

Advancements in Kimberlite Geology After 30 Years of Kimberlite Exploration, Evaluation and Mining in Canada

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Introduction

Over the last 30 years, our understanding of the geology of kimberlites has evolved significantly following the discovery, evaluation, and mining of pipes across Canada. Previously, our knowledge of the geology of kimberlite pipes was primarily based on occurrences in southern Africa. Several hundred pipes have been discovered across diverse geological settings in Canada, and seven diamond mines have been developed. These mines include Ekati, Diavik, Jericho, Snap Lake, Victor, Gahcho Kué, and Renard. Of the seven mines developed, three were closed prematurely. In this contribution, I will present the three significant developments in kimberlite geology within Canada over the last 30 years, which have helped geologists better understand the wide spectrum of pipe shapes, pipe sizes, variable internal architectures and diamond distributions. These developments include: 1) Appreciating that the country rock environment has a direct impact on external pipe shape, size, infill, and internal geology; 2) the volcanic history and maturity displayed within a cluster or province is often complex and can be highly variable between individual pipes, and 3) through various eruption and depositional processes, the kimberlite becomes texturally modified having a significant impact on the microdiamond and macrodiamond populations within a particular kimberlite. These developments have allowed those involved in kimberlite exploration and evaluation to generate better predictive models, focusing resources on pipes with greater economic potential. However, it is not enough to have a good understanding of kimberlite geology; representative drilling and sampling must be undertaken before a realistic economic assessment may be completed for a particular kimberlite. Globally, there are thousands of kimberlites, and many have undergone very limited drilling and sampling for diamonds. Rather than focusing on discovering new kimberlites, is it time to revisit previous discoveries within Canada and worldwide to reassess their potential?

The Impact of Country Rock Setting on Pipe Shape and Infill

Across Canada, pipes have been emplaced within a range of rock types, including granitoids and other igneous and metamorphic rocks, as well as sedimentary rocks, including carbonates, shales, sandstones, and mudstones. The Field and Scott Smith (1999) summary diagram (Fig. 1) presents the main geological features of pipes emplaced across Canada. It illustrates a wide range of pipes characterized by very different shapes, sizes, infills and host rock. There are three broad endmembers of pipes, including Fort à la Corne, Gahcho Kué, and Lac de Gras type kimberlites.

Exploration and evaluation work on kimberlites in Saskatchewan revealed some of the largest kimberlite pipes in the world with well-preserved craters greater than 100 ha in diameter. These shallow, bowl-shaped craters lack diatremes and are infilled with a distinctive type of pyroclastic kimberlite called Fort à la Corne-type pyroclastic kimberlite or “FPK” (Smith et al., 2013). The craters of the Saskatchewan kimberlites were developed within relatively weak, poorly consolidated mudstones and sandstones, allowing for the formation of very wide, shallow craters. In contrast, another group of pipes formed within very hard and competent Archean granitoids and metamorphic rocks at Gahcho Kué (Hetman et al., 2004) and Renard (Fitzgerald et al., 2009). The Gahcho Kué and Renard pipes display external shapes, sizes (< 3 ha) and, pipe infills similar to the pipes described from the Kimberley area of South Africa (Clement, 1982). The main pipe infill within these pipes is called Kimberley-type pyroclastic kimberlite (KPK) – previously

called tuffisitic kimberlite breccia (TKB). In addition, these pipes may contain significant amounts of hypabyssal kimberlite (HK). The last end member is the Lac de Gras kimberlites (Nowicki et al., 2004) emplaced within Archean granitoids and gneiss covered by completely eroded Phanerozoic rocks comprised of relatively weak shales and mud. The pipes are typically small (< 5 ha), steeply dipping, and dominantly infilled with xenolith or mud-rich resedimented volcanoclastic kimberlite (RVK). Other kimberlites, like Victor (Webb et al., 2004) and Buffalo Head Hills (Eccles et al., 2004), are variations of the three endmembers. These three broad-end members require different approaches to exploration and evaluation and have unique challenges concerning geological development.

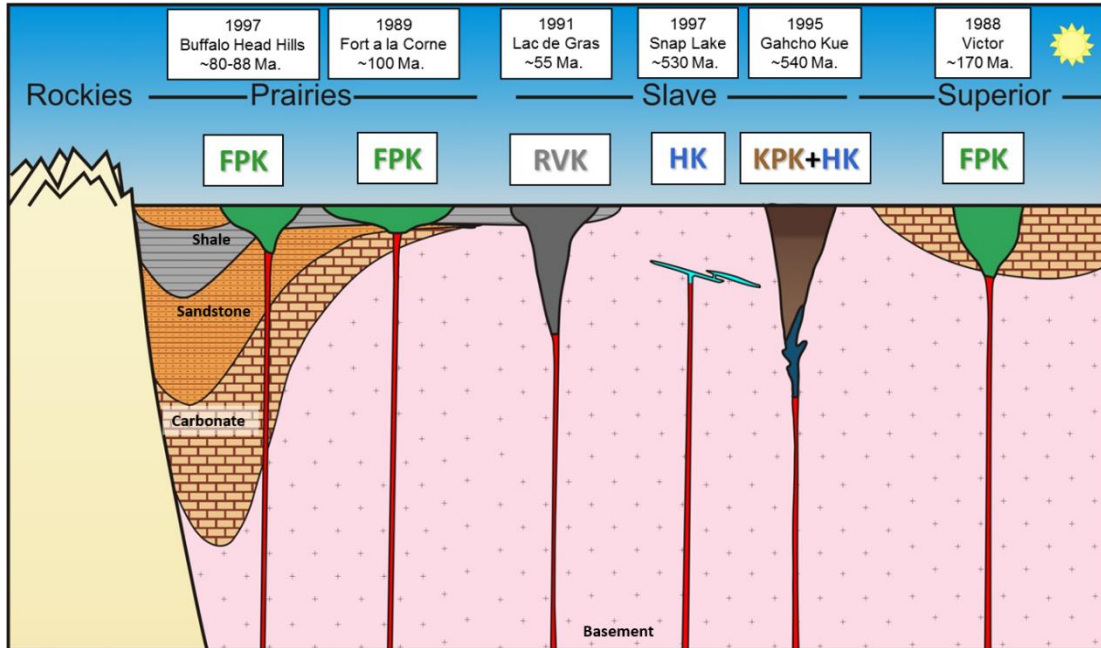


Figure 1: Modified from Field and Scott Smith (1999). A cross-section of kimberlites across Canada.

Kimberlite Pipe Volcanic History and Maturity

To establish the economic potential of any kimberlite, it is necessary to understand the volcanic history of a particular body. Most pipes are formed by multiple eruptive events (Sparks et al., 2006), and different batches of kimberlite magma transported to the surface will carry different diamond packages. At Gahcho Kué, there is a complete spectrum of kimberlite bodies, including dykes, blind intrusions, a very complex root zone body infilled with HK, as well as steep-sided pipes infilled with KPK. Large variations in external shapes and pipe development, or volcanic maturity between pipes within a cluster, are typical of KPK systems in Canada and globally. Due to their complexity, particularly kimberlites that are not mature in terms of pipe development and excavation of country rock, can be the most challenging for geologists to explore, evaluate, and generate geological models for.

Textural Modification

The redistribution of juvenile components within a kimberlite occurs through various emplacement and depositional processes. This impacts both the microdiamond and macrodiamond populations within kimberlites and not only occurs in pipes but also dykes, for example, in filter pressing environments. The greater the degree of textural modification a particular kimberlite experiences, the more significant the impact is on the diamonds it carries. The highest degrees of textural modification are observed within upper crater environments where there is more space and various processes that can concentrate or potentially

redistribute a specific size fraction of particles within a kimberlite. Some pipes observed in Canada have lost their fine juvenile components (<1 mm) and subsequently have a modified microdiamond population. In contrast, we see many examples of pipes where larger (> 4 mm) juvenile components have been concentrated. Therefore, the grade of that particular kimberlite may be significantly higher than that of the original kimberlite before being modified (Smith and Smith 2009). Geologists must be aware of textural modification when reviewing and interpreting diamond data and adjust sampling programs to ensure sampling is representative and meaningful.

Conclusions

The developments in kimberlite geology over the last 30 years have helped us better understand the wide spectrum of shapes, sizes, internal architectures, and diamond distributions encountered within kimberlite pipes. We appreciate that there can be a wide spectrum of pipe development within a particular cluster of pipes and a complex volcanic history within single occurrences. Concerning the textures we observe in kimberlites, we understand that as the kimberlite is texturally modified and various particles are redistributed during eruption and final depositional processes, the diamonds, including both the microdiamond population and macrodiamond population, may be modified significantly. Geologists are much more knowledgeable about kimberlite geology after 30 years of diamonds in Canada. However, to understand a particular kimberlite and accurately assess the economic potential of a body, it is a requirement to have representative information, typically derived from core drilling campaigns. Many kimberlites within Canada and globally have been under-drilled and/or sampled, meaning we may not fully appreciate the potential that could exist within already discovered bodies.

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