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Kimberlite emplacement models — The implications for mining projects

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Abstract

The significance of the emplacement model for kimberlite pipes, or sheets, is commonly recognized in resource geology. However, its importance is not always appreciated in the mine design process. The fact is that knowledge of the orebody geometry, character of the contact zones, internal structures, rock mass competency and distribution of inclusions could directly influence the selection of the underground mining method, pit wall stability, dilution, treatability, and the dewatering strategy. The problems are exacerbated in smaller pipes and narrower sheets, and in more irregular shapes; they are more apparent in underground mining as opposed to open cast.

Various kimberlite emplacement processes have a major impact on the nature of the kimberlite orebody and host rocks that will influence the mine design and mining strategy. Failure to understand these processes can adversely affect the economic outcome for developing a mine. It is therefore important to investigate those processes in order to better characterize the mining constraints and risks, and more accurately predict the mine's economic viability.

Keywords: kimberlite; diamonds; emplacement models; diamond mining

1. Introduction

Based on De Beers statistics, world rough diamond mine production for 2006 was worth approximately 13.1 billion US dollars. Of that total, it is estimated that approximately 70% was mined by the conventional open cast method and 7% by mechanized underground methods, mainly by caving. The remaining 23% was accounted for by the placer and off-shore mining of secondary deposits.

Past experiences with project performance evaluations show that the leading sources of technical risk for mining projects are identified principally in mine design and scheduling and in resource estimation. All of these risks are derived from the geology and in order to minimize them, there is a clear need for a thorough understanding of the geological context of the deposit.

The objective of this paper is to illustrate some of the mining problems that could arise if the kimberlite emplacement model is flawed or poorly understood. Mining issues could potentially arise as a consequence of poor understanding of the model. The paper helps to justify studies that are vital for developing a viable mining strategy for primary diamond deposits.

2. Mining issues as a result of kimberlite emplacement

For the mining project to succeed, the mining method chosen must always be appropriate to the specific context of the geological setting. This is a basic condition that *cannot be changed*. If the mining method is in conflict with the geological context, the mine will not perform as expected (Jakubec et al., 2004).

In essence, the choice of a mining method depends on the following factors:

1. Geology (external and internal)
2. Orebody size and geometry
3. Grade and grade distribution
4. Rock mass competency
5. Disturbances
6. External constraints

In order to appreciate how these factors affect the choice of method, it is important to illustrate some of the costs associated

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with mining. As reported earlier, about 70% of diamond mining is done by the open cast method. Since the open pit is currently the least expensive way to mine most near surface deposits, it is reasonable to expect that it will be the leading mining method for new discoveries (pipes). Dykes, such as Snap Lake (Northwest Territories, Canada), however, will be mined primarily by underground or by a combination of underground and open cast method.

For purposes of illustration, the ranges of typical mine operating costs in Northern Canada are provided below (in Canadian funds).

Direct mining cost	
Open pit	\$5–10/t
Block caving	\$10–20/t
Open benching	\$20–35/t
Sublevel caving	\$25–40/t
Backfill methods	\$60–100/t
Processing cost	\$10–20/t
Other costs (G&A, Marketing etc)	\$15–35/t

While total typical operating costs could range from \$30–65/t for open pit mining to well over \$100/t for the backfill underground method, in reality the costs of some recent diamond projects are higher. The estimated open pit operating cost for Diavik Mine is approximately \$80–90/t (Ellis Consulting Services, 2000; SNC Lavalin, 2000), with \$90–100/t for Jericho Mine (Tahera, 2007) and similar values of \$78–88/t reported for Ekati Mine (BHP Billiton, 2007). Operating costs for the Diavik underground operation are expected to be approximately \$140/t (Ellis Consulting Services, 2000), and \$156/t for the Snap Lake underground mine (De Beers, 2007). Using the same source of information for Snap Lake, the value in 1 t of ore is \$192 at certain levels of expected dilution. If dilution would increase by 20% due to the complex geometry of the orebody or due to poor quality contact zones, the cost per tonne could exceed the value per tonne.

Clearly, mining and processing costs are sensitive to geological, geotechnical and hydrogeological conditions; thus, the data that is entered into the design must be accurate, sufficient and of high quality — on the same level as data used for making the resource estimation. Kimberlite emplacement processes determine the geological, geotechnical and hydrological conditions and therefore influence a number of operational aspects of a mine. The most critical parameters determined by the emplacement processes are pipe size and geometry, dilution and diamond grades, country rock damage, physical parameters of the kimberlite, and hydrogeology. A mind map of the main issues is illustrated in Fig. 1.

3. Pipe morphology

Current primary diamond mining operations are located in kimberlite pipes and sheets that take form in a variety of shapes and sizes. At one end of the size spectrum are the large pipes in Africa, such as Mwadui (Tanzania), Orapa or Jwaneng (Botswana), as well as Star and Orion (Saskatchewan, Canada) which are several hundreds of meters across. At the other end, there are economically mined pipes that have diameters less than one hundred or so meters, such as Koala North at Ekati (NWT, Canada) or Internationalnaya in Siberia.

The size and geometry of the pipe or dyke is one of the most critical factors that determine the mining method and strategy, and that factor is not always well characterized. In the literature, the size is often limited to the surface area of the pipe footprint and to the volume, while the geometry is typically poorly defined and/or described.

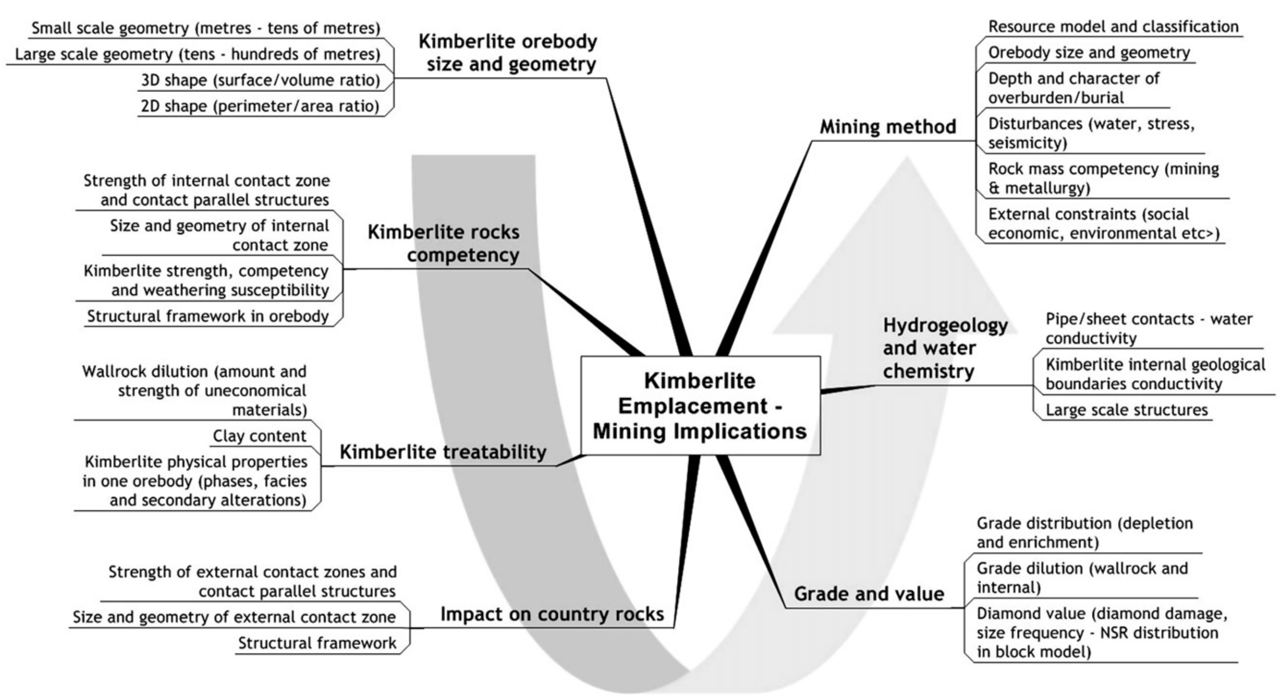

Fig. 1. Mind map illustrating the main mining issues impacted by the pipe emplacement processes.