
The Victor Diamond Mine, Northern Ontario, Canada: Successful Mining of a Reliable Resource

B. D. Wood, B. H. Scott Smith, and B. Rameseder

Abstract

The Victor Diamond Mine opened in 2008. Different phases of evaluation were used from 1997 to 2003 to systematically build a resource. The Mineral Resource Model suggested an extremely variable and overall relatively low grade for Victor, but that the diamonds would be of superior value. The development of a robust geological model and understanding the emplacement processes were critical to the design and implementation of sampling programs and to the establishment of a reliable resource for mine planning. Victor comprises two kimberlite pipes; the larger pipe, Victor North, includes the highest predicted grades and is the focus of current open pit mining and this paper. The variability in grade reflects the complex geology of Victor North which comprises two cross-cutting volcanic craters. The later crater was infilled by the products of two separate eruptions; a central high grade pyroclastic kimberlite nested within previous unlithified low grade pyroclastic infill. Extensive mixing produced a wide, gradational, inhomogeneous internal contact zone with variable, but overall intermediate grades. Apart from macrodiamond bulk sampling, the contrasting grade zones can only be differentiated using micropetrography and groundmass mineral compositions which creates a practical mining issue in separating ore from kimberlite waste. Ore versus waste is identified during mining by routine bulk sampling of newly exposed kimberlite which is treated in a separate processing plant. The mining bulk sample data and mined mineral resource performance data show that the Victor North Mineral Resource is accurate, significantly contributing to the success and reliability of commissioning and operating the mine.

Keywords

Diamond • Evaluation • Mineral resource • Kimberlite geology • Victor • Exploration • Mining

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Introduction

The Victor Diamond Mine was officially opened, six - months ahead of schedule, in 2008. The ~170 Ma Victor kimberlite occurs in a cluster of twenty-three kimberlites located 90 kms west of the Attawapiskat First Nation coastal community in the James Bay Lowland of northern Ontario (Fig. 1; Kong et al. 1999). The Attawapiskat area is

part of the Hudson Platform that consists of Paleozoic sedimentary rocks which overlie the Precambrian Superior craton (inset of Fig. 1). Victor is located on the southern flank of the Cape Henrietta Maria Arch (Fig. 1) which separates the erosional remnants of the Hudson Bay and Moose River cratonic sedimentary basins.

Since the discovery and exploration of the Victor kimberlite between 1988 and 1995, different phases of evaluation included macrodiamond bulk sampling by Reverse Circulation (RC) drilling and trenching between 1997 and 2003 (Fowler et al. 2001; Wood 2000). Experiences gained from each successive program were used to systematically build a reliable Mineral Resource based on the integration of both kimberlite geology and diamond results. This paper summarises the different stages in the development of the Victor North Mineral Resource (Table 1). Macrodiamond data for early and advanced evaluation bulk samples, the Mineral Resource Block Model, as well as mining bulk samples collected up to the end of 2011 are compared to show that the Victor Mineral Resource Model is reliable which has significantly contributed to the successful open pit mining of Victor. The terminology follows the Canadian Institute of Mining (CIM) Definition Standards on Mineral Resources and Reserves (www.cim.org). A Mineral Resource is a concentration or occurrence of diamonds (or

other materials) in or on the Earth's crust in such form and quantity and of such grade or quality that it has reasonable prospects for economic extraction.

1988–1995: Discovery and Exploration

The Attawapiskat kimberlite cluster (Fig. 1) was discovered in 1988 by traditional glacial sediment sampling for kimberlite indicator minerals and subsequent airborne magnetic surveys (Kong et al. 1999). The geophysical anomalies were confirmed as kimberlites by a core drilling program in 1988/1989. Initial exploration results for the cluster, with low microdiamond recoveries and a paucity of high interest kimberlite indicator mineral compositions, suggested the bodies were only of moderate interest and further work was deferred until 1995 when the mineral claims were due to lapse.

Work on the Attawapiskat bodies resumed in 1995 with further investigation of the 1988/1989 exploration drill-cores. The remainder of the drillcore was treated for microdiamonds to improve previous grade predictions, and for macrodiamonds to support the apparent coarse size frequency distribution. This prompted the claims to be retained and further mini-bulk sampling on selected bodies.

Fig. 1 Location and geological setting of the Victor Mine, Northern Ontario, Canada (after Fig. 1 of Kong et al. 1999). Victor occurs within the Attawapiskat kimberlite cluster which comprises twenty-three kimberlites (not all evident), eighteen of which were discovered by De Beers Canada Inc. The Victor kimberlite was emplaced into 275 m of Paleozoic sediments and the underlying basement of the Precambrian Superior craton (pink; inset after Hoffman 1988)

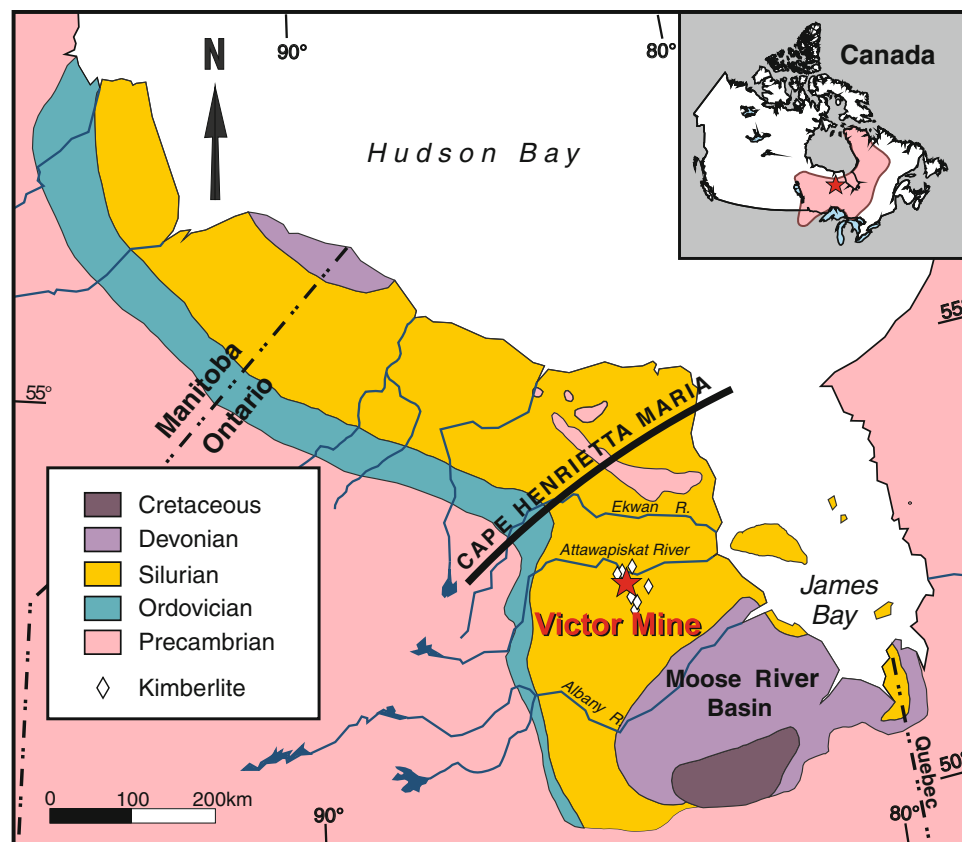


Table 1 Summary of different phases of investigation during the evaluation of Victor North

Year	Level of investigation	Geological model	Material investigated	Investigation type	Tonnes treated ^a	Carats recovered ^a	Comment
1988–1989	Discovery	Victor seen as single pipe; infill of HK with variable textures, some unusual and poorly understood	BQ/NQ drillcore (8 holes in Victor North)	Microdiamonds; KIM abundances; KIM compositions			Attawapiskat kimberlite cluster considered of moderate interest; further work was deferred
1995	Exploration	Pipe infill includes possible VK with less HK; textures not straightforward	Remainder of 1988–1989 drillcore	Microdiamonds; Macrodiamonds; Kimberlite geology			Coarse microdiamond distribution prompted claims to be retained and triggered early evaluation
1997	Early evaluation	2 adjacent but separate pipes, VN and VS, evident based mainly on ground magnetics (Fig. 2)	14 RC holes (132 mm to 87 mm)	Macrodiamonds	19	4 (+1 mm)	Recovered grade and stone quality in Victor, especially VN, higher than initial expectation; prompted further early evaluation
1998–1999	Early evaluation	Separate VN and VS pipes confirmed; VN interpreted as 2 cross cutting pipes with sharp internal contact: VM infilled with 1 uniform phase of subaerial FPK; VNW infilled with complex and unusual HK	21 RC holes (185 mm to 185 mm); NQ/HQ drillcore	RC: macrodiamonds; Drillcore: kimberlite geology	195	55 (+1 mm)	Recovered sample grades: up to >30 cpht in VM and low grade <5cpht in VNW; advanced evaluation focused on VM warranted
1999	Early evaluation		Surface pit	Macrodiamonds	334	27 (+1 mm)	Indicated high stone value potential for VM; VM advanced evaluation warranted
2000–2001	Advanced evaluation		26 RC holes (610 mm to 242 mm); HQ drillcore, some twinned with RC holes	Macrodiamonds	3,033	713 (+1.5 mm)	VM yielded variable sample grades up to >100 cpht; further assessment of economic viability warranted; detailed kimberlite geology required to explain variable diamond distribution
2000–2001	Advanced evaluation		Trench	Macrodiamonds	3,750	2,332 (+1.5 mm)	High value stones in VM confirmed; pre-feasibility warranted
2002	Pre-feasibility	3 concentric internal zones defined within VM by high, moderate and low grades (Fig. 3b)		Geological interrogation of all diamond data			3 internal zones within VM have average grades of 52, 24, 2 cpht; Mineral Resource identified; feasibility warranted
2002–2003	Pre-feasibility/Feasibility			Geostatistical analysis of all diamond data			2 internal zones of ore and kimberlite waste defined within VM; VM Mineral Resource defined

(continued)

Table 1 (continued)

Year	Level of investigation	Geological model	Material investigated	Investigation type	Tonnes treated ^a	Carats recovered ^a	Comment
2002–2003	Pre-feasibility/ Feasibility	VM found to comprise 2 nested craters infilled by separate phases of FPK with a wide inhomogeneous mixed contact zone (Figs. 3b, 4); Blip is separate earlier pipe infilled with different FPK; VNW recognised as complex crater-fill of CK, FPK and CRB	HQ and previous drillcore	Micropetrography of 1160 representative drillcore and RC chip samples of many VM drill holes			Detailed 3D VM internal geological and emplacement models add confidence to, and justify, Mineral Resource Model; part of VM classified as an Indicated Mineral Resource; De Beers board approved construction of the Victor Diamond mine
2005	UBC research	Supports VM infill is 2 separate phases of FPK	Selected drillcore samples	Groundmass mineral electron microprobe analysis			Verification of 2002–2003 VM geological and emplacement models, and thus the VM Mineral Resource Model
2006–2010	UBC research	VNW interpreted as complex crater-fill including VK, FPK and CRB but dominated by CK comprising an extrusive coherent-to-clastogenic lava lake (Fig. 8)	Previous drillcore	Mega-, macro- and micropetrography of all previous VNW drillcores			3D geological model of VNW used by mine to complete VN geological and emplacement models; provides basis for development of additional resource from VNW kimberlite waste; the Victor Diamond Mine commenced operation in Feb 2008
2008–2011	Mining	Confirmed: VM crater cross cuts earlier Blip and VNW pipes; VM nested craters; VNW lava lake (Fig. 9)	353 Mining bulk samples (Fig. 3d); Open pit exposures (Fig. 9)	Macrodiamonds; Megascopic kimberlite geology	24,325	3,682 (+1.5 mm)	Victor North Resource Model shown to be accurate (Fig. 7); VN geological and emplacement models correct; both contribute to the successful and reliable mining to end 2011

VN and VS see Fig. 2, VNW, VM, Blip see Fig. 3a; KIM Kimberlite indicator minerals; UBC University of British Columbia
HK hypabyssal kimberlite, *VK* volcanoclastic kimberlite, *FPK* Fort à la Corne-type pyroclastic kimberlite, *CK* coherent kimberlite, *CRB* country rock breccias (after Scott Smith et al. 2012, 2013)

^a Tonnes and Carats for Victor North only

From their discovery, the Attawapiskat kimberlites were recognised to be geologically unusual. In 1989, based on very limited work, Victor was considered to be one pipe composed of hypabyssal kimberlite with variable textures including some which were unusual and poorly understood. In 1995, after further limited megascopic investigation of

the 1988/1989 drillcores, it was determined that Victor contained mainly possible volcanoclastic kimberlite and less hypabyssal kimberlite. The volcanoclastic kimberlite was different from typical southern African type pipes and their infills (tuffisitic kimberlite). The textures of both rock types were not straightforward to understand.

1997–1999: Early Evaluation

In 1997 mini-bulk sampling of four selected Attawapiskat bodies was undertaken. The best results were obtained from Victor which then was the focus of further evaluation. In 1997 reinterpretation of 1989 ground magnetics suggested that Victor comprises two kimberlite pipes termed Victor North and Victor South (Fig. 2). The initial open pit mining of Victor to the end of 2011 was confined to Victor North which is, therefore, the focus of this paper. The 1997 mini-bulk sampling of Victor North yielded 4 carats (cts; +1 mm cut off) from 19 tonnes (t) of kimberlite extracted from 14 RC holes drilled using a heliportable rig developed by De Beers (Fig. 3a; 132 mm diameter to depths of up to 87 m from surface; drill locations restricted to areas with minimum glacial cover). These results showed that Victor, in particular Victor North, was of greater interest than initially thought, both in terms of grade and stone quality, and a scoping study indicated an optimistic project return.

Early evaluation of Victor continued in 1998/1999 with more bulk sampling and core drilling. The latter confirmed the interpretation of early ground magnetics that Victor comprises two adjacent, but separate, kimberlite pipes that nearly coalesce at the present surface (Fig. 2). The two pipes have a combined surface area of ~15 ha making Victor the largest identified kimberlite of the Attawapiskat cluster. At the same time as the Attawapiskat discovery, a new province of kimberlites was found at Fort à la Corne, Saskatchewan (Lehnert-Thiel et al. 1992). These bodies were investigated in more detail shortly after their discovery and shown to comprise new types of kimberlite pipes (Scott Smith et al. 1994; Field and Scott Smith 1999; Scott Smith 2008a, b). Applying the findings from Fort à la Corne, it was shown that many of the Attawapiskat bodies, including much of Victor, were composed of crater-fill Fort à la Corne-type pyroclastic kimberlite (Kong et al. 1999; terminology after Scott Smith et al. 2012, 2013).

The 1998/1999 drilling confirmed suspicions based on geophysics (Fig. 2) that Victor North comprises two distinctly different parts, termed Victor Main and Victor Northwest (Fig. 3a). Victor Main was considered to be a later cross-cutting pipe composed of uniform subaerial xenolith-poor olivine-rich Fort à la Corne-type-pyroclastic spinel-carbonate kimberlite. Less hypabyssal carbonate kimberlite infilled much of Victor Northwest (Kong et al. 1999). The absence of apparent internal contacts and the consistency in components and texture suggested that Victor Main was a single phase of pyroclastic kimberlite which was expected to be homogeneous in diamond content. Thus, no internal geological model within Victor Main was developed except for the separation of a small northeastern part based on some potentially significant geological

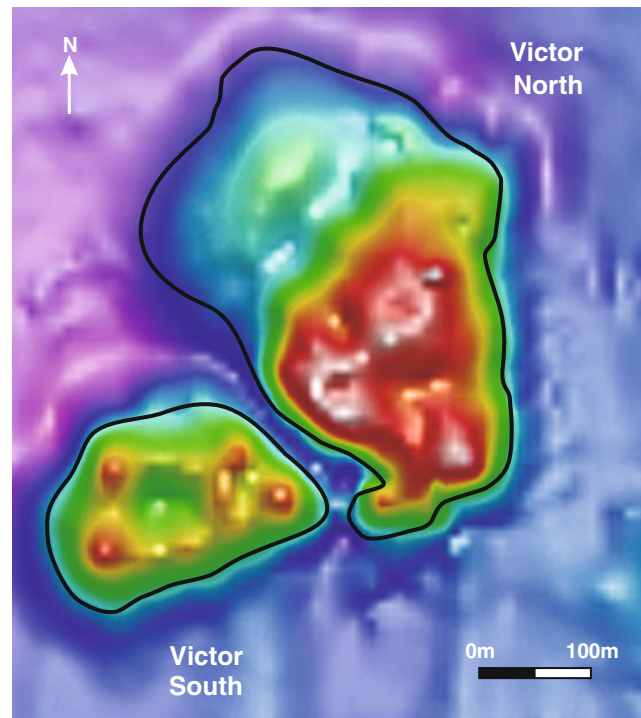
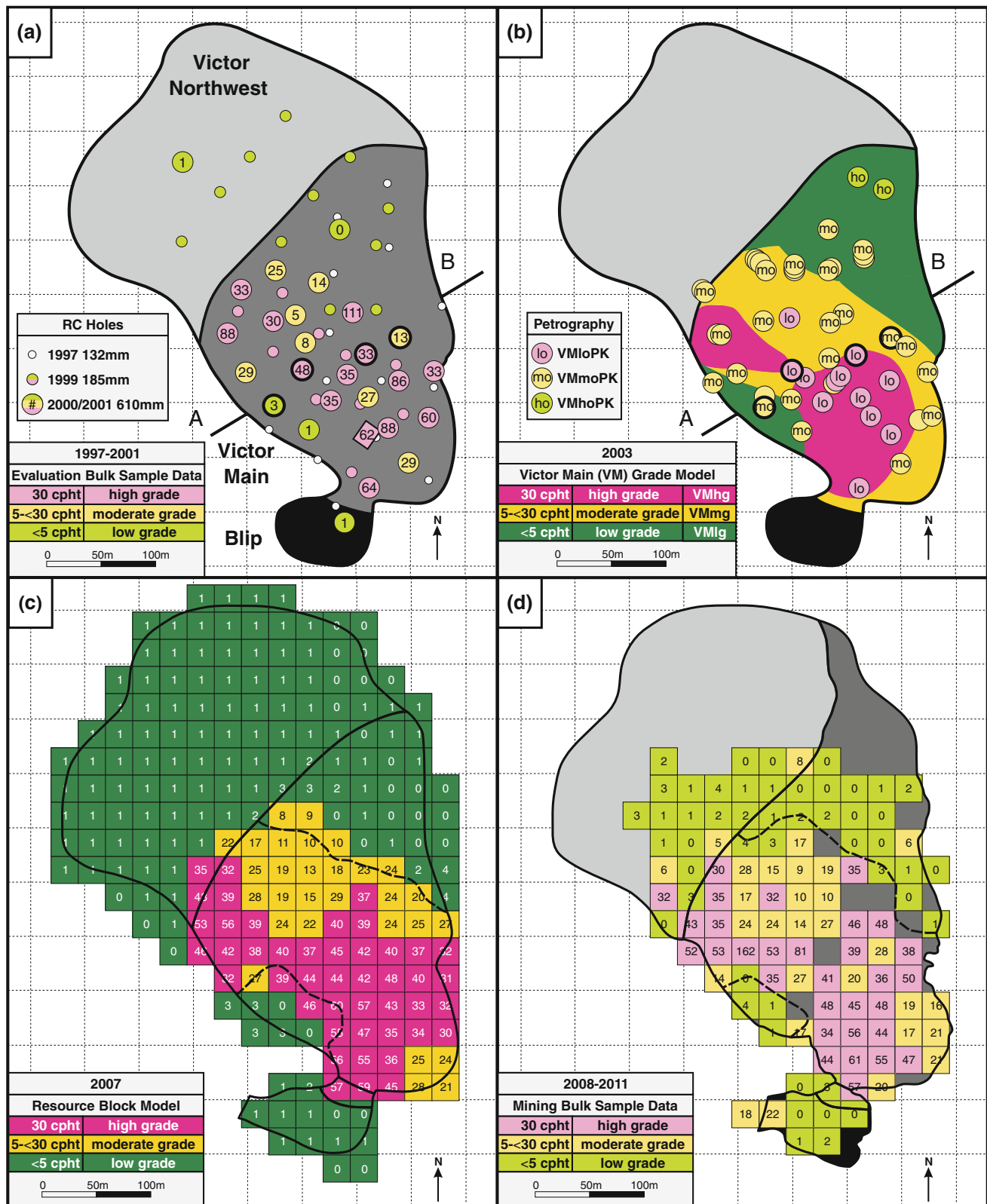


Fig. 2 Interpreted ground magnetic signature over the Victor kimberlite based on 50 m line spaced surveys completed in 1989 and reinterpreted in 1997. This, together with limited drill hole information, showed that Victor comprises two pipes Victor North and Victor South. The surface outlines (black lines) shown here derive from the same 2002 geological model as the subsurface outline in Fig. 3a. Note the contrasting magnetic signature between subsequent subdivisions of Victor North shown in Fig. 3a, in particular Victor Main and Victor Northwest

differences (e.g. better bedding, finer grained). In contrast to Victor Main, Victor Northwest was found to be internally complex. One major unit was initially thought to be a subsurface intrusion as it superficially resembled hypabyssal kimberlite and occurred below what was then presumed to be in situ country rock sediments. In other Attawapiskat bodies alternative and unusual emplacement processes, such as effusive lava lakes, were considered for similar coherent hypabyssal-like kimberlites (Kong et al. 1999).

The 1998/1999 small bulk samples of Victor North produced 55 cts of +1 mm diamonds from 195 t of kimberlite recovered from 21 RC holes (Fig. 3a; total of 28 cts per hundred tonnes (cpht); diameter of 185 mm to variable depths up to 185 m; 50 m sample intervals). These data showed that the grade varies with the kimberlite geology: (i) much of Victor Main has sample grades ≥ 30 cpht, and (ii) both the northeastern part of Victor Main as well as Victor Northwest have different and much lower sample grades (< 5 cpht). Although the diamond content was shown to be variable, the results indicated that advanced evaluation on Victor Main (and Victor South) was warranted. An



◀ **Fig. 3** Plan view of Victor North for 160 Bench which is 53–63 m below surface (shown as *black bar* in Figs. 4 and 5) presenting evaluation, Mineral Resource Block Model and mining bulk sample macrodiamond data (cpht = carats per hundred tonnes). *Pink* = ≥ 30 cpht or high grade (hg); *yellow* = 5– <30 cpht or moderate grade (mg); *green* = <5 cpht or low grade (lg); *pale shades* = data, *dark shades* = models. Background 50 m grid. **a** Early and advanced evaluation bulk sample data (1997–2001) and the 2002 geological model. *Solid black lines* = external and sharp internal geological boundaries separating Victor Northwest (*pale grey*), Victor Main (*dark grey*) and Blip (*black*) interpreted from drill hole data and 2002 ground magnetics. *White circles* = 1997 small diameter (132 mm) RC holes (results in Early Evaluation section). *Coloured circles*: small = 1999 medium diameter (185 mm) RC holes; large = 2000/2001 large diameter (610 mm) RC holes. *Rectangle* = 2000/2001 trench. Numbers = 2000/2001 macrodiamond sample grades relevant to 160 Bench. The RC holes shown in cross section A–B in Fig. 4 are highlighted by *thicker black borders*. **b** 2003 Victor Main (VM) grade zone model based on data shown in (a): high grade (VMhg), moderate grade (VMmg), low grade (VMlg). *Coloured circles* = petrographic results for RC and drill core samples located within 160 Bench.

additional small surface pit yielded a further 27 cts (+1 mm) from 334 t.

2000–2007: Advanced Evaluation and Development

Advanced evaluation in 2000/2001 focused on the high grade area of Victor Main based on the 1998/1999 results (Fig. 3a). Prior to this next phase of macrodiamond bulk sampling, a core drilling program improved the understanding of the pipe shape and internal geology. Also many of the planned RC holes were twinned with core holes providing information which was used to verify and enhance the planned RC program. The bulk sampling utilised (i) 26 RC holes to investigate grade (40 m grid, diameter of 610 mm, variable depths to 242 m) and (ii) a trench to ascertain the stone value (Fig. 3a). Unseasonably warm weather caused a delay of most of the 2000 program to 2001, allowing the application of the 2000 results in the optimisation of the 2001 drill program. For example, some of the large diameter drill holes were terminated shallower than originally planned within, or close to, the higher grade portions of the kimberlite (e.g. compare depths of 2001 holes V-01-126L and V-01-153L with the 2000 holes V-107-00L and V-109-00L in Fig. 4).

A total of 2,332 cts of +1.5 mm diamonds were recovered from 3,750 t of kimberlite from the trench (total 62 cpht). The RC bulk samples, importantly, were planned to have vertical sample intervals of 12 m (as shown in Fig. 4) to provide detailed macrodiamond data and determine the spatial variations in diamond content. The results showed the diamond distribution was more complex than expected, both laterally and vertically, with sample grades

Petrographic subdivisions: lo, mo, ho = VMloPK, VMmoPK, VMhoPK (Victor Main low, mixed and high olivine pyroclastic kimberlite). The holes with petrographic data shown in cross section A–B in Fig. 4 are highlighted by *thicker black borders*. **c** 2007 Mineral Resource Block Model for Victor North with modified geological boundaries compared to Fig. 3b (*solid black lines*). Numbers = modelled grade (cpht) per mining block based on data in (a). Each block is 25 × 25 × 10 m in size. *Dashed black lines* show the subdivision within Victor Main based on the block model between ore and kimberlite waste termed VMgrd and VMnogr (for Victor Main grade and no grade, respectively and discussed in Advanced Evaluation and Mining section; also shown in Fig. 5). The separate block models for each of the four parts of Victor North (VMgrd, VMnogr, Victor Northwest and Blip) are combined and, where these models overlap near boundaries between them, the data shown are for VMgrd. **d** 2008–2011 mining bulk sample results for the same blocks shown in (c) *Pale grey*, *dark grey* and *black* = not sampled. *Dashed black lines* = updated 2011 internal boundaries between ore and kimberlite waste determined using these data and open pit geology (contrast with modelled boundaries in (c)). Open pit exposures in Cut 1 confirmed that Blip is a separate small pipe cross cut by Victor Main

ranging from 0 to over 100 cpht (Figs. 3a, 4). Stringent quality control and security procedures were adhered to during the processing of the evaluation samples and tailings from selected samples were audited through a separate treatment plant. The results showed that the processing of the advanced evaluation samples was highly reliable and consistent and not responsible for variations in recovered grade. These results prompted further investigation of the internal geology of Victor Main to determine the reason for the variation.

The first step in this geological investigation was to use the distinct changes in bulk sample macrodiamond content, both carats (cpht) and the number of stones per hundred tonnes (spht) (pale colours in Figs. 3a, 4), to develop initial three dimensional internal geological boundaries within Victor Main. The model indicated three spatially coherent and broadly concentric zones of contrasting diamond grade (Figs. 3b, 4) within the seemingly uniform pyroclastic kimberlite:

- Victor Main high grade (average 52 cpht) = VMhg,
- Victor Main moderate grade (average 24 cpht) = VMmg,
- Victor Main low grade (average 2 cpht) = VMlg.

Using this model, the geology of the Victor Main kimberlite was examined in much more detail and in stages (Webb et al. 2004; van Straaten et al. 2008; unpublished internal reports, some by Webb). These studies showed the Victor Main pyroclastic kimberlite (VMPK) infill, although apparently megascopically and macroscopically uniform, resulted from two separate eruptions of different batches of magma with different diamond contents. Micropetrography showed that the products of the two different eruptions of kimberlite could be distinguished using the contrasting average size (0.15 vs. 0.25 mm), habit (complex versus simple crystal shapes) and particularly the abundance of the olivine phenocrysts occurring in the melt-bearing pyroclasts

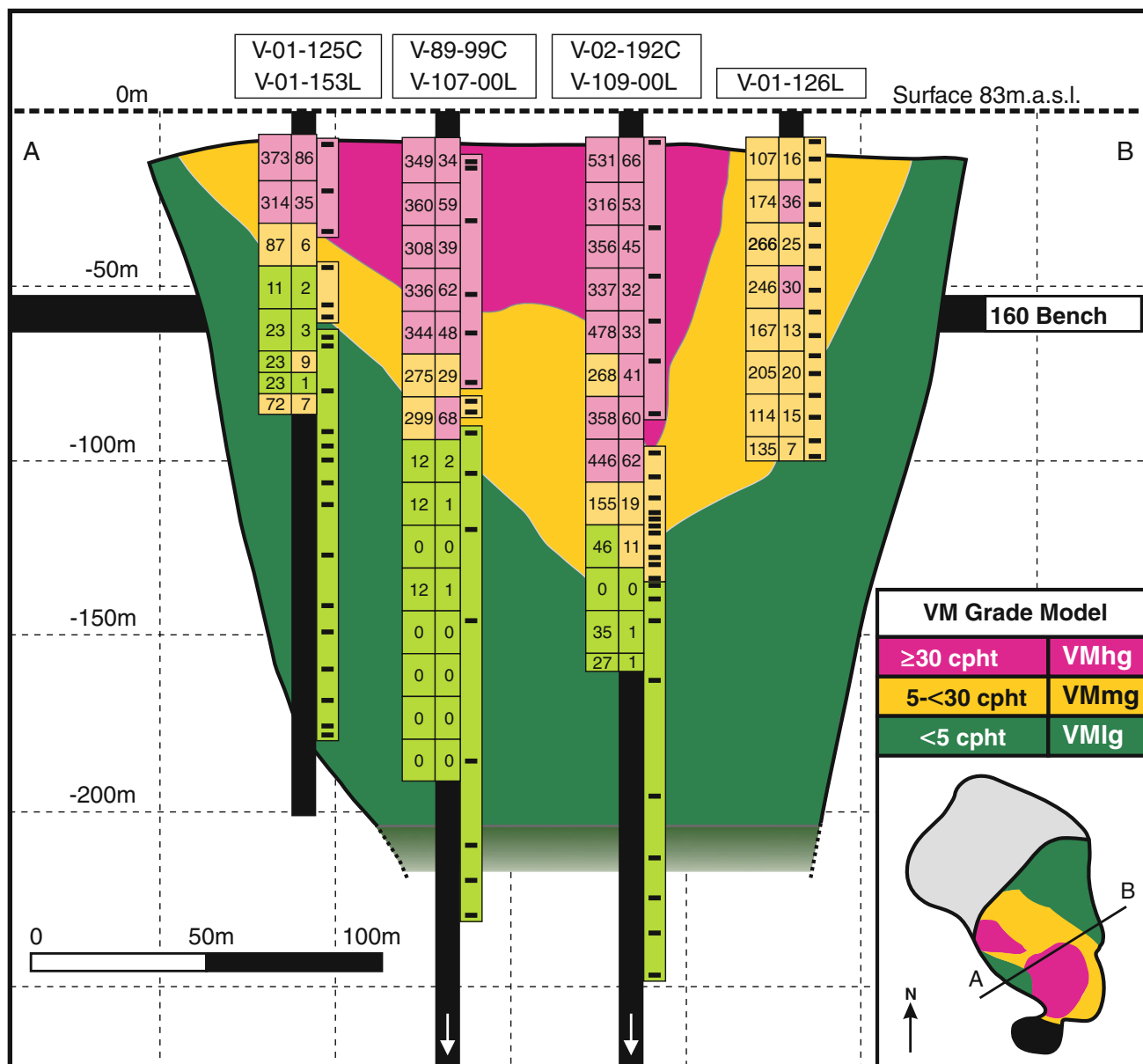


Fig. 4 Cross section A–B through Victor Main as shown for 160 bench in Fig. 3a and b presenting advanced evaluation bulk sample macrodiamond data and kimberlite petrography. Background 50 m grid with depths below surface (m.a.s.l. = metres above sea level). Darker colours = 2003 grade model zones as in Fig. 3b; paler colours = drill hole sample results. Four 2000–2001 large diameter (L) RC holes highlighted in Fig. 3a and three nearby core (C) holes highlighted in Fig. 3b are shown. Vertical black bars include location of RC and core holes when paired and indicate bottom depth of the core holes. Left and centre columns = RC bulk sample results. Left = stones per hundred tonnes (pink = ≥300 spht;

yellow = 50–<300 spht; green = <50 spht). Centre = carats per hundred tonnes (pink = ≥30 cpht; yellow = 5–<30 cpht; green = <5 cpht). Right column = location of petrographic samples (black dashes) and petrographic subdivisions (pink = VMloPK, yellow = VMmoPK, green = VMhoPK as in Fig. 3b). Note the correlation of the latter with VMhg, VMmg and VMIg. The depths separating mining ore from kimberlite waste (VMgrd to VMnogr) discussed in Advanced Evaluation and Mining section, Fig. 5) that correspond to each pair of holes are 42.1, 90.8 and 121.5 m from left to right. Hole V-01-126L occurs entirely within VMgrd

(28 vs. 8 modal %) and as melt-free grains (Webb et al. 2004). This distinction was later supported by differences in the composition of the primary groundmass carbonate and spinel within melt-bearing pyroclasts (van Straaten et al. 2008).

Based on the petrographic examination of 1,160 samples from 56 RC and twinned core holes, the samples were divided into three broad groups (Figs. 3b, 4):

- Victor Main low olivine Pyroclastic Kimberlite = VMloPK,

- Victor Main mixed olivine Pyroclastic Kimberlite = VMmoPK,
- Victor Main high olivine Pyroclastic Kimberlite = VMhoPK.

The VMloPK and VMhoPK are composed of the melt-bearing pyroclasts which have low olivine phenocryst (lo) and high olivine phenocryst (ho) contents, respectively. The VMmoPK contains a mixture of the two types of pyroclasts (mo = mixed ho and lo). These three broad petrographic groups form spatially coherent pipe zones that correlate with the three grade zones (Figs. 3b, 4) as follows:

- VMhg = VMloPK,
- VMmg = VMmoPK,
- VMlg = VMhoPK.

The above correlation shows that the first eruption of VMhoPK was low grade and the later central eruption of VMloPK was high grade (<5 , ≥ 30 cpht, respectively; Fig. 3b, 4). The later VMloPK appears to have formed two nested craters within the earlier infill corresponding with the two separate areas of VMhg (two pink lobes in Fig. 3b better illustrated in Fig. 15a of Webb et al. 2004). The later nested craters were emplaced within the earlier low grade infill before lithification. Large scale mixing of pyroclasts from each eruption produced a wide (~ 100 m), inhomogeneous gradational internal contact zone (VMmoPK) with variable but overall intermediate moderate grades (VMmg, $5 < 30$ cpht; Figs. 3b, 4; emplacement process is illustrated in Fig. 16 of Webb et al. 2004). Variations in grade within the inhomogeneous contact zone result from the mixing of different proportions of pyroclasts from each of the two eruptions, VMloPK and VMhoPK. The northeastern area of Victor Main which was initially separated based on mainly megascopic and macroscopic features did prove to have a different lower grade (Fig. 3a, b) but petrographically it was shown to be part of VMlg and this internal boundary was removed. Also, the so-called Blip in Victor North (black in Fig. 3a) was shown to be composed of a different pyroclastic kimberlite to that of Victor Main and interpreted, similar to the Victor Northwest pipe, to be a separate earlier low grade pipe cross cut by Victor Main.

The good correlation between kimberlite petrography and emplacement models with the macrodiamond results provided the necessary geological justification for the significant grade variation within Victor North, especially Victor Main. Thus, the combined understanding of the kimberlite geology and macrodiamond content for Victor North led to a 2002 mining pre-feasibility study followed in 2003 by a mining feasibility study focused on Victor Main. The studies concluded that the grade of Victor Main is variable and overall relatively low by worldwide standards but, that the diamonds would be of high value due to the high proportion of gem quality diamonds recovered from large bulk test trenches in both Victor North (Fig. 3a) and

Victor South. Based on these conclusions, in 2003 the De Beers Board gave approval for the construction of the Victor Diamond Mine. Construction of the mine started in February 2006 after receiving all the necessary approvals from the provincial and federal governments.

The approval to build a mine is based on a Mineral Resource Estimate. A Mineral Resource can be sub-divided or classified into Inferred, Indicated and Measured categories in order of increasing geological confidence and must have a reasonable probability of being economically extracted in the future. For ongoing Mineral Resource Estimates and classifications during the period 2002–2007, as well as mine planning purposes, all the available evaluation data were used to develop and update the Mineral Resource Block Models to best fit the bulk sample data. The latest block model before the start of mining, the 2007 Mineral Resource Block Model (Fig. 3c), was used in the 2007 resource update which classified 12 million tonnes at 33 cpht of Victor Main as an Indicated Mineral Resource. An Indicated Mineral Resource is part of a Mineral Resource with a level of confidence sufficient to allow the appropriate application of technical and economic parameters to support mine planning and evaluation of the economic viability of the deposit.

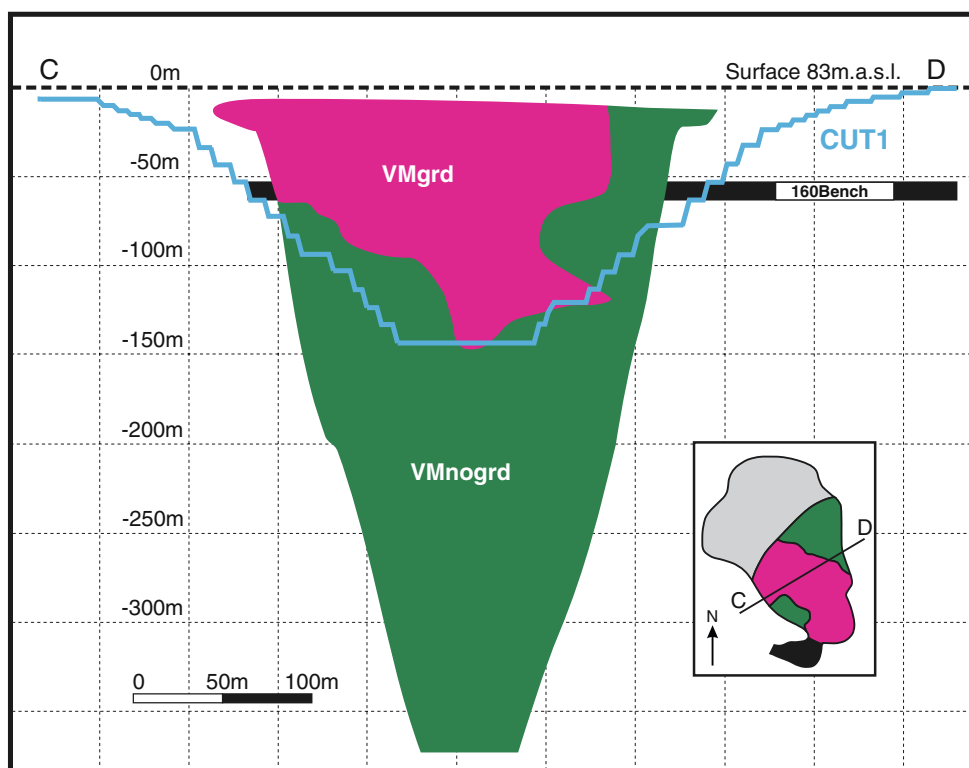
The 2007 Mineral Resource Block Model subdivided Victor North into four separate parts. Victor Northwest and Blip had been shown to be separate pipes both cross cut by Victor Main and they were isolated using kimberlite geology and extrapolations of the observed sharp internal contacts as shown in Fig. 3a. Within Victor Main, given the complex geology resulting from the wide and inhomogeneous, mixed and gradational internal contact zone (VMmoPK), a different approach based on the diamond results alone was used.

Indicator kriging, a geostatistical approach to geospatial modelling, of the evaluation RC drill hole macrodiamond results within Victor Main generated statistically-derived internal boundaries (dashed lines in Fig. 3c). The boundaries defined two zones, a single central ‘grade’ zone ($> \sim 5$ cpht) and other low grade more marginal areas expected to be non-economic ($< \sim 5$ cpht). For mine planning purposes, the ‘grade’ and non-economic zones were attempting to predict ore versus kimberlite waste (additional mine waste includes country rock) and were termed:

- Victor Main grade = VMgrd ore,
- Victor Main no grade = VMnogr kimberlite waste.

Indicator kriging of the macrodiamond results within each of the four defined three dimensional volumes (VMgrd, VMnogr, Blip, Victor Northwest) was used to populate the four separate block models with predicted diamond grades, which together comprise the 2007 Mineral Resource Block Model. The data for one bench are shown in Fig. 3c in which predicted grades range up to 60 cpht and

Fig. 5 Cross section C–D of the 2007 Victor Main Mineral Resource Model showing the first phase of open pit development (Cut 1; inset 2007 plan view boundaries from Fig. 3c). Background 50 m grid with depths below surface (m.a.s.l. = metres above sea level). For mining purposes Victor Main is subdivided into ore (VMgrd; grd = grade or economic) and kimberlite waste (VMnogr; nogrd = non-economic) based on the 2007 Victor Main Mineral Resource Block Model (data for the 160 Bench shown in Fig. 3c; see also Fig. 9a). Note the irregular nature of the internal boundary. A nearly perpendicular cross section of the same subdivision is shown in Fig. 8a



each block is coloured using the same three broad grade subdivisions used in Fig. 3a, b for easy comparison. Comparing the location of the dashed boundaries between VMgrd and VMnogr in Fig. 3c with the grade zones in Fig. 3b shows that they occur within the intermediate zone VMmg or the internal gradational contact zone (VMmoPK). The irregular nature of the VMgrd to VMnogr boundaries is a direct reflection of the inhomogeneous mixed nature of the gradational contact zone. The 2007 Mineral Resource Block Model was used to develop a mine plan with the first open pit cut (Cut 1, Figs. 5, 6a) focusing on the highest grade area of Victor, the Victor Main VMgrd zone.

2008–2011: Mining

Approximately C\$1 billion was spent on the construction of the new mine, with approximately C\$167 million spent with Aboriginal joint venture businesses. The first diamond recovery occurred on 25th December 2007 during process plant commissioning; mine production started in February 2008. A mining ramp up phase was completed by mid-September 2008. In 2011 the mine produced 780,000 cts from treating 2.7 million tonnes of ore almost all of which derived from Victor Main in Cut 1. Mining of Victor South in Cut 2 started in late 2011.

Victor Main, with the highest predicted grades in the Victor Mineral Resource, has been the focus of open pit mining since the mine opened. The fact that (i) the

contrasting grade zones in Victor Main can only be differentiated using micropetrography, groundmass mineral compositions determined using electron microprobe or macrodiamond bulk sampling, and (ii) the VMgrd to VMnogr boundary is irregular (Figs. 5, 8) and occurs within the complex and gradational mixed zone (compare dashed lines in Fig. 3c with VMmg in Fig. 3b) creates a practical mining issue in the megascopic separation of ore from kimberlite waste. The low grade kimberlite waste (VMnogr) and high grade ore (VMgrd) are distinguished in the open pit to some extent using three dimensional delineation based on the 2007 Mineral Resource Block Model (Figs. 3c, 5, 6, 8). To better manage the Victor Main grade boundary, the mine design included a separate bulk sample plant to, concurrent with mining, routinely test newly exposed kimberlite in the open pit and identify ore, especially in the complex mixed zone. Each bulk sample of 100 t attempts to represent one block ($25 \times 25 \times 10$ m) of the Mineral Resource Block Model (Fig. 3c). The resulting mining bulk sample data provide an opportunity to assess the evaluation work, both the diamond content and the geology.

Overall, the 2008–2011 mining bulk sample results show that the diamond grades are, *as predicted*, extremely variable. Data for 160 Bench are presented in Fig. 3d; most of the sample grades vary up to 61 cpht with two outliers at 81 and 162 cpht. Importantly, the sample grades are consistent with both the 2007 Mineral Resource Block Model (Fig. 3c)

and the geological model (Fig. 3b). In more detail, the mining bulk sample data are continually used to refine the Mineral Resource Block Model which shows the grade (meaning economic or ore) to no grade (meaning non-economic or kimberlite waste) boundary determined during mining. The 2011 boundaries shown in Fig. 3d vary somewhat from those predicted by the 2007 Mineral Resource Block Model (Fig. 3c). Determining such changes in the location of the grade to no grade boundary between ore versus kimberlite waste using the mine bulk sample plant prior to the main production ore extraction and treatment in the main processing plant has significant operating cost benefits for the mine. Also, all the kimberlite waste is managed and stockpiled so that it may potentially be added to the Victor Mineral Resource inventory (see Victor Northwest Evaluation section below). Non-mineralised country rock waste is removed to stockpiles that are progressively rehabilitated to minimise the mine's impact on the environment.

Mine production data to the end of 2011 are demonstrated by the Mine Call Factor in Fig. 7. This figure shows that the Victor North Mineral Resource has performed well, showing an adherence of $\pm 15\%$, the threshold defining a Measured Mineral Resource. A Measured Mineral Resource is that part of a Mineral Resource for which the data are so well established that they can be estimated with sufficient confidence to support production planning and evaluation of the economic viability of a deposit. Also, the diamonds with an average value of over US\$450/cts in 2011 are currently amongst the highest value diamonds in the world. The diamond assortment across Victor North is very consistent. The bulk sample results and the mine production data, therefore, show that the Victor Mineral Resource is reliable which in turn validates the geological and emplacement models. As of the end of 2011, the remaining Victor North Mineral Resource was 4.8 million tonnes and 1.5 million carats.

Future Mining

The Victor Mine plan includes a second phase of open pit development (Cut 2, Fig. 6b) which started in late 2011. This extension to the open pit focuses on the mining of Victor South which has been sub-divided into three major kimberlite units (Fig. 6b). The upper two units have different diamond grades (16 cphr for VS-MPK, 19 cphr for VS-OPK) both of which have been determined to be economic, forming another part of the Victor Mineral Resource and will be mined during Cut 2 (Fig. 6b). At the end of 2011 the remaining Victor South Mineral Resource was

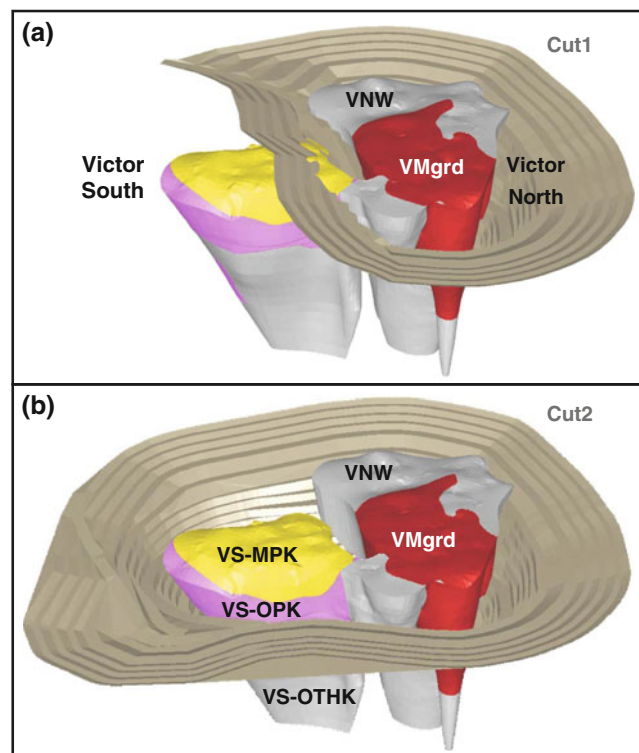


Fig. 6 Oblique external view looking north of the three dimensional mine design model of Victor North and South showing the two phases of open pit development. **a** Cut 1 commenced in 2008 and current mining focuses on the Victor Main Mineral Resource, VMgrd. **b** Cut 2 commenced in late 2011 and focuses on the Victor South Mineral Resource; the ore includes Victor South-main pyroclastic kimberlite (VS-MPK) and Victor South-other pyroclastic kimberlite (VS-OPK). The remaining kimberlite, Victor South-other kimberlite (VS-OTHK), is kimberlite waste. Note that substantial amounts of Victor Northwest (VNW) are extracted during mining. Mining of both cuts is planned to continue to the end of mine life. Final pit is 1 km in diameter; benches are 10 m high (Fig. 9a)

15.4 million tonnes and 2.6 million carats. The Victor South diamonds have a slightly coarser size distribution and resultant higher value per carat than Victor Main. The third and deepest unit of kimberlite in Victor South (VS-OTHK, Fig. 6b) is currently considered to be non-economic but will undergo further evaluation using the bulk sample plant.

The three units in Victor South are Fort à la Corne-type pyroclastic kimberlites broadly comparable to those of Victor Main. In contrast to Victor Main, they are readily distinguished on the basis of contrasting macroscopic and microscopic textures and components such as crustal and mantle-derived xenocryst and xenolith types and abundances (Webb et al. 2006 and internal unpublished reports by Webb). This shows that the units are separate phases of kimberlite which form spatially coherent zones each representing a nested crater (Fig. 6b). The three phases of

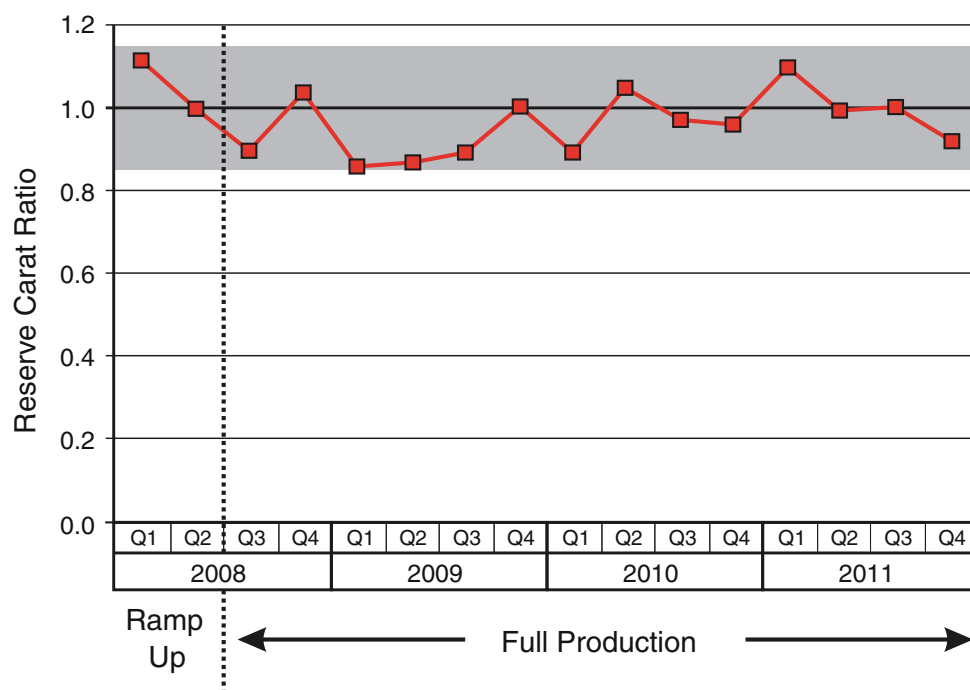


Fig. 7 Mine Call Factor for the Victor Mine to end of 2011. The first two quarters of 2008 include ramp up with process plant commissioning, after which there is full production. *Red data points* = Reserve Carat Ratio (ratio of recovered carats from mining/predicted carats based on the Victor Mineral Reserve; a Mineral Reserve is the economically mineable part of an Indicated or Measured Mineral

Resource that includes diluting materials and allowances for losses that may occur when the material is mined). Correct predictions have a value of 1. Values above and below 1 indicate recoveries higher or lower than predicted, respectively. *Shaded area* shows adherence of 15 %, the threshold defining a Measured Reserve

kimberlite are bounded by sharp internal contacts because, unlike Victor Main, the earlier phase of pyroclastic kimberlite was lithified prior to the formation of each subsequent nested crater. The megascopic recognition of these phases of kimberlite and the sharp internal boundaries should make grade predictions and the separation of ore from kimberlite waste during mining much more straightforward than in Victor Main. The bulk sample plant, however, will be used to further characterise the diamond content of these units and to determine optimal metallurgical blends of ore for the main treatment plant.

Continued monitoring of the Victor Mineral Resource performance through understanding the geology, run of mine bulk sampling, careful ore tracking and analysis of the processing plant efficiency will ensure continued confidence in the Mineral Resource. Based on the 2012 Business Plan, the current Mineral Resource will be exhausted in 2018. Future sustainability of the mine depends on aggressively evaluating Victor Northwest (see next section) as well as the other kimberlites within the Attawapiskat cluster (Januszczak et al. 2012, 2013) while continually improving mine operating costs.

Victor Northwest Evaluation

The development of Cut 1 of the open pit which focused on Victor Main includes the removal of significant parts of Victor Northwest as kimberlite waste (Fig. 6a). All the evaluation data, albeit limited, for Victor Northwest suggest that it comprises low grade kimberlite (<5 cph; Fig. 3a, d) and, therefore, it does not form part of the current Victor Mineral Resource. The Victor Northwest kimberlite waste, however, is sampled and stockpiled at surface to investigate the potential for profitable treatment of some, or all, of this material later in the mine life. Thus, it was relevant to determine the internal geology of Victor Northwest in greater detail based on available drillcores.

By 2003, further drilling and investigation had shown that there was no true intrusive hypabyssal kimberlite present and that Victor Northwest was an early-formed open crater infilled with contrasting extrusive kimberlites possibly resulting from effusive lava flows (an idea proposed for other Attawapiskat bodies by Kong et al. 1999), low-energy lava spatter producing clastogenic lavas, more explosive fire

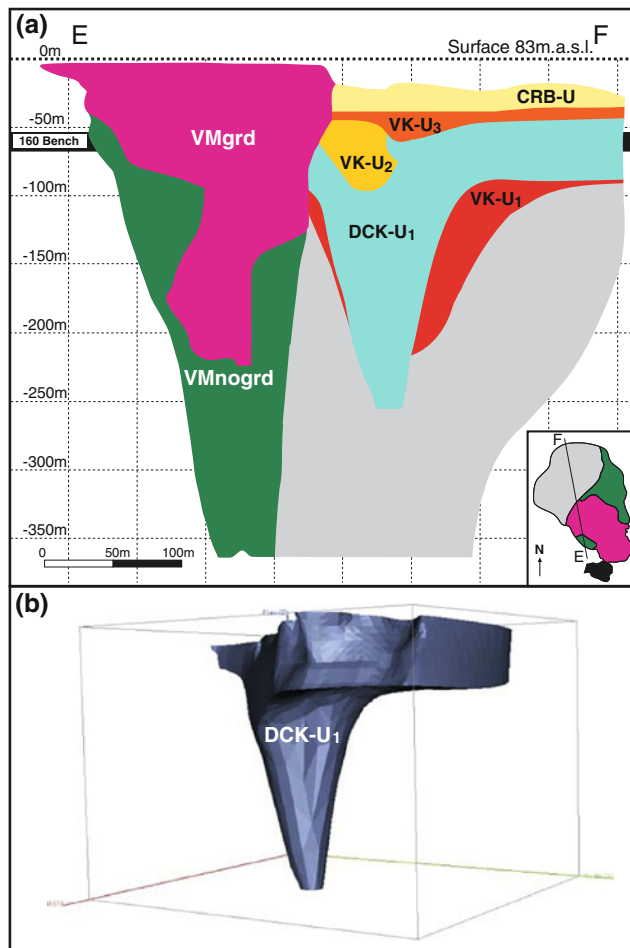


Fig. 8 Geology of Victor Northwest. **a** Cross section E–F through the Victor North 2011 three dimensional geological model (location shown in inset). Background 50 m grid with depths below surface (m.a.s.l. = metres above sea level). The left hand side is a second cross section through the Victor Main Mineral Resource Model virtually perpendicular to that in Fig. 5, showing the same subdivision between ore and kimberlite waste, VMgrd and VMnogr, and the irregular boundary between them. Victor Main cross cuts Victor Northwest which is shown on the right hand side using the 3D internal geological model developed using the data of van Straaten et al. (2009, 2011) and van Straaten (2010). Victor Northwest is subdivided into two parts: upper (U, coloured) and lower (grey). Abbreviated names are shown only for the better defined upper units. DCK-U₁ (DCK = dark coherent kimberlite) is the main unit of the upper part interpreted as a lava lake. The three VK units are different types of volcanoclastic or pyroclastic kimberlite over which lies a country rock breccia (CRB-U). See van Straaten et al. (2009, 2011) for more details. **b** The three dimensional shape of unit DCK-U₁ shown in (a) at same scale looking southwest. The typical crater-fill funnel shape has been truncated by the later cross-cutting Victor Main crater

fountaining and crater wall debris avalanche (Webb et al. 2004, 2006). Lateral correlation between units was not straightforward and an internal geological model was not developed. To allow De Beers personnel and consultants to

focus on the Mineral Resource, the required investigation of Victor Northwest was undertaken during mine construction as a postgraduate research project at the University of British Columbia, Canada (van Straaten 2010; van Straaten et al. 2009, 2011).

van Straaten (2010) concluded that Victor Northwest comprises numerous contrasting small-volume units. The recognition and definition of these units were used by the mine to build a three dimensional internal geological model of Victor Northwest, thus completing the model for Victor North (Fig. 8). van Straaten (opt cit.) suggested that Victor Northwest comprises nested craters which contain diverse kimberlite ranging from different types of Fort à la Corne-type pyroclastic kimberlite formed from explosive eruptions (VK-U₁ in Fig. 8) to less explosive nested-crater-filling, effusive, coherent-to-clastogenic kimberlite lavas (e.g. DCK-U₁ in Fig. 8).

Based on the funnel-shape of unit DCK-U₁ (Fig. 8a, b) it is interpreted as a lava lake. Additional evidence for this conclusion has been provided by mining exposures of Victor Northwest during the development of Cut 1. The observed boundary of this unit as shown in Fig. 9a is broadly similar to that of the geological model (Fig. 8). Also, as shown in Fig. 8, the uppermost overlying rock type is a breccia (CRB-U) composed of diverse blocks of country rock derived from mainly now-eroded country rock sediments. In contrast to the model (Fig. 8), it can be seen in Fig. 9a that the upper boundary of DCK-U₁ is extremely irregular. The irregularities reflect the location of overlying blocks of country rock (Fig. 9a). In one area blocks of country rock occur completely enclosed within this kimberlite (Fig. 9b). This shows that the unit DCK-U₁ must have been emplaced into an open vacant crater and was still molten when the country rock blocks were deposited, as a result of crater wall collapse on top of and, in some cases, sank into and were immersed by the molten kimberlite. Thus, the evidence from the open pit exposures has verified the suggestion that Victor Northwest includes a rare well-documented example of a kimberlite lava lake. The observed features also confirm that (i) the pyroclastic unit VK-U₂ is a pyroclastic equivalent of the lava lake supporting the proposed clastogenic origin and (ii) VK-U₃ is a more kimberlite-rich equivalent of the overlying CRB.

The lava lake is the volumetrically dominant unit within the upper part of Victor Northwest and a substantial amount of this, together with adjacent units, has been and will be removed during ongoing mining (Figs. 6, 8, 9). This material is carefully stockpiled and bulk sampled for further evaluation to determine if there is potential for the profitable treatment of some, or all, of this material later in the mine life.

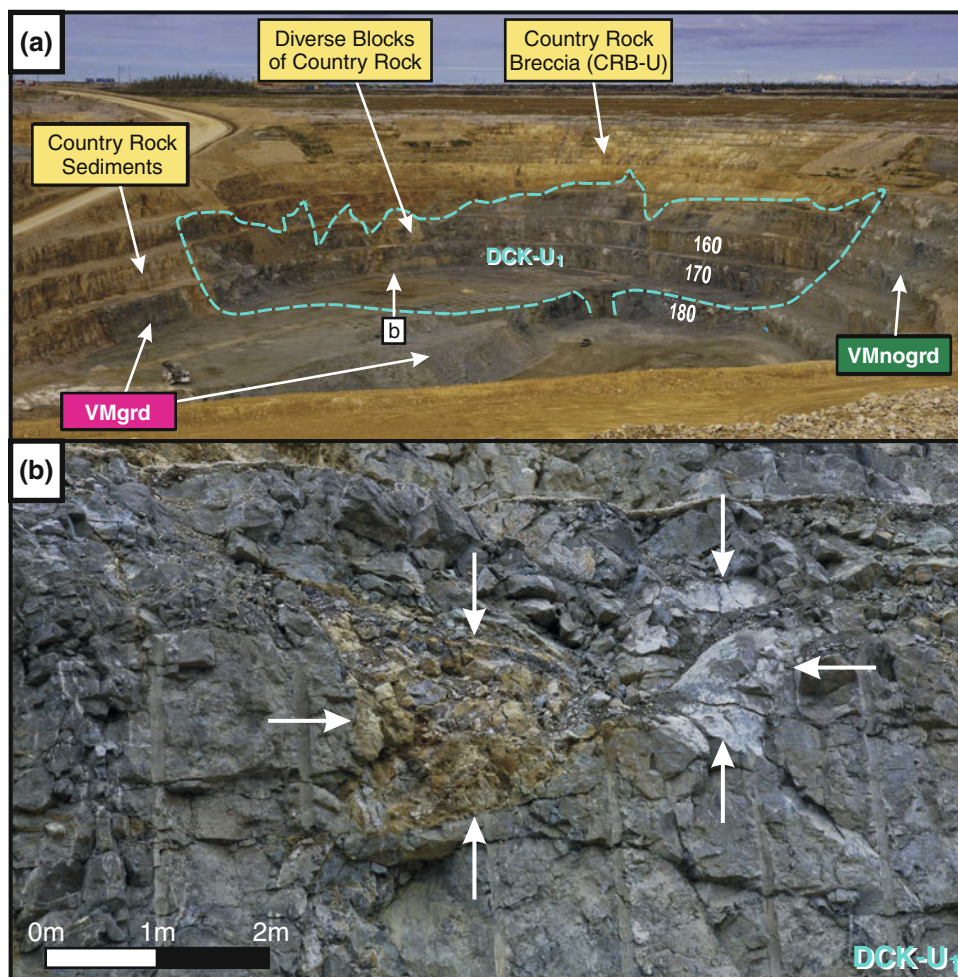


Fig. 9 Photographs of the open pit from August 2011 looking northwest. *White numbers* = bench numbers. **a** Shows the ongoing mining of the ore VMgrd and remnants of VMnogrd in the final pit wall. *Dashed blue line* outlines the unit DCK-U₁ shown in Fig. 8; this is the main unit of the upper part of Victor Northwest which is interpreted as a lava lake. Also shown are the adjacent in situ country rock sediments, the overlying country rock breccia (unit CRB-U in Fig. 8a) and the location of an area within DCK-U₁ containing

common and diverse blocks of country rock sediments. The latter coincide with the more irregular upper contact of DCK-U₁. Bench height = 10 m. Deepest bench is 180 (80 m from surface). Fig. 3a, b, d and 4 show data for 160 bench. **b** Close-up of the upper part of the 170 bench face at the location shown in (a). Two different blocks of country rock (*arrows*) are completely enclosed within the kimberlite forming DCK-U₁

Conclusions

Evaluation macrodiamond data have been presented to show that the Victor pipes have a complex diamond distribution and that the development of a detailed and robust geological model together with an understanding of the emplacement processes was critical to the design and implementation of sampling programs and to the establishment of a reliable Mineral Resource used to justify mine construction and to support the ongoing mine planning.

The Mineral Resource Model indicates that the grade of Victor is extremely variable and overall relatively low but that the diamonds would be of high value. Mining bulk sample data, mineral reserve performance data and open pit

geological data show that the Victor Main Mineral Resource has proven to be accurate which has significantly contributed to the success and reliability of commissioning and operating the mine.

The variability in grade throughout Victor reflects a complex multi-phase kimberlite emplacement history with adjacent, cross-cutting and nested craters infilled from contrasting eruption styles including diverse variably explosive pyroclastic processes with sharp or mixed gradational internal contacts, a rare confirmed example of a less explosive effusive, coherent-to-clastogenic eruption forming a lava lake and country rock sediment crater wall collapse. The mining bulk sample macrodiamond data and open pit geological data show that the kimberlite internal geological model and emplacement model for Victor North are correct.

The validation of the Victor geology is a conclusion of the US\$1 billion dollar test: successful mining of the reliable Victor Mineral Resource. This type of verification cannot be duplicated in the more academic-style of publications where conclusions are largely judged by peer review processes.

Acknowledgments The authors are grateful to De Beers Canada Inc. and De Beers Consolidated Mines Ltd. for permission to publish this paper. Many current and former employees of De Beers Canada Inc. and other De Beers operations are acknowledged for their significant contributions to the team effort of developing and operating the Victor Mine and to the findings presented here. Stuart Smith is thanked for his assistance in preparation of the illustrations. Reviewers Jennifer Pell and Casey Hetman and our guest editor Herman Grütter are all thanked for thoughtful and constructive comments that significantly improved the manuscript.

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Proceedings of 10th International Kimberlite
Conference

Volume 2

Pearson, D.G.; Grütter, H.S.; Harris, J.W.; Kjarsgaard,
B.A.; O'Brien, H.; Rao, N.V.C.; Sparks, S. (Eds.)

2013, XVIII, 296 p. 193 illus., 152 illus. in color.,

Hardcover

ISBN: 978-81-322-1172-3