Density Measurement of the Kelvin and Faraday Kimberlites in the Northwest Territories of Canada.

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Introduction

Core and reverse-circulation drilling programs have been undertaken on the Kelvin-Faraday kimberlite cluster for exploration, evaluation and resource classification by Kennady Diamonds Inc. All of the pipes and dykes in this cluster are diamondiferous and are located a few kilometres north of the Gahcho Kué mine (operated by De Beers Canada). The country rocks are metaturbidites of the Yellowknife Supergroup with minor amphibolite and narrow diabase dikes, with Archean granitoids occuring immediately to the west of the kimberlite cluster. In support of the resource development work undertaken on the Kelvin and Faraday kimberlites, density data collection were included into the geotechnical data-acquisition program for the project.

The determination of the volume-amount of kimberlite takes precedence in most drilling-delineation programs because it is the basic measure of "how much" material is to be mined and processed. The less understood and more variable parameter is the density of the material to be handled. Mineral resource statements are issued in terms of grades and tonnages, with kimberlite diamond grade reported as either carats per hundred tonnes (cpht), or less commonly, as carats per cubic metre (cts/m^3). The significance of the bulk density of the materials to be mined, is that they are used as input parameters for most stages of mine design, including; slope stability analysis, blast design, equipment fleet, comminution and mill design, tailings storage facility design, and waste rock management.

Density Measurement Methods

There are several methods available for determining the bulk density of rocks – some of which are relatively easy (and inexpensive) to implement in-field, while others require open drillholes for geophysical tools or at the extreme, controlled laboratory conditions. The rock mass characterization program of the Kelvin and Faraday kimberlites included the collection of bulk density data using buoyancy, calipered dimensioning, liquid displacement of pulverized rock, and *in situ* gamma-gamma downhole geophysical meththods. The reason for testing using multiple density measurement methods, and comparing them to one another, is that there is currently no standard method which describes how this should be done for kimberlites.

Rock Mass Density Data

The drilling and logging program, from 2014 to 2017, included basic geotechnical logging on all holes. All samples in this program were differentiated by rock type, geotechnical (GT) textural classes, intact strength, magnetic and weathering susceptibility, and three-dimensional position within the bodies. The primary in-field classification was done according to major rock type (gneiss or kimberlite), added to which the textural components within these rocks further sub-divided them into five somewhat equal classes with the end-members labelled G1..5 and K1..5 – as illustrated in Figure 1. This formed the start of the geotechnical domain delineation in the absence of a detailed geological model (which has subsequently been constructed).

Xenoliths and country-rock often have densities that are different than those of the kimberlite. This density contrast and 'blending' is illustrated in Figure 2. For VK rocks, the xenolith percentages can be estimated using line-counts (of relative percentages of the two components) and then the density of the kimberlite 'matrix' adjusted by adding in the density of the xenoliths, to arrive at an overall density for the rock. This is the 'cumulative' method of whole rock density determination. In the case of Kelvin, the country rock is an anistropic gneiss with varying amounts of platy-minerals which have a relatively consistent range of densities (G1 ≈ 2.68 to G5 ≈ 2.76) that are, however, sometimes difficult to differentiate in hand-sample – and in this case, using a cumulative-density type of strategy is difficult to implement if the xenoliths are small. We therefore opted for sampling of long-lengths of core and measuring them using calipered dimensioning, and also added the full hole-length gamma-gamma data to reduce the influence of the variable amounts and distribution of xenoliths.

Figure 1: Texture in the host-rock (gneiss) is based on an estimate of the percentage visible platy-minerals (biotite and micas) using a linear scale of approximately 0 - 10% (G1) through to > 40% (G5). In kimberlite, the texture codes are based on an estimate of the xenolith content and uses a linear scale of approximately 0 - 10% mostly fine-grained (K1) through to > 40% xenolithic volcaniclastic (K5) rock.

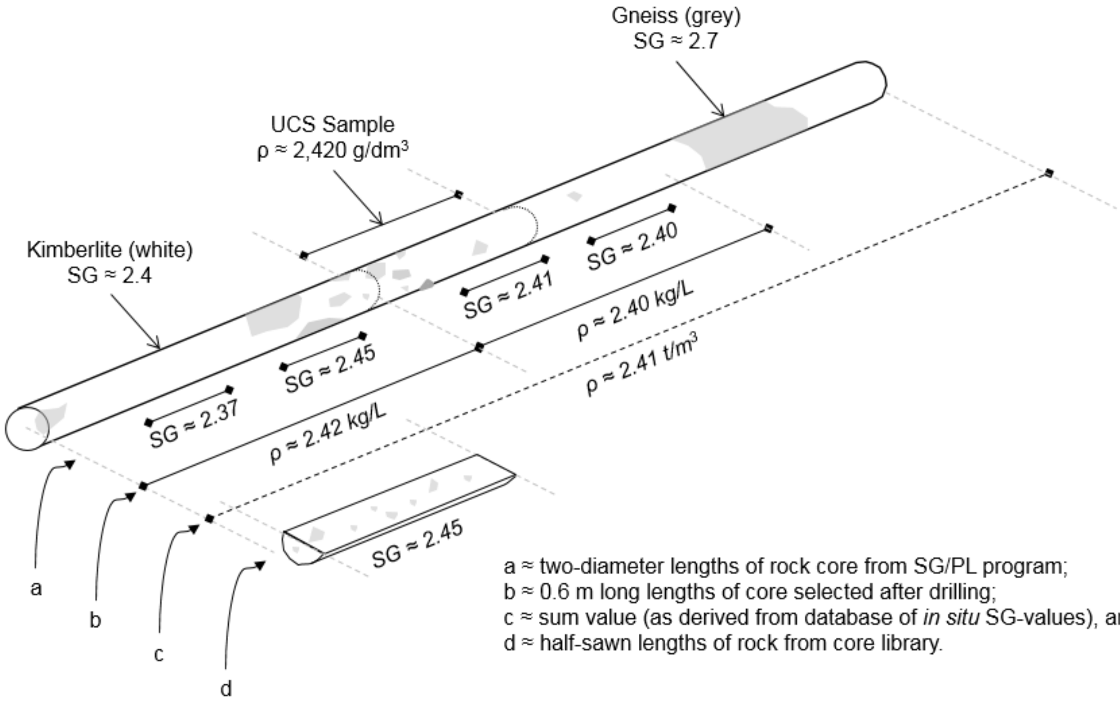

Figure 2: Schematic example of the sampling and testing strategy of rock core; a) is the in situ buoyancy-method measurement of **ρ**, b) post-drilling checks using a calipered dimensioning for ρ_b, c) an 'average' **ρ** value from within the kimberlite solid, and d) crushed samples for independent verification of ρ_b.

The buoyancy-method data were compared to laboratory and field-based calipered dimensioning, and the geophysical method. An independent check, using pulverized samples in a liquid displacement method, was also done – as illustrated in the table and chart of Figure 3. General agreement was found in the summarized data from each of the methods used; in particular, the trends in the density-data associated with changes in xenolith content are consistent. These overlapping data sets could allow for calibration of the global density model to reflect the required density measurement, dry (for grade and processing) or wet (for mining).

GT-Texture	Drill rig		Camp	Laboratory	
	Buoyancy (ρ)	Gamma-gamma (ρ_e)	C-Caliper (ρ_b)	L-Caliper (ρ_b)	Grain volume (ρ_g)
K1	2.42	2.52	2.46	2.39	2.49
K2	2.38	2.41	2.34	2.37	2.46
K3	2.38	2.47	2.36	2.35	2.44
K4	2.43	2.51	2.40	2.43	2.46
K5	2.50	2.57	2.52	2.49	2.52
Avg.	2.41	2.46	2.41	2.40	2.46
St.Dev	0.11	0.13	0.12	0.05	0.09
n	4029	157	70	10	90
Wt. (kg)	3000	null	220	10	60

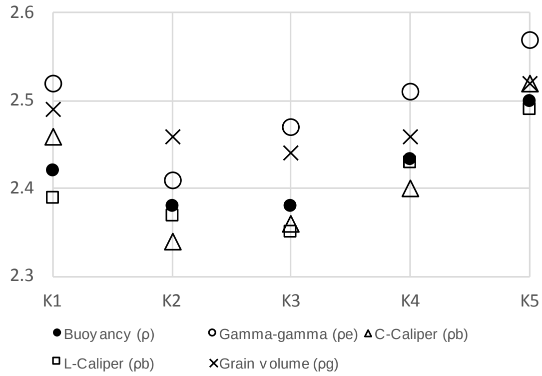

Figure 3: Summarized density data for kimberlite geotechnical textures, tabulated by location and method of data-acquisition for the Kelvin and Faraday kimberlites.

Discussion

The study found that the bulk density contrast between the Kelvin and Faraday kimberlites ($\rho \approx 2.4$ g/cm^3) and the gneissic country rock ($\rho \approx 2.7$ g/cm^3) is sufficient to differentiate the kimberlites within the country rock based on their density and the point-load strength of the individual hand-sized samples. The increase in xenolith content is reflected in the progressively increasing K3 to K5 GT-testural class densities. These results are in-line with other reported global values of VK (1.4 to 2.2) and CK (2.2 to 3.0) as described by Arnott and Kostlin (2003). The K1 class have densities between 2.4 and 2.5, which is consistent with coherent material (Reed and Witherly, 2007) within the lower diatreme to root zone transition within kimberlites.

A systematic increase in all of the country-rock gneiss densities with depth, from on average 2.72 at surface, to 2.74 at 400 m depth, occurs. This probably reflects increased micro-defects and fracturing near surface which may be a consequence of mechanical unloading of the country rock mass in this post-glacial environment. Using a geotechnical rock-texture classification method based on xenolith abundance and magnetic susceptibility measurements, the kimberlite samples can be separated into cement- (coherent / hypabyssal) and matrix-dominated (volcaniclastic) rocks with varying xenolith populations. In addition, because there are several thousand point samples within the Kelvin kimberlite (measured at a rate of approximately one per 3 m long drill-run) these facilitate 'visualization' of the internal geometry of the main geological zones within the kimberlites.

Conclusions

For pre-production characterization, the use of the bouyancy method with laboratory precision caliper checks is sufficient to characterize the VK and CK infills within Kelvin and Faraday. Because the number of samples was high on this program, it helped demonstrate that the pipes are variable in terms of their internal physical properties and in the spatial arrangement of these properties within the different kimberlite units. A single 'average' density number does not adequately define the *in-situ* densities of these kimberlites or their internal zones – a better approximation is achieved by estimating densities in three dimensional block models. Until such time as there are detailed industry and kimberlite-texture specific density-measurement guidelines, the combined use of volumetric (ct/m3) and weight based (ct/100t) grade statements are a more transparent way of reporting diamond results.

References

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