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Uncertainty-based grade modelling of kimberlite: A case study of the Jay kimberlite pipe, EKATI Diamond Mine, Canada

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ABSTRACT

Understanding uncertainty in resource models is a significant requirement of mineral resource evaluation. Geostatistical simulation is one method that can be used to quantify uncertainty and Sequential Gaussian Simulation (SGS) is one of the easiest techniques to understand and implement. Using SGS provides both a spatial model of a given variable and the ranges around that variable at any number of scales.

The Jay kimberlite pipe is located in the southeastern quadrant of the EKATI property. Drilling to date has identified three kimberlitic domains characterized by varying lithological properties. These domains are not separated by hard contacts, but rather by boundaries that are transitional. Within these domains, vertical trends exist; in particular, diamond grade increases with depth. For these reasons, Jay required an in-depth investigation of the best uncertainty-based grade modelling method to use.

Grade was modelled by organic SGS and by using the stepwise conditional transform (SCT) to incorporate a trend into the simulation routine. Although the SGS results were valid, they did not fully reproduce the trend and therefore, the results did not fully match the geological interpretation of the deposit. The SCT results reproduced the trend, however, did not correspond to the variability of the data and therefore under-represented the actual uncertainty in the model. This was confirmed through detailed uncertainty calculation and probabilistic resource classification. Therefore, the SGS model was chosen as the preferred uncertainty-based grade model for the Jay pipe.

1. Introduction

Understanding uncertainty in resource models is a significant requirement of mineral resource evaluation. Uncertainty analysis allows the modeller to explicitly quantify the risk around their estimate, as well as to provide high and low estimates for mine design, assess the project up-side or down-side, model financial forecasts, and reconcile the deposit after mining. There are many sources of uncertainty in a mineral resource, such as tonnage, diamond value, or grade. Geostatistical simulation is one method that can be used to quantify uncertainty around spatial variables such as grade and Sequential Gaussian Simulation (SGS) is one of the easiest techniques to understand and implement. Using SGS provides both a spatial model of a given variable and the ranges around that variable at any number of scales.

The Jay kimberlite pipe is located in the southeastern quadrant of the EKATI property (Fig. 1) in a 30 m deep depression in Lac du Sauvage, approximately 2 km from the lake shore. It is within the EKATI Resource Development Plan and is currently at a concept study level. As a relatively large, yet lower value pipe, understanding the risk associated with its value per tonne, and therefore diamond grade, is imperative.

Drilling to date has identified three kimberlite domains characterized by varying lithological characteristics, diamond grade, dry bulk density, and moisture content. These domains are not separated by hard contacts, but rather by boundaries that are transitional. Within these domains, vertical trends exist; in particular, diamond grade increases with depth. These conditions impacted grade modelling and therefore special attention was paid to ensure the results were the best possible.

Understanding the geology of Jay was paramount to choosing the best modelling method and understanding the results. This contribution will introduce the geology of the Jay kimberlite pipe and discuss how the geological interpretation affected the grade modelling technique chosen. Two modelling methods will be compared and discussed with a focus on uncertainty analysis.

2. Exploration history and data

The Jay kimberlite pipe was first identified as a conductive feature on an airborne electromagnetic survey in 1992. A core hole collared in 1993 confirmed the anomaly as kimberlite and following this, Jay was delineated by eleven additional core holes, with the deepest kimberlite

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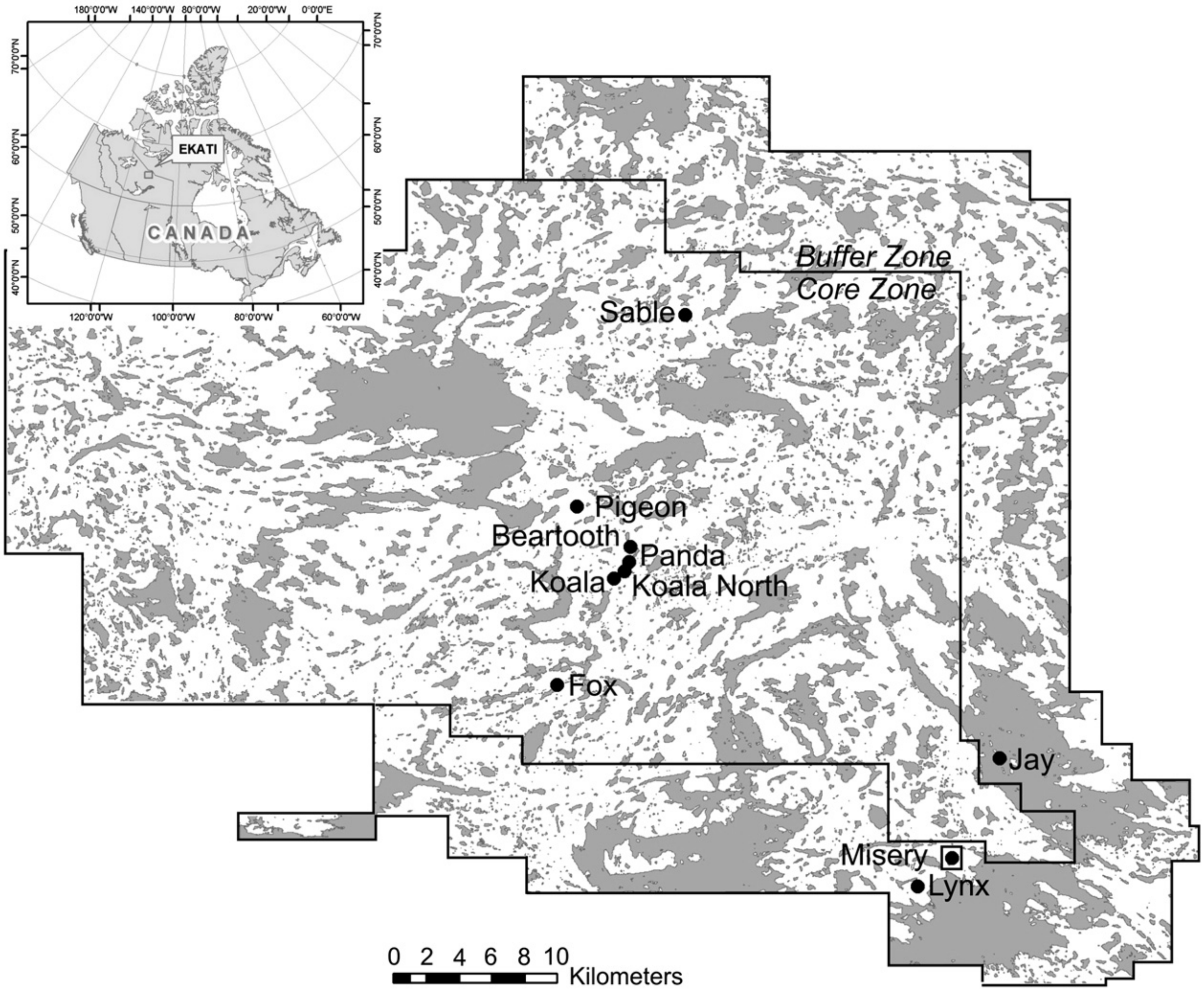

Fig. 1. A map of the EKATI Claim Block and the kimberlites in the current Resource Development Plan. Grey indicates bodies of water.

intersection at 20 m elevation (roughly 380 m below the kimberlite surface). Five 31 cm reverse circulation (RC) holes drilled in 1996 provided initial grade data from samples collected at 30 m intervals. A further twelve 45 cm RC holes drilled in 2006, with samples collected at 15 m intervals, provided a detailed assessment of grade and filled in a roughly 50 m grid across the surface area of the pipe.

Core and RC holes have been macroscopically logged in detail with microscopic inspection where required. For RC holes, logging samples were collected every 2 m to provide material for description. Due to the disaggregated and non-continuous nature of the material collected, small-scale properties are difficult to ascertain from RC drill holes. Detailed macroscopic and microscopic descriptions have been undertaken on drill cores, with RC drilling proving the spatial continuity of the larger-scale properties. Two spatially representative core holes were sampled for thin section analyses to confirm petrographic classifications.

To date, 223 valid grade samples totalling over 1100 dry metric tonnes have been collected, with the deepest sample ending approximately 350 m below the surface of the kimberlite at 50 m elevation. All samples were processed at +1 mm cut-off. They include enough stones (average 154 stones) and are materially large enough (average 5 tonnes per sample) to be deemed statistically representative of the Jay kimberlite.

Downhole caliper surveys were undertaken for all RC drillholes to provide a measure of sample volume. Recovered carats and sample volumes were used to calculate carats per cubic meter (cpm^3), the modelled grade variable. Collected "slough" carats (carats collected from mass caving events during drilling) were applied to all up-drillhole samples weighted on the number of carats collected and the "slough percentage" of a given sample. Slough percentage is defined as [(caliper volume − theoretical volume) / theoretical volume] × 100%, where theoretical volume is that estimated based on the nominal hole diameter.

All samples were assigned a single spatial coordinate at the midpoint of the sample and allocated to a lithological domain based on the sample midpoint. A dry bulk density model was created and used to convert the cpm^3 model to carats per dry metric tonne (cpt). This contribution will focus on the techniques and uncertainty surrounding the cpm^3 model. Further information on the methods used for RC drilling and grade calculation are outlined in Dyck et al., 2004.

3. Geology

The EKATI property is situated in the center of the Slave Structural Province of the Canadian Shield. The general regional setting and general bedrock geology of the EKATI property is well-documented; it is comprised of supercrustal metasediments, intrusive granitoids, and mafic dyke swarms (Nowicki et al., 2004; Kjarsgaard et al., 1994; LeCheminant and van Breemen, 1994; Wilkinson et al., 2001). A description of the host-rocks surrounding Jay and the kimberlite pipe's morphology and internal geological domains are provided below.

3.1. Host-rock geology

Regional geophysics and drilling indicate that the Jay kimberlite pipe is situated fully within granitoid host-rocks, ranging from granite to