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KIMBERLITE TERMINOLOGY AND CLASSIFICATION

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INTRODUCTION

Reliable evaluation and mining of primary diamond deposits is founded on a good understanding of the geology of kimberlites and related rocks. Description, classification and interpretation of these rocks and communication of that information underpin the development of three-dimensional geological models. Such models are essential in generating reliable diamond resource estimates. Current kimberlite terminology has evolved over more than four decades. Issues of terminology result from (i) kimberlites and related rocks having attributes not adequately addressed by standard igneous petrological or volcanological terminology, and (ii) the inconsistent use and misuse of terms. Here we present a rationalisation of kimberlite terminology and classification based on the detailed definition of over three hundred petrological, volcanological and kimberlite-specific terms which have been compiled in a Glossary. The purpose of the Glossary is to clarify terms relevant to kimberlite geology, as far as possible to align kimberlite terms with those of mainstream geology, and to recommend terminology that is applicable to the economics of diamond deposits. In this paper the terminology from the Glossary is summarised and presented in a practical, systematic framework, or scheme, intended to assist in the description, recognition and understanding of the complex and unusual rocks encountered during diamond exploration and mining.

KEY PRINCIPLES AND OBJECTIVES

The five-stage scheme (Table 1; after Scott Smith et al. 2008) is subdivided into two broad parts:
(i) observation (Stage 1), and
(ii) progressive interpretation (Stages 2 to 5).
Stage 1 requires only limited genetic interpretation whereas Stages 2 to 5, where possible, involve classification into specific rock types based on increasing degrees of genetic inference. The descriptive stage is considered to be the most critical part of the nomenclature scheme. This stage provides the evidence for the interpretations undertaken in Stages 2 to 5. Importantly, Stage 1 also provides the basic information required for the definition and internal subdivision of potential primary diamond deposits into different units or phases that can be used in the development of economically relevant geological models.

This concept is partly inspired by the approach of McPhie et al. (1993) and has similarities to Cas et al. (2008, 2009). However, there are key differences between our scheme for kimberlite nomenclature and these approaches. The latter begin with an initial textural subdivision into coherent or volcaniclastic facies (or “fragmental” in the case of Cas et al., 2008, 2009) and the descriptive terminology used for each of these facies is different. Further description of the deposit or rock depends upon this initial facies assignment (e.g., coherent vs. volcaniclastic) and if this is changed after additional investigation, the original descriptors need to be replaced. Our experience is that the subdivision of kimberlite into either coherent or volcaniclastic commonly requires detailed investigation and, in some instances, may not be possible with any acceptable degree of confidence. On this basis, the textural-genetic classification in our scheme is considered a later stage in the rock naming process. The scheme builds upon a series of descriptors that are applied independently of, and prior to, textural-genetic classifications (Table 1). This is aimed at reducing incorrect textural-genetic assignments that can be very misleading, especially with respect to predictions of deposit structure and diamond distribution.

THE SCHEME

The scheme (Table 1) is applied to rock bodies, lithological units (subdivisions having unifying characteristics that are distinct from adjacent parts) and samples derived from them. Typically, the scheme is applied progressively, with a decreasing scale of observation, increased sample density, greater integration of other data and higher level of interpretation as investigations proceed.

Table 1 The Scheme: A systematic framework for the description, classification and interpretation of kimberlites

<table>
<tr><th>Stage 1</th><th>Stage 2</th><th>Stage 3a</th><th colspan="2">Stage 3b</th><th>Stage 4</th><th>Stage 5</th></tr>
<tr><th>OBSERVATION</th><th colspan="6">PROGRESSIVE INTERPRETATION</th></tr>
<tr><th>Rock Description</th><th>Petrogenetic Classification</th><th colspan="3">Textural-Genetic Classification</th><th>Genetic / Process Interpretation</th><th>Intrusive / Volcanic Spatial Context</th></tr>
<tr>
<td rowspan="6">**Alteration:**
intensity; distribution; mineralogy; imposed textures; timing; preservation; xenolith reaction
Structure:
e.g. massive; inhomogeneous; layered; flow zoned; laminated; cross-bedded; jointed
Components:
crystals (e.g. olivine macrocrysts, crustal xenocrysts); compound clasts (e.g. magmaclasts, xenoliths, autoliths, accretionary clasts); interclast matrix
Texture:
component distribution; shape; size distribution (e.g. well sorted; inequigranular); packing; support (e.g. clast or matrix supported)</td>
<td rowspan="6">**Parental Magma Type:**
e.g. kimberlite; lamproite; melnoite; alnoite; olivine melilitite
Mineralogical Classification:
e.g. monticellite; phlogopite; carbonate</td>
<td rowspan="2">**Coherent:**
[descriptors] coherent *kimberlite* (CK)</td>
<td colspan="2">**Intrusive:**
[descriptors] intrusive coherent *kimberlite* (ICK) or hypabyssal *kimberlite* (HK)</td>
<td>e.g. composite; flow differentiated</td>
<td>e.g. intra-crater ICK sheet; non-volcanic plug; sub-volcanic root-zone pipe fill</td>
</tr>
<tr>
<td colspan="2">**Extrusive:**
[descriptors] extrusive coherent *kimberlite* (ECK)</td>
<td>e.g. effusive lava; fountain-fed clastogenic ECK</td>
<td>e.g. extra-crater lava flow; intra-crater lava lake</td>
</tr>
<tr>
<td rowspan="4">**Volcaniclastic:**
[descriptors] volcaniclastic *kimberlite* (VK)</td>
<td rowspan="2">**Pyroclastic:**
[descriptors] pyroclastic *kimberlite* (PK) or *[descriptors]* *kimberlitic* [standard pyroclastic rock name]</td>
<td>**Kimberley-type:**
[descriptors] Kimberley-type pyroclastic *kimberlite* (KPK)</td>
<td rowspan="2">e.g. fallout; base surge; pyroclastic flow; fluidised; column collapse</td>
<td rowspan="2">e.g. vent-proximal spatter; intra-crater fall; crater rim surge; distal extra-crater fall; subsurface diatreme-fill massive KPK; crater-fill diffusely bedded KPK</td>
</tr>
<tr>
<td>**Fort à la Corne-type:**
[descriptors] Fort à la Corne-type pyroclastic *kimberlite* (FPK)</td>
</tr>
<tr>
<td colspan="2">**Resedimented Volcaniclastic:**
[descriptors] resedimented volcaniclastic *kimberlite* (RVK) or *[descriptors]* resedimented *kimberlitic* [standard sedimentary rock name]</td>
<td>e.g. grain flow; debris flow; lacustrine RVK; alluvial fan; turbidite</td>
<td>e.g. pipe-fill mass flow; intra-crater lake sediments; distal extra-crater reworked crater rim</td>
</tr>
<tr>
<td colspan="2">**Epiclastic Volcanic:**
[descriptors] epiclastic volcanic *kimberlite (EVK)* or *[descriptors]* epiclastic *kimberlitic* [standard sedimentary rock name]</td>
<td>e.g. lithified crater rim scarp slope mass wasting</td>
<td>e.g. pipe-proximal EVK; HK sheet-derived epiclastic sediment</td>
</tr>
<tr>
<td>**Example names:** fresh, uniform, xenolith-poor, medium-grained, olivine macrocryst-rich rock; intensely serpentinised, massive, xenolith-rich, fine to medium grained, olivine-poor rock</td>
<td>**Example names:** olivine macrocryst-rich carbonate phlogopite monticellite kimberlite; leucite lamproite; olivine macrocryst-poor phlogopite orangeite</td>
<td>**Example names:** xenolith-poor, flow zoned, variably macrocrystic CK; xenolith-rich, well bedded VK</td>
<td colspan="2">**Example names:** macrocryst-poor ICK; uniform macrocrystic HK; flow banded crystal-poor ECK; thickly bedded PK; kimberlitic lapilli tuff; massive unsorted very macroxenolith-rich KPK; graded xenolith-poor olivine pyrocryst-rich FPK; cross-bedded very fine-grained crystal-dominated RVK; well-sorted resedimented kimberlitic sandstone; poorly-sorted EVK</td>
<td>**Example names:** graded, olivine pyrocryst-rich FPK fall deposit; kimberlitic lacustrine mudstone; clast-supported very-xenolith-rich RVK mass flow deposit</td>
<td>**Example names:** steep discordant HK sheet; diatreme-fill massive xenolith-rich KPK; crater-fill olivine pyrocryst-dominated mega-graded fall FPK</td>
</tr>
</table>

Stage 1: Rock Description

Stage 1 of the scheme is rock description (*alteration*, *structure*, *components*, *texture*) and involves only limited genetic interpretation. The sequence in which the descriptions are made reflects a progressive decrease in the scale of observation from megascopic through macroscopic to microscopic. For example, *alteration* is considered first because it is commonly an initially readily recognisable mega- and macroscopic feature. Some understanding of *alteration* is necessary to assess the degree of confidence in the description, classification and interpretation of the original nature of the rock and in turn of the geological model. *Structure* encompasses the megascopic features or internal organization of the rock. The *components* (Fig. 1) are ascribed to three classes or groups: *crystals* (observable with the unaided eye or binocular microscope, in particular olivine), *compound clasts* (clasts comprising assemblages of crystals or grains) and *interstitial matrix* (material between crystals and/or compound clasts) each of which are further subdivided as shown in Fig. 1. *Kimberlitic compound clasts* include *magmaclasts* (a non-genetic descriptive term for a physically distinct, fluidal-shaped body of solidified magma formed prior to emplacement by any process; includes *melt-bearing pyroclasts* and *melt segregations*). The *interstitial matrix* is considered last because it is difficult to discern and microscopic examination is usually required to determine its character. New descriptors for the sizes and abundances of (i) *crystals* and *magmaclasts* are given in Tables 2 and 3 and of (ii) *xenoliths* (accidental rock or lithic inclusions) and *autoliths* (accidental inclusions of pre-existing consolidated kimberlite) in Tables 4 and 5. *Texture* summarises the small-scale arrangement of, and relationships between, the components of a rock or part thereof.

Although Stage 1 is primarily descriptive, it does require a broad understanding of these rock types, particularly in terms of identifying the primary components and their replacement products. The observations are summarised as a *Descriptive Rock Name* which highlights the significant and characteristic features of that sample/unit (see Example names in Table 1). Importantly, Stage 1 emphasizes the components (i.e. olivine, other mantle-derived xenocrysts and all types of xenoliths) that are economically relevant in the prediction of diamond distributions, regardless of whether the texture and genesis of the host rock are understood. The Stage 1 descriptors overlap substantially with those of Cas et al. (2008, 2009) but we include some key modifications:

(i) a single set of non-genetic size descriptors for crystals that can be applied to a rock irrespective of texture (Table 2);
(ii) discontinue usage of the term *breccia* to indicate a certain proportion of xenolithic material and replace with specific xenolith abundance descriptors (Table 5);
(iii) retain the term *magmaclast* (Fig. 1, Tables 2 and 3), and
(iv) avoid a 25% cutoff for crystal abundance subdivisions because this value is the average mode for olivine macrocryst abundance in typical hypabyssal kimberlites.

Stage 2: Petrogenetic Classification

Stage 2, petrogenetic classification, includes the *parental magma type* and *mineralogical classification*. *Parental magma type* is based on typomorphic and characteristic magmatic mineral assemblages (or their pseudomorphs). The *mineralogical classification* subdivides rocks of one *parental magma type* using the main constituent minerals (or their pseudomorphs) listed in increasing order of abundance. The resulting terms are combined into a *petrogenetic classification name* (see Example names in Table 1*)*. This stage requires the identification of the products of crystallisation and is best undertaken on either fresh holocrystalline coherent rocks or magmaclasts. The *parental magma type* and *mineralogical classification* is of prime economic significance, i) to confirm that the rock is kimberlite or other related rock with the potential to contain diamonds and, ii) to identify different phases of kimberlite intrusion or eruption within a particular body.

Stage 3: Textural-Genetic Classification

Stage 3 consists of two sub-stages of textural-genetic classification (Table 1) that require increasing information and interpretation. Stage 3a is the broad textural-genetic classification into *coherent* and *volcaniclastic*. The term *coherent* is applied to rocks formed by the solidification of magma lacking evidence for magmatic fragmentation or disruption or pyroclastic features. *Volcaniclastic* is the preferred non-genetic term applied to deposits and rocks composed of a substantial proportion of volcanic particles. This includes clastic rocks occurring within the diatreme, conduit zone or subsurface parts of volcanic pipes. Where the *parental magma type* is known, this is applied as the rock name (e.g. *coherent kimberlite or volcaniclastic kimberlite*). Where possible, *coherent* can be sub-divided into *intrusive* or *extrusive* and *volcaniclastic* into *pyroclastic kimberlite* (formed from explosive volcanic eruptions), *resedimented volcaniclastic* (formed by sedimentary re-deposition of unconsolidated pyroclastic and other surface materials) and *epiclastic volcanic kimberlite* (consolidation of material containing epiclasts produced from pre-existing lithified volcanic kimberlite by surface processes).

As discussed by Scott Smith et al. (2008), tuffisitic kimberlite (TK) is a distinctive textural variety of kimberlite and it has long been recognised that the term TK is not appropriate. Also, pipe zone terms (e.g. diatreme-facies kimberlite) should not be used to denote a specific process of formation or type of infill material. Here we suggest that *pyroclastic kimberlite* is sub-divided into two main classes named after their type areas: *Kimberley-type pyroclastic kimberlite* (formerly tuffisitic kimberlite) and *Fort à la Corne-type pyroclastic kimberlite* (formerly pyroclastic kimberlite; e.g. Scott Smith, 2008). Different levels of *textural-genetic rock names* combine the results of Stage 3 (see Example names in Table 1). Where appropriate, standard volcanological and sedimentological rock names can be used.

Stage 4: Genetic / Process Interpretation

Stage 4 involves advanced interpretation of the rock formation process by integrating the information obtained in Stages 1 to 3. These interpretations are based on well-known processes and products in other volcanic systems, many of which also occur in kimberlite volcanoes. The unusual characteristics of kimberlite magmas, however, result in certain unique kimberlite-specific deposit and rock types. Also, most kimberlite studies focus on material occurring in subsurface bodies which can be expected to reveal processes and products that are not well known.

Stage 5: Intrusive/Volcanic Spatial Context

Stage 5 incorporates an assessment of the spatial relationship of the rocks under investigation to the kimberlite body from which they derive and the morphology of the body as illustrated in Fig. 2.

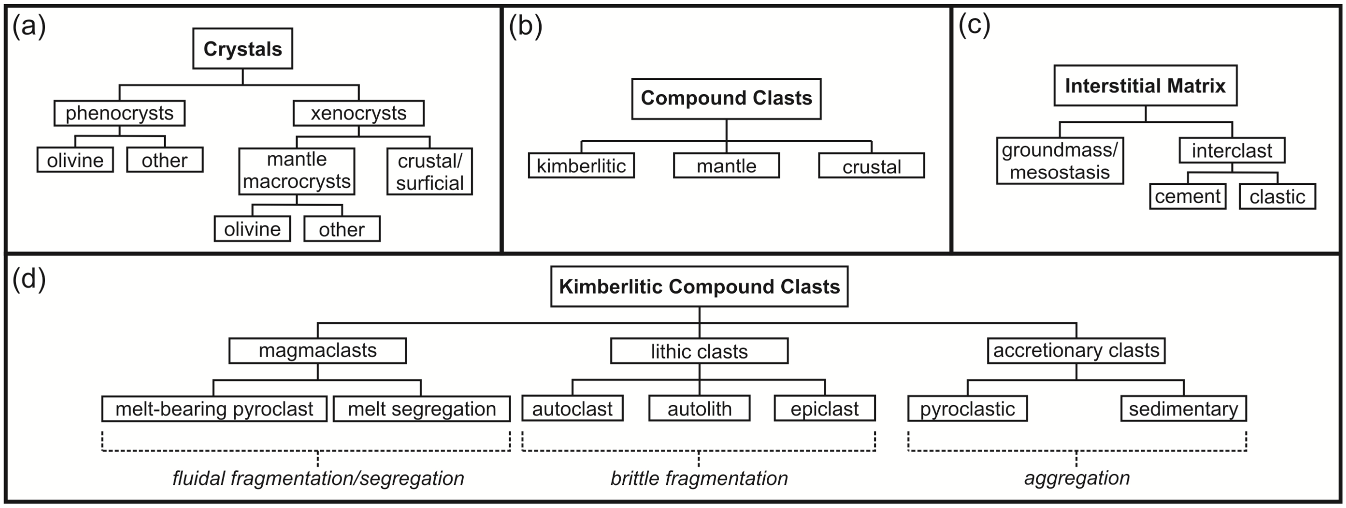

Fig. 1. Conceptual framework for the description of kimberlite components. The components are ascribed to three main classes (a) crystals, (b) compound clasts and (c) interstitial matrix. Further subdivision is based on composition and origin.

APPLICATION

The nomenclature approach outlined here, Stages 1 to 5 (Table 1), can conclude with the formulation of the three-dimensional geological models required for kimberlite exploration, evaluation, resource classification and mining. Critically, it focuses on important descriptive criteria that permit reliable and relevant application at an early stage of investigation and potentially by geologists that are not necessarily kimberlite experts. It is very important that each stage of the scheme is applied only if the nature of the rock and the scale of observation allows. The level to which the scheme can be applied, and thus the degree of confidence in the outcome, depends on the nature of the rocks, the experience of the user with these rock types, and the degree of detail in the investigation. Understanding the different and varying degrees of confidence in the conclusions is important, particularly in the economic application of the results. The degree of confidence reflects (i) the accuracy of the recognition of primary features and constituents in Stage 1, and (ii) the validity of the interpretation of that evidence in Stages 2 to 5. It is important to note that units of kimberlite, the basis of internal geological models, can be established using Stage 1 and without much of the further interpretation in Stages 2 to 5. Geologists should however strive to make further interpretations. Accurate interpretations will significantly improve the degrees of confidence in the geological models as well as in the predictions of diamond distributions.

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Table 2 Size descriptors for crystals and magmaclasts (excludes xenoliths; see Table 4)

Size range (mm)	Descriptor	Abbreviation
< 0.125	ultrafine	uf
> 0.125 - 0.25	superfine	sf
> 0.25 - 0.5	very very fine	vvf
> 0.5 - 1	very fine	vf
> 1 - 2	fine	f
> 2 - 4	medium	m
> 4 - 8	coarse	c
> 8 - 16	very coarse	vc
> 16	ultracoarse	uc

Table 3 Abundance descriptors for crystals and magmaclasts (excludes xenoliths; see Table 5)

Percentage range	Descriptor
0	[crystal]-free
> 0 - 5	very [crystal]-poor
> 5 - 15	[crystal]-poor
> 15 - 50	[crystal]-rich
> 50 - 75	very [crystal]-rich
> 75	[crystal]-dominated

Table 4 Size descriptors for xenoliths (and autoliths)

Size range (cm)	Modifier	Descriptor
< 1.6	-	microxenolith
> 1.6 - 6.4	small	macroxenolith
> 6.4 - 25.6	medium	
> 25.6 - 102.4	large	
> 102.4 - 409.6	small	megaxenolith
> 409.6 - 1600	medium	
> 1600	large	

Table 5 Abundance descriptors for xenoliths (and autoliths)

Percentage range	Descriptor
0	xenolith-free
> 0 - 5	very xenolith-poor
> 5 - 15	xenolith-poor
> 15 - 50	xenolith-rich
> 50 - 75	very xenolith-rich
> 75	xenolith-dominated

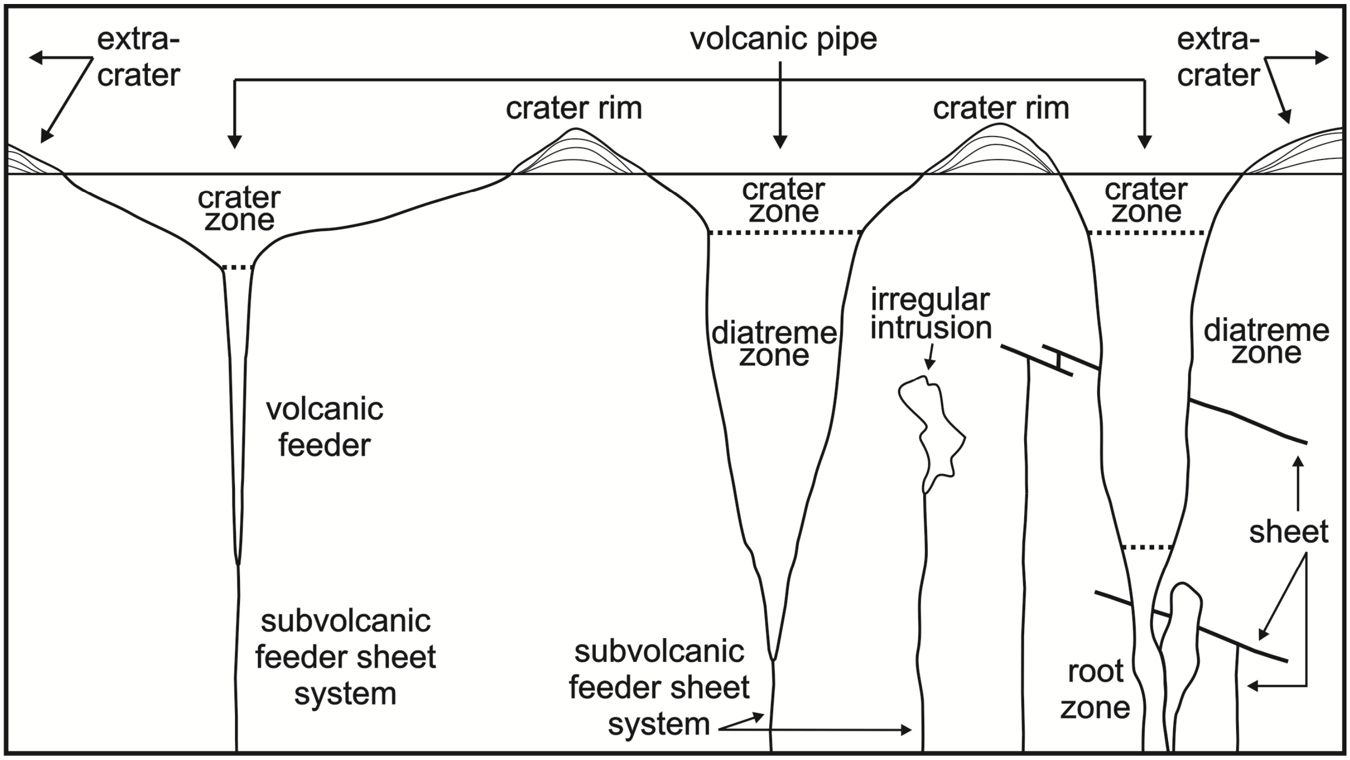

Fig. 2. Guide to terminology for kimberlite body morphology and pipe zones.