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Kimberlites are complex hybrid rocks containing minerals that may be derived from (1) the fragmentation of upper mantle xenoliths (2) the megacryst or discrete nodule suite and (3) the primary phenocryst and groundmass minerals that crystallized from the kimberlite magma itself. The contribution to the overall mineralogy of kimberlite from each of these sources varies widely and significantly influences the petrographic character of the rocks. Further modal variations result from differentiation processes. Recognizing this complexity kimberlites are defined as follows:

Kimberlites are a clan of volatile-rich (dominantly CO_2) potassic ultrabasic rocks. Commonly they exhibit a distinctive inequigranular texture resulting from the presence of macrocrysts (0.5-10 mm), and in some instances megacrysts (>10 mm) set in a fine grained matrix. The megacryst-macrocryst assemblage consists of rounded anhedral crystals of magnesian ilmenite, Cr-poor titanian pyrope, olivine, Cr-poor clinopyroxene, phlogopite, enstatite and Ti-poor chromite. Olivine is the dominant member of the macrocryst assemblage. The matrix minerals include second generation euhedral primary olivine and/or phlogopite, together with perovskite, spinel (titaniferous magnesian aluminous chromite, titanian chromite, members of the magnesian ulvöspinel-ulvöspinel-magnetite series), diopside (Al- and Ti-poor), monticellite, apatite, calcite and primary late-stage serpentine (commonly Fe-rich). Some kimberlites contain late-stage poikilitic eastonitic phlogopites. Nickeliferous sulphides and rutile are common accessory minerals. The replacement of early-formed olivine, phlogopite, monticellite and apatite by deuteric serpentine and calcite is common. Evolved members of the clan may be devoid of, or poor in, macrocrysts and composed essentially of calcite, serpentine and magnetite, together with minor phlogopite, apatite and perovskite (Mitchell 1986).

Compositional data and textural observations suggest that the cryptogenic macrocrystal olivine population consists of a mixture of xenocrysts (lherzolite/harzburgite-derived) and several batches of resorbed phenocrysts. Depending upon the presence or absence (<5% vol.) of macrocrysts, kimberlites may be termed macrocrystal or aphanitic varieties respectively.

Currently kimberlites are described, and classified in part, on the basis of their groundmass modal mineralogy. Five varieties based upon the predominance of diopside, monticellite, phlogopite, calcite and serpentine are recognized by Skinner and Clement (1979). Groundmass olivine is considered to be ubiquitous and subdivisions are not made upon the basis of olivine content. In some highly differentiated kimberlites, apatite, perovskite or spinel may be present in more than accessory quantities and in such cases are included in the descriptive name.

Current textural-genetic classifications of kimberlites (Clement 1982, Clement and Skinner 1985) recognize the existence of crater, diatreme and hypabyssal facies kimberlites. Their relationships are illustrated in figure 1. Rocks from each facies can be described according to the terminology outlined in figure 2. Of particular importance is the description of the groundmass as uniform or segregationary. In the case of diatreme facies rocks the presence of pelletal lapilli appears to be a characteristic diagnostic feature. In figure 2 the term "autolithic" is used in the original sense of referring to fragments of an earlier generation of kimberlite found within a younger kimberlite and not to rounded or ball-shaped inclusions of kimberlite termed "nucleated autoliths". The latter are better termed globular segregations (Clement 1982, Mitchell 1986).

Bona fide kimberlite lavas are unknown, the only current candidate being a small flow at the Igwisi Hills, Tanzania (Dawson 1980). Pyroclastic kimberlites are known from craters in Tanzania and Botswana and as xenoliths in diatremes. Epiclastic kimberlites preserved in craters represent reworked pyroclastics and material dervied from country rocks deposited in crater-lakes. They consist of a complex sequence of alluvial fan and lacustrine deposits. The volume of kimberlite pyroclastics appears to be small and they are confined to craters and thinly-bedded tuff rings and small cones. Complex stratovolcanoes are not formed. Lava lakes are absent. Hydrovolcanism may have played a dominant role in the formation of crater-facies kimberlites.

Diatremes are vertical cone-shaped bodies that range from 300-2000 m in axial length. Maximum diameters are approximately 1000 m. Diatremes are filled primarily with tuffisitic kimberlite breccias containing a heterogeneous assemblage of locally-derived clasts, autoliths, pelletal lapilli and mantle-derived xenoliths. Some country rock xenoliths appear to have descended within the diatreme. Central conduits filled with hypabyssal kimberlite are absent. There is little evidence of tuffisitization and diatremes appear to have been emplaced passively without regard to the local structure at relatively low temperatures.

Diatremes are gradational with depth into "root zones" (Clement 1982). These irregular bodies (figure 1) consist of several batches of hypabyssal kimberlite. Their emplacement has been controlled by the local structure. Root zones are believed to develop by a variety of subsurface processes including hydraulic fracturing and wedging, stoping, intermittant explosive and/or implosive brecciation and rock bursting (Clement 1982, Mitchell 1986). With depth root zones are transitional into dikes (figure 1) which may represent feeders to the system.

Diatreme-root zone relationships suggest that explosive volcanism or simple fluidization does not play a significant role in diatreme emplacement. Embryonic pipe modification by fluidization (Clement 1982) or hydrovolcanism (Mitchell 1986) are preferable processes.

Hypabyssal kimberlites also form dike swarms and sill complexes, the latter commonly exhibiting differentiation and segregation features.

The megacrysts are primarily Cr-poor titanian pyrope ($0-3\%$ Cr_2O_3, $0-1.5\%$ TiO_2), magnesian ilmenite (3-23% MgO), subcalcic to calcic diopside, and enstatite, together with lesser quantities of iron-rich olivine (Fo = 88-78) and zircon. Coexisting megacrysts define regular trends in their Ca/Ca + Mg and Mg/Mg + Fe ratios suggesting formation from a differentiating magma. Megacrysts are regarded as being mantle-derived xenocrysts or high pressure phenocrysts (Dawson 1980, Mitchell 1986).

Macrocrysts include olivine (see above), phlogopite and Ti-poor spinels. Phlogopite and spinel may represent intermediate pressure phenocrysts (lower crust-uppermost mantle).

Important primary groundmass phases include olivine (Fo = 93-85), phlogopite, diopside, spinel, perovskite, monticellite, apatite, calcite and serpentine. Only phlogopite and spinel show extensive compositional variation. Phlogopites range from TiO_2(0-6%)-bearing varieties to TiO_2-poor phlogopite, tetra-ferriphlogopite and eastonitic phlogopite. Spinels exhibit two compositional trends. Trend 1 found in serpentine-calcite-monticellite kimberlites is from titanian magnesian aluminous chromite to magnesian ulvospinel-magnetite and appears to be unique to kimberlites. Trend 2 is from titanian magnesian chromite to Ti-magnetite and is a Cr- and Mg-rich variant of spinel compositional trends found in lamprophyres, and alkali basalt. A similar trend is found in lamproites.

Kimberlites are alumina-poor volatile-rich potassic ultrabasic rocks (Table 1). It is not possible to identify unequivocally the composition of primitive kimberlite magma as lavas are unknown and most bulk compositions are biased as a result of contamination or by the presence of significant amounts of xenocrystal (macrocrystal) olivine. Rocks free of crustal contamination can be recognised by Clement's (1982) contamination index (C.I. = SiO_2 + Al_2O_3 + Na_2O/MgO + $2H_2O$).

The trace element geochemistry of kimberlite (Table 2) is dominated by significant contents of compatible elements (Co, Cr, Ni, Sc) and incompatible elements (REE, Th, U, Nb, Zr, Sr, Rb). Only the latter may provide information regarding the sources of kimberlites in the mantle. Rare earth element distribution patterns are light REE enriched suggesting formation of the magma by either small degrees (0-2%) of melting of a cryptically metasomatized source or large degrees (1-10%) of melting of a patently metasomatized source.

In terms of their Sr, Nd and Pb isotopic composition kimberlites form two groups (Smith 1983). Isotopic group I (equivalent to serpentine-calcite-monticellite kimberlites) have Sr and Nd isotopic compositions suggesting derivation from a source that was undifferentiated or slightly depleted relative to the bulk earth composition. Isotopic group II (equivalent to micaceous or phlogopite kimberlites) appear to have been derived from an ancient light REE- and Rb-enriched source. Such kimberlites are apparently a unique magma type. Stable isotopic studies suggest that groundwater has played a significant role during the emplacement of kimberlites.

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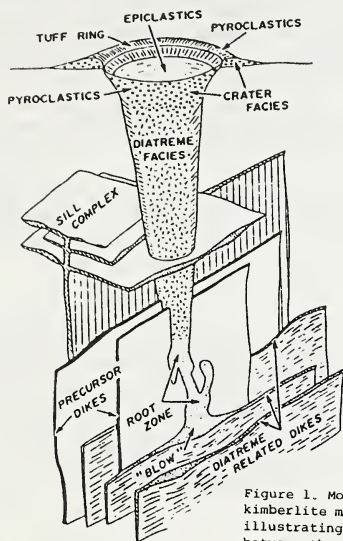
Figure 1. Model of an idealized kimberlite magmatic system illustrating the relationships between the different facies. (after Mitchell 1986)
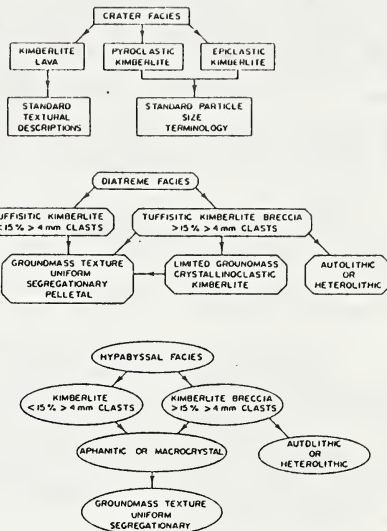

Figure 2. Textural genetic classification of kimberlites, after Clement (1982) and Clement & Skinner (1985).

Table 1. Average major element compositions of kimberlite.

	1	2	3	4	5	6	7	8	9
SiO_2	35.2	31.1	33.21	36.36	34.03	30.18	30.00	27.64	27.03
TiO_2	2.32	2.03	1.97	0.98	1.52	3.39	1.52	1.65	1.47
Al_2O_3	4.4	4.9	4.45	5.13	3.37	2.48	2.45	3.17	2.46
Cr_2O_3	-	-	0.17	0.22	0.20	0.22	0.25	0.14	0.15
Fe_2O_3	-	-	6.78	-	4.58	3.92	5.98	5.40	5.53
FeO	9.8*	10.5*	3.43	7.71*	3.78	8.68	2.99	2.75	1.71
MnO	0.11	0.10	0.17	0.16	0.16	0.19	0.16	0.13	0.10
MgO	27.9	23.9	22.78	17.43	25.39	27.53	28.57	24.31	25.53
CaO	7.6	10.6	9.36	11.16	9.45	9.65	10.12	14.13	13.56
Na_2O	0.32	0.31	0.19	0.42	0.48	0.25	0.18	0.23	0.12
K_2O	0.98	2.1	0.79	1.52	1.60	1.82	0.46	0.79	0.34
P_2O_5	0.7	0.7	0.65	0.55	1.12	0.51	0.65	0.55	0.46
CO_2	3.3	7.1	4.58	n.d.	5.08	7.39	n.d.	10.84	11.12
H_2O+	7.4	5.9	8.04	n.d.	7.25	3.70	n.d.	7.89	10.15
H_2O	-	-	2.66	n.d.	0.99	-	n.d.	0.24	
	100.30	99.24	99.23	81.64	99.01	99.91	83.33	99.36	99.73 1
No.	-	-	(25)	(80)	(11)	(41)	(14)	(63)	(229)

Table 2. Average trace element content of kimberlite (after Mitchell 1986)

Li	29	Ge	0.5*	Sb	-	Yb	(1.2)
Be	1.6*	As	-	Te	-	Lu	(0.16)
B	(36)*	Se	0.15*	I	-	Hf	5.6
F	2774	Br	-	Cs	2.2*	Ta	11
P	(3880)	Rb	73	Ba	1100	W	-
S	1687	Sr	851	La	(150)	Re	0.069*
Cl	202	Y	(22)	Ce	(200)	Os	1.34*
Sc	14	Zr	184	Pr	(22)	Ir	0.003*
Ti	(11800)	Nb	141	Nd	(85)	Pt	(0.19)*
V	100	Mo	1.7*	Sm	(13)	Au	0.012*
Cr	893	Ru	0.065*	Eu	(3.0)	Hg	(0.008)*
Mn	(1160)	Rh	0.0071	Gd	(8.0)	Tl	(0.219)*
Co	65	Pd	0.0081*	Tb	(1.0)	Pb	15.3
Ni	965	Ag	0.134*	Dy	-	Bi	(0.024)*
Cu	93	Cd	(0.073)	Ho	(0.55)	Th	17
Zn	69	In	-	Er	(1.45)	U	3.1
Ga	5.7*	Sn	5.4*	Tm	(0.23)		

Values in parentheses from Muramatsu (1983).
*=unreliable data or inadequate data base.

1-2, kimberlite and micaceous kimberlite (Dawson 1980); 3-4 Lesothon and S.African kimberlites (Gurney & Ebrahim, Lesotho Kimberlites, 280-294, 1973); 5 S.Africa (Muramatsu, Geochem.J. 17, 71-86, 1983); 6 Holsteinsborg, Greenland (Scott, Proc.2nd. Internat.Kimb.Conf.1, 190-205, 1979); 7 Shandong and Liaoning, China (Zhang & Liu, Geochem.J.17, 209-221, 1983); 8 Siberia (Ilupin & Lutts, Sov.Geol.6, 61-73, 1971); 9 Alakit region, Siberia (Ilupin et al., Geochem. Internat.11, 357-370, 1974).