GEOLOGY OF THE VICTOR KIMBERLITE, ATTAWAPISKAT, NORTHERN ONTARIO, CANADA: CROSS-CUTTING AND NESTED CRATERS

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INTRODUCTION

The ca. 170 Ma Victor kimberlite is the largest in a cluster of 19 kimberlites discovered in the James Bay Lowland, some 100km west of Attawapiskat in Northern Ontario (Kong et al., 1999). Victor comprises two adjacent but separate pipes, termed Victor North and Victor South, with a total area of approximately 15 hectares (Fig. 1). The pipes were emplaced into flat-lying Paleozoic sedimentary rocks, dominated by limestones and dolostones, which unconformably overlie the Precambrian basement rocks of the Superior Province. Bulk sampling of Victor indicates an estimated average grade of 25cpht, but diamond distribution within Victor North is complex and highly variable, most probably due to the complex internal geology, which shows evidence for both cross-cutting and nested craters.

GENERAL KIMBERLITE GEOLOGY

Victor is composed predominantly of archetypal or Group I spinel carbonate kimberlite; monticellite kimberlite is less common. The pipes are dominated by two contrasting textural types of kimberlite (Fig. 1): pyroclastic and so-called hypabyssal kimberlite (Figs. 2-4). Kong et al. (1999) proposed that Victor South and much of Victor North formed in subaerial conditions by an overall two-stage process of: (1) pipe excavation *without* the development of a diatreme (sensu: Clement and Reid, 1989) and (2) subsequent pipe infilling by primary pyroclastic airfall processes. The pipes have been significantly eroded since emplacement, with only approximately half the original pipe depths now preserved. Victor South appears to have a relatively simple pipe shape and primary pyroclastic infill and, therefore, is used to illustrate the above emplacement model in Fig. 5. Victor South has a bowl-like shape that appears to flare from just below the basal sandstone of the sediments that overlie the basement. The sandstone is a known aquifer, suggesting that the crater excavation process was possibly phreatomagmatic. Victor, therefore, differs from most of the southern African kimberlite pipes in terms of the nature of the pipe infill and emplacement processes involved in its formation (Field and Scott Smith, 1999).

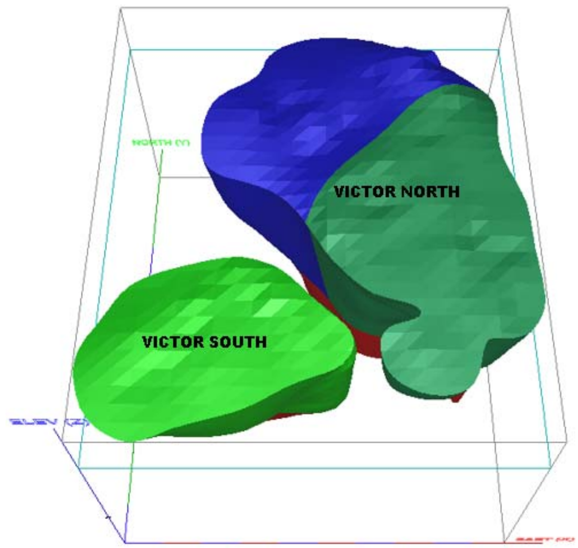

Figure 1: Victor South and Victor North kimberlite pipes. Green=pyroclastic kimberlite; blue=so-called hypabyssal kimberlite. Intervals on the east axis are 50m.

Kong et al. (1999) interpreted the so-called hypabyssal kimberlite, which occurs only in the northwestern part of Victor North, as a subsurface intrusion below sedimentary rocks that were considered to be in situ. The so-called hypabyssal kimberlite and the complex internal geology of Victor North are discussed further below.

GEOLOGY OF VICTOR NORTH

Victor North has a more complex pipe shape and internal geology compared to Victor South. Both of the main textural types of kimberlite are present (Figs. 2-4). The northwestern part of Victor North is dominated by dark competent rocks that superficially resemble fresh hypabyssal kimberlite (HK, Fig. 4a). Further drilling and more detailed investigations indicate a very different type of emplacement for this area of Victor North than proposed by Kong et al. (1999). The internal geology is complex, contrasts with kimberlites elsewhere and is not straightforward to interpret. Single drillcores contain many phases of kimberlite that cannot readily be correlated laterally. The so-called HK is intimately associated with a number of minor, but important, juvenile lapilli tuff horizons and sedimentary rock breccias. Similar breccias also occur along parts of the pipe margins and as a thick unit (20-60m) overlying the so-called HK. The breccias are composed of sedimentary rocks that contrast with the present country rocks and thus appear to derive from now-eroded stratigraphic units. The breccias are sometimes associated with extrusive volcaniclastic kimberlite including graded beds. The features mentioned above suggest that the northwestern part of Victor North was an open crater subsequently infilled by a number of contrasting rock types. The so-called HK is thus not intrusive. The groundmasses of the so-called HK do *not* display typical HK textures and in some areas magmaclastic textures can be discerned (Fig. 4b). The contact between the northwestern and main parts of Victor North (Fig. 1) is steep and curved and coincides with a distinct contrast in geophysical signature. This suggests that the northwestern part of Victor North represents a separate, earlier phase of emplacement. Thus, the remaining area of Victor North must have formed by a later eruption event that excavated a second crater cross-cutting the original crater. The second crater was infilled with pyroclastic kimberlite, the detailed nature of which is discussed below.

PYROCLASTIC KIMBERLITE

The Victor pyroclastic kimberlite (PK, Fig. 2a) is composed predominantly of poorly sorted, clast supported discrete and often fresh grains of olivine (macrocrysts and lesser phenocrysts) and subround to curvilinear shaped, sometimes vesicular juvenile lapilli (Fig. 2b). The juvenile lapilli are usually modally less abundant than the single grains of olivine, mostly less than 1 cm in size and composed of olivine macrocrysts and phenocrysts set in a groundmass of carbonate laths, spinel and interstitial cryptocrystalline carbonate. The PK also contains variable, but overall low, proportions of angular country rock xenoliths (Fig. 2a) dominated by limestone. Mantle-derived xenocrysts, megacrysts and mantle xenoliths are also present. These constituents are set in an inter-clast matrix dominated by serpentine, with lesser carbonate. Subtle variations in the nature, proportion and size of the juvenile and lithic clasts throughout the PK intersections are typical and suggest sorting and/or change in phase of kimberlite. Diffuse stratification and normal graded bedding (1-3m thick) is discernible. The PK is typically fine to coarse grained (terminology after Field and Scott Smith, 1998), although some bedded very very fine (ash-rich) and very coarse grained intersections also occur. The Victor pyroclastic kimberlite is interpreted as partly bedded, juvenile lapilli-bearing olivine tuffs that appear to have formed by subaerial fire-fountaining airfall processes.

The pyroclastic kimberlite of Victor North (Fig. 1) was initially considered to display limited noteworthy internal variations. However, the results of a bulk sampling programme conducted in 2000/2001 indicated significant macrodiamond sample grade variations within the Victor North pyroclastic kimberlite (Fig. 6). Sample grades obtained from the large diameter drillholes shown in Fig. 6 vary from zero to >70 carats/100 tonnes (Fowler et al., 2001), showing that the diamond distribution is complex.

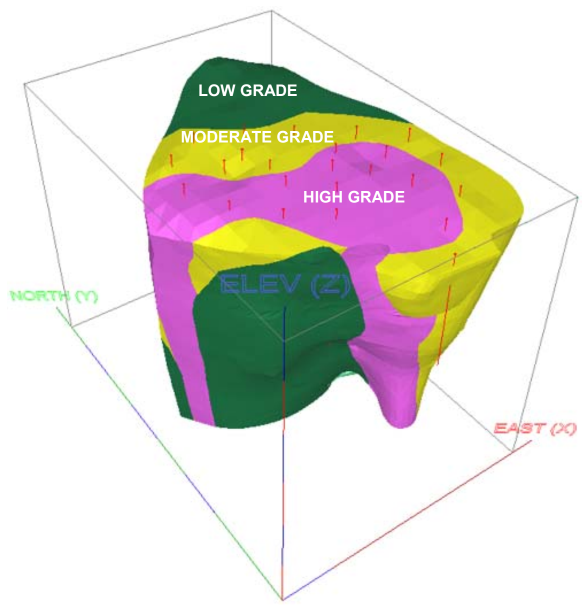

Figure 6: Macrodiamond sample grade distribution in Victor North PK (2001/2002 bulk sampling programme), courtesy of the Victor Project. Intervals on the vertical axis are 50m. Red markers indicate large diameter drillholes.

Detailed petrography of the Victor North pyroclastic kimberlite (VNPK) indicates internal variations that appear to correlate with the macrodiamond sample results. Three petrographically distinct kimberlite types were identified, termed VNhoPK, VNloPK and VNmoPK (ho=high, lo=low, mo=mixed olivine phenocryst content). The three types are distinguished based on the relative modal abundance, size and habit of the olivine phenocrysts that occur both as primary phases within juvenile lapilli and as discrete crystals derived from disruption of the magma. The VNhoPK contains a high proportion of such olivine phenocrysts. They are relatively coarse grained, typically serpentinised and display euhedral to subhedral, often complex shapes (Fig. 3a). The VNloPK, in contrast, is characterised by a comparatively low proportion of finer-grained, dominantly simple subhedral and partly fresh olivine phenocrysts (Fig. 3b). The contrasting nature of the olivine phenocrysts shows that the VNhoPK and VNloPK derive from different pulses, or phases, of kimberlite and thus separate eruptions. The VNhoPK and VNloPK correlate with the low and high sample grades, respectively. The third kimberlite type identified, VNmoPK, is not a separate phase of kimberlite, but instead appears to represent a mixture between the other two phases of juvenile lapilli-bearing olivine tuffs, as supported by the presence in some areas of discrete juvenile lapilli derived from both the VNloPK and VNhoPK. The VNmoPK correlates with moderate sample grades (Fig. 6).

The three types of kimberlite not only appear to correlate with the macrodiamond sample grades, but also occur as spatially coherent zones within the pipe (Fig. 6). The basic Victor emplacement model (Fig. 2) has been developed further for the Victor North pipe to cater for this internal geology as follows and illustrated in Fig. 7: initial crater excavation and subsequent infilling with phase (i), a low grade olivine phenocryst-rich PK (VNhoPK), followed by the eruption of phase (ii), a high grade olivine phenocryst-poor PK (VNloPK), as a separate vent nested within the original phase (i) crater. The second eruption was accompanied by the formation of an intermediate mixed zone with moderate grade (VNmoPK), through sloughing and mixing of the unconsolidated tephra from the low grade phase (i) with the erupting high grade phase (ii) kimberlite along the margins of the second eruption vent. Fig. 6 suggests that the high grade kimberlite in Victor North was not emplaced as one vent (Fig. 7), but as two separate vents nested within the original low grade crater.

CONCLUSIONS

The Victor kimberlite pipes appear to have formed by several eruptive events resulting in adjacent, cross-cutting and nested craters infilled by two contrasting textural types of kimberlites. Victor South and much of Victor North are composed of pyroclastic juvenile lapilli-bearing olivine tuffs. The northwestern part of Victor North contrasts in that it is dominated by rocks resembling hypabyssal kimberlites. The latter are texturally unusual and, because of the association with juvenile lapilli tuffs and breccias±volcaniclastic kimberlite, they are now interpreted as being of probable extrusive origin. The larger and more complex Victor North pipe, therefore, is proposed to have formed by a number of eruptive events: (1) the crater excavation and infilling of the northwestern part of the pipe, (2) the excavation of a cross-cutting crater that was infilled with low grade olivine phenocryst-rich pyroclastic kimberlite, and (3) the eruption of high grade olivine phenocryst-poor pyroclastic kimberlite from two vents nested within crater (2). The two phases of pyroclastic kimberlite are macroscopically similar, but have contrasting grades and microscopic characteristics. This study highlights the meaningful role of kimberlite petrography in the evaluation of diamond deposits and provides further insight into the emplacement and volcanic processes occurring in kimberlites.

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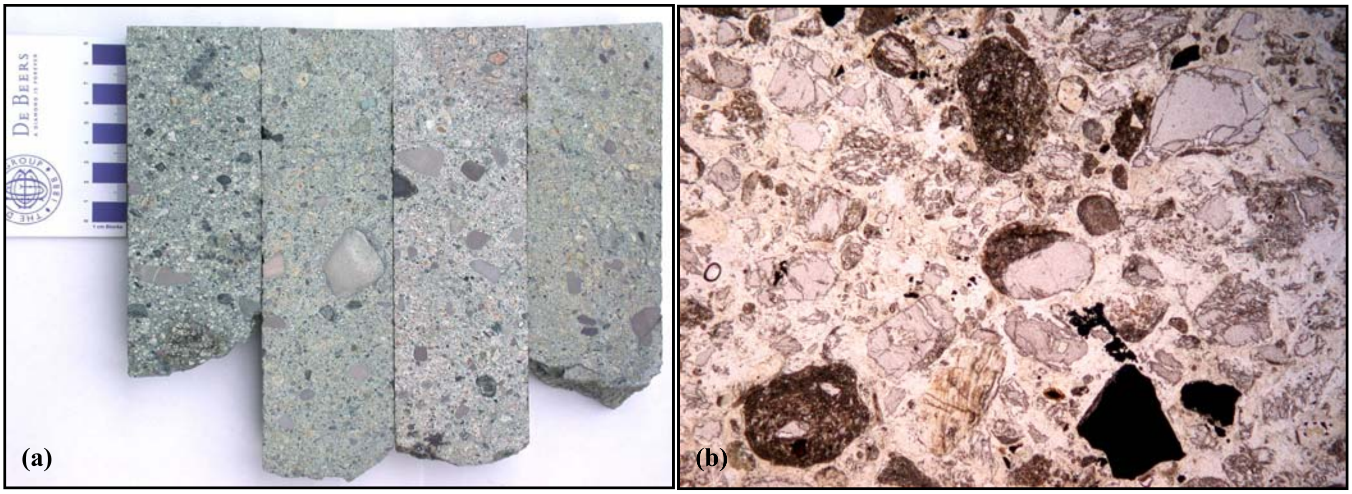

Figure 2: Typical Victor pyroclastic kimberlite shown in (a) polished drillcore and (b) thin section. The photomicrograph shows abundant clast supported discrete fresh and altered olivine and lesser subround juvenile lapilli set in a serpentine matrix. PPL. FOV = 9mm.

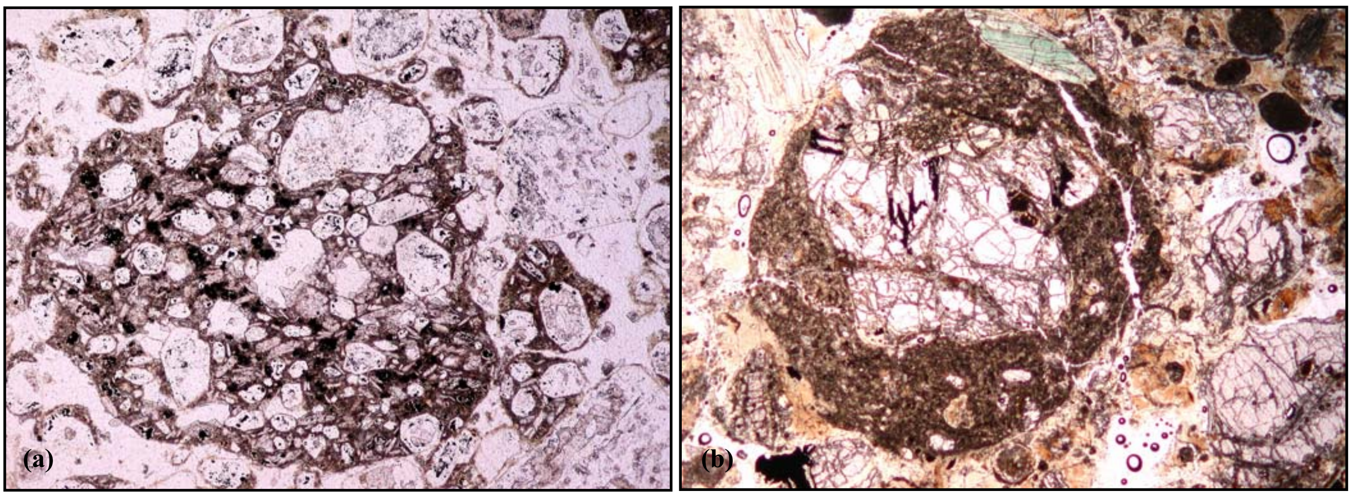

Figure 3: Photomicrographs of the (a) olivine phenocryst-rich pyroclastic kimberlite and (b) olivine phenocryst-poor pyroclastic kimberlite, showing the contrasting modal abundance, size and habit of the primary olivine phenocrysts that occur both within the juvenile lapilli and as discrete grains. PPL. FOV = (a) 3mm, (b) 8mm.

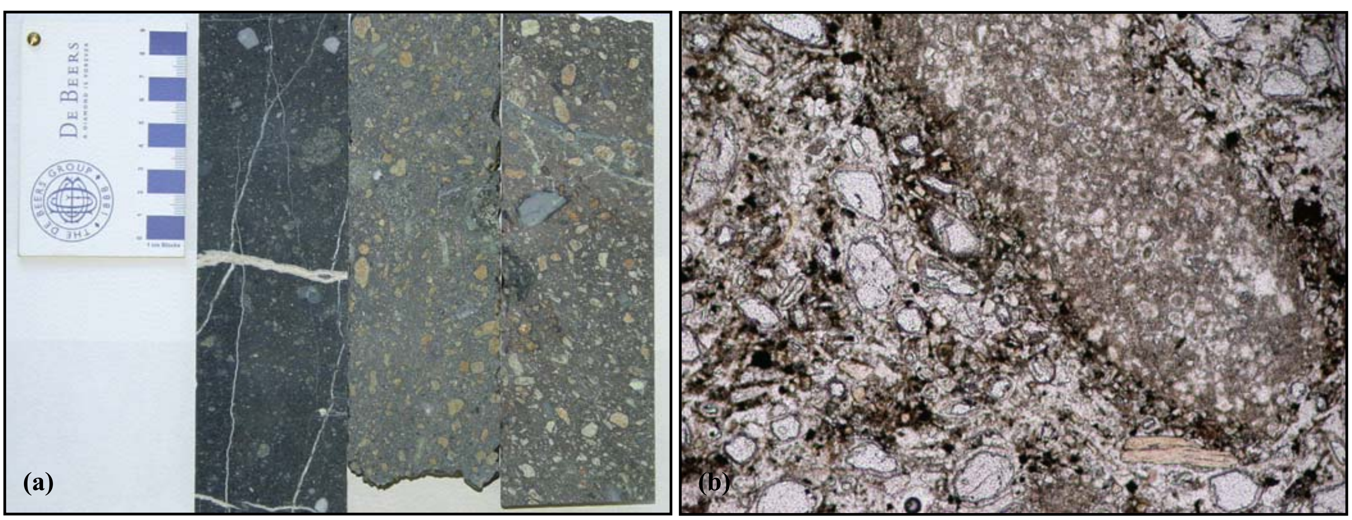

Figure 4: The dark competent so-called hypabyssal kimberlite shown in (a) polished drillcore and (b) thin section. The photomicrograph shows the unusual uniform to magmaclastic texture of these rocks. PPL. FOV = 6mm

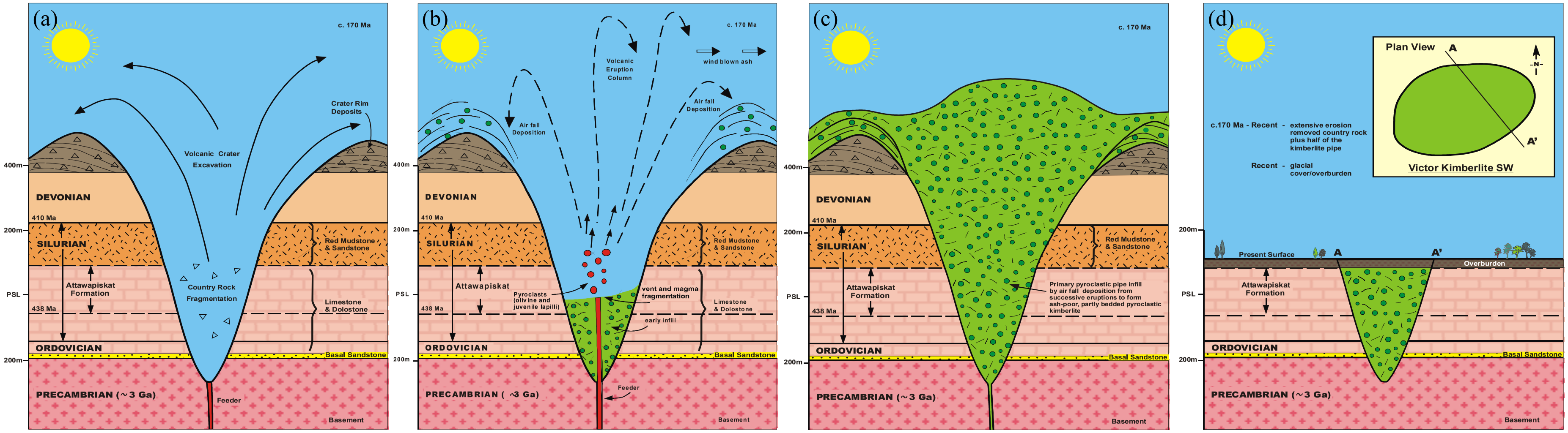

Figure 5: Emplacement model for Victor pyroclastic kimberlite: (a) initial crater excavation by possible phreatomagmatic eruption processes (crater flares from basal sandstone unit, a known aquifer), (b) subsequent crater infilling by subaerial pyroclastic fire-fountaining processes, (c) the crater infill and (d) the present erosional surface with a thin veneer of glacial overburden; pipe shape based on modeled cross-section through Victor South pipe.

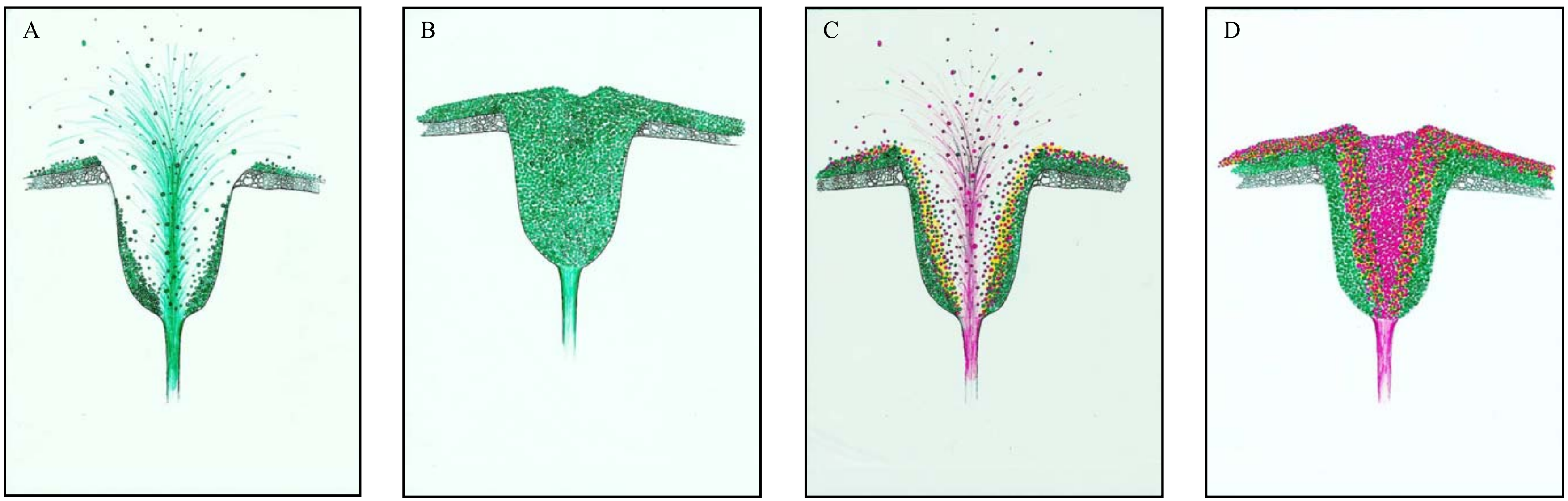

Figure 7: Schematic representation of the emplacement of the low (green), high (magenta) and moderate (yellow) grade pyroclastic kimberlites in the main part of Victor North: (A) initial crater excavation and subsequent eruption of phase (i), a low grade olivine phenocryst-rich pyroclastic kimberlite; (B) low grade pipe infill; (C) eruption of phase (ii), a high grade olivine phenocryst-poor pyroclastic kimberlite through the earlier-formed low grade pipe infill; sloughing and mixing of the unconsolidated low grade tephra with the erupting high grade pyroclastic kimberlite along the margins of the central eruption vent results in an intermediate zone of mixed composition and moderate grade (VMmoPK); (D) the three geological/grade zones of the final pipe infill.

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LONG ABSTRACTS

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