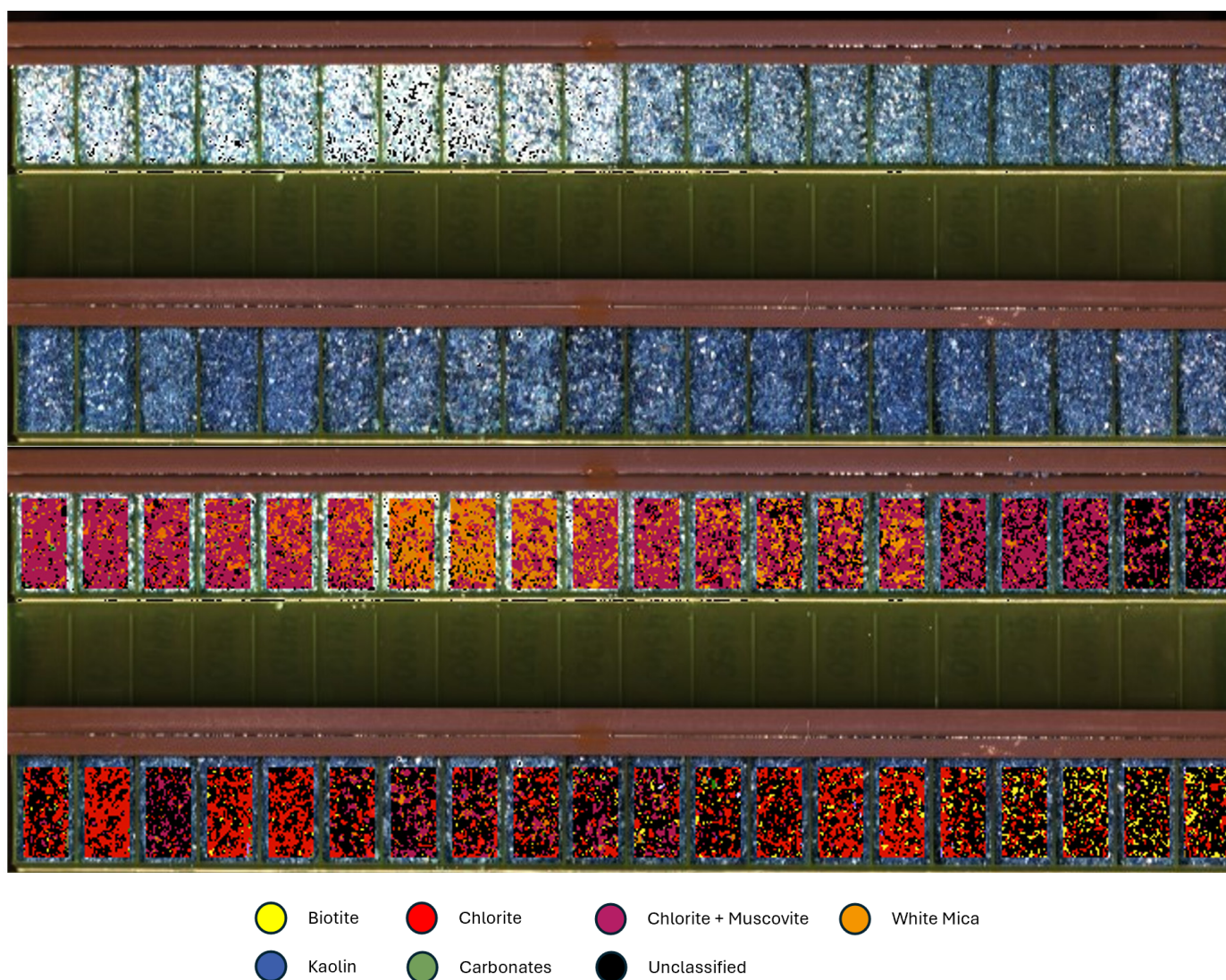


Figure 3: Drill chip analysis from the Coso Geothermal Field. Top: False-color RGB, scanned at 1.0m working distance achieving a 0.75 x 0.75 mm pixel resolution. Bottom: Mineral mapping based on USGS MICA classification.

Applications Beyond Mineral Mapping

The utility of hyperspectral imaging extends beyond alteration mineral mapping. By analyzing thermal gradients, companies can assess a geothermal system's lifespan and sustainability. For example, the presence of smectite or illite-smectite at depths beyond their typical thermal stability suggests recent heating events, which may indicate ongoing geothermal activity. Such insights are invaluable for long-term resource management and efficient energy extraction.

As the demand for renewable energy grows, the need for innovative exploration techniques becomes more pressing, hyperspectral imaging via HySpex instruments provides a non-invasive way to add significant value to drill core analysis.

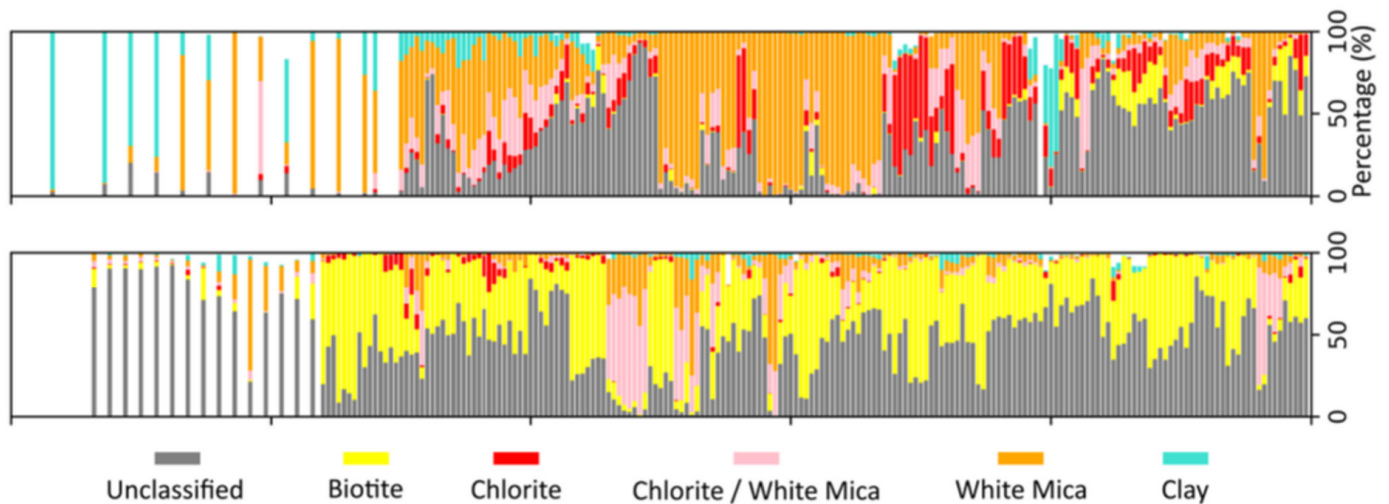


Figure 4: USGS Library mineral mapping results for two drill holes for the depth from the surface to 2500 ft depths.

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