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NEW TECHNOLOGIES: A PARADIGM SHIFT IN KIMBERLITE CORE LOGGING

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Introduction

In the dynamic and highly competitive landscape of diamond exploration, the ability of a company to execute a discovery phase program swiftly and effectively is critically important. Over the years, core drilling coupled with manual core logging has served as the cornerstone of exploration. The invaluable subsurface geological information provided by the drill core is essential in all phases of exploration and mining. As a pillar of diamond exploration, core logging provides the first pass geological information, including internal waste or dilution estimation for subsequent diamond potential evaluation. The process involves a systematic visual examination and description of the drill core features to identify distinct geological units and design a micro-diamond sampling plan. Geological logging is essential, albeit time-consuming, labour-intensive, and subjective, with an inherent degree of bias that stems from the loggers' experience, training, and preferred geological models. Attempting to acquire more objective geoscientific data from drill core and to overcome any bias, De Beers Exploration tested two rapidly emerging technologies that re-shaped the exploration methodologies over the last decades: the hyperspectral and X-ray fluorescence technologies. The large hyperspectral and geochemical datasets acquired by several service providers for De Beers on hundreds of drill cores and samples were tested against the geological observations acquired during core logging. An example from proof-of-concept trials is presented in this paper and establishes a case for the integration of hyperspectral and X-ray fluorescence geochemical data with geological logging, and to open the access to AI processing solutions.

Hyperspectral analysis in kimberlite drill core logging

De Beers-Exploration has tested various systems from several companies that provide a combination of hyperspectral core imaging and/or discrete analysis and high-resolution digital core photography. Hyperspectral coverage ranges from visible and near-infrared to short- and long- wave infrared wavelengths (VNIR-SWIR-LWIR). The spectral data acquired with SWIR and VNIR wavelengths revealed mineral assemblages related to kimberlite alteration (e.g. serpentine, smectite, dolomite), country rock mineral components, as well as aspectral domains of the kimberlite and country rock. The multiple hyperspectral products range from spectral logs and reports with unclassified or partially classified mineral assemblages, to comprehensive mineral maps. The distinct mineral assemblages displayed in the spectral products can be reconciled with the geological units established in drill core, or with the geological features that support distinct geological units identified on the core photos. Therefore, a spectral log illustrates downhole alteration complexity and enables the discrimination of alteration domains that can be correlated with the geological units. Alteration reflects and sometimes enhances the subtle differences in the original mineral composition of the kimberlite units in most of the investigated drill cores.

Several spectral products are displayed as examples in Figures 1 & 2. In Figure 1, the geological log of a drill core is juxtaposed with high resolution drill core photos, a mineral map, and several mineral logs acquired with an imaging hyperspectral scanning system. The three kimberlite units discriminated in the field log and photos correspond to distinct mineral assemblages dominated by saponite and serpentine. The geological log and the mineral map show consistency in the discrimination of the geological units. Individual units dominated by saponite or serpentine and the country rock xenoliths can be distinguished in the mineral logs of serpentine and saponite produced for specific wavelengths and absorption features. In Figure 2, the same geological log is juxtaposed with a spectral log acquired with a non-imaging scanning system. Combinations of distinct mineral assemblages labelled Kimb 1 to Kimb 9 match with the three units of the geological log.

Dilution is recognized in photos and spectral images, but delineation is challenging. AI solutions requiring good spectral data quality and high-resolution photos may soon enable automated xenolith recognition, delineation, and quantification to replace the traditional line scanning method.

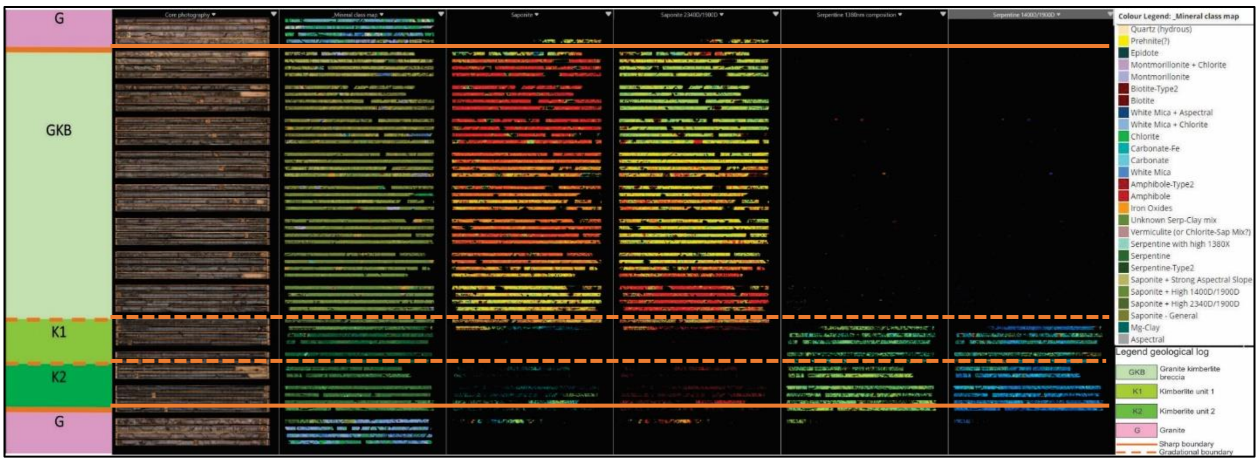

Figure 1. An example of integrated data showing (left to right) the geological log, core photos, the mineral map, and the mineral logs of serpentine and saponite acquired with continuous spectral imaging technology.

X-ray fluorescence analysis in kimberlite drill core logging

Portable X-ray fluorescence (pXRF) technology has been tested with the Olympus Vanta handheld analyser to assess its potential to identify the kimberlite and inform a real-time decision about drilling. Thousands of tests performed on kimberlite and country rock samples in pilot studies both in Canada and South Africa have proven the reliability of XRF analysis to chemically discriminate kimberlite. A subset of the analyses was validated with XRF and/or ICP-MS and ICP-ES laboratory analyses. As a result of these pilot studies, pXRF analysis is now embedded in the De Beers-Exploration workflow as a logging aid in Discovery phase drilling to support near real-time exploration decision-making to rapidly assess and resolve geophysical targets. In kimberlite logging, a systematic pattern of multiple discrete XRF chemistry measurements ensures that XRF chemistry can be integrated with petrography and hyperspectral analysis to discriminate the geological units and identify the chemistry of kimberlite and country rock xenoliths (Figure 2). The dataset can be maximized with continuous XRF scanning of drill core providing a much larger volume of geochemistry results for AI processing solutions.

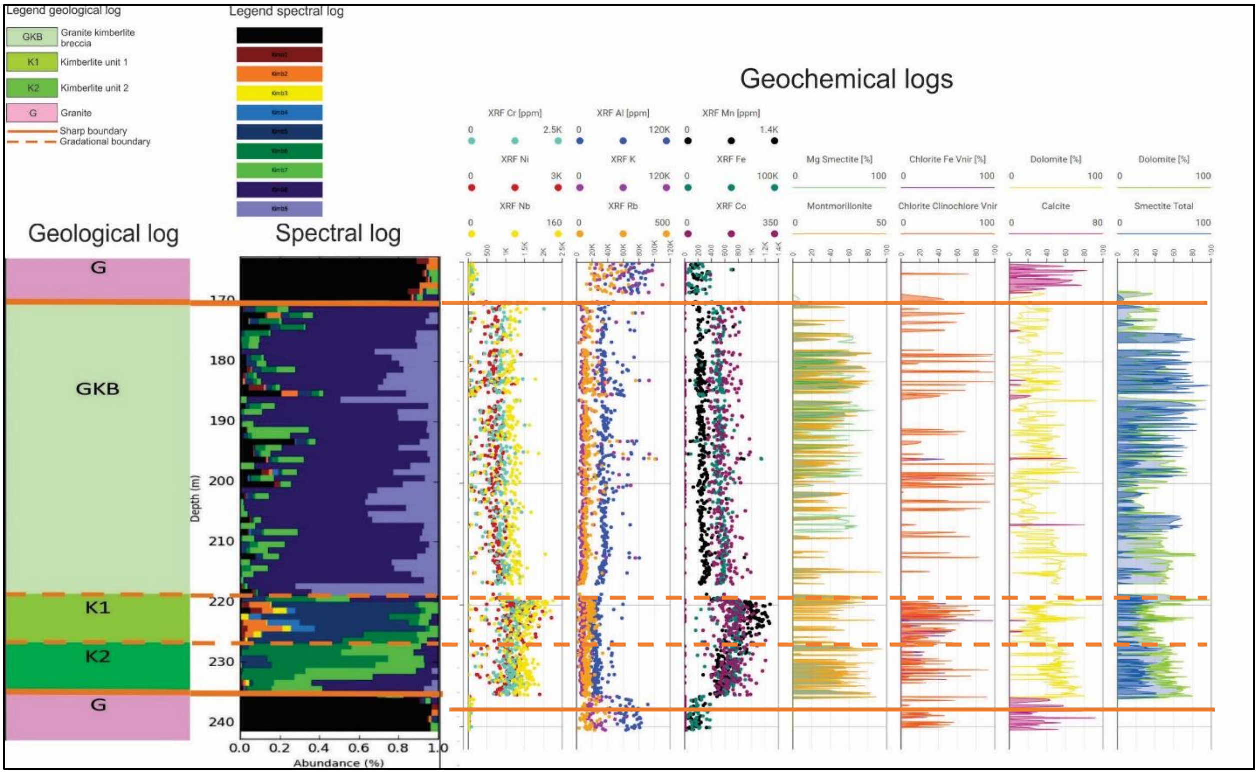

Figure 2. An example showing (left to right) integrated geological log, spectral log with combined unclassified mineral assemblages, and pXRF geochemical and mineral logs.

Conclusions

Implementing pXRF analysis and hyperspectral core scanning in our exploration discovery phase drilling programs has enabled us to provide rapid and comprehensive mineralogical and geochemical data interpretations, allowing for real-time decision-making regarding further exploration efforts. Furthermore, these digital technologies have introduced vast multivariate datasets that have significantly enhanced data accuracy and reliability, reducing the risk of interpretation bias. This proactive approach streamlines the exploration process, leading to more efficient kimberlite discoveries and project prioritization for further resource development. The next steps on the core logging workflow digitalization journey will be to leverage machine learning and artificial intelligence (AI) algorithms and develop predictive models based on the large multivariate pXRF and hyperspectral datasets to identify complex patterns and correlations across multiple boreholes. The AI-powered systems will be trained to continuously learn from new data inputs, refining their predictive capabilities over time and adapting to changing geological conditions. Ultimately, this integration of advanced technologies will foster a data-driven approach to the exploration pipeline, reducing uncertainty, improving efficiency, and maximizing the success rate of kimberlite discovery and resource development.

The integration of hyperspectral and X-Ray fluorescence analysis in drill core logging is a paradigm shift from the perspective of the small-scale data engrained in the traditional core logging, to the perspective of the access to large-scale datasets and AI processing that augments geologists' knowledge reducing subjectivity and bias.