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Evolution of Kimberlite Exploration – Systematic exploration using a ground geophysical toolbox for Kimberlites, Slave Craton, NWT, Canada (Part 1)

Darrell Epp[1], Chris Hrkac[1], Gary Vivian[1], Eileen Lyon[1], Tom McCandless[2], Dave Sacco[3]
[1] Aurora Geosciences Ltd., Yellowknife, Canada, darrell.epp@aurorageosciences.com
[2] MCC Geoscience Inc., Vancouver, Canada, temccandless@gmail.com
[3] Palmer, a part of SLR Consulting Ltd., Vancouver, Canada, dave.sacco@pecg.ca

Introduction

Areas prospective for kimberlite emplacement are identified through a combination of kimberlite indicator mineral analysis in glacial sediments (drift prospecting) and geophysics. Historically, identification of kimberlite targets for drilling has relied on the 'classic' vertical, carrot-shaped kimberlite pipe model. A 'good' geophysical anomaly interpreted to represent a kimberlite is typically defined as an intense circular magnetic low or high and/or electrical resistivity low, and at times is limited to airborne datasets. Since 2012, the Kennady Diamonds Inc. (KDI) owned Kennady North Project (KNP) in the Northwest Territories (NWT) has challenged the 'classic' kimberlite emplacement model. KDI recognized a new, subhorizontal emplacement model by evaluating multiple ground geophysical datasets in combination (*i.e.,* horizontal loop electromagnetics (HLEM), capacitively coupled resistivity (CCR), gravity, and magnetics). This success at the KNP asserts a systematic approach to kimberlite exploration that uses a ground geophysical 'toolbox', which recognizes that one method cannot be relied upon entirely.

Methodology

The successful application of geophysics in kimberlite exploration relies on the kimberlite body, and/or its emplacement, forming a measurable contrast in physical rock properties.

HLEM and CCR methods map subsurface contrast in electrical properties. In kimberlite exploration, a CCR response typically associated with kimberlite is a resistivity low that can be correlated with host rock structure produced during emplacement and potential country rock alteration. Conversely, fresh, coherent kimberlite can cause a resistivity high. HLEM is another method that measures conductive subsurface responses using electromagnetic induction. Anomalous HLEM responses often correspond to a clay-weathered surface expression of kimberlites that is hard to differentiate from fine-grained, lake bottom sediments. Therefore, other geophysical datasets are required to assist in the interpretation.

Gravity methods measure the contrast in subsurface material densities. In kimberlite exploration, such contrasts are dominantly controlled by structure, rock porosity, lithological variation and changes in overburden thickness. Kimberlites in the Slave Craton are typically associated with a low gravity response and often are a reflection of the emplacement of the kimberlite, not the kimberlite itself (Meju 2002).

Magnetic methods measure variations in the magnetic field strength of bedrock. Kimberlites may contain magnetite and ilmenite. In the right quantities and distributions, these minerals can produce a magnetic high or a magnetic low, if remanent magnetization is present. In the Slave Craton, kimberlites are often associated with magnetic lows or dipoles, and less commonly, are associated with magnetic highs.

Kelvin and Faraday kimberlite evaluation using the ground geophysical ‘toolbox’

The Kelvin and Faraday kimberlites at the KNP were first drilled by DeBeers: Faraday 1 in 1999; Kelvin in 2000 and Faraday-2 and -3 in 2003. The drill targets were presumedly defined using a combination of drift prospecting, airborne survey results, and concurrent HLEM surveys. After 2003, no further drilling was completed until KDI restarted exploration in the area. In the winter of 2013, KDI completed ground gravity and HLEM surveys to support the evaluation of new drilling results (2012) at the Kelvin and Faraday kimberlites and along the Kelvin-Faraday Corridor (KFC). The gravity survey provided infill and expansion on previous datasets, and increased resolution over the Kelvin kimberlite from 80 m station centres to 40 m station centres (Figure 1A). Additionally, similar gravity infill was later completed along the KFC. The gravity low coincident with the near, and at, surface portions of the kimberlite has been correlated by a density study completed during geotechnical drilling (Bloem et al. 2017).

In the spring of 2013, KDI followed up the gravity results over the Kelvin kimberlite with a CCR survey using the Geometrics OhmMapper^{TM} system. The acquired data was inverted and a 3D model of subsurface resistivity was generated. Model depth slices at 30 m (Figure 1B) and 60 m (Figure 1C) below the surface, along with a cross-section through the model (Figure 1D), show close overlap of a resistivity low feature and the Kelvin kimberlite. Subsequent drilling that targeted the resistivity low resulted in consistent, high-volume kimberlite intercepts, and marked an improvement over previous efforts. The limitation, however, of the OhmMapper^{TM} survey is a maximum depth of investigation between 60 m and 70 m (Szalai et al. 2009). This shortcoming prompted development of the Aurora Rapid Reactance Tomography (ARRT), a proprietary CCR system, so as to allow for greater depth of resolution. A comparison of survey results over the Kelvin kimberlite between the OhmMapper^{TM} and ARRT shows an increase to the depth of investigation by at least another 50 m to 60 m below surface with the ARRT survey (Figure 1D).

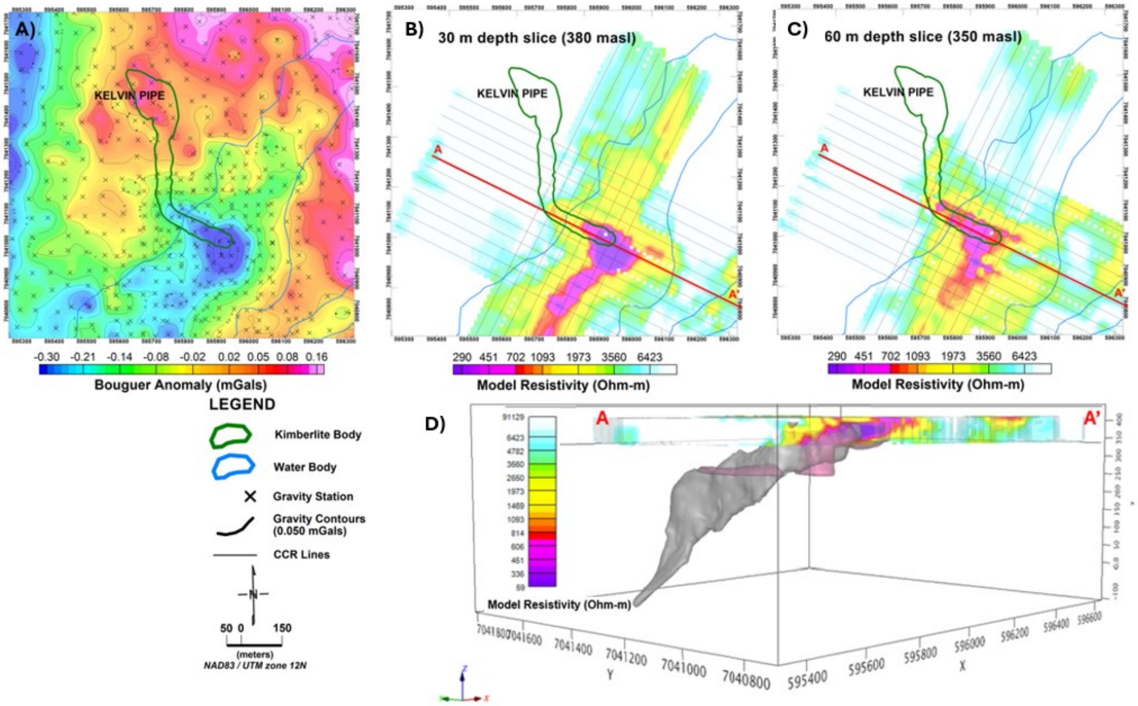

Figure 1: A) A bouguer anomaly map (2nd order trend removed) over the Kelvin kimberlite with 80 m and 40 m station centres; **B)** Plan map of 30 m depth slice from OhmMapper^{TM} survey modelled resistivity; **C)** Plan map of 60 m depth slice from OhmMapper^{TM} survey modelled resistivity; and **D)** A 3D view of the Kelvin kimberlite model (grey surface) looking NE with 1) a cross section veiw of the OhmMapper^{TM} survey resistivity model along profile A-A’ and 2) a resistivity model isosurface from the ARRT survey (pink surface) showing the increased depth of resolution achieved by that survey system.

In 2016, a high-resolution ground magnetics survey was completed along the KFC. The results show a magnetic low conforming to nearly the full extent of the plan outline of the Kelvin kimberlite, while no distinct magnetic responses overlap with either of the Faraday kimberlites (Figure 2). The noisy magnetic background observed, local to the Kelvin and Faraday kimberlites, is characteristic of the metamorphosed sedimentary country rock and can make it difficult to identify more subtle magnetic responses associated with kimberlite emplacement.

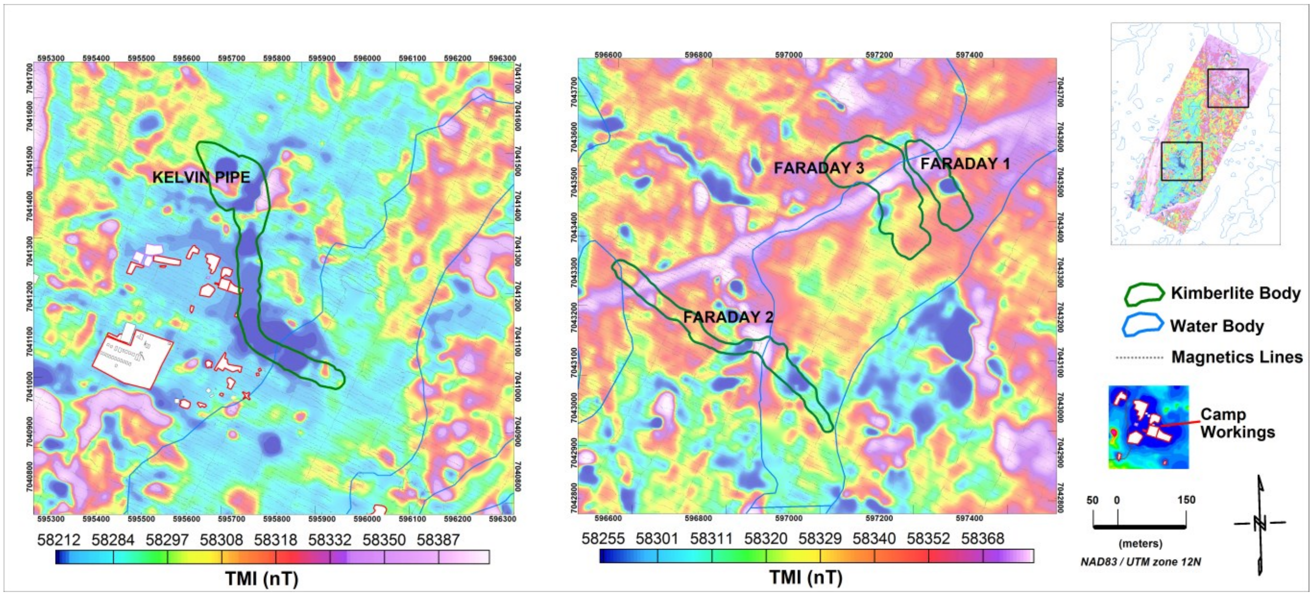

Figure 2: Magnetic response observed over the Kelvin (left panel) and Faraday (right panel) with kimberlite model outlines overlain and the location of Kelvin camp infrasture shown as red outlined white polygons.

Conclusion

Electromagnetics, magnetics, gravity, and resistivity geophysical methods are complementary in their application to kimberlite exploration in the Slave Craton. This is particularly true for the evaluation of kimberlites with unconventional and complex geometries like the Kelvin and Faraday kimberlites. Whenever possible, inversion models of CCR-based resistivity should be considered given the positive results in highlighting kimberlites like Kelvin. Indeed, the ground-based geophysical campaigns carried out over these kimberlites have shown that one survey type is unlikely to tell the whole story. Consideration of results from all survey types together is required to provide an accurate assessment of the target. Integrating a more full geophysical ‘toolbox’ systematically has the potential to discover numerous overlooked kimberlites, and potentially identify the source of numerous orphaned indicator mineral dispersals.

References

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