Kimberlite

What is a kimberlite? Based on Clement et al. (1984), kimberlite is a volatile-rich, potassic, ultrabasic, igneous rock which occurs as small volcanic pipes, dykes, and sills. It has a distinctively inequigranular texture resulting from the presence of macrocrysts set in a finer-grained matrix. This matrix contains, as prominent primary phenocrystal and/or groundmass constituents, olivine and several of the following minerals: phlogopite, carbonate (commonly calcite), serpentine, clinopyroxene (commonly diopside), monticellite, apatite, spinel, perovskite and ilmenite. The macrocrysts are anhedral, mantle-derived, ferromagnesian minerals which include olivine, phlogopite, picroilmenite, chromian spinel, magnesian garnet, clinopyroxene (commonly chromian diopside), and orthopyroxene (commonly enstatite). The macrocrysts and relatively early-formed matrix minerals are commonly altered by deuteric processes, mainly serpentinization and carbonatization. Kimberlite commonly contains inclusions of upper mantle-derived ultrabasic rocks.

Petrology

Kimberlites are divided into Group I (basaltic) and Group II (micaceous) kimberlites. This division is made along mineralogical grounds.

The general consensus reached on kimberlites is that they are formed deep within the mantle, at between ١٥٠ and ٤٥٠ kilometres depth, from anomalously enriched exotic mantle compositions, and are erupted rapidly and violently, often with considerable CO٢ and volatile components. It is this depth of melting and generation which makes kimberlites prone to hosting diamond xenocrysts.

The mineralogy of Group I kimberlites is considered to represent the products of melting of lherzolite and harzburgite, eclogite and peridotite under lower mantle conditions. The mineralogy of Group II kimberlites may represent a similar melting environment to that of Group I kimberlites, the difference in mineralogy being caused by the preponderance of water versus carbon dioxide .

Group I kimberlites

Group I kimberlites are of CO suoengi cissatop cifamartlu hcir-٢ citiretsrof fo egalbmessa larenim yramirp a yb detanimod skcor ،eporyp-enidnamla ،eporyp naimorhc ،etinemli naisengam ،enivilo etitatsne ،etipogolhp ،(ciclacbus sesac emos ni) edispoid naimorhc evitcnitsid a tibihxe setilrebmik I puorG .etimorhc roop-iT fo dna ١٠-٠,٥) citsyrcorcam yb esuac erutxet ralunargiuqenimm (to megacrystic ٢٠٠-١٠) mm (phenocrysts of olivine, pyrope, chromian diopside, magnesian ilmenite and phlogopite in a fine to medium grained groundmass.

The groundmass mineralogy, which more closely resembles a true composition of the igneous rock, contains forsteritic olivine, pyrope garnet, Cr-diopside, magnesian ilmenite and spinel .

Group II kimberlites

Group-II kimberlites (or **orangeites** enilaklarep ،cissatopartlu era (۲H yltnanimod) selitalov ni hcir skcorO). The distinctive characteristic of orangeites is phlogopite macrocrysts and microphenocrysts, together with groundmass micas that vary in composition from phlogopite to "tetraferriphlogopite" (anomalously Fe-rich phlogopite). Resorbed olivine macrocrysts and euhedral primary crystals of groundmass olivine are common but not essential constituents.

Characteristic primary phases in the groundmass include: zoned pyroxenes (cores of diopside rimmed by Ti-aegirine); spinel-group minerals (magnesian chromite to titaniferous magnetite); Sr- and REE-rich perovskite; Sr-rich apatite; REE-rich phosphates (monazite, daqingshanite); potassian barian hollandite group minerals; Nb-bearing rutile and Mn-bearing ilmenite .

Kimberlitic indicator minerals

Kimberlites are peculiar igneous rocks because they contain a variety of mineral species with peculiar chemical compositions. These minerals such as potassic richterite, chromian diopside (a pyroxene), chromium spinels, magnesian ilmenite, and garnets rich in pyrope plus chromium are generally absent from most other igneous rocks, making them particularly useful as indicators for kimberlites.

These indicator minerals are generally sought in stream sediments in modern alluvial materials. Their presence, when found, may be indicative of the presence of a kimberlite within the erosional watershed which has produced the alluvium.

Kimberlite and some rare xenoliths within it are the principal primary terrestrial source of the strategic mineral, **diamond**, and the study of kimberlite may eventually outline the conditions for the formation of diamond in nature.

Geochemistry

The geochemistry of Kimberlites is defined by the following parameters:
Ultramafic; MgO >١٢% and generally > ١٥%
Ultrapotassic; Molar K٢O/Al٢O ٣<٣
Near-primitive Ni (>٤٠٠ppm), Cr (>١٠٠٠ppm), Co (>١٥٠ppm)
REE-enrichment
Moderate to high LILE enrichment; ΣLILE = >١,٠٠٠ppm
High H٢O and CO ٢

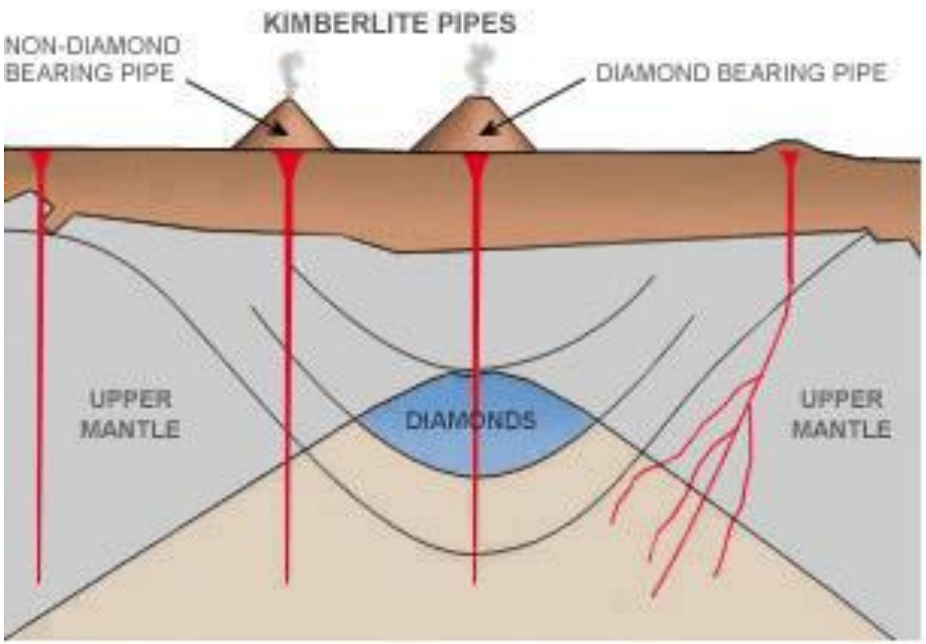
Kimberlite magmas form "pipes" as they erupt. A tuff cone is at the surface and formed by base-surge deposits. In the subsurface, a funnel-shaped body narrows to a depth of hundreds of meters. The pipe (also called a diatreme) is filled with kimberlite, with or without diamonds (only 1 in 5 of the pipes at Kimberley contain diamonds). Simplified from Hawthorne (1975).

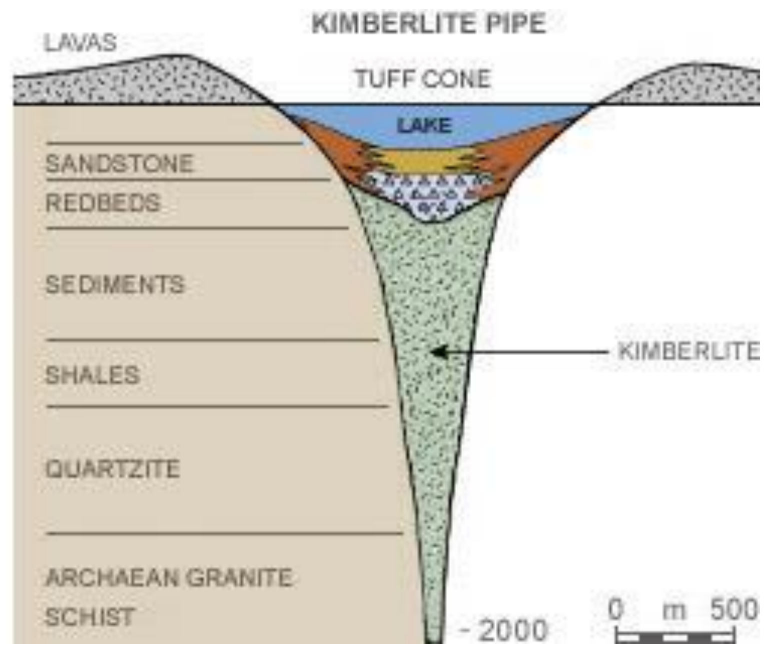
Just how many diamonds are needed to make a pipe economical? Some South African mines operate at 25 carats of diamond per 100 cubic meters of rock or about 2 grams of diamonds per 100 tons of rock. Because diamond has a specific gravity of 3.5 grams per cubic centimeter, 1 cubic centimeter of diamond weighs 16 carats. Picture a giant 100-ton ore truck full of kimberlite - that truck contains only half of a cubic centimeter of diamonds! Only about 35% of those diamonds are gem quality.

Diamond Geology

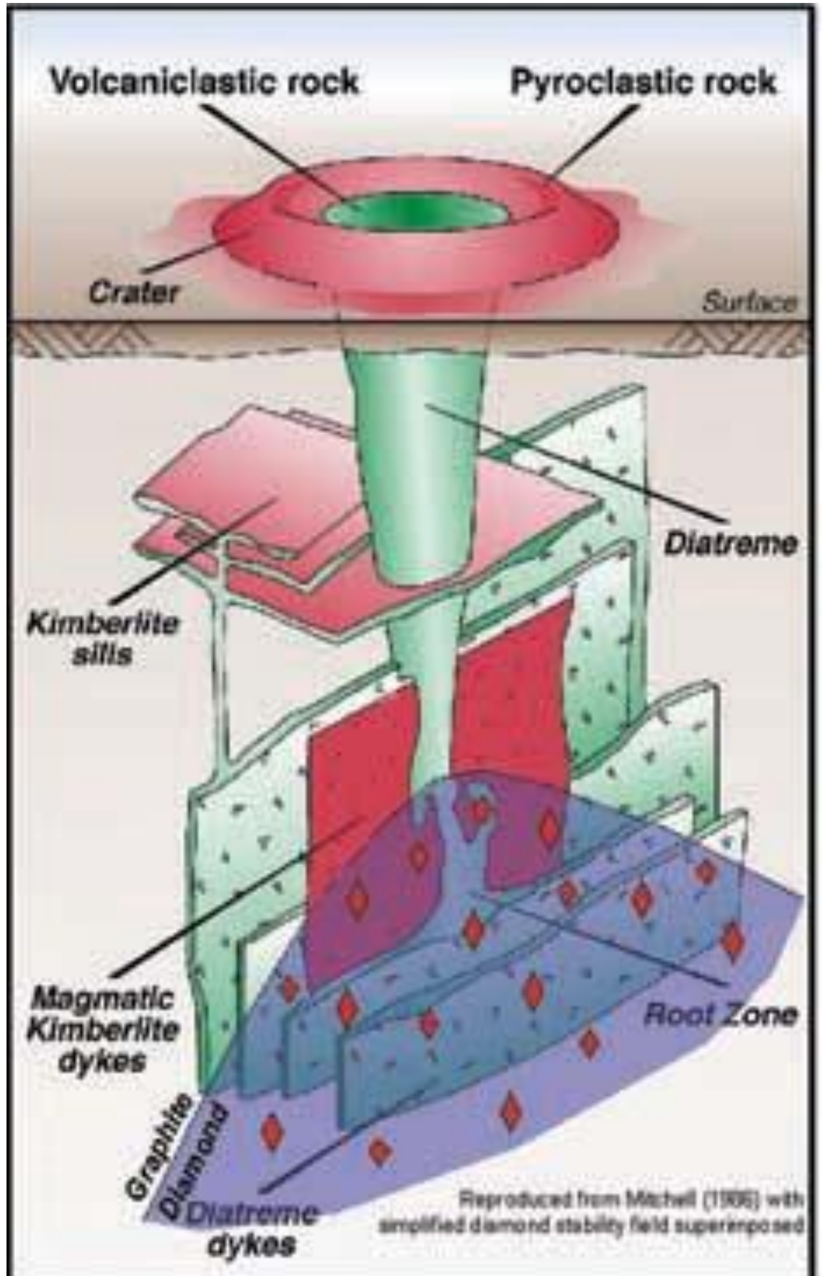
Kimberlite Pipes

Diamonds form at a depth greater than 93 miles (150 kilometers) beneath the earth's surface. After their formation, diamonds are carried to the surface of the earth by volcanic activity. A mixture of magma (molten rock), minerals, rock fragments, and occasionally diamonds form pipes shaped like champagne flute glasses as they approach the earth's surface. These pipes are called kimberlites (see diagram below). Kimberlite pipes can lie directly underneath shallow lakes formed in the inactive volcanic calderas or craters.

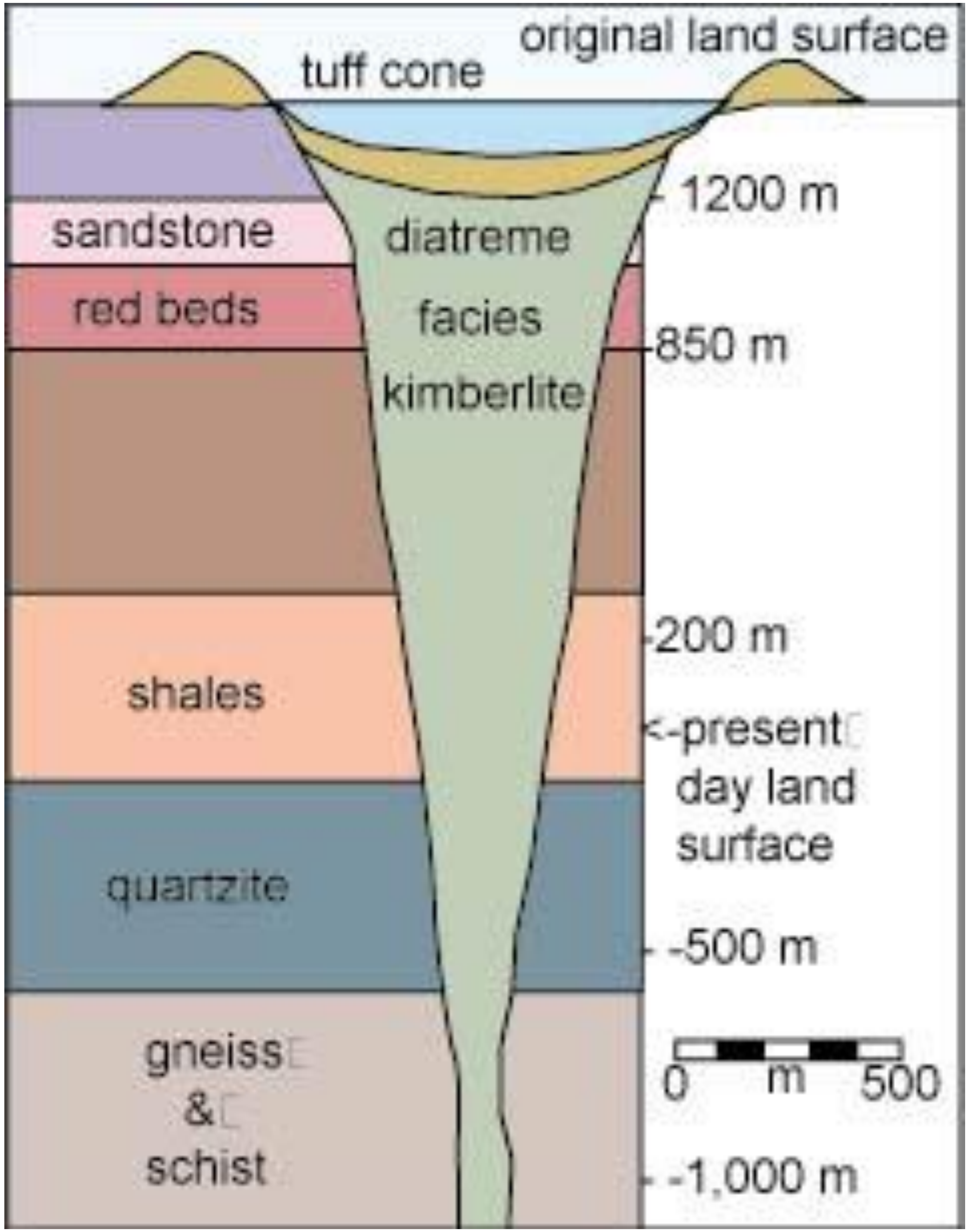

KIMBERLITE PIPES
NON-DIAMOND
BEARING PIPE
DIAMOND BEARING PIPE
UPPER
MANTLE
DIAMONDS
UPPER
MANTLE


KIMBERLITE PIPE
LAVAS
TUFF CONE
LAKE
SANDSTONE
REDBEDS
SEDIMENTS
SHALES
QUARTZITE
ARCHAEAN GRANITE
SCHIST
KIMBERLITE
- 2000
0 m 500

Diamonds in the kimberlite



Volcaniclastic rock
Pyroclastic rock
Crater
Surface
Diatreme
Kimberlite sills
Magmatic Kimberlite dykes
Root Zone
Graphite
Diamond
Diatreme dykes
Reproduced from Mitchell (1986) with simplified diamond stability field superimposed


original land surface
tuff cone
1200 m
sandstone
diatreme
red beds
facies
850 m
kimberlite
200 m
shales
<-present
day land
surface
quartzite
-500 m
gneiss
&
schist
0
m
500
-1,000 m