THE GEOLOGY OF THE PANDA KIMBERLITE, EKATI DIAMOND MINE ™, CANADA

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INTRODUCTION

The Panda kimberlite is located in the Lac de Gras area, Northwest Territories (Figure 1).

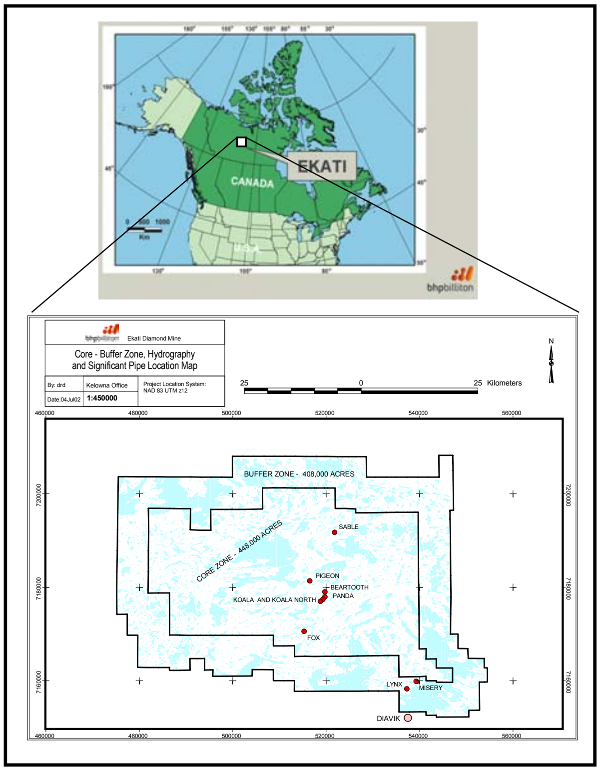

Figure 1. Map of Ekati property showing the location of kimberlite pipes (red dots) in mine plan. Blue indicates water bodies.

It is a highly diamondiferous pipe and was the first diamond mine in Canada. The Panda pipe was discovered in 1993, based on a coincident indicator mineral and conductivity anomaly. Evaluation of the pipe, involving delineation drilling and sampling by reverse circulation (RC) drilling and underground excavation, was carried out between 1993 and 1995. Following the decision to mine, pre-stripping of waste rock was initiated in 1997 and the first ore from Panda was produced in October 1998. Through the logging of drill materials and mapping of the open pit excavation, a large amount of geological information has been gathered for Panda, providing a unique opportunity to better understand the nature and genesis of this body and Lac de Gras style kimberlites in general.

GEOLOGICAL SETTING

The Ekati property is situated above an eastward dipping Archean cryptic suture located in the central part of the Slave Structural Province of the Canadian Shield, within the Contwoyto Terrane. The Panda kimberlite occurs in the central portion of the Ekati property and is situated immediately northeast of the Koala and Koala North pipes. The Ekati main site facilities were constructed adjacent to the Koala pipes and several kilometres east of the Panda pipe (Figure 2). The pipe lies within a depression formerly occupied by Panda Lake and was originally covered by boulder- and gravel-dominated glacial till overburden.

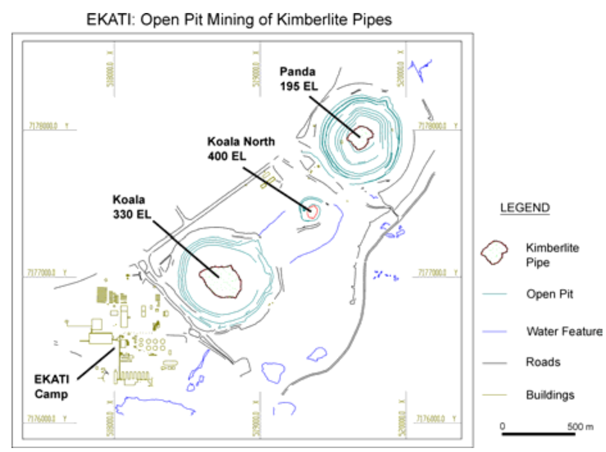

Figure 2. Plan view of the current topography of Panda, Koala, and Koala North pits.

The Panda pipe is emplaced within biotite granodiorite of the Koala Batholith (Kjarsgaard et al., 1994). Granodiorite in the vicinity of Panda is remarkably unaltered and unhematized in comparison with host rocks of other pipes in the area. Eight major joint sets have been mapped in Panda pit. Two of these in particular, the Atom and Dagger faults (060°/70°SE) and their conjugate set (~160°/90°), appear to play a major role in the emplacement and shape of the Panda pipe (Figure 3).

Pipes of the Panda/Koala area were intruded at approximately 52 Ma, coinciding with the younger of two important episodes of emplacement of highly diamondiferous kimberlite in the Lac de Gras field.

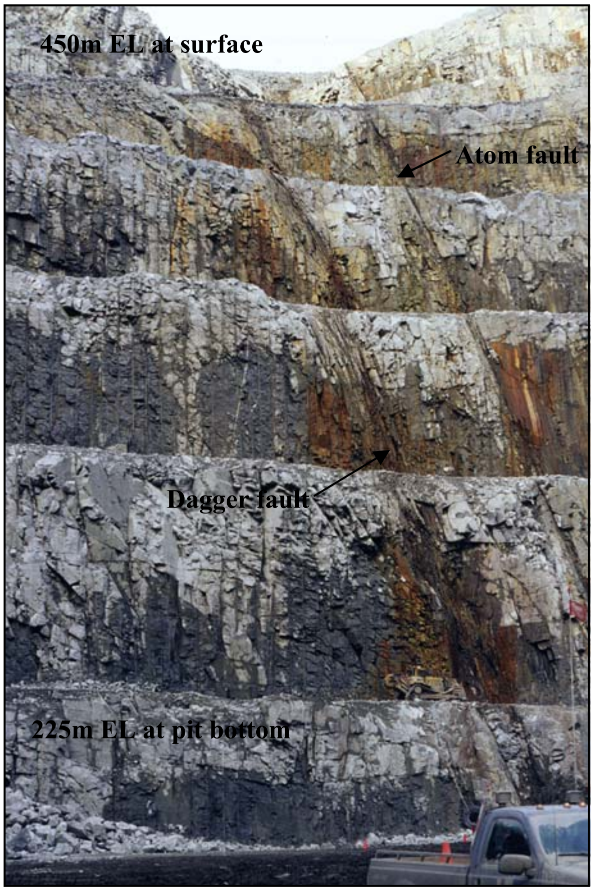

Figure 3. The Atom and Dagger faults on the northeast wall of Panda pit. Photograph by Brock Riedell, September 2003.

EXPLORATION, RESOURCE, AND MINING

The Panda pipe was first identified in a 1992 *Dighem* airborne data as a moderately strong conductivity anomaly coincident with a weak positive magnetic response. Subsequent follow-up work included a heavy mineral till sampling program and ground geophysical surveys. The discovery drill hole was collared in August 1993. High microdiamond counts prompted a bulk sample program by RC drilling during the winter of 1994 and further delineation core drilling. An additional bulk sample program was conducted later in 1994 via an underground decline.

In 1995, total Panda resources were estimated at 15.4 million carats (14M tonnes at ca. 1.1 carats per tonne).

The Panda mine plan calls for open-pit mining of the upper 300 m of the pipe followed by underground mining. The mine is currently nearing the end of the open pit development.

KIMBERLITE GEOLOGY

Current understanding of the Panda pipe morphology and geology is based on information gathered from open-pit mining and drilling programs.

MORPHOLOGY

Panda pipe forms an irregular, steeply-dipping inverted cone, with a diameter of 150 to 200 m covering 3.1 ha (Figure 4).

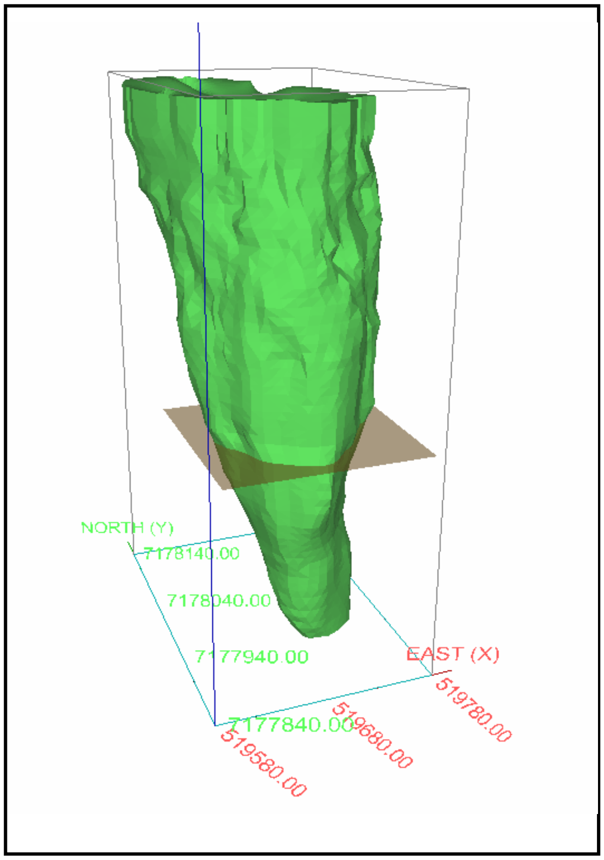

Figure 4. Isometric view (looking northeast) of the Panda pipe model. The grey surface represents the planned open pit bottom.

Overall, the south-eastern portion of the pipe dips more steeply than the north-western portion resulting in a plunge (ca 70^{o}) to the southeast with depth. The northwest and southeast sides of the pipe are controlled by the 060°/70°SE joint set (i.e. Atom and Dagger orientation) and the southwest and northeast sides of the pipe are controlled by the conjugate set at 240°/90°. The hanging-wall of the Dagger fault cuts through the Panda kimberlite.

DOMINANT ROCK TYPES

Panda pipe is filled, to a vertical depth of 400 to 450 m, with a complex mixture of extrusive volcaniclastic rocks and sedimentary infill material recognized in both drill core and pit mapping. The volcaniclastics display widely varying olivine content and grain size, amounts and types of xenolithic fragments (mostly mudstone and granite), and degrees and scales of bedding. The units mined to date are typically near vertical, and likely represent crater rim deposits which have slumped into the pipe. Although minor amounts of possible primary volcaniclastic kimberlite (PVK) have been identified in certain drill holes, the open-pit portion of the pipe is comprised almost entirely of resedimented volcaniclastic kimberlite (RVK). This occurs as relatively small, laterally discontinuous, irregularly shaped and variably oriented units (Figure 5) that cannot be reliably modelled on the basis of current drill intersections. The dominant rock types identified to date at Panda are described below.

Crater sediments

A variety of sediments have been mapped in Panda pit. Moist, pliable, black mud possibly incorporating very fine-grained kimberlitic ash occurs dominantly at or near the northwest pipe margin. The most abundant accumulation is a 2 to 5 m thick sequence at the northwest margin, and in-pit mapping indicates complex interbedding of this material with other phases.

Spatially and depositionally related to this mud is fine-grained, weakly consolidated to unconsolidated, brown-grey sand. This unit is seen only near the margin on the northwest side of the pipe and within or proximal to the Dagger Fault zone (~060°/80°SW). It contains up to 40% quartz with no macroscopically observable olivine or indicator minerals and therefore, is assumed to be predominantly non-kimberlitic. Steeply dipping to vertical beds with gravel pebbles have been observed.

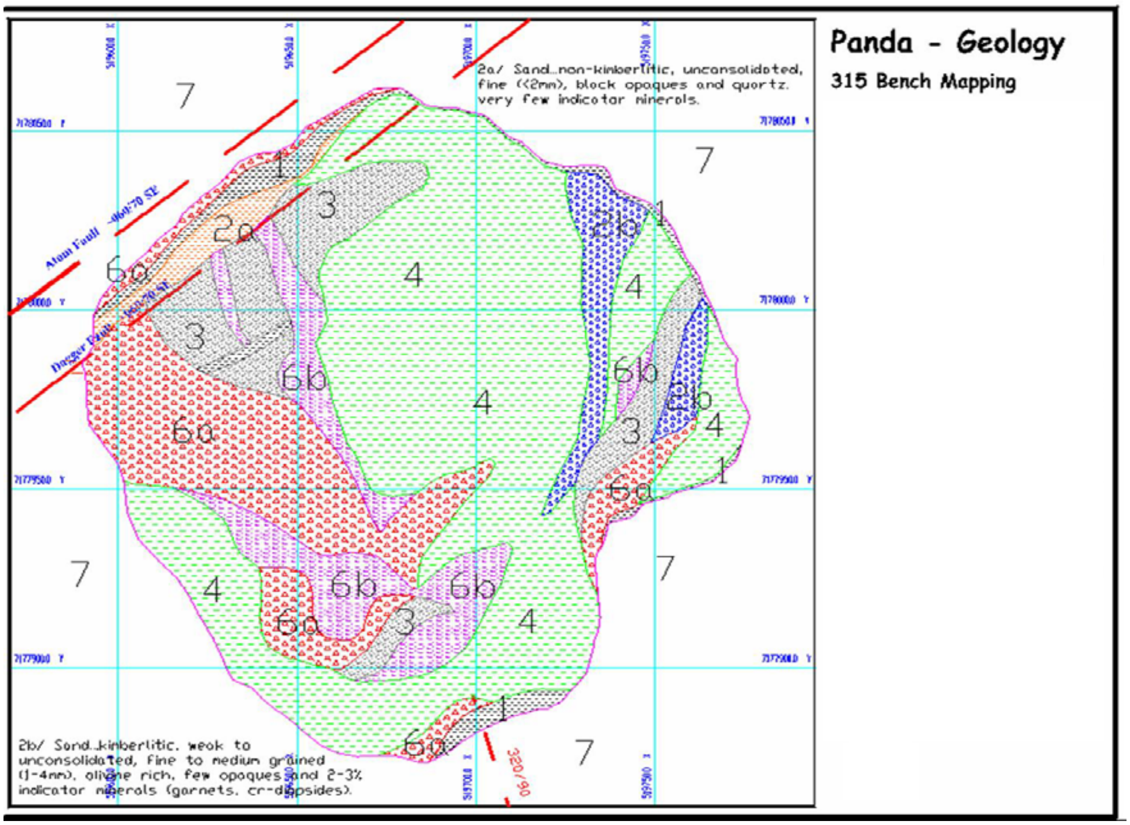

Figure 5. Plan of the 315 bench in the Panda pit illustrating the distribution of different kimberlite types. Unit 1: Moist, pliable, black mud. Unit 2a: Non-kimberlitic sand. Unit 2b: Kimberlitic sand. Unit 3: Massive pale olivine-rich RVK. Unit 4: Bedded pale olivine-rich RVK. Units 6a&b: Dark fine-grained RVK (unit 6 has been divided for mining purposes).

A fine-grained, unconsolidated, grey-green, sandy unit with kimberlite fragments occurs as a somewhat continuous channel (2 to 10 m wide) that runs in a north-northeast direction. It has been sporadically observed down to the 270 bench, in roughly the same location. The unit has abundant olivine and indicator minerals.

Abundant well preserved wood has been recovered within the portion of Panda mined to date. Several hundred pieces of wood, including some parts of logs up to 2 metres long, as well as tree stumps, have been recovered. A moderate amount of mineral matter occurs within the cell lumens, but for the most part the organic material of the cell walls is intact and has not been affected by mineralization such that the anatomical features of wood cell walls are well preserved. Features observed, such as distinct annual rings with moderate thickness, are typical of wood growing under mesic seasonal conditions. The wood has been related to types most common to swamps of the Eocene in mid to high latitudes, and is ubiquitous within northern Paleogene (Paleocene–Oligocene) deposits (Basinger, 1991). The amount of wood recovered has lessened below approximately the 240 bench.

Dark, fine-grained resedimented volcaniclastic kimberlite

Within the southwest quadrant of the Panda pipe a dark-grey to black, very hard, unit with both coarse-grained, altered (serpentinsed) olivine and finer-grained, unaltered olivine was observed. When blasted, this material commonly displays concoidal fracture demonstrating its competence compared to other lithologies found in Panda. It consists of varying concentrations of olivine macrocrysts and typically minor amounts of mudstone and granite xenoliths, set in a very fine-grained matrix made up of variable proportions of serpentine and black, fine-grained, dissagregated mud. Large wood fragments and soft sediment deformation features are common.

Pale olivine-rich resedimented volcaniclastic kimberlite

Mapping indicates that two varieties of RVK appear in association with the crater sediments described above. These lithologies are both pale and olivine-rich, but one is massive while the other is bedded and includes breccias (>15% shale and/or granite xenoliths). The friable matrix of both the massive and bedded pale, olivine-rich varieties is dominated by serpentine with relatively minor amounts of mud present. They have very little disaggregated surficial or exotic sedimentary material incorporated and appear to be dominated by juvenile kimberlitic material (olivine crystals and juvenile lapilli with magmatic kimberlite rims). Bedding in the bedded variety is defined by varying olivine content and in particular, by the presence of fine (<1 cm), dark, mud-rich beds. Soft sediment deformation features are commonly present in this material.

It is possible that these lithologies represent beds of pyroclastic material that have slumped into Panda pipe but have undergone minimal reworking.

Dark, olivine-rich primary volcaniclastic kimberlite

A distinct variety of dark, homogeneous, competent, olivine-rich volcaniclastic kimberlite is evident in several of the Panda drill holes that intersect the deeper portions of the pipe. It is generally coarse to very coarse-grained and contains relatively minor concentrations (mostly ≤5%) of unaltered shale and granite xenoliths. Juvenile lapilli are abundant and the matrix is dominated by fine-grained serpentine. Contacts between this material and adjacent resedimented material are sharp. The origin of the primary volcaniclastic material is not certain, however, the predominance of juvenile material and the lack of any features suggestive of resedimentation or reworking imply that it may be of primary *pyroclastic* origin. It is not possible to model intersections of this kimberlite variety as a single continuous phase, but currently available drilling data suggest that it may represent a volumetrically important component in the deep southern and western portions of the pipe.

Macrocrystic magmatic kimberlite

Macrocrystic magmatic kimberlite is restricted to narrow peripheral intrusions intersected in only a few drill holes

EMPLACEMENT OF THE PANDA KIMBERLITE

The Panda pipe, as well as the associated Koala and Koala North bodies, was emplaced into competent Archean granodiorite. The Atom and Dagger faults appear to have been a major structural control in Panda's emplacement and shape (Figure 3). The morphology of the Panda pipe and its relationship to these faults suggests that they may have undergone some post-emplacement reactivation.

Evidence from xenoliths within Panda and other Ekati kimberlites, indicates that the basement was covered by a relatively thin sequence of fine-grained sediments at the time of emplacement (now eroded). While it is not possible to directly constrain the amount of erosion and the sediment thickness immediately prior to kimberlite eruption, the presence of wood and mudstone bearing RVK at depths of up to 450 m suggests that it is likely to have been significantly less than ca. 1000 m.

Geological features observed to date are consistent with an emplacement process involving (see also Kirkley et al., 1998): explosive eruption and excavation of a steep-sided pipe to minimum depths of ca. 500 m; deposition of pyroclastic kimberlite together with variably consolidated fine-grained surficial sediments, likely in a relatively steep-sided tuff-ring; large scale slumping and resedimentation of pyroclastic kimberlite and associated surficial sediments into the pipe; possible direct deposition of juvenile-rich pyroclastic kimberlite within the pipe during the early stages of resedimentation; and minor amounts of water-borne deposition of fine-grained clastic sediments in association with RVK during periods of quiescence in the later stages of pipe infilling. While several eruptions may have occurred in the early stages of pipe filling, it would appear that the upper ca. 300 m of the pipe was filled predominantly by resedimentation of previously ejected kimblerlite with no clear evidence for additional eruptions. The size and morphology of the Panda pipe and the highly fragmented nature of the majority of kimberlite tephra indicate a violent eruption style (possibly vulcinian or violent strombolian).

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