SCOTT-SMITH PETROLOGY

CONTRASTING KIMBERLITES AND LAMPROITES

Notes to accompany a talk to be given at the International Seminar on Kimberlite in Beijing, China in August 1987.

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INTRODUCTION

Kimberlite was traditionally considered to be the only important, primary source of diamond but recently various diamondiferous bodies have been classified as lamproites. Previously lamproites were not considered to be of economic interest but rather as academic curiosities. Some workers (e.g. Wade and Prider 1940) did comment on certain similarities with kimberlites and hence infer a potential to carry diamonds. Innumerable kimberlites are known around the world and many contain diamonds such as Men Ying in China. At present only relatively few diamondiferous lamproites are known. They include several bodies in the Kimberley region of Western Australia which now include an operating mine at Argyle, Prairie Creek in Arkansas, USA, certain bodies at Kapamba in Zambia and Majghawan in India. All of these bodies were initially referred to as kimberlites. In this presentation various aspects of the geology of kimberlites and then lamproites are outlined to show that they are distinct rock types. It is important to consider them as separate rock types when considering both economic and petrogenetic aspects.

KIMBERLITE

The term kimberlite was first used by Lewis (1887) to describe the host rock of diamond at the type locality, Kimberley in South Africa. Kimberlite has been the subject of many subsequent investigations and considerable effort has been expended in finding an adequate petrological definition of these unusual rocks (Dawson 1971, Mitchell 1979, Clement et al. 1984, Mitchell 1986). Most significantly diamondiferous bodies including all those in Russia, South Africa, other producing African countries as well as China are kimberlites sensu stricto. For this reason kimberlite has long been regarded as the only primary source of diamond. Not all kimberlites contain diamond.

PETROGRAPHY : Kimberlites are petrographically complex rocks. They are hybrid rocks typically containing mantle-derived xenoliths and xenocrysts and primary phases crystallising from a kimberlite magma. Kimberlites exhibit a distinctive inequigranular texture resulting from the presence of relatively large (up to 10mm) anhedral (typically rounded) grains termed macrocrysts (devoid of genetic inferences) set in a finer matrix. The macrocrysts are dominated by olivine. Kimberlite may contain diamond but only as a very rare constituent. The origin of the macrocryst suite is still debated although some do represent xenocrysts derived from the mantle xenoliths and megacrysts. In rare instances aphanitic kimberlites do occur where macrocrysts may be rare or absent. Primary phases comprise : (1) phenocrysts (and microphenocrysts) which are generally subhedral to euhedral and crystallised from the kimberlite magma prior to emplacement. They are typically dominated by olivine but phlogopite may also occur; (2) minerals which have crystallised in situ to form the fine grained groundmass (phlogopite, carbonate, serpentine, clinopyroxene, monticellite, apatite, spinels, perovskite and ilmenite). These primary phases display wide modal variations and any one kimberlite does not contain all these minerals.

DEFINITION (modified from Mitchell 1986 and Clement et al. 1984) : "Kimberlites are a clan of volatile-rich (CO_2 and H_2O), potassic, ultrabasic rocks. They exhibit a distinctive inequigranular texture resulting from the presence of macrocrysts (and in some instances megacrysts) set in a finer grained matrix. The macrocryst assemblage consists of anhedral (typically rounded) grains which are dominated by olivine but may include phlogopite, magnesian ilmenite, chromian spinel, magnesian garnet, clinopyroxene and orthopyroxene. The matrix contains phenocrysts of olivine and sometimes phlgopite together with several of the following groundmass minerals: phlogopite, carbonate (typically calcite), serpentine (commonly Fe-rich), clinopyroxene (Al- Ti-poor typically diopside), monticellite, apatite, spinels (Ti-, Mg-chromite), perovskite and ilmenite. Alteration of macrocrysts and some matrix minerals by deuteric processes, typically serpentinisation and carbonatisation, is common."

MINERALOGICAL CLASSIFICATION (Fig. 1) : Hypabyssal kimberlites can be described using the modal mineralogy of the primary groundmass minerals (e.g. diopside, phlogopite kimberlite; Skinner and Clement 1979). For the purposes of this classification macrocrystal and phenocrystal olivine are ignored as they are ubiquitous. The dominant groundmass minerals are monticellite, phlogopite, diopside, calcite and serpentine. Other minerals typically present in accessory amounts may in rare instances be sufficiently abundant to be included in a descriptive name.

TEXTURAL CLASSIFICATION (Fig. 2; Clement 1982, Clement and Skinner 1985) : The textural-genetic classification of kimberlite recognises the existence of crater, diatreme and hypabyssal facies and provides a useful indication of the markedly different ways in which the rocks were emplaced. Hypabyssal kimberlites most commonly have macrocrystic textures with a fine matrix which crystallised from a kimberlite magma. The matrix may have a uniform or segregationary texture. Diatreme-facies kimberlites comprise mainly tuffisitic kimberlite breccias which are the end products of complex fluidised intrusive systems. They are characterised by fragmental textures and commonly incorporate juvenile lapilli-like bodies, abundant country rock xenoliths, cognate kimberlite fragments (autoliths), upper mantle and crustal-derived xenoliths and xenocrysts and discrete kimberlite minerals (phenocrysts) set in a fine grained cementing medium. The fine grained (commonly microlitic) matrix consists of minerals that represent the quenched products of the transporting fluids of the fluidised system (mainly microlitic diopside and serpentine). Crater-facies rocks comprise epiclastic and pyroclastic material. The volume of pyroclastic material appears to be small. Glass, including shards or scoriaceous lapilli, has not been observed. Epiclastic material comprises complex alluvial fan and lacustrine deposits to which standard terminology can be applied.

GEOLOGY : (Fig. 3; Hawthorne 1975, Clement 1982). Kimberlite craters are only occasionally preserved, but downrafted fragments of previously formed crater-facies material do occur in the diatremes. The craters are relatively limited in extent when compared to the rest of the pipe. They are typically shallow basin-like structures less than 1500m in diameter with inward dips of 25-70deg. and are commonly less than 150m deep (up to 300m). Kimberlite diatremes are vertical cone- or carrot-shaped bodies which are typically circular in plan (single intrusion). They range up to 1000m in diameter and 2000m in axial length. Typical inward dips are 75-85 deg. The diatremes are composed predominantly of tuffisitic kimberlite breccias. Country rock xenoliths are common and the larger ones (>1m) have typically descended within the pipe. Diatremes grade with depth into the 'root zones' which are irregular bodies that consist of hypabyssal kimberlite. Hypabyssal kimberlite also occurs in dykes and sills. Most kimberlite bodies result from multiple intrusions over a significant period of time resulting in complex detailed geology within kimberlite pipes. Bona fide kimberlite lavas are unknown and lava lakes absent.

RECOGNITION: The identification of many rocks as kimberlites is not easy. The classification of a body as a kimberlite should be based primarily on petrography. Most important is the occurrence of two generations of olivine (anhedral macrocrysts and euhedral phenocrysts). Typically the macrocrysts are rounded and the phenocrysts have simple shapes. Aphanitic kimberlites do occur but are rare. The mineralogy of the (primary) groundmass is also important. The mineral assemblage used to define kimberlites is not unique and could be applied to certain other alkaline ultrabasic rocks. The fact that certain minerals are rare, or absent, however is useful; feldspar and feldspathoids are absent while amphibole and andradite-schorlomite garnet are very rare. Contrary to some reports melilite probably occurs in some kimberlites. Some extreme varieties of kimberlite do occur, e.g. calcite kimberlites. Minerals charactersitic of carbonatites are absent in calcite kimberlites. Secondary carbonate which results from alteration should not be confused with primary calcite. The chemistry of the primary groundmass minerals (e.g. Mitchell 1986, p. 19-20) and of the xenocrysts and macrocrysts can support a classification as kimberlite. The whole rock geochemistry of most kimberlites is complex and can only be used as a guide. It should be noted that none of the geochemical features are particularly diagnostic of kimberlite. The problems of identifying kimberlites have lead to a variety of other rocks being referred to as kimberlites, including (olivine) lamproites. Often the classification of individual samples may be problematic, but the examination of a suite of samples from one or several related intrusives normally provide sufficient criteria. Also alteration, both deuteric and as a result of weathering, can severely hamper investigations and petrographic examinations are generally the best way to determine the primary features of the rock.

DISCUSSION : The nature of kimberlite is relatively well understood and defined. Identification of kimberlites may be difficult but should be based on petrography which may be supported using geochemical data. Geochemical characteristics of kimberlites are seldom unique and this includes the composition of the mantle-derived xenocrysts. The mineralogical classification is best applied to hypabyssal kimberlites and is useful in comparing kimberlites within and between provinces world-wide. The recognition of two varieties of kimberlite in South Africa (Smith 1983, Skinner 1986) illustrates the importance of such classifications. The Group 1 and 2 kimberlites can be distinguished on the basis of their distribution, petrography, isotopic character, whole-rock geochemistry and content of mantle-derived xenocrysts and xenoliths. Group 1 kimberlites carry a full suite of mantle-derived constituents (e.g. olivine, ilmenite, garnet, chromite, clinopyroxene, orthopyroxene, zircon). Group 2 kimberlites do not appear to contain ilmenite and zircon and the other minerals appear to be compositionally more homogeneous than similar population from Group 1's (Skinner 1986).

LAMPROITE

The term lamproite was introduced by Niggli (1923) for leucite-bearing rocks from Spain and Wyoming which had unusual "Niggli" parameters. Subsequently Troger (1935) referred to lamproites as potassium-, magnesium-rich, lamprophyric rocks. Wade and Prider (1940) used the term (as defined by Troger) to embrace rock types in the West Kimberley area of Western Australia. Although not all rocks which have been included in the lamproite clan are lamprophyric in appearance or possess the designated Niggli parameters, it is desirable that this name be retained for these distinctive rocks. The interest in lamproites has been revived with the discovery of diamondiferous lamproite in the Kimberley region of Western Australia (Atkinson et al. 1984; Jaques et al. 1984). Known lamproite occurrences are relatively few. Until recently only barren varieties had been recognised and include the Leucite Hills in Wyoming, SE Spain, Holsteinsborg in West Greenland, Smoky Butte in Montana and Hills Pond in Kansas (see Mitchell 1985). Those which contain significant quantities of diamonds and were all initially referred to as kimberlites, include Argyle and Ellendale A and B in the Kimberley region of Western Australia (Atkinson et al. 1984), Prairie Creek in Arkansas (Scott Smith and Skinner 1984a), Kapamba P1 and P2 in Zambia (Scott Smith et al. in press), Majhgawan in India (Scott Smith et al. in preparation) and possibly Seguela on the Ivory Coast (Mitchell 1985).

PETROGRAPHY : Lamproites display a wide range of modal mineralogy. They have an unusual mineralogy which is a reflection of their unusual compositions. Macrocrysts of olivine and other mantle-derived minerals occur in certain lamproites.

DEFINITION (modified from Mitchell 1985, Scott Smith and Skinner 1984a) : The lamproite clan are a group of ultrapotassic mafic rocks characterised by the presence of one or more of the following primary phenocrystal and/or groundmass constituents with widely varying modal amounts : titanian, alumina-poor phlogopite, leucite (typically sodium-poor but may be replaced by analcime), titanian tetraferriphlogopite, titanian potassic richterite, forsteritic olivine, diopside and sanidine. Minor and accessory phases include priderite, apatite, wadeite, spinel, ilmenite, shcherbakovite, armalcolite, perovskite and jeppeite. Glass may be an important constituent of rapidly chilled lamproites. Other minerals such as carbonate, chlorite and zeolite may be secondary.

MINERALOGICAL CLASSIFICATION (Fig. 4; Scott Smith and Skinner 1984 a, b) : It has been suggested that lamproites should be classified according to the modal mineralogy (e.g. olivine, phlogopite lamproite) following a scheme similar to that used for kimberlites. In lamproites no mineral is truly ubiquitous or in reasonably constant proportions, so none are excluded from the classification (in contrast to olivine in kimberlites). Six basic subdivisions can be made according the six most dominant minerals : leucite, phlogopite, amphibole, clinopyroxene, olivine and sanidine. Glass may also be abundant. Mitchell (1985) has suggested that these terms should be modified to take into account the habit of the phlogopite; phlogopite lamproite for those with phenocrystal phlogopite and madupitic lamproite where the phlogopite has a poikilitic groundmass habit. A similar subdivision should perhaps be devised to cater for variations in the habit of other minerals such as olivine.

TEXTURAL CLASSIFICATION : Lamproite intrusions are predominantly composed of volcanoclastic and magmatic rocks. The rocks are similar to those of other volcanic bodies and existing terminology is applicable (e.g. Fisher and Schmincke 1984). The volcanoclastic rocks include pyroclastic rocks (clastic materials ejected from volcanic vents) and probably epiclastic rocks (produced by the weathering and erosion of lithified volcanic rocks). Autoclastic rocks (fragmentation by mechanical friction during movement of lava) are also present. Bedding may result from either primary volcanic or epiclastic processes. Many rocks examined from lamproite bodies are probably pyroclastic and comprise extremely variable proportions of accidental and juvenile lapilli. The latter are typically glassy to scoriaceous. In many instances the xenolithic material consists mainly of single grains of quartz and when juvenile material is rare or absent, a rock may resemble sandstone. Pyroclastic rocks can be classified according to grains size (fine ash tuff, coarse ash tuff, lapilli tuff, agglomerate or pyroclastic breccia).

GEOLOGY : (Fig. 5; Atkinson et al. 1984, Scott Smith and Skinner 1984b, Jaques et al. 1986). Lamproite pipes comprise craters which typically have circular to elliptical plan shapes (single intrusion) and range in size up to 1.5km in diameter (or 110 hectares). They generally appear to have a champagne-glass shapes. The crater is irregular or assymmetrical and relatively shallow (typically less than 300m) with inward dips typically of 30 deg. Most pipes comprise mainly volcanoclastic rocks which appear to be predominantly of pyroclastic origin. The volcanoclastic rocks are often intruded by younger magmatic lamproite that forms ponded lava lakes or domes and may comprise a relatively large proportion of the crater. Dykes and sills also occur which may, or may not, be associated with pipes. Lamproite lavas are common at the Leucite Hills in Wyoming but are not reported elswhere. Many lamproites bodies are formed by multiple intrusions resulting in complex pipe geology.

RECOGNITION : Lamproites comprise an extremely wide range of petrographic types even within one province. The examination of a suite of related rocks is essential if there are problems in recognition of the rock type. The mineral assemblages (from the definition) are in most instances fairly distinctive for lamproites. Some assemblages, such as phlogpite-olivine-clinopyroxene, are not unique to lamproites. They, however, have unusual and characteristic whole rock and mineral compositions which can be used to help recognise them. The more diagnostic features are : deep orange-brown Ti-rich, Al-poor phlogopite which may display polysynthetic twinning, titanian potassic richterite which is typically pleochroic from pink to yellow, Na-poor leucite and in accessory amounts priderite [$(K,Ba)(Ti,Fe^{3+})_8O_{16}$] which is typically pleochroic from browny colours to dark green and has a banded appearance, wadeite [$K_4Zr_2Si_6O_{18}$] which typically occurs as rectangular crystals with fairly high relief and high birefringence. Characterisitic whole rock criteria include high K2O/Al2O3 (>0.7), K2O/Na2O (>4), high Ti, Rb, Sr, Zr and Ba (Bergman in press). Some lamproites may be confused with other rock types. Olivine lamproites which contain two generations of olivine can resemble kimberlites. If no diagnostic lamproitic minerals occur, they can be distinguished by the occurrence of olivines which have complex shapes reflecting imposed morphology of the macrocrysts and crystal aggregates among the phenocrysts, a paucity of primary serpentine and calcite, the occurrence of glass in magmatic rocks and the occurrence of scoriaceous juvenile lapilli in the crater-facies rocks as well as the pipe geology. The more evolved lamproites which typically contain abundant phlogopite and sanidine may be confused with other potassic rocks such as minettes. The absence of certain minerals will help preclude classification as some other rock types. These minerals include plagioclase, monticellite, kalsilite, nepheline and other sodic minerals, melanite and schorlomite garnets and probably in most instances melilite. It is important to note that although lamproites generally lack primary sodic minerals, they may occur through secondary processes (e.g. analcime after leucite). The identification of rapidly chilled lamproites, in particular the juvenile lapilli of the crater-facies rocks, are problematic. For example a single lapilli may be composed of olivine and/or phlogopite phenocrysts in a glassy base. Such an assemblage is not diagnostic although the composition of the phlogopite may be a guide. In these instances associated coarser grained autoliths or magmatic material should be sought after.

DISCUSSION : There is a very wide range in mineralogy within the lamproite clan, particularly considering the relatively small number of lamproite provinces which are known. Also each province exhibits its own variations. The nature of lamproites is not particularly well understood but the recent recognition of lamproites as a source of diamond has revived interest in them. Petrological relationships within the lamproite clan have been obscured by confusing and archaic terminology. The recognition of magmatic lamproites is reasonably straight forward, particularly if a suite of samples are examined, and should be based on petrography and probably some geochemical criteria. The mineralogical classification is best applied to magmatic rocks and is useful for comparing rocks within and between provinces world-wide. The recogniton of two varieties of lamproites, leucite lamproite and olivine lamproite (sensu lato), illustrates the importance of such classifications. Significant quantities of diamond have only been found so far in olivine lamproites which were all initially referred to as kimberlites (Scott Smith and Skinner 1984b). These lamproites form an extension to the previously known lamproite suite of rocks. Grade may also vary with the geology within single pipes, for example the magmatic material may have a different grade from that of the pyroclastics (Jaques et al. 1986).

CONCLUSIONS

The summaries of various aspects of kimberlites and lamproites given above show that they are very distinct rock types. They show differences in their near surface emplacement, petrography and petrology.

Kimberlites occur as carrot-shaped diatremes which grade upwards into shallow craters and down into irregular root zones. Lamproites, on the other hand, form craters infilled predominantly with pyroclastic material which may then be intruded by magmatic lamproite forming a ponded lava lake. Lamproites do not form diatremes as found in kimberlites. Ponded lava lakes and scoriaceous juvenile lapilli, both of which are common in lamproites, do not occur in kimberlites. The geology of lamproites is thus similar to that of other small alkaline volcanics and existing terminology can be used. Kimberlite textures, particularly within the diatreme, are unusual and have neccessitated a special classification to be devised. The different modes of emplacement of these two rock types probably largely reflect contrasting volatile contents. Kimberlites contain more abundant total volatiles with abundant by CO_2. Volatiles in lamproites are dominated by H_2O.

The petrography of lamproites and kimberlites are different although there may be some limited overlap in mineral assemblages. The lamproite clan exhibits a much wider range of modal mineralogy than do kimberlites. The mineral chemistry of the constituent minerals and the whole-rock geochemistry are also different. This serves to illustrate that lamproites and kimberlites are not genetically related and, therefore, have different petrogeneses, even though they both may be mantle derived and contain diamonds. The recognition of these rock types is not always easy, particularly if they are altered.

Both kimberlites and lamproites can be usefully classified using modal mineralogy. These classifications can be used to highlight some similarities between the two rock types. Within the lamproite clan, olivine lamproites begin to resemble kimberlites, particularly the Group 2 kimberlites. Both typically contain common phlogopite, diopside and olivine as well as mantle-derived minerals (indicators) including diamond but not ilmenite. There are also some geochemical and isotopic similarities.

Both kimberlites and lamproites are products of continental intra-plate magmatism. Kimberlite magmatism appears to be confined to stable cratonic areas while economic kimberlites are found in portions of the craton older than 2.4Ga (summarised by Mitchell 1986). In contrast lamproites generally occur towards craton margins (e.g. Bergman in press). Neither lamproites nor kimberlites occur in rift valleys.

The differences between lamproites and kimberlites obviously have important implications for prospecting. For example different tectonic settings affect target selection, different geology affects the outlining and/or mapping of a pipe and ore reserve determinations, differences in mineralogy may affect geophysical properties, variations in mantle-derived consitituents affects prospecting based on heavy 'indicator' minerals. The nature of many of the mantle-derived minerals such as garnet and spinel as well as diamond appear to be similar in both kimberlites and lamproites (e.g. Hall and Smith 1984, Lucas et al. 1986).

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Fig. 1 Examples of the mineralogical classification of kimberlites

(from Skinner and Clement 1979).

Note : the classification ignores olivine which is ubiquitous in most instances. Five major sub-divisions are used based on the modally most abundant groundmass mineral. A modifier is used if a second mineral exceeds two thirds of the abundance of the dominant mineral.

Source	1		2		3		4		5		6		7		8		9	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Phlogopite	44	67	43	73	67	85	61	73	46	69	28	38	<1	1	13	23	9	15
Calcite	8	12	tr	tr	6	5	13	16	11	16	<1	1	29	50	14	25	19	32
Serpentine	4	6	7	12	3	4	3	>3	4	6	25	35	11	19	12	22	6	10
Diopside	-	-	-	-	2	3	1	1	1	1	18	25	-	-	-	-	-	-
Monticellite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	11	-	-
Apatite	1	1	7	12	-	-	3	>3	3	>4	tr	tr	5	9	1	2	-	-
Opaque Minerals	6	9	1	2	1	1	2	3	2	3	<1	1	11	19	7	13	20	33
Perovskite	3	5	<1	1	-	-	-	-	-	-	-	-	1	2	2	4	6	10
Olivine	34		41		21		17		33		28		42		45		40	

Source	10		11		12		13		14		15		16		17		18	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Phlogopite	13	24	-	-	<1	1	1	2	22	34	24	37	20	34	16	29	1	2
Calcite	12	22	14	32	25	34	5	10	tr	tr	1	2	4	7	-	-	tr	tr
Serpentine	14	27	21	47	28	39	14	28	16	25	9	14	5	9	7	14	6	13
Diopside	-	-	-	-	-	-	27	54	26	40	20	31	-	-	-	-	-	-
Monticellite	-	-	-	-	-	-	-	-	-	-	-	-	18	31	22	41	26	58
Apatite	4	7	3	7	6	8	-	-	tr	tr	-	-	tr	tr	1	2	tr	tr
Opaque Minerals	8	15	6	14	10	14	1	2	1	1	5	8	5	9	4	8	8	17
Perovskite	<3	5	tr	tr	3	4	2	4	-	-	5	8	5	9	3	6	4	9
Olivine	47		56		27		50		34		36		42		46		55	

Column A Volume percentages recalculated to exclude all cryptogenic constituents except olivine.
Column B Volume percentages of A recalculated to exclude all olivine.

Analysis	1	Sydney-on-Vaal -dyke	Phlogopite kimberlite
"	2	De Beers - pipe	Phlogopite kimberlite
"	3	Swartruggens -Main dyke	Phlogopite kimberlite
"	4	Star -Byrnes dyke (fine zone)	Phlogopite kimberlite
"	5	Star -Byrnes dyke (coarse zone)	Phlogopite kimberlite
"	6	Finsch -pipe	Serpentine-phlogopite kimberlite
"	7	De Beers -dyke	Calcite kimberlite
"	8	Wesselton -pipe	Serpentine-phlogopite-calcite kimberlite
"	9	Wesselton -dyke	Opaque mineral-rich calcite kimberlite
"	10	Frank Smith -pipe	Calcite-phlogopite-serpentine kimberlite
"	11	Dutoitspan -dyke	Calcite-serpentine kimberlite
"	12	Wesselton -dyke	Calcite-serpentine kimberlite
"	13	Letlhakane DK1 -pipe	Diopside kimberlite
"	14	Bellsbank -Intermediate dyke	Phlogopite-diopside kimberlite
"	15	Letseng Satellite -dyke	Diopside-phlogopite kimberlite
"	16	Matsoku -pipe	Monticellite-phlogopite kimberlite
"	17	Wesselton -pipe	Phlogopite-monticellite kimberlite
"	18	De Beers -pipe	Monticellite kimberlite

Fig. 2 Textural-genetic classification of kimberlites (from Clement and Skinner 1985).

Note : this classification is based on macroscopic textures but it can be augmented by microscpic examinations.

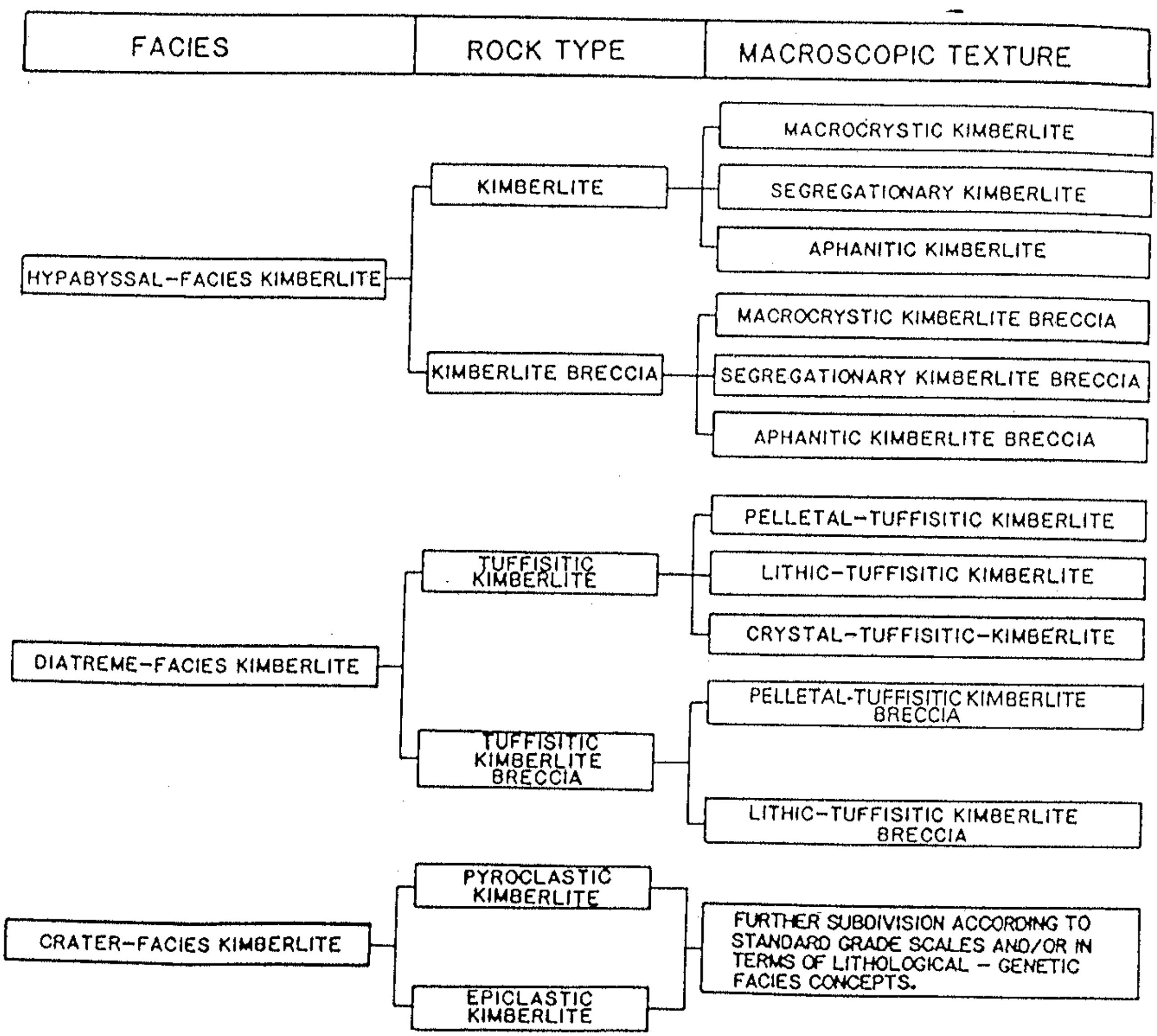

Fig. 3 Diagrammatic kimberlite pipe model

(after Hawthorne 1975 from Scott Smith and Skinner 1984b)

Note : typical maximum depth is 2km.

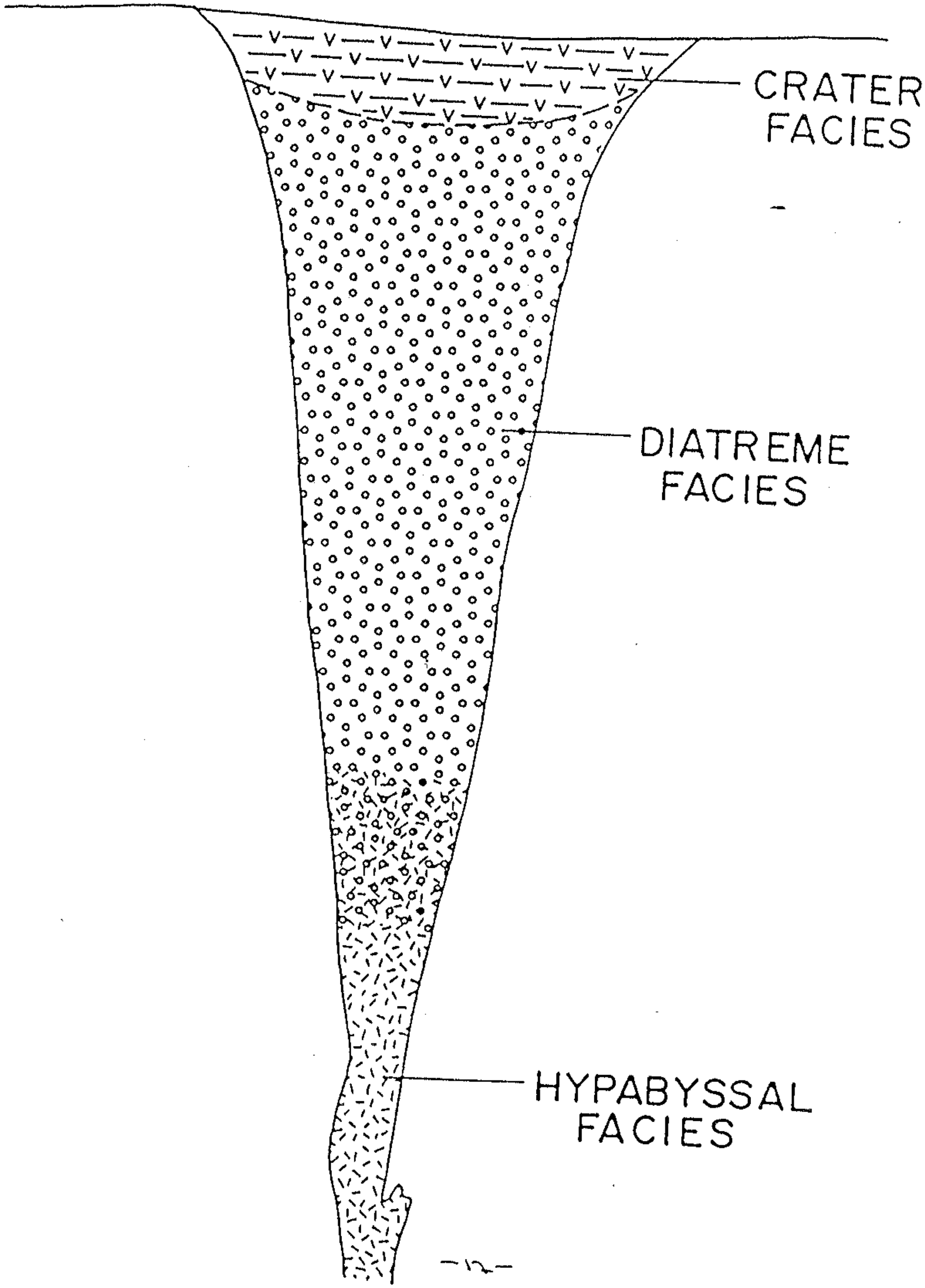

Fig. 4 <u>Examples of the mineralogical classification in terms of a comparison with existing terminology used in the literature</u>

(from Mitchell 1985)

Note : The classification (Scott Smith and Skinner 1984a,b) does not ignore any mineral but is otherwise similar to that used for kimberlites.

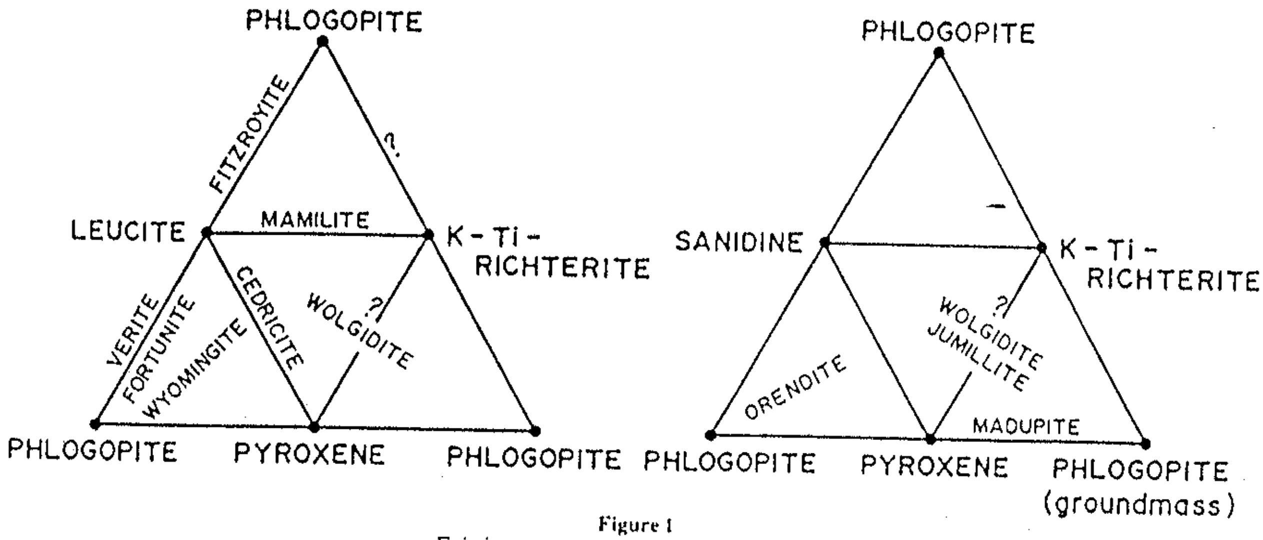

Figure 1
Existing nomenclature of lamproitic rocks.

Revised Nomenclature of Lamproitic Rocks

wyomingite	=	diopside-leucite phlogopite lamproite
orendite	=	diopside-sanidine phlogopite lamproite
madupite	=	diopside madupitic lamproite
jumillite	=	olivine-richterite madupitic lamproite
verite	=	olivine phlogopite lamproite
fortunite	=	enstatite phlogopite lamproite
fitzroyite	=	leucite phlogopite lamproite
cedricite	=	leucite diopside lamproite
wolgidite	=	diopside-leucite-richterite madupitic lamproite
mamillite	=	leucite richterite lamproite

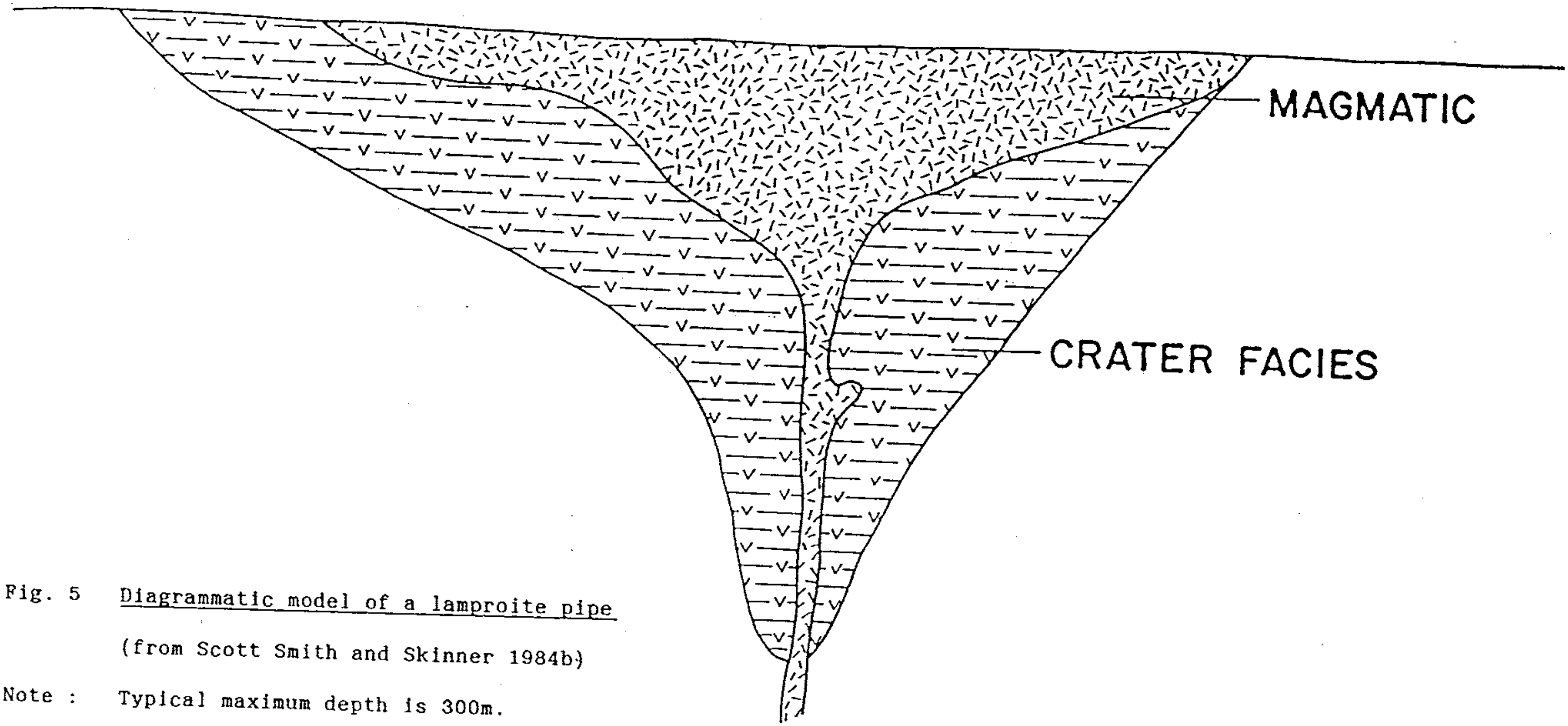

Fig. 5 Diagrammatic model of a lamproite pipe

(from Scott Smith and Skinner 1984b)

Note : Typical maximum depth is 300m.