

Study of Kimberlites

Introduction

Kimberlites, constitute a hybrid group of rocks that encompass a group of volatile rich (dominantly CO₂) potassic, ultrabasic rocks and that displays a pronounced inequigranular texture, resulting from the presence of macro-crysts (and/or mega-crysts) that are set in a fine-grained matrix. It is a highly variable mixture of melt, minerals crystallizing from the melt, and foreign crystals and rock pieces. They commonly contain mantle xenoliths in which diamonds occur. The term Kimberlite was introduced by Lewis (1887) to describe the diamond-bearing, porphyritic mica peridotites of the Kimberley area of South Africa. Kimberlite has attracted attention because it serves as a carrier of diamonds and garnet peridotite mantle xenoliths to the Earth's surface.

Mineralogy

Kimberlites contain large crystals (magacrysts) of olivine, enstatite, Cr-rich diopside, phlogopite, pyropealmantidine and Mg-rich ilmenite set in a fine-grained matrix containing several of the following 4 minerals as prominent constituents: olivine, phlogopite, calcite, perovskite and ilmenite (Clement et al. 1984).

Mode of Occurrence

Kimberlite typically occur as carrot-shaped, vertical intrusions termed 'pipes', generally less than 1 km² in plan view. In sectional view, they appear in the shape of inverted tear drop/carrot and become narrower and irregular at depth, some ultimately assuming a dike like form. Most kimberlite occurrences involve multiple intrusive events which form a cluster of a few discrete intrusions

Classification of Kimberlite

Based on studies on a large number of kimberlite deposits, geologists divided the kimberlites into 3 separate units based on their morphology and petrology. A typical uneroded kimberlite contains the following three texturally distinctive facies from bottom upwards:

These units are:

1. Hypabyssal Facies Kimberlite: Hypabyssal facies kimberlites are porphyritic and result from crystallization of kimberlite magma. Generally, they lack fragmentation features and appear igneous. Macroscopically they are massive rocks in which the macro-crystal olivine and other macro-crysts (ilmenite, phlogopite, garnet) are commonly visible. They show the igneous textures and effects of magmatic differentiation. Some of the characteristic textural features of this facies include: 1. Absence of pyroclastic fragments and textures, 2. Presence of late stage poikilitic growth of phlogopite, 3. Segregation textures involving segregation of calcite and serpentine. 4. Flow banding marked by the preferred orientation of micro-phenocrysts.
2. Diatreme Facies Kimberlite: Kimberlite diatremes are 1-2 kilometer deep, generally carrot-shaped bodies which are circular to elliptical at surface and taper with depth. The dip contact with the host rocks is usually 80-85 degrees. The zone is characterized by fragmented volcanoclastic kimberlitic material and xenoliths plucked from various levels in the Earth's crust during the kimberlites journey to surface.

3. **Crater Facies Kimberlite:** The surface morphology of an unweathered kimberlite is characterised by a crater, up to 2 kilometers in diameter, whose floor may be several hundred meters below ground level. The crater is generally deepest in the middle. Around the crater is a tuff ring which is relatively small, generally less than 30 meters, when compared to the diameter of the crater. Two main categories of rocks are found in crater facies kimberlite: pyroclastic, those deposited by eruptive forces; and epiclastic, which are rocks reworked by water.

Based on difference in their isotopic composition, Smith (1983) classified the kimberlites in to two groups.

Group I kimberlites: Group I includes the most classical kimberlites, originally termed basaltic kimberlites: that is, ultrabasic ($\text{SiO}_2 < 45 \text{ wt}\%$), potassic (K/Na atomic ratio > 1), volatile-rich (dominantly CO_2) rocks, characterized by the presence of macro- and mega-crysts of magnesium-rich minerals such as olivine, ilmenite, pyropic garnet, variably chromium-rich diopsidic pyroxene, phlogopite, enstatite, and Ti-poor chromite, set in a fine matrix of olivine, serpentine, carbonate, and other accessory Mg- and/or Ca-rich minerals. Group-I kimberlites exhibit a distinctive inequigranular texture.

Group II kimberlites (orangeites): originally termed micaceous or lamprophyric kimberlites, are ultrapotassic ($\text{K/Na} > 3$), peralkaline ($[\text{K} + \text{Na}]/\text{Al} > 1$), volatile-rich (dominantly H_2O) rocks, characterized by the presence of phlogopite and olivine as macro-crysts, in a groundmass made of phlogopite, olivine, and diopside, commonly zoned to titanian aegirine, spinel ranging in composition from Mg-bearing chromite to Ti-bearing magnetite, perovskite, and other minerals. They have greater mineralogical affinity with lamproites than with group I kimberlites.

Formation of Kimberlite

The general consensus is that kimberlites are formed deep within the mantle, at depths between 150 and 450 kilometers, from anomalously enriched exotic mantle compositions. They are erupted rapidly and violently, often with the release of considerable amounts of carbon dioxide (CO_2) and volatile components. The violent explosions produce vertical columns of rock—volcanic pipes or kimberlite pipes—that rise from the magma reservoirs. The depth of melting and the process of generation makes kimberlites prone to hosting diamond xenocrysts.

Economic importance

Kimberlites are the most important source of primary diamonds. Many kimberlite pipes also produce rich alluvial diamond placer deposits. Only about 1 in 200 kimberlite pipes contain gem quality diamonds

Diamonds form about 100 miles (161 km) below the Earth's surface, in the molten rock of the Earth's mantle, which provides the right amounts of pressure and heat to transform carbon into diamond. The magma inside the kimberlite pipes acts like an elevator, pushing the diamonds and other rocks and minerals through the mantle and crust in just a few hours. These eruptions were short, but many times more powerful than volcanic eruptions that happen today. The magma eventually cooled inside these kimberlite pipes, leaving behind conical veins of kimberlite rock that contain diamonds.