KIMBERLITE-HOSTED DIAMONDS N02

by Jennifer Pell[1]

IDENTIFICATION

SYNONYMS: Diamond-bearing kimberlite pipes, diamond pipes, group 1 kimberlites.

COMMODITIES (*BYPRODUCTS*): Diamonds (some gemstones produced in Russia from pyrope garnets and olivine*)*.

EXAMPLES (British Columbia - *Canada/International*): No B.C. deposits, see comments below for prospects; *Koala, Panda, Sable, Fox and Misery (Northwest Territories, Canada), Mir, International, Udachnaya, Aikhal and Yubilenaya (Sakha, Russia), Kimberly, Premier and Venetia (South Africa), Orapa and Jwaneng (Botswana), River Ranch (Zimbabwe).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Diamonds in kimberlites occur as sparse xenocrysts and within diamondiferous xenoliths hosted by intrusives emplaced as subvertical pipes or resedimented volcaniclastic and pyroclastic rocks deposited in craters. Kimberlites are volatile-rich, potassic ultrabasic rocks with macrocrysts (and sometimes megacrysts and xenoliths) set in a fine grained matrix. Economic concentrations of diamonds occur in approximately 1% of the kimberlites throughout the world.

TECTONIC SETTING: Predominantly regions underlain by stable Archean cratons.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: The kimberlites rise quickly from the mantle and are emplaced as multi-stage, high-level diatremes, tuff-cones and rings, hypabyssal dikes and sills.

AGE OF MINERALIZATION: Any age except Archean for host intrusions. Economic deposits occur in kimberlites from Proterozoic to Tertiary in age. The diamonds vary from early Archean to as young as 990 Ma.

HOST/ASSOCIATED ROCK TYPES: The kimberlite host rocks are small hypabyssal intrusions which grade upwards into diatreme breccias near surface and pyroclastic rocks in the crater facies at surface. Kimberlites are volatile-rich, potassic ultrabasic rocks that commonly exhibit a distinctive inequigranular texture resulting from the presence of macrocrysts (and sometimes megacrysts and xenoliths) set in a fine grained matrix. The megacryst and macrocryst assemblage in kimberlites includes anhedral crystals of olivine, magnesian ilmenite, pyrope garnet, phlogopite, Ti-poor chromite, diopside and enstatite. Some of these phases may be xenocrystic in origin. Matrix minerals include microphenocrysts of olivine and one or more of: monticellite, perovskite, spinel, phlogopite, apatite, and primary carbonate and serpentine. Kimberlites crosscut all types of rocks.

DEPOSIT FORM: Kimberlites commonly occur in steep-sided, downward tapering, cone-shaped diatremes which may have complex root zones with multiple dikes and "blows". Diatreme contacts are sharp. Surface exposures of diamond-bearing pipes range from less than 2 up to 146 hectares (Mwadui). In some diatremes the associated crater and tuff ring may be preserved. Kimberlite craters and tuff cones may also form without associated diatremes (e.g. Saskatchewan); the bedded units can be shallowly-dipping. Hypabyssal kimberlites commonly form dikes and sills.

TEXTURE/STRUCTURE: Diamonds occur as discrete grains of xenocrystic origin and tend to be randomly distributed within kimberlite diatremes. In complex root zones and multiphase intrusions, each phase is characterized by unique diamond content (e.g. Wesselton, South Africa). Some crater-facies kimberlites are enriched in diamonds relative to their associated diatreme (e.g. Mwadui, Tanzania) due to winnowing of fines. Kimberlite dikes may display a dominant linear trend which is parallel to joints, dikes or other structures.

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ORE MINERALOGY: Diamond.

GANGUE MINERALOGY (Principal and *subordinate*): Olivine, phlogopite, pyrope and eclogitic garnet, chrome diopside, magnesian ilmenite, enstatite, chromite, carbonate, serpentine; *monticellite, perovskite, spinel, apatite. Magma contaminated by crustal xenoliths can crystallize minerals that are atypical of kimberlites.*

ALTERATION MINERALOGY: Serpentinization in many deposits; silicification or bleaching along contacts. Secondary calcite, quartz and zeolites can occur on fractures. Diamonds can undergo graphitization or resorption.

WEATHERING: In tropical climates, kimberlite weathers quite readily and deeply to "yellowground" which is predominantly comprised of clays. In temperate climates, weathering is less pronounced, but clays are still the predominant weathering product. Diatreme and crater facies tend to form topographic depressions while hypabyssal dikes may be more resistant.

ORE CONTROLS: Kimberlites typically occur in fields comprising up to 100 individual intrusions which often group in clusters. Each field can exhibit considerable diversity with respect to the petrology, mineralogy, mantle xenolith and diamond content of individual kimberlites. Economically diamondiferous and barren kimberlites can occur in close proximity. Controls on the differences in diamond content between kimberlites are not completely understood. They may be due to: depths of origin of the kimberlite magmas (above or below the diamond stability field); differences in the diamond content of the mantle sampled by the kimberlitic magma; degree of resorption of diamonds during transport; flow differentiation, batch mixing or, some combination of these factors.

GENETIC MODEL: Kimberlites form from a small amount of partial melting in the asthenospheric mantle at depths generally in excess of 150 km. The magma ascends rapidly to the surface, entraining fragments of the mantle and crust, en route. Macroscopic diamonds do not crystallize from the kimberlitic magma. They are derived from harzburgitic peridotites and eclogites within regions of the sub-cratonic lithospheric mantle where the pressure, temperature and oxygen fugacity allow them to form. If a kimberlite magma passes through diamondiferous portions of the mantle, it may sample and bring diamonds to the surface provided they are not resorbed during ascent. The rapid degassing of carbon dioxide from the magma near surface produce fluidized intrusive breccias (diatremes) and explosive volcanic eruptions.

ASSOCIATED DEPOSIT TYPES: Diamonds can be concentrated by weathering to produce residual concentrations or within placer deposits (C01, C02, C03). Lamproite-hosted diamond deposits (N03) form in a similar manner, but the magmas are of different origin.

COMMENTS: In British Columbia the Cross kimberlite diatreme and adjacent Ram diatremes (MINFILE # - 082JSE019) are found near Elkford, east of the Rocky Mountain Trench. Several daimond fragments and one diamond are reported from the Ram pipes.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Kimberlites commonly have high Ti, Cr, Ni, Mg, Ba and Nb values in overlying residual soils. However, caution must be exercised as other alkaline rocks can give similar geochemical signatures. Mineral chemistry is used extensively to help determine whether the kimberlite source is diamondiferous or barren (see other exploration guides). Diamond-bearing kimberlites can contain high-Cr, low-Ca pyrope garnets (G10 garnets), sodium-enriched eclogitic garnets, high chrome chromites with moderate to high Mg contents and magnesian ilmenites.

GEOPHYSICAL SIGNATURE: Geophysical techniques are used to locate kimberlites, but give no indication as to their diamond content. Ground and airborne magnetometer surveys are commonly used; kimberlites can show as either magnetic highs or lows. In equatorial regions the anomalies are characterized by a magnetic dipolar signature in contrast to the "bulls-eye" pattern in higher latitudes. Some kimberlites, however, have no magnetic contrast with surrounding rocks. Some pipes can be detected using electrical methods (EM, VLF, resistivity) in airborne or ground surveys. These techniques are particularly useful where the weathered, clay-rich, upper portions of pipes are developed and preserved since they are conductive and may contrast sufficiently with the host rocks to be detected. Ground based gravity surveys can be useful in detecting kimberlites that have no other geophysical signature and in delineating pipes. Deeply weathered kimberlites or those with a thick sequence of crater sediments generally give negative responses and where fresh kimberlite is found at surface, a positive gravity anomaly may be obtained.

OTHER EXPLORATION GUIDES: Indicator minerals are used extensively in the search for kimberlites and are one of the most important tools, other than bulk sampling, to assess the diamond content of a particular pipe. Pyrope and eclogitic garnet, chrome diopside, picroilmenite, chromite and, to a lesser extent, olivine in surficial materials (tills, stream sediments, loam, etc.) indicate a kimberlitic source. Diamonds are also usually indicative of a kimberlitic or lamproitic source; however, due to their extremely low concentration in the source, they are rarely encountered in surficial sediments. Weathered kimberlite produces a local variation in soil type that can be reflected in vegetation.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: When assessing diamond deposits, grade, tonnage and the average value ($/carat) of the diamonds must be considered.. Diamonds, unlike commodities such as gold, do not have a set value. They can be worth from a few $/carat to thousands of $/carat depending on their quality (evaluated on the size, colour and clarity of the stone). Also, the diamond business is very secretive and it is often difficult to acquire accurate data on producing mines. Some deposits have higher grades at surface due to residual concentration. Some estimates for African producers is as follows:

Pipe	Tonnage (Mt)	Grade (carats*/100 tonne)
Orapa	117.8	68
Jwaneng	44.3	140
Venetia	66	120
Premier	339	40

* one carat of diamonds weighs 0.2 grams

ECONOMIC LIMITATIONS: Most kimberlites are mined initially as open pit operations; therefore, stripping ratios are an important aspect of economic assessments. Serpentinized and altered kimberlites are more friable and easier to process.

END USES: Gemstones; industrial uses such as abrasives.

IMPORTANCE: In terms of number of producers and value of production, kimberlites are the most important primary source of diamonds. Synthetic diamonds have become increasingly important as alternate source for abrasives.

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