VICTOR NORTHWEST KIMBERLITE PIPE, ONTARIO: ALTERNATING VOLCANICLASTIC AND APPARENT COHERENT EXTRUSIVE ROCKS

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INTRODUCTION

The Victor Kimberlite is located in the James Bay Lowland, Northern Ontario and is scheduled for open pit mining by De Beers Canada in 2008. The Middle Jurassic Victor kimberlite is a complex of several pipes. The steeply dipping (~70°) pipes occur in an Ordovician to Silurian sedimentary succession, and are unconformably overlying Precambrian granitoid basement. The unconformity occurs at ~275m depth. The kimberlite is overlain by ~10-30m of glacial overburden. Victor North comprises two parts (Fig. 1): the Victor North Pyroclastic Kimberlite (VNPK) pipe, and the Victor Northwest kimberlite (VNW) pipe. These pipes are composed of contrasting types of kimberlite (see Van Straaten *et al.*, this volume). The adjacent Victor South pipe comprises a similar rock type to the VNPK pipe.

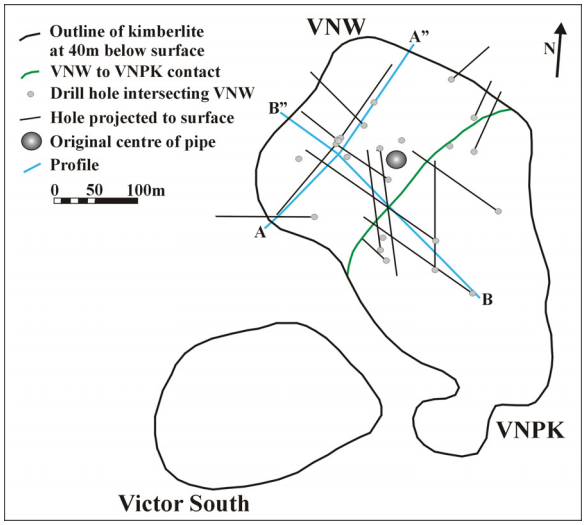

Figure 1: Map showing modelled geophysical outline of the Victor kimberlite complex. All drill cores intersecting VNW are shown on this map. The VNW to VNPK boundary, approximate centre of the reconstructed VNW pipe and profiles A and B (see Figs. 2, 3) are indicated as well. Figure modified from Webb *et al.* (2004).

The VNW pipe is the least well understood part of the Victor kimberlite complex. It comprises the enigmatic apparent coherent extrusive kimberlite, previously described as 'possible kimberlite lava or clastogenic lava flows' (Webb *et al.* 2004). This contribution presents new data on the volcanology and petrology of the VNW pipe. The geology of the VNW pipe is based on detailed logging of 6 representative drill cores (including the study of polished core samples and thin sections), evaluation of De Beers' internal reports on an additional 17 drill cores, and a ground magnetic survey. Additional work is ongoing.

PIPE MORPHOLOGY

The current geophysical outline of the VNW pipe is modelled at 40m below the surface (this is completely below the glacial overburden). At this level the pipe diameter is approximately 280m in a SW-NE direction and 160m NW-SE. Existing drilling shows that the contacts are fairly steeply dipping (roughly 70°). The kimberlite extends to a minimum depth of 370m below the present day surface. The south-eastern side of the VNW pipe is in contact with the Victor North Pyroclastic Kimberlite (VNPK) pipe. The following observations show that the early VNW pipe is cross-cut by the later VNPK pipe: **(i.)** the contrasting magnetic signature of the VNW and VNPK pipes define an outward curving pipe contact (see Fig. 1), **(ii.)** various drill holes intersecting the VNW to VNPK contact allow reconstruction of a steeply SE-dipping contact, **(iii.)** at a smaller scale: broken clasts (olivine crystals, country rock clasts) on the VNW side of the knife-sharp contact, and **(iv.)** autoliths (angular and broken fragments of previously lithified kimberlite) of probably VNW-kimberlite within VNPK.

Assuming that the VNW pipe had an approximately circular outline prior to eruption of the VNPK, then the pipe diameter at 40m below the present day surface was about 280m, and a considerable part of the VNW pipe has been removed by the formation of the VNPK pipe. The approximate centre of the reconstructed VNW pipe is indicated in Figure 1. Since Middle Jurassic time, about half the vertical extend of the pipe is believed to have been eroded (Kong *et al.* 1999).

KIMBERLITE LITHOLOGIES

The initial investigation focused on the central and upper portion of the VNW pipe. The distribution of rock types in the upper 100-170m of the pipe is remarkably consistent and comprises four approximately horizontal tabular to more irregular shaped units (Figs. 2, 3). The four lithologies are described below, in order of increasing depth:

- Uppermost country rock breccia unit
- Upper volcaniclastic unit
- Intermediate apparent coherent unit
- Lower volcaniclastic unit

UPPERMOST COUNTRY ROCK BRECCIA UNIT

A thick (11-24m) unit composed of various types of large country rock sedimentary fragments occurs below approximately 20-30m of glacial overburden. Minor or no kimberlite has been found within this unit. Country rock fragments include various siltstones, mudstones and limestones. Bedding angles, when observed, are extremely variable (0-90°). The unit appears to thicken towards the original pipe wall contacts (35m in SW part of pipe, see Fig. 2). There is usually high core-loss in this unit.

UPPER VOLCANICLASTIC UNIT

This unit is consistently present in-between the over- and underlying units, and is quite variable in nature. The thickness of the upper volcaniclastic kimberlite unit varies from 5-27m. Clear round-ovoid shaped juvenile lapilli (crystal plus melt selvage) are a common feature, but are outnumbered by discrete olivine macrocrysts (crystal without melt selvage). The kimberlite is clast- to matrix-supported, and contains both olivine macrocrysts (anhedral, commonly 0.5-10mm large, mantle derived grains) and primary olivine phenocrysts (commonly euhedral and <0.5mm). Olivine macrocrysts are usually pseudomorphed by carbonate and/or serpentine. Country rock fragments are common (5-100%, average ~10-20%), and the thicker intersections contain several country rock breccia intervals and/or large country rock xenoliths. The unit often exhibits 1-6m thick fining upward beds. Fining upward units are characterised by a decreasing abundance and size of country rock fragments, accompanied by a decrease in size of olivine crystals. Possible autoliths (angular and broken fragments of previously lithified kimberlite) of (apparent) coherent kimberlite are present in this unit.

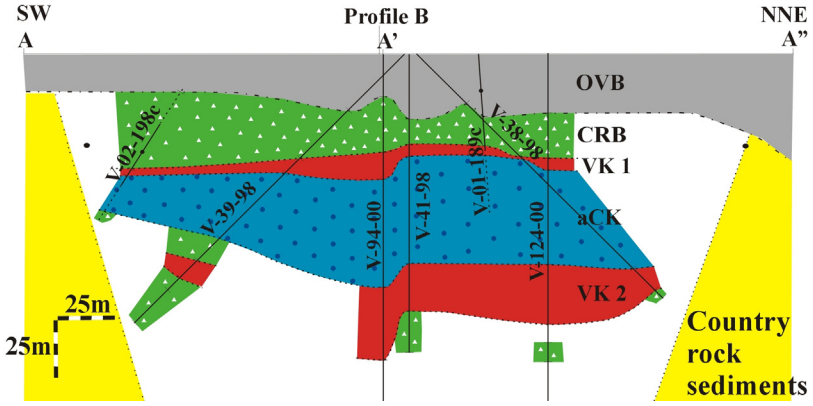

Figure 2: SW – NNE profile (A-A'-A") through the Victor Northwest kimberlite pipe. For location, see Figure 1. Key: OVB = glacial overburden, CRB = uppermost country rock breccia, VK 1 = upper volcaniclastic kimberlite, aCK = intermediate apparent coherent kimberlite, VK 2 = lower volcaniclastic kimberlite.

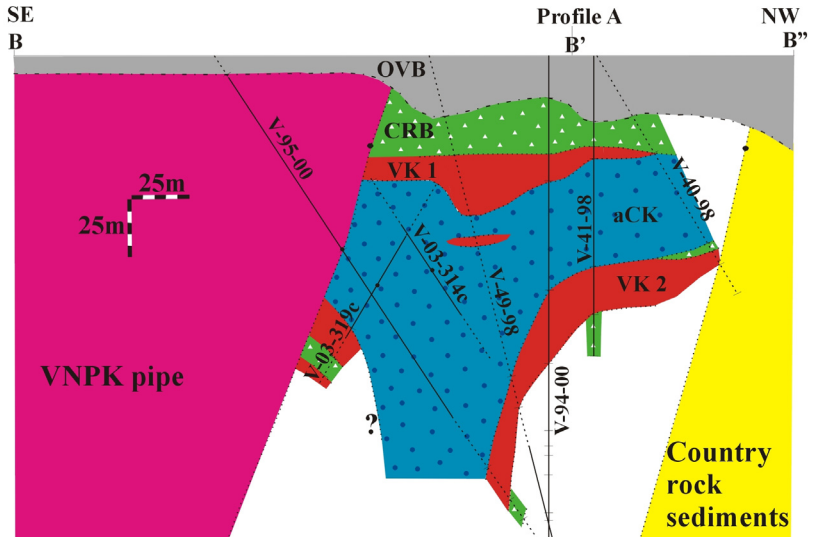

Figure 3: NW – SE profile (B-B'-B") through the Victor Northwest kimberlite pipe. For location, see Figure 1. See Figure 2 for key.

INTERMEDIATE APPARENT COHERENT UNIT

This unit is macroscopically featureless, competent, and dark-coloured. It comprises matrix-supported olivine macrocrysts and olivine phenocrysts. The olivine macrocryst population is characterised by abundant large (5-10mm) and common fresh grains. The unit contains only a few country rock fragments (~4%), increasing towards the upper and lower contacts. Macroscopically identifiable diffuse selvages around olivine macrocrysts can be discerned. Distinct intervals (~1-5m) with more abundant diffuse selvages are commonly observed in the upper parts of this unit. The diffuse selvages typically contain slightly finer-grained carbonate laths compared to the matrix (defined in this context as the area in between selvages), and show gradational contacts with the surrounding matrix (Fig. 4). The matrix in this unit is variable. In some cases, it is clearly coherent (Fig. 5), and formed by a uniform network of carbonate and phlogopite laths and dispersed spinel and perovskite crystals set in a cryptocrystalline carbonate groundmass (base). More often the matrix has pools of coarser carbonate, which might resemble similar segregationary textures in hypabyssal kimberlites. Additional observations further suggest a coherent nature for certain parts of this deposit: uniform distribution of olivine crystals, and absence of sorting and bedding. However, certain intervals in the lower parts of this unit are overall finer grained, and show subtle variations in grain size. In addition, a slight preferred orientation of clasts is commonly observed in drill core. These features, and the presence of diffuse selvages on some olivine macrocrysts, prevent a straightforward interpretation, and should also be accounted for in any geological model.

The apparent coherent unit is on average ~45m thick, but increases in thickness towards the original centre of the pipe (at least 90-110m thick, see Fig. 3), and appears to decrease in thickness towards the original pipe wall contacts (16m in the SW part of the pipe, see Fig. 2). The thickening of the apparent coherent unit occurs close to the reconstructed centre of the pipe, and might represent the feeder zone of this unit.

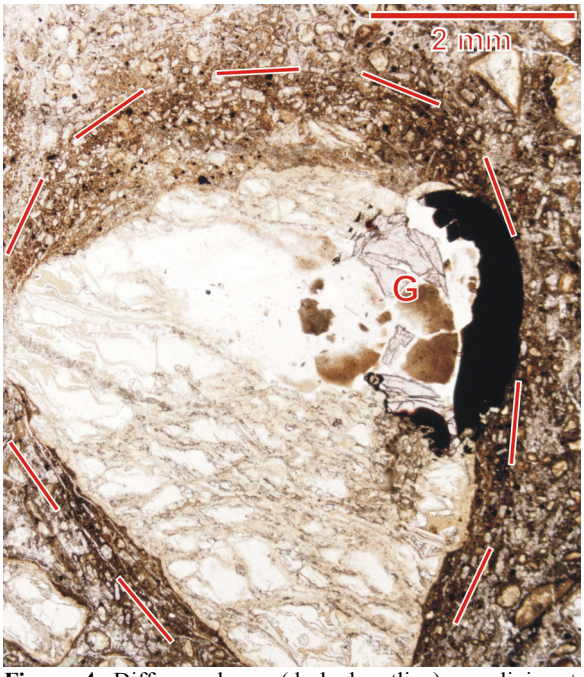

Figure 4: Diffuse selvage (dashed outline) on olivine + garnet (G) micro-xenolith in apparent coherent unit.

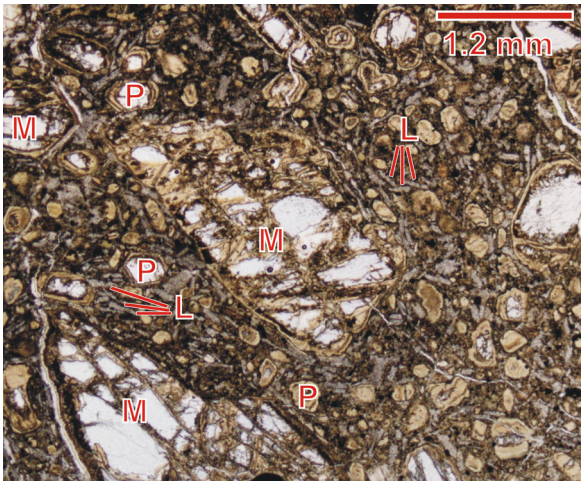

Figure 5: Coherent matrix (groundmass) in apparent coherent unit: olivine macrocrysts (M), olivine phenocrysts (P), and a network of abundant carbonate laths (L). PPL image.

An extrusive origin for this unit is proposed, based on the following observations: **(i.)** the apparent coherent unit occurs in between two clearly extrusive volcaniclastic units, **(ii.)** the contact between the apparent coherent unit and upper volcaniclastic unit appears gradational (no sharp intrusive contacts), **(iii.)** presence of normal graded, 1-2m thick volcaniclastic beds within this unit in one drill core (V-49-98, see Fig. 3), **(iv.)** variable amount of country rock fragments, commonly increasing in

abundance towards the upper and lower contacts, and the presence of large country rock fragments and/or possible country rock breccia intervals, **(v.)** a lack of evidence for intrusive kimberlite in the country rock stratigraphy, and **(vi.)** autoliths of (apparent) coherent kimberlite in the upper volcaniclastic unit, which might be derived from the underlying apparent coherent kimberlite.

LOWER VOLCANICLASTIC UNIT

This unit comprises mainly massive intervals, and rarer fining upward 2-9m thick beds. The kimberlite is clast- to matrix-supported, and contains both olivine macrocrysts and olivine phenocrysts. Olivine macrocrysts are usually pseudomorphed by carbonate and/or serpentine. The country rock fragment abundance is variable, from 5-100%, with an estimated average of 15-25%. Abundant small (<1-2 cm) country rock fragments are present in this unit. The juvenile pyroclasts with melt selvage in this unit range from ovoid juvenile ash particles (minimum size 50-100 μm, Fig. 6) to small (1-3mm) uncored ovoid juvenile lapilli. Some juvenile lapilli are more amoeboid shaped, and occasional moderately vesicular juvenile lapilli (10-20% vesicles) are present. Additional features in this volcaniclastic unit include ash balls with fine ash rims, and common broken olivine crystals (Fig. 7). Some unequivocal autoliths of (apparent) coherent kimberlite are also present. The unit is about 16-32m thick, and commonly underlain by country rock breccias.

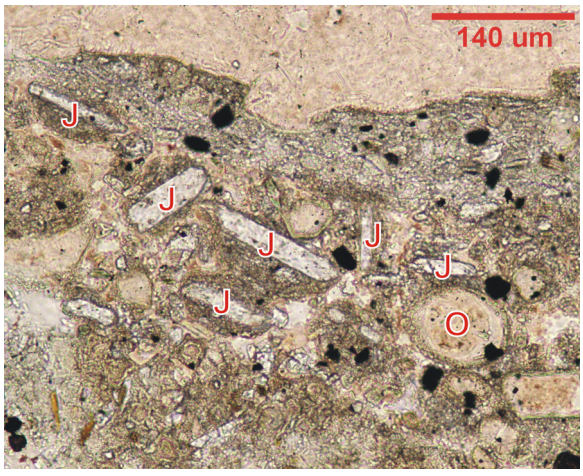

Figure 6: Ovoid juvenile ash particles (J) in lower volcaniclastic unit. Juvenile ash particles are mostly cored by carbonate laths. Some serpentine pseudomorphed olivine phenocrysts (O) also occur. PPL image.

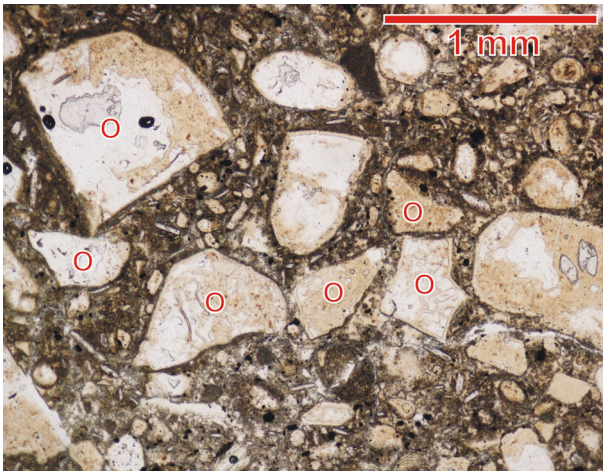

Figure 7: Broken clast-supported olivine crystals (O) in lower volcaniclastic unit. Note that the area below the broken crystals is more matrix-supported, and probably contains more ash-sized fragments. PPL image.

UNDERLYING UNITS

The lithological succession below 100-170m depth is mainly a repetition of the above rock types. However, correlation of various country rock breccias, apparent coherent units and possible volcaniclastic units between drill cores is difficult. Apparent coherent kimberlite with diffuse selvages on olivine macrocrysts occurs to 370m depth in drill core V-94-00.

MINERALOGY

The groundmass mineralogy of the apparent coherent unit and the juvenile lapilli in the volcaniclastic units is similar. The main groundmass constituents are olivine phenocrysts, carbonate laths, phlogopite laths, opaque minerals (mainly spinel) and perovskite, usually set in a carbonate ± serpentine base. Occasionally the base is formed by small (10-20 μm) six-sided serpentine crystals, believed to be pseudomorphs after monticellite.

DISCUSSION

Four distinct extrusive kimberlite phases are found in the upper part of the Victor Northwest pipe (VNW). The presence of solely extrusive phases indicates that the VNW pipe was an open crater, subsequently infilled by each of these kimberlite phases.

As suggested by Webb *et al.* (2004), the uppermost country rock breccia unit, and country rock breccia intervals in the upper volcaniclastic unit, were most

likely formed due to pipe wall collapse and/or rock avalanching. This could have occurred during periods of volcanic activity (for country rock breccia units found in between volcaniclastic units, as well as country rock fragment-rich volcaniclastic intervals), or during periods of volcanic quiescence (thick country rock breccia intervals with no kimberlite).

The upper and lower volcaniclastic units show several features which suggest a primary pyroclastic origin. The most important observations are: abundant fining upward 1-9m thick beds and moderate-well sorted appearance. The more massive intervals in the lower volcaniclastic unit clearly produced (and retained) abundant fine grained fragments during eruption (and deposition). This is mainly shown by the range in juvenile lapilli sizes (75µm-3mm), the very fine grained rims on ash balls, the variation from matrix- (ash-rich) to clast-supported (ash-poor) textures, broken olivine crystals and abundant small country rock fragments.

The diffuse selvages on olivine macrocrysts in the apparent coherent unit are difficult to interpret. It is possible that these selvages are similar to so-called globular segregations described by Clement (1982) in coherent rocks in the root zones and dykes of several South African kimberlite pipes (type 1 kimberlite pipes, Field and Scott Smith 1999). This would imply an origin as a globular segregationary-textured kimberlite lava. Conversely, the rocks could have a clastogenic origin, having been reconstituted by agglutination or welding processes (i.e. clastogenic lava, agglutinated spatter, or welded pyroclastic rocks). In this case, the diffuse selvages represent juvenile lapilli. Alteration of certain primary minerals and textures is likely to have occurred in parts of the deposit, and complicates an interpretation in certain cases. Further work on these rocks is ongoing.

CONCLUSIONS

The Victor Northwest pipe is an early-formed, steep-sided crater, crosscut by the later Victor North Pyroclastic Kimberlite pipe. The upper part of the VNW crater is infilled by a number of entirely extrusive events. The upper four units comprise:

- *Uppermost country rock breccia unit:* most likely formed by pipe wall collapse and/or rock avalanching.
- *Upper volcaniclastic unit*: contains common fining upward 1-6m thick beds, and clast- to matrix-supported discrete olivine crystals with lesser juvenile lapilli.
- *Intermediate apparent coherent unit:* commonly contains uniformly distributed, matrix-supported olivine macrocrysts and phenocrysts. Diffuse selvages on olivine macrocrysts are present in certain upper parts of the unit, and might represent either globular segregations or juvenile lapilli.
- *Lower volcaniclastic unit:* mainly massive unit, with matrix- to clast-supported olivine crystals and juvenile lapilli. Relatively intense fragmentation is suggested by the abundance of ash-sized components, numerous small country rock fragments and broken olivine crystals. In addition, fine-grained components were retained during deposition of the kimberlite.

ACKNOWLEDGEMENTS

We would like to thank De Beers Canada for their financial and logistical support, and their permission to publish this long abstract. Thanks to Cliff Revering and Stephen Moss for comments on the abstract.

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