Paper 46

Kimberlite Pipe Models: Significance for Exploration

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ABSTRACT

Kimberlite bodies typically form from multiple intrusive and/or extrusive events; these discrete events are recognizable as distinctive kimberlite phases. Differing textures, mineralogy, geochemistry and geophysical properties, and diamond grades, size populations and values characterize the individual phases. The recognition that there is a wide variation in the size and morphology of economically viable kimberlites strongly affects how to explore for, and sample diamonds from these bodies.

INTRODUCTION

Kimberlite magmas generate a range of rocks that form a wide variety of landforms and intrusions, in many aspects similar to that generated by small volume alkali basaltic volcanic systems. Current exploration models for kimberlite-hosted diamond deposits are undergoing significant revisions as a consequence of recent discoveries in Canada, and a re-assessment of southern African kimberlites. According to Hodgson (1987) "An ore deposit model is a conceptual and/or empirical standard, embodying both the *descriptive features* of the deposit type, and an explanation of these features in terms of *geological processes*". Furthermore, Hodgson (1987) suggested that perhaps the most significant problem in exploration is the "tendency to rely too much on simple models". The main purpose of this paper is to present an overview of the kimberlite models generated in the 1960's through 1990's (and still in use today), in the context of the historical data available at the time the model was generated. This is followed by new ideas on different kimberlite deposit models, and their implications and significance for the diamond explorationist.

For the diamond explorer, it is important to describe the rocks observed using non-genetic terminology. A very simple, non-genetic, two-fold nomenclature system (Mitchell, 1995; Kjarsgaard, 2003; Sparks et al., 2006) to describe rocks from kimberlite magmatic systems is preferred by this author: volcaniclastic kimberlite (VK), i.e., fragmental rocks, and; hypabyssal kimberlite (HK), i.e., non-fragmental rocks (Figure 1). With more detailed information, one of the fundamental kimberlite rock types can be further-subdivided e.g. pyroclastic kimberlite (PK), resedimented volcaniclastic kimberlite (RVK), massive volcaniclastic kimberlite (MVK) are varieties of VK (see Figure 1). However, it should be noted that not everyone agrees with this kimberlite terminology, e.g. see Cas et al. (2006) for an alternate nomenclature system.

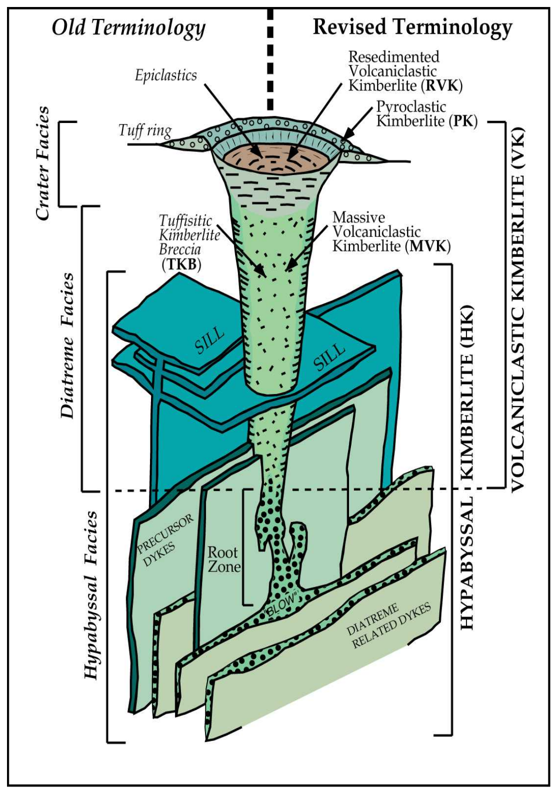

Figure 1: The 'classic South African model' of a kimberlite pipe (Mitchell, 1986) with old nomenclature (left side of figure) and a simpler, revised two-fold nomenclature system (right side of figure) to describe rocks from kimberlite magmatic systems as recently suggested by Mitchell (1995), Kjarsgaard (2003) and Sparks et al. (2006). VK = volcaniclastic (fragmental) kimberlite; PK = pyroclastic kimberlite; RVK = resedimented volcaniclastic kimberlite; MVK = massive volcaniclastic kimberlite; HK = hypabyssal kimberlite. Figure modified after Kjarsgaard (2003, 2007).

In "Proceedings of Exploration 07: Fifth Decennial International Conference on Mineral Exploration" edited by B. Milkereit, 2007, p. 667-677

THE SOUTH AFRICAN KIMBERLITE PIPE MODEL

The model of a South African kimberlite pipe (Figures. 1, 2: Dawson, 1971; Hawthorne, 1975; Mitchell, 1986) was primarily based on observations from exploration and mining in southern Africa. The lower part of the kimberlite pipe model is derived from the Kimberley area of South Africa, where about 1400 - 1600 m of erosion was interpreted to have occurred (Dawson, 1971; Hawthorne, 1975), i.e. only the lower portions of the kimberlite pipes where preserved for economic beneficiation (and study). The top of the kimberlite pipe model utilized observations from the preserved upper portions of kimberlites from Tanzania (e.g. Tremblay, 1956), Botswana, Angola and the Democratic Republic of Congo (DRC). To this a tuff ring was added based on observations from Mali (Hawthorne, 1975). Rock-types in the 'classic South African model' were assigned to different facies (e.g. Dawson, 1967, 1971, 1980; Clement, 1982; Mitchell, 1986, 1995). In this respect, Dawson (1967, 1971, 1980) believed it was justifiable to use the term facies *'the aspect, appearance, and characteristics of a rock, usually reflecting the* ***conditions*** *of its origin'* (AGI definition), since he believed the *geological process* that formed the kimberlite pipe was well constrained and understood. The process envisaged by Dawson was degassing of CO_2 (and H_2O) from the kimberlite magma, coupled with the known significant volume change in the degassed CO_2 at a pressure of ~80 MPa (i.e. at a depth equivalent of ~2.6 km) to create a fluidized bed of gas and quenched kimberlite magma. Dawson (op. cit.) further noted that in the Kimberley area, the flaring or widening of the mined kimberlites pipes occurred at ~2.4 km depth (800 m preserved + 1600 m removed by erosion), consistent with his degassing - gas expansion - fluidisation model for pipe formation. Currently, most kimberlite petrologists discuss these rocks in the general terms of facies associations and not in the strict sense of facies, because it is recognized that the conditions of formation of VK is imperfectly to poorly understood.

The Dawson model, in general has been adapted by many, but not all kimberlite geologists. Over the past three decades it has undergone subtle modifications and has also been simplified (e.g. Clement, 1982; Field and Scott-Smith, 1999; Scott-Smith, 2006) At present, the 'classic South African kimberlite pipe model' (Figure 2) shows a simple stratification of rock types, with pyroclastic kimberlite (PK) and resedimented volcaniclastic kimberlite (RVK) at the top of the pipe (occupying the crater zone), the main part of the pipe (the diatreme zone) is in-filled by massive volcaniclastic kimberlite (MVK) aka tuffisitic kimberlite breccia, (TKB; e.g. Hetman, 2006), and hypabyssal kimberlite (HK) occupies the root zone at the base of the pipe. Recent models (e.g. Clement, 1982; Field and Scott-Smith, 1999) of pipe formation ascribe a number of pre-cursor intrusive events, but the formation of MVK in the pipe is a single event, which homogenizes and typically obliterates any previous discrete kimberlite events within the diatreme zone.

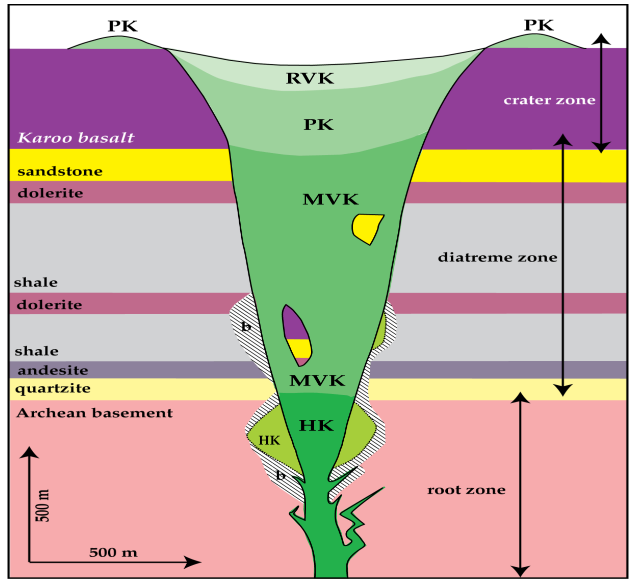

Figure 2: Classic model of a South African kimberlite pipe. Adapted from Hawthorne (1975), Clement (1982).

The South African Kimberlite Pipe Model - Old Observations Revisited

Previous descriptive geological observations (e.g. Moulle, 1885, Wagner, 1914; Dawson, 1962; Nixon, 1973; Clement, 1982) clearly demonstrated the multiple intrusive (HK/MVK) and/or extrusive (MVK/PK/VK) nature of numerous kimberlite pipes in the Kimberley area, and in southern Africa in general. For example, at the Du Toit's Pan (South Africa) kimberlite (Figure 3a), the upper part of the pipe (the 250 m level) is occupied by one MVK phase and six different HK phases. At the Letseng (Lesotho) kimberlite (Figure 3b), the upper part of the pipe is occupied by four different MVK phases and three different HK phases. At the Koffiefontein (South Africa) kimberlite (Figure 3c), the pipe on the 470 m level is occupied by two different MVK phases, two RVK phases and three different HK phases. Taken together, the geological observations from three different classic South African kimberlite pipes are consistent with the idea of multiple kimberlite phases in a single pipe, as originally suggested by Moulle (1885), Wagner (1914) and Dawson (1962). Although Clement and Reid (1989) did note that in some southern African kimberlites HK and MVK are observed at the same structural level within a pipe, the model illustrated in Figures 1 and 2 shows a simple stratification of different kimberlite rock types with depth, in contrast to what is observed (compare Figures 1 and 2 with Figures 3a, b, c).

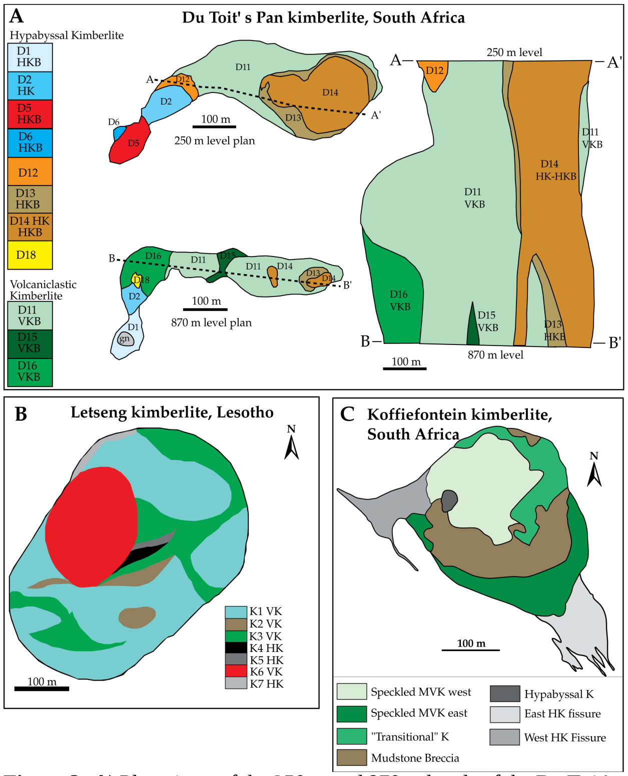

Figure 3: A) Plan views of the 250 m and 870 m levels of the Du Toit's Pan, South Africa kimberlite and section view from the 250 m to 870 m level (after Clement, 1982). **B)** Plan view of the Letseng, Lesotho kimberlite (after Bloomer and Nixon, 1973). **C)** Plan view of the Koffiefontein, South Africa kimberlite (after Naidoo et al., 2004). Note that for each kimberlite the multiple varieties of distinct phases of kimberlite identified. The 'classic South African model' kimberlite pipe shown in Figures 1 and 2 exhibits a regular change in geologic units from PK and RVK (top) to MVK (middle) to HK (bottom), which is an oversimplification of the morphology of this style of kimberlite pipe.

More recent observations on South African kimberlite pipes are also highly significant to the kimberlite diamond deposit model from the perspective of *geological processes*. For example, there is now thought to be less than 850 m of erosion at Kimberley (Hansom et al., 2006), and not 1400 - 1600 m (Dawson, 1971; Hawthorne, 1975). This means the depth at which the kimberlite pipe started to flair is ~1.6 km (50 MPa pressure equivalent) below the paleo-land surface. This observation is inconsistent with the *geological process* that decribes pipe formation to be related to CO_2 (and H_2O) degassing and the volume change of the degassed fluid at a depth of 2.4 km (pressure equivalent of ~80 MPa). Furthermore, in the Kimberley area, Wagner (1914) noted the significant change in the size of the adjacent Kimberley and St. Augustine kimberlite pipes (see Figure 4). This observation is also inconsistent with the CO_2 (and H_2O) degassing and fluidization model, that 'predicts' that all kimberlites should flare or widen into pipes at ~2.5 km depth and that this depth is constant i.e. within a cluster of pipes the same age that have been subject to the same amount of erosion, all the kimberlite pipes should be approximately equal in size. From Figure 4, it is clear in the Kimberley area that individual kimberlite pipes are highly different in size, and perhaps more importantly, the transition from the root zone (HK) to the diatreme zone (MVK + HK) occurs at quite variable depths. In Canada, in the Lake Timiskaming field adjacent individual kimberlites 96-1, 95-2 and MR-6 are observed to be quite different in that they preserve lower (HK), mid (MVK), and upper (PK) parts of a pipe, respectively (Kjarsgaard, 2004). These simple observations from the Kimberley and new Liskeard areas do not support the CO_2 degassing and fluidization model as the process for formation of South African type kimberlite pipes.

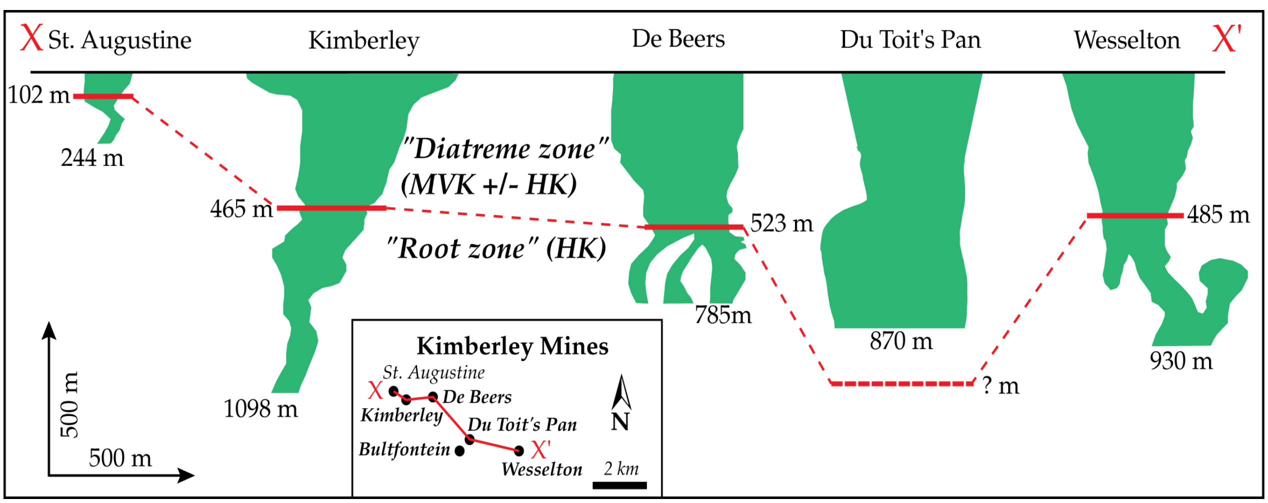

Figure 4: Cross sections of kimberlite pipes in the Kimberley cluster, South Africa, illustrating the variation in pipe size, and the variation in depth to the diatreme zone to root zone transition. Data from Wagner (1914), Clement (1982) and Mitchell (1986).

A revised South African pipe model?

It must be recognized first that the 'classic South African kimberlite pipe model' is a composite model (Kjarsgaard, 2003; Gurney et al. 2005), as illustrated in Figure 5. The volcanic edifice at Kasama, Mali, is 4 m high; in the Hawthorne (1975) model a tuff ring 80 m high and 300 m wide was incorporated. Current drilling at Orapa (or Mwadui) is to a depth of 600 - 700 m. In the Kimberley area ~800 m of kimberlite was mined. Thus, the 'middle' part of the diatreme zone in the model (Figure 5) is unknown, either from a lack of drilling (Orapa, Mwadui) or it was removed by erosion (Kimberley). Hence the Orapa (or Mwadui) pipe may not go to 2.5 km depth, as inferred in the composite model. The possibility that the pipe geometry changes significantly at depth also cannot be discounted (see Figure 6); this of course would influence tonnage parameters.

It is clear from numerous observations over the past 100 years that within the lower (e.g. Clement, 1982) and upper parts (e.g. Dawson, 1962; Nixon, 1973; Field et al., 1997) of southern African kimberlite pipes that there are multiple intrusive and/or extrusive and or resedimented kimberlite phases. Importantly, there are also known grade variations between these different phases within a single kimberlite pipe, that can be highly significant i.e. greater than an order of magnitude (Figure 7). Although kimberlite pipes may be generally circular in plan view, in detail the pipes are typically highly irregular in shape. This effect is pronounced if local faulting, fracture sets, or host rock geology has strongly influenced the growth of the pipe during the eruptions (Dawson, 1962; Barnett and Lorig, 2007). Hence the determination of the potential economics for any kimberlite must take the geometry, architecture and multiple event nature of the pipe into consideration.

So how do these southern African kimberlite pipes form and what are the processes involved? Lorenz and co-workers over the past 30 years have presented an alternate model to magmatic degassing and fluidization that invokes phreatomagmatism (e.g. Lorenz, 1975; Lorenz et al., 1999, Lorenz and Kurszlaukis, 2007). In this model, hot kimberlite magma interacts with groundwater to produce explosive volcanism. This model utilizes multiple magmatic events that variably interact with groundwater, and it provides a logical explanation for the occurrence of fragmental MVK and non-fragmental HK at the same level within the diatreme part of a kimberlite pipe, as well a variation in the size of individual kimberlites within a cluster.

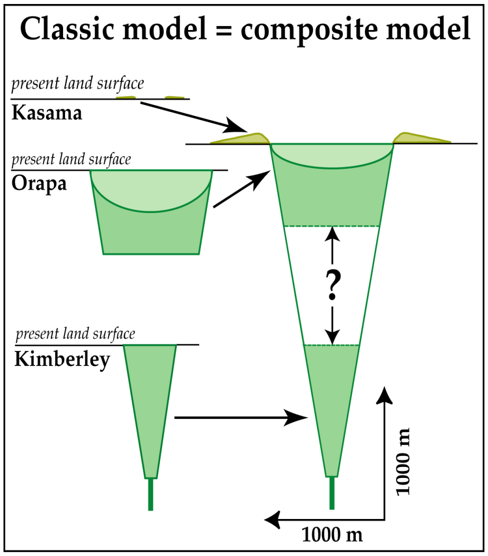

Figure 5: The classic South African kimberlite pipe model is a composite model, shown with its three known parts: top, tuff ring from Kasama, Mali and re-sedimented crater in-fill and upper pipe from Orapa, Botswana; base, root zone and lower pipe from Kimberley, South Africa. Note the lack of any information in the central portion of the composite model, and how a significantly larger tuff ring was added. Figure modified after Kjarsgaard (2003).

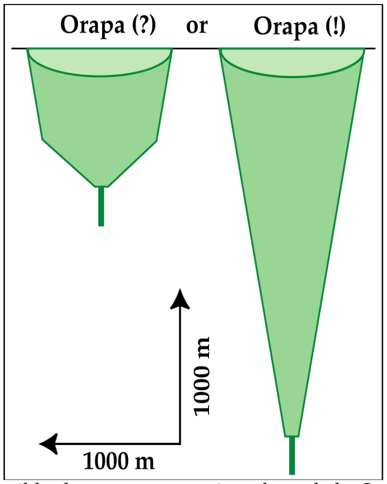

Figure 6: Possible alternate cross sections through the Orapa pipe.

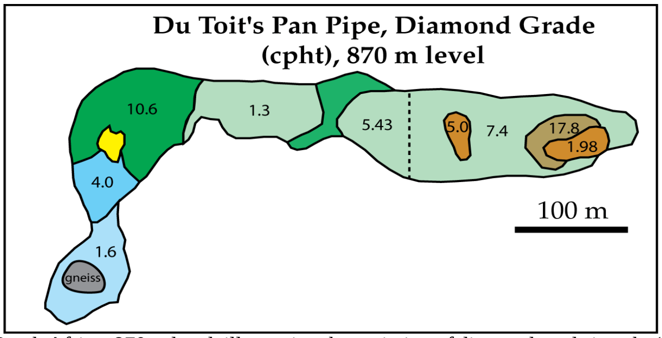

Figure 7: Du Toit's Pan kimberlite, South Africa, 870 m level, illustrating the variation of diamond grade in cpht (carats per hundred tonnes) in relation to the different geological phases of kimberlite as defined in Fig. 3a (after Clement, 1982).

However, kimberlite is an exceptionally volatile-rich melt and the effects of de-gassing cannot be dismissed entirely. In reality, phreatomagmatism is likely the primary mechanism, and volatile de-gassing a secondary mechanism, which together account for the formation and variation of the 'South African type' kimberlite pipes.

HYPABYSSAL (DYKES, SILLS, BLOWS) KIMBERLITE BODIES

The root zones of South African kimberlite pipes are well studied (Clement, 1982) and are known to consist of multiple intrusive units of hypabyssal kimberlite. There are also sills and dykes that may predate or postdate the formation of the root zone (Figure 1). Flow banding (or flowage differentiation) is a well documented igneous process in basic sills and dykes (Bhattacharji and Smith, 1964; Drever and Johnston, 1966), which is applicable to kimberlite magmatic systems (Figure 8a). Filter pressing in dykes, sills or plugs (Figure 8b) and flowage differentiation processes can lead to the formation kimberlites of quite variable grain sizes, including aphanitic kimberlite. Crystal settling appears to be a rare process in kimberlite magmatic systems, but has been observed at the Benfontein sill in South Africa (Dawson and Hawthorne, 1973). These magmatic processes can potentially have an effect on diamond grade and diamond size distribution within a single intrusive phase. The known variation in diamond content (grade) within the DB3 hypabyssal kimberlite phase at the De Beers pipe in the Kimberley cluster (Figure 9) is potentially consistent with these known magmatic processes.

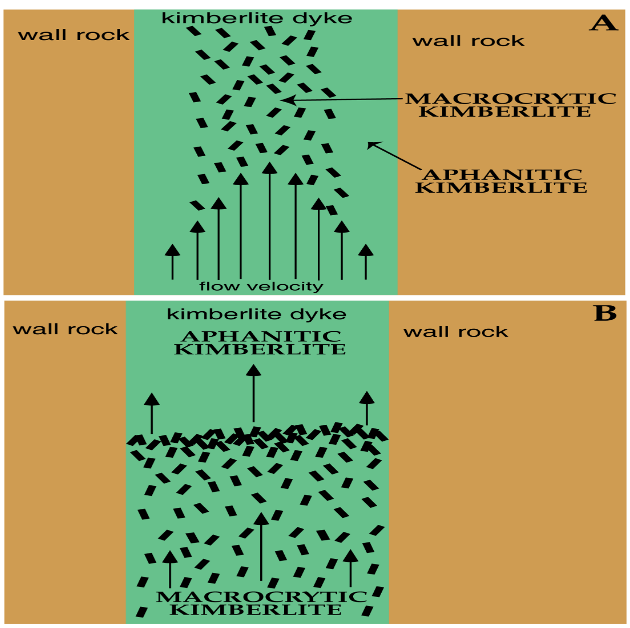

Figure 8: A) Schematic representation of flow banding in a kimberlite dyke, with increased flow rates at the centre due to dispersive shear pressure. **B)** Schematic representation of filter pressing in a kimberlite dyke. Figures modified from Kjarsgaard (2003, 2007).

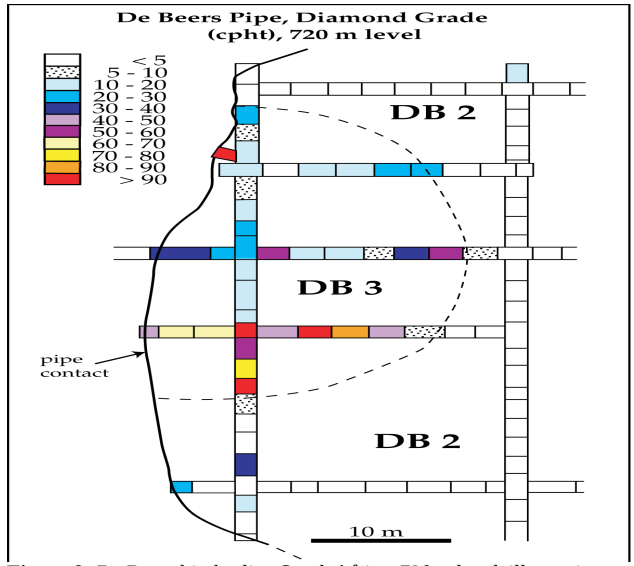

Figure 9: De Beers kimberlite, South Africa, 720 m level, illustrating the variation of diamond grade in cpht (carats per hundred tonnes) between the DB2 and DB3 kimberlite intrusions and within the DB2 and DB3 intrusions (adapted from Clement, 1982).

The morphological classification of igneous dykes (and sills) is well understood (Figure 10a; Hoek, 1991). For example, at Somerset Island the K24 intrusion (Kjarsgaard, 1996) and in the Iron Mountain field (Coopersmith et al., 2003), the dykes consist of a series of en echelon lenses of kimberlite. Perhaps more important however, is the continuity within a single dyke segment. It is far too simplistic to regard dykes as simple, linear features. Within dyke segments and between dyke segments, there are bridged interfaces that are quite variable in their constituent geometry (Figure 10b; Hoek, 1991). For example, in the Snap Lake kimberlite 'sheet', Kirkley et al. (2003) describe the kimberlite sheet splitting and bifurcating, with 'horsetail' features at off-sets. These features are consistent with known observations from basic dyke swarms (e.g. Hoek, 1991). Recognition that kimberlite dykes, sill and blows have rheological behaviour similar to other basic igneous magmas has important consequences to understanding their potential economic viability in terms of ore body continuity, tonnage estimates, amount of waste rock generated and mining methods.

VOLCANICLASTIC DOMINATED KIMBERLITE BODIES

The Fort à la Corne field in Saskatchewan contains a number of exceptionally large volcaniclastic-dominated kimberlite bodies. There are kimberlites in other parts of the world e.g. Angola, DRC, Alberta that have some resemblance to the Saskatchewan kimberlite bodies. In detail, within the Fort à la Corne kimberlite field there is a huge range in variation in architecture, morphology and size of the individual bodies (Kjarsgaard et al., 2005a, 2006; Harvey et al., 2006). Figure 11 presents a 'schematic' diagram of a typical Fort à la Corne kimberlite according to Scott-Smith (2006). Scott-Smith et al. (1994, 1998, 2006) suggested these kimberlites formed by a two-stage process of crater excavation followed by a single subaerial kimberlite in-filling event of the existing bowl-shaped crater. The postulated single crater in-filling event is eerily reminiscent of the 'single pipe-forming event' ascribed to the formation of the diatreme zone in the South African kimberlite pipe model (Clement, 1982; Field and Scott-Smith, 1999), which in my opinion, can now be discounted (see The South African Kimberlite Pipe Model, above).

In contrast, more detailed examination of the Fort à la Corne kimberlite bodies has revealed that they contain multiple phases (Figure 12) of different types of kimberlite (e.g. PK, VK, RVK) that formed by a variety of eruptive and resedimentation processes. Subaerial, phreatomagmatic and submarine eruption styles have been documented by Leckie et al. (1997), Kjarsgaard et al. (2005a, 2006), Pittarri et al. (2006), and Lefebrve and Kurszlaukis et al. (2006) The re-sedimentation processes are described by Leckie et al. (1997), Nixon and Leahy (1997), and Zonneveld et al. (2004, 2006). The Fort à la Corne kimberlite bodies in general, are best described as feeder vent(s) with overlying tephra (tuff rings and cones) of variable geometry and preservation (Leckie et al., 1997; Kjarsgaard et al. 2005a, 2006; Zonneveld et al., 2004). Individual kimberlite phases can be distinguished on the basis of their macroscopic appearance, mineralogy, and geochemistry (Figure 13; Grunsky and Kjarsgaard, 2007). Furthermore, microdiamond populations (Harvey, 2004; Kjarsgaard et al. 2005b) and macrodiamond grades can be correlated with discrete eruptive phases within a pipe (Shore Gold, 2006, 2007). The occurrence of multiple phases of kimberlite within a single Fort à la Corne body is consistent with observations from multi-phase South African pipes (see The South African Kimberlite Pipe Model - Old Observations Revisited, above). Recognition that the Fort à la Corne kimberlite bodies are multi-phase has important consequences to understanding their potential economic viability in terms of diamond grades, and ore tonnage estimates.

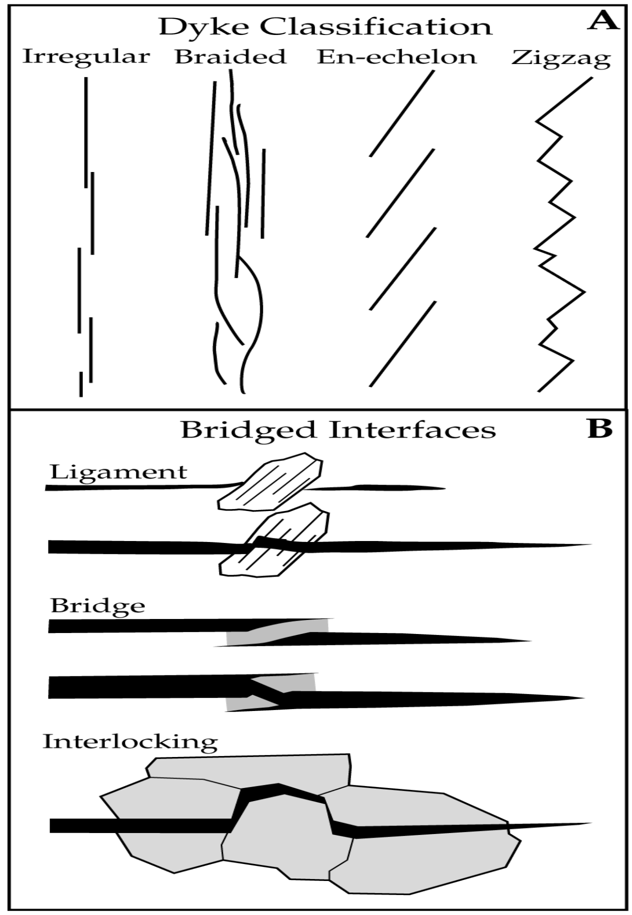

Figure 10: **A)** Classification of types of dykes. **B)** Details of types of bridged interfaces features observed within individual dyke segments. Adapted from Hoek (1991).

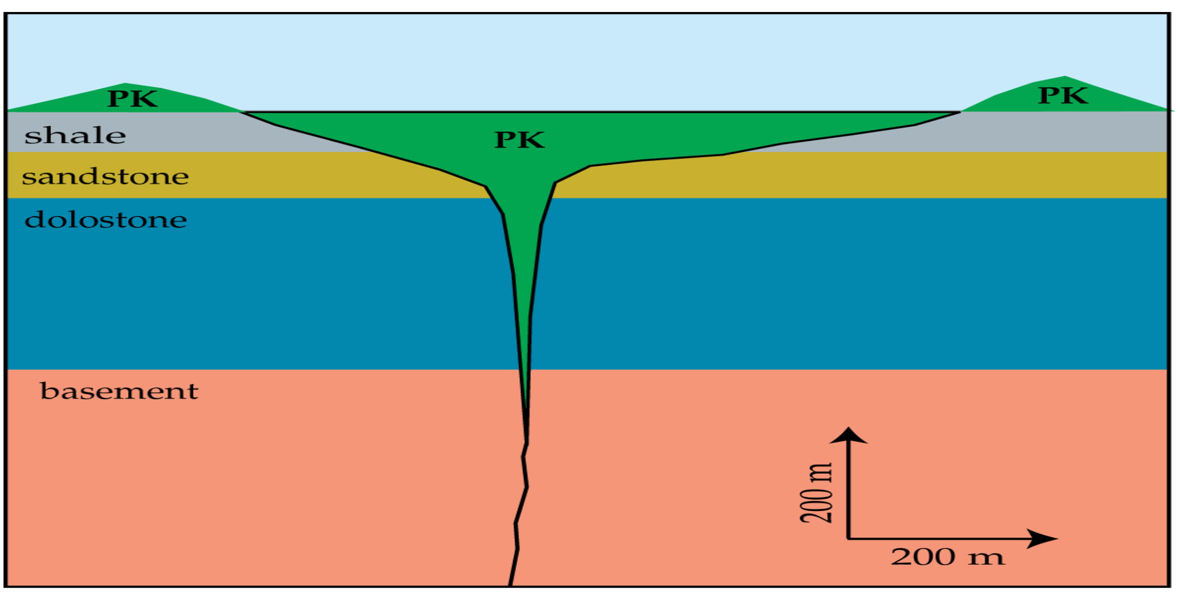

Figure 11: Schematic model of a "Prairie-type" kimberlite pipe (Field and Scott-Smith, 1999; Scott-Smith, 2006), which is highly oversimplified (compare to Figure 12)

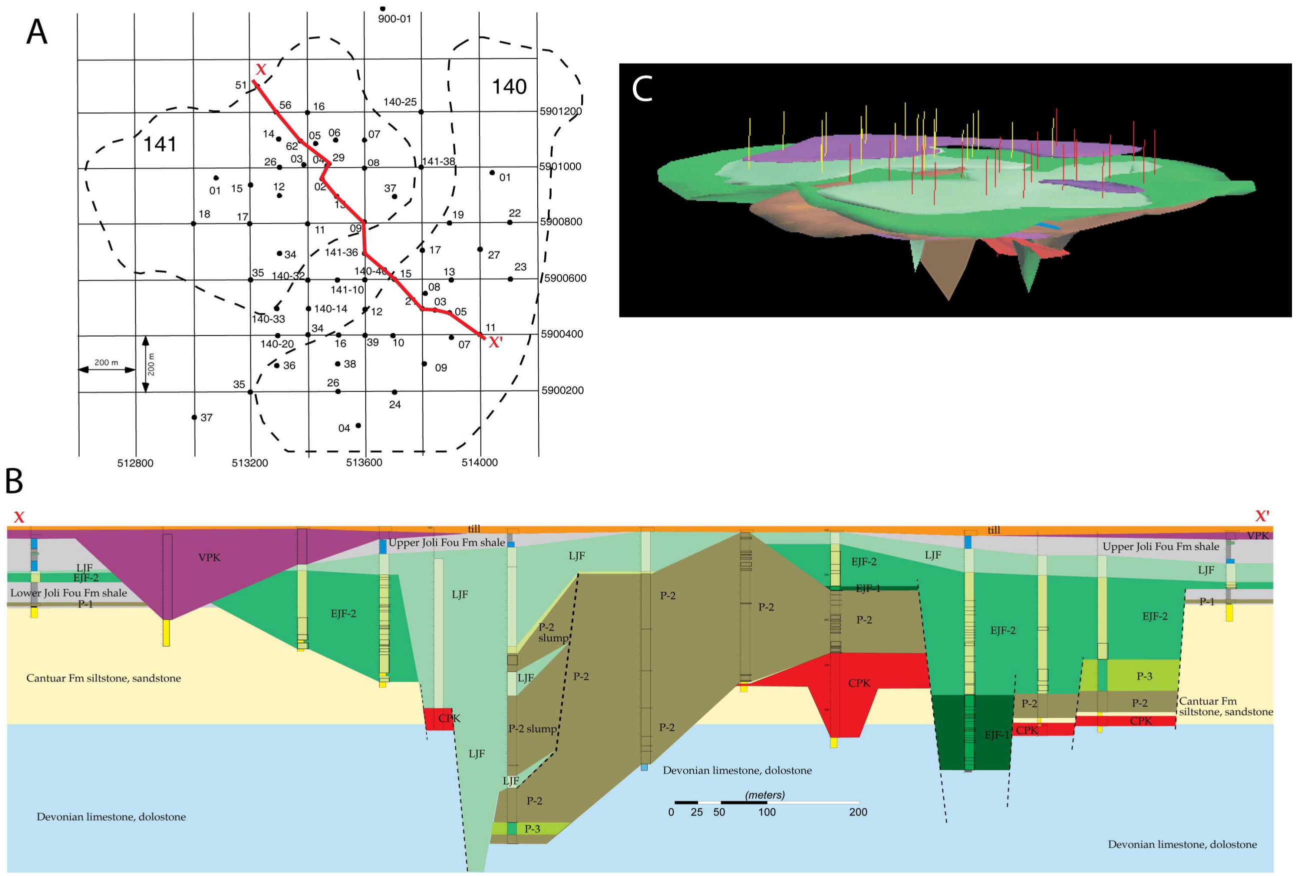

Figure 12: A) Plan view of Orion South (140/141) kimberlite, Fort à la Corne field, Saskatchewan. Line of cross section X - X' shown in red. **B**) Northwest - southeast cross section of the Orion South (140/141) kimberlite, 1:1 scale, no vertical exaggeration. Seven distinct eruptive phases are identified in this model: purple = VPK; light green = LJF; green = EJF-2; dark green = EJF-1; brown = P-2; lime green = P-3; red = CPK. One minor phase also shown in brown = P-1. Note that four distinct feeder vents are identified (CPK, EJF-1, P-2, LJF). Compare Figures 12B and 11 and note there is no relationship. See the text and also Kjarsgaard et al. (2007) for further discussion of the geometry and architecture of Fort à la Corne kimberlites. Adapted from Kjarsgaard (2007). **C)** 3-D solids model of the Orion South kimberlite illustrating relationships between the major eruptive phases and their feeder vents. Adapted from Harvey et al., (2004).

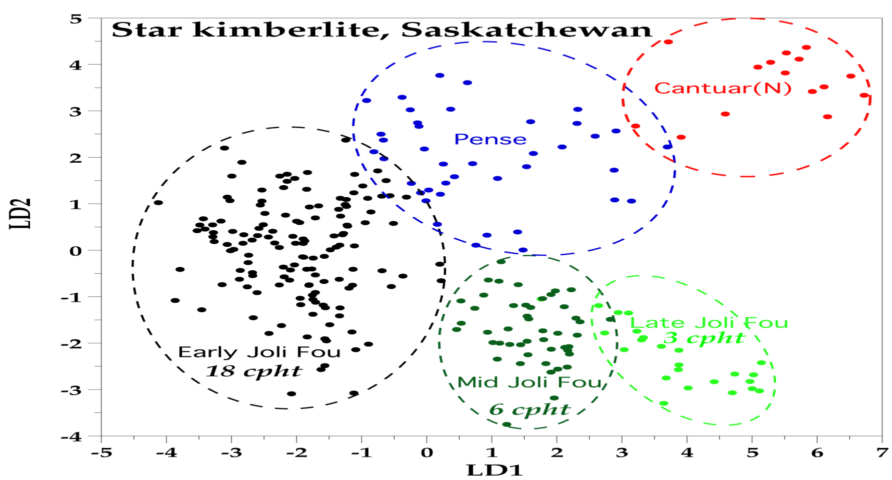

Figure 13: Whole-rock geochemistry linear discriminant (LD) scores based on 21 elements as cation equivalents. Bivariate plot of LD1 versus LD2 scores for five phases of kimberlite from the Star kimberlite body, Saskatchewan. The variation in diamond grade (from bulk sampling) for the three Joli Fou phases is from Shore Gold (2006). Adapted from Grunsky and Kjarsgaard (2007)..

RESEDIMENTED VOLCANICLASTIC DOMINATED KIMBERLITE BODIES

Kimberlites in the Lac de Gras field tend to be small (50 - 200 m diameter) steep sided bodies which are dominated by a wide variety of different types of volcaniclastic kimberlite that constitute the main pipe in-fill (Figure 14). At Lac de Gras, consequent or subsequent input of PK contributes to the pipe in-fill (e.g., Kirkley et al. 1998; Graham et al., 1999; Moss and Russell, 2006), as do a variety of different types of resedimented volcaniclastic kimberlite (RVK) including slump and grain flow deposits from tephra cones (Kjarsgaard, 2003, 2007), and crater lake deposits. Some of the in-fill is derived from eruptive events associated with adjacent kimberlite pipes (Graham et al., 1999; Moss and Russell, 2006). Kimberlite pipes with similar morphologies have been suggested to occur elsewhere e.g. in Botswana and Angola. In detail, within the Lac de Gras kimberlite field there is a huge range in variation in architecture, morphology and size of the individual bodies (e.g. Graham et al., 1999, Nowicki et al., 2003).

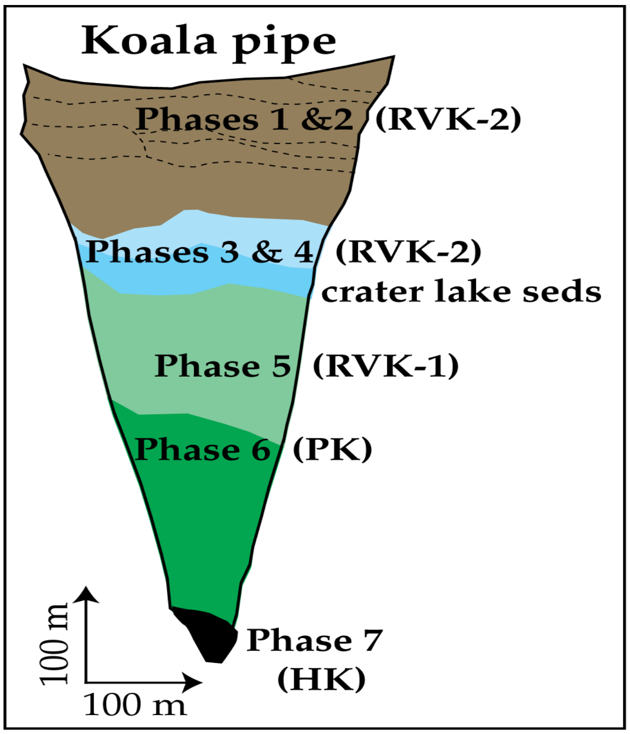

Figure 14: Geological cross section of the steep sided, inverted cone shaped Koala kimberlite body, Ekati Mine, Lac de Gras field. Phase 7 is hypabyssal kimberlite (HK) and Phase 6 is pyroclastic kimberlite (PK) (Crawford et al., 2006). Phase 5 is interpreted here as syn-eruption resedimented volcaniclastic kimberlite (RVK-1), phase 4 and 3 are interpreted here as crater lake sediments, and phases 2 and 1 are interpreted as post-eruption resedimented volcaniclastic kimberlite (RVK-2). Internal phases within phase 1 & 2 demarcated by dashed lines. Modified after Nowicki et al. (2003) and Crawford et al., (2006) by Kjarsgaard (2007).

PHYSICAL AND CHEMICAL PARAMETERS OF KIMBERLITES

The physical properties of kimberlite are quite variable, depending upon the type of kimberlite (HK, MVK, VK, PK, and RVK) and style(s) of alteration. Kimberlite bulk densities range from ~2.5 to 3.1 g/ml for non-fragmental HK, to much lower values of 1.6 to 2.5 g/ml for fragmental VK (Katsube and Kjarsgaard, 1996). Kimberlite electrical resistivity measurements range from ~3,000 to 60,000 Ωm for non-fragmental HK to much lower values of ~10 to 3,000 Ωm for fragmental VK (Katsube and Kjarsgaard, 1996). Kimberlite magnetic susceptibility ranges from ~1 to 100 (10^{-3} S.I. units) for both HK and VK (Katsube and Kjarsgaard, 1996).

Kimberlites have a characteristic geochemical signature, being rich in the 'incompatible' elements Sr, Ba, LREE (La, Ce, Sm, Nd), Nb, Ta, Zr, P, Th and U ('alkaline signature'), as well as having high concentrations of the first order transition elements Mg, Ni, Cr, and Co ('ultramafic signature'). There are essentially no other rocks that have this distinctive alkaline and ultramafic geochemical signature, with the exception of a few rare magnesio-carbonatites. Some ultramafic lamprophyres (e.g. alnöite, aillikite) may also appear to have 'similar' geochemistry, but typically these rocks have higher contents of TiO_2, Al_2O_3, Na_2O and K_2O and can also be distinguished on a petrographic basis (e.g. see Tappe et al., 2005).

Applications to Exploration

Known, economically viable kimberlites range in size from thin (1 - 4 m) dykes or sills, to small pipes of ~75 m in diameter to very large pipes with sizes of ~1.5 km diameter. Just about any type of rock can host kimberlite bodies. The physical and geochemical signatures of the host rocks are widely variable in terms of their magnetic response, electrical resistivity, density and elemental distributions. Hence a variety of kimberlite - host rock responses are possible i.e. positive anomaly, negative anomaly, or no anomaly. In addition, the known significant variation in size (and geometry) of kimberlite bodies has a strong influence on possible line spacing for ground or airborne geophysical surveys, and sampling densities for kimberlite indicator minerals, or soil or till geochemical surveys (McClenaghan and Kjarsgaard, 2007).

Lessons learned from assumptions of pipe models are that exploration of any district is likely to encounter significant variability of rock type and corresponding geophysical properties. Therefore local and regional surveys need to be combined with orientation measurement of background petrophysical rock properties. The distinctive geochemical fingerprint needs to be applied to surficial geochemical surveys to screen geophysical targets.

CONCLUSIONS

There has been a renewed recognition over the past decade that kimberlite diamond deposits are complex, multiple intrusive/extrusive bodies (Kjarsgaard, 2007). Furthermore, as a result of the recent discoveries of kimberlites in Canada, it is clear that the old South African pipe model does not have universal applicability. Although the complex nature of kimberlite pipes has been known for over 100 years, over-simplified kimberlite pipe models developed in the 1970's, 80's and 90's, are still (2006), in part, being perpetuated which has led to non-optimum exploration methods, and diamond sampling strategies in some instances. The newer, but still highly over-simplified three end member kimberlite pipe model (e.g. Scott-Smith, 2006; Skinner and Marsh, 2004) for which little data exists to support, should be used with extreme caution. The near surface emplacement of kimberlite depends on numerous factors (e.g. host rock lithologies, groundwater and aquifers) and is not simple. However, kimberlite melts follow the basic rules of magma physics, and behave similarly to small volume alkali basaltic magma systems. In this respect they are not 'unique' as is sometimes suggested.

ACKNOWLEDGEMENTS

Comments on the manuscript by Tom Lane and Roger Mitchell were quite helpful; the opinions expressed in this paper however, are soley those of the author.

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