Kelvin and Faraday Kimberlite Emplacement Geometries and Implications for Subterranean Magmatic Processes

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Introduction

The Kennady North Project kimberlites are located approximately 280 kilometres east-northeast of Yellowknife, in the Northwest Territories of Canada. The unusual geometry and extent of the kimberlite magmatic system is revealed by renewed exploration drilling by Kennady Diamonds since 2012. The system comprises multiple intrusive kimberlite dykes and several volcaniclastic bodies, all within 11 kilometres of the Gahcho Kué kimberlite cluster and diamond mine. The detailed exploration of the entire system provides unique evidence for subterranean volcanic conduit emplacement and/or growth processes that may have scientific and practical exploration benefits.

Kimberlite Geometries

The identified Kennady North Project volcaniclastic bodies are named Kelvin, Faraday 1, Faraday 2 and Faraday 3, and have complex geometries atypical of the more common subvertical kimberlite pipes. Rather, these pipe-like bodies are generally inclined between 7° and 41° towards the northwest (Figure 1), with some notable exceptions discussed below. Pipes are contained within a shallow 20° to 27° northwest dipping kimberlite sheeted dyke system. The entire system represents a kimberlite fluid corridor aligned fairly precisely along a N210°E trend over at least 3 km. Locally around Faraday 1 and 2, some deeper dykes have shallower 11° to 15° dips.

The pipes could be described as tubular in shape, in contrast to the spatially associated sheeted dykes. Kelvin and Faraday 2 (and possibly Faraday 1) also have a subvertical elongated profile perpendicular to the tubular shaped NW plunge. The tubular shapes are similar to chonolith geometries decribed from Ni-Cu-PGE sulphide deposits in ultramafic intrusions (Barnes et al., 2016). Chonoliths are interpreted to have developed their tubular shape from thermo-mechanical erosive processes and channeling of magma flow in the dyke system. On-going detailed petrographic studies at Kennaday North have shown that the pipes contain layers of complex volcaniclastic units with variable volumes of xenolithic fragments, as well as coherent magmatic layers. The pipe textures include evidence for high energy magma and country rock fragmentation processes typically observed in open volcanic systems. However, at least a significant component of the fragmentation process must have occurred at depth within the pipe system, similar to that described in ultramafic chonoliths (Barnes et al., 2016).

The sheeted kimberlite dykes have been 3-D modelled along with the pipes. Three possible renditions of the dykes have been created, based on different interpretations of dyke segment continuity. These have been labelled “Optimistic”, “Realistic” and “Pessimistic”. The assumptions made significantly impact interpreted kimberlite continuity and illustrate the importance of understanding continuity and segmentation when developing dyke-type mineral resources.

The Realistic dyke model defines sheeted dyke segments that intersect the Kelvin and Faraday pipes, and those intersections correspond to geometric trends and irregularities in the pipe shapes. In the Faraday pipes, the most prominent dykes appear to define the basal geometery of the pipes. A similar spatial preference of dykes towards the stepped base of the Kelvin pipe is also evident, although the sheeted dykes are not as continuous along the length of the pipe. The coincidental geometries strongly imply that the pipe development interacted with a penecontemporaneous dyke system. It is also plausible that the pipe shapes developed the upward-elongated profile over time by chonolith type erosive growth processes, either from an original sheeted dyke system or independent chonolith.

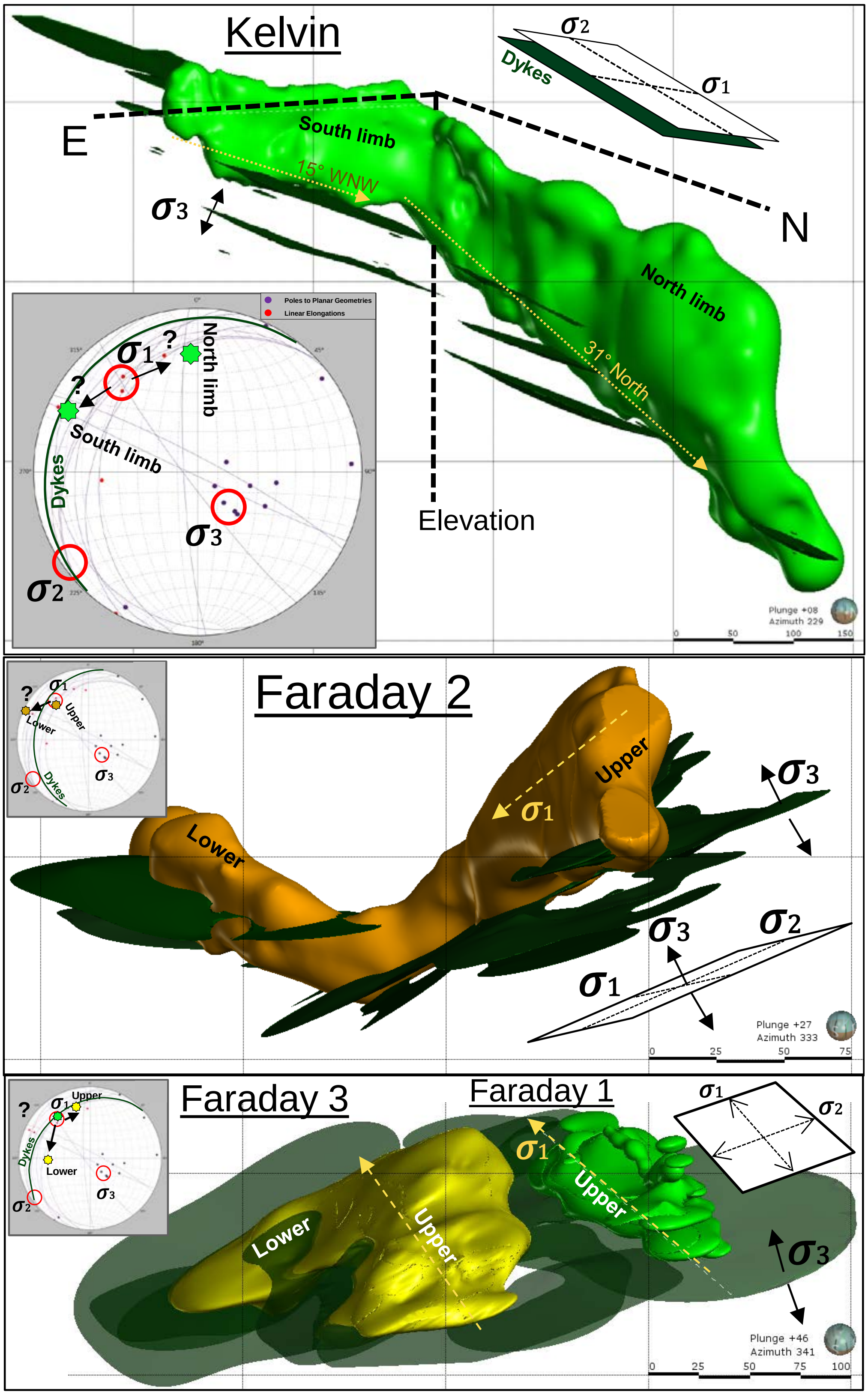

Figure 1: Images showing the 3-D geometries of each Kennady North kimberlite body (labelled). In general, the dykes and chonolith-like bodies dip northwest, but there are some significant deviations. All measured planar and linear elongations in the shapes are represented on insert stereonets, along with the interpreted stress tensor.

The 3-D interpreted kimberlite tubular pipe shape plunges, elongations and planar geometries, as well as sheeted dyke planes were measured. The 3-D interpretation is well constrained by drilling in most areas, except towards depth along the down-plunge extensions of the pipes. The measurements are represented on Figure 1, and are used in combination with our understanding of dyke emplacement mechanics to interpret the property-scale stress tensor orientation at the time of emplacement. In summary, the sheeted dykes are interpreted to occupy the σ_1-σ_2 plane, with northwest plunging Faraday pipes parallel to σ_1.

Emplacement Complexities

Detailed structural geology studies, using fault observations in oriented and unoriented drill core, have identified at least two important fault-fracture trends. The first fault-fracture system is parallel to the sheeted dyke segments, and likely related to the intrusion of the dykes and the regional stress tensor during emplacement. The second fault system is subvertical and north-south striking, parallel to the lithological layering within the metasedimentary country rock. Kelvin has a sharp angular change in trend. The Kelvin northern limb plunges 31° towards the north, effectively within the north-south fault system, and this suggests the magma has exploited the faults (oriented approximately 45° to the model σ_1) and allowed a magma conduit to develop. The Kelvin southern limb plunges 15° west-northwest (approximately 20° west of the model σ_1) and this may be due to a local σ_1 stress reorientation; one explanation would be a rotation of σ_1 subparallel to locally west-northwest striking faults (as per Barnett et al., 2013) observed in oriented drill core.

Faraday 2 pipe has a pronounced change in orientation at a depth of 150 m below current surface. It swings in trend towards the west with a change in plunge to 7°, and then curves back towards the northwest. There is also a corresponding change in the dip of the adjacent sheeted dykes from 27° to 11°. This curve is interpreted as a linkage zone (common in dyke systems) that possibly developed between two *en echelon* magma feeder systems. As the system evolved and underwent thermo-mechanical erosion, the linkage zone could have expanded and merged as part of the overall kimberlite pipe system. Faraday 3 has a similar change in pipe trend and dyke dip, also starting at a similar depth. Faraday 1 and 3 pipes, as currently modelled, are within 30 m of each other and connected via the same sheeted dyke system, and may also be connected via a short linkage zone at depth where there are currently inadequate drill holes to define the pipe boundaries. We interpret a spatially and temporally complex interactive system of sheeted and tubular intrusive bodies to depth.

Conclusions

We conclude that the Kennady North subterranean kimberlite development, and its internal textures and resultant geometries are governed by a combination of stress, structure and magmatic fluids, in a system that evolves over a prolonged period of time. There seem to be significant similarities to chonolith-type Ni-Cu-PGE sulphide ultramafic intrusive deposits. We consider the intial intrusive geometry of each pipe to have either evolved from an initial single chonolith-like tubular body or from the linkage zone (or other similar irregularities) of segmented, sheeted dyke systems, with pipe expansion driven by magmatic fluid brecciation and thermo-mechanical erosion processes and channelled flow of magma-xenoliths, fluids and volatiles.

References

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