DIAMONDS 101

Diamonds 101 is a generalised summary of information commonly discussed or used in diamond exploration.   This information is intended for those with no or little background in diamonds and diamond exploration.

Table of Contents

Some Statistics..2
Common Terms..2
Diamond Genesis..4
Characteristics of Kimberlites 4
Characteristics of Lamproites 5
Diamond Indicator minerals 6
Commonly Used Exploration Methods 8

Some Statistics

- ♦ Kimberlites and lamproites are the only two known economic primary sources of diamonds.
- ♦ Globally, less than 1% of kimberlites are economically viable.
- ♦ Within three years, Canada went from no mines to Ekati™, which produced 6.9 million carats between October 1998 and August 2001.
  - ♦ Diavik is expected to commence operations in early 2003.
- ♦ Canada is expected to produce 12% of the world's diamonds by 2004.
- ♦ Canadian diamonds, considered to be "ethical" diamonds, are highly prized and sought after.

Common Terms

Diamond Stability Field Specific temperature and pressure regime in which diamonds are formed and preserved.

Eclogite Course-grained ultramafic rock, consisting of pyrope-almandine garnet and omphacitic clinopyroxene. Accessory minerals may include rutile, kyanite, coesite, sanidine, graphite and diamond.

Facies A genetically related group of rocks in a single rock mass, that display chemical or petrographical variations based on their stratigraphic position relative to each other.

Harzburgite A type of peridotite that contains mainly olivine and orthopyroxene, and no clinopyroxene. Found in the upper mantle and as xenoliths in kimberlite.

Kimberlite A potassic, ultrabasic rock with an inequigranular texture (macrocrysts in a fine-grained matrix). Matrix contains primarily olivine, phlogopite, carbonate, serpentine, monticellite, apatite, spinels, perovkite and ilmenite. Macrocrysts are mantle-derived, ferromagnesium minerals, including olivine, phlogophite, picroilmenite, chromium spinel, magnesium garnet, clinopyroxene (chromium diopside), monticellite, apatite, spinels, perovskite and ilmenite. Commonly contains inclusions of upper mantle-derived ultramafic rocks. May contain crustal xenoliths and xenocrysts. Diamonds are rare.

Lamproite A group of dark-coloured, ultrapotassic, hypabyssal or extrusive rocks that represent the end members of the syenites. Enriched in both compatible and incompatible elements, especially Rb, Ba, Ti, Zr, and LREE. Typically contain leucite and/or glass as their primary phenocrystal and/or groundmass constituents. May contain phlogopite (often titaniferous), clinopyroxene (diopside), amphibole (titanifereous potassic richterite), olivine and sanadine.

Lamprophyre A group of dark coloured, porphyritic, hypabyssal igneous rocks characterized by a panidiomorphic texture → a high percentage of mafic minerals (biotite, hormblende and pyroxene) forming both the phenocrysts and the fine-grained groundmass. Often highly altered and associated with carbonatites.

Lherzolite A type of peridotite containing mainly olivine, orthopyroxene and clinopyroxene. May contain garnet or spinel. Dominant rock type in the upper mantle. Very common as xenoliths in kimberlites

Macrocryst Non-genetic term, that includes phenocrysts and xenocrysts between 0.5 and 15mm in size.

Macrodiamond Diamonds that measure >0.5mm in the longest dimension.

Megacryst Crystals commonly found in kimberlites that are >2cm and up to 20cm long. May include some or all of the following phases: olivine, ilmenite, garnet, clinopyroxene, orthopyroxene, phlogopite and zircon.

Microdiamond Diamonds that measure <mm in the longest dimension

Peridotite A class of ultramafic rocks consisting of predominantly olivine, with or without ferromagnesium minerals.

Phenocryst A relatively larger crystal in a fine-grained matrix of a porphyritic rock. Indicates two stages of cooling and crystallization.

Pyroxenite An ultramafic rock consisting of predominantly of clino- and orthopyroxene.

Xenocryst A crystal fragment enclosed by magma. No genetic relationship exists between the two.

Xenolith A rock enclosed by magma. No genetic relationship exists between the two.

Diamond Genesis

- Macrodiamonds are derived from diamondiferous peridotites and eclogites that formed in the lithospheric upper mantle
  - They are accidental xenocrysts in the host kimberlite or lamproite.
  - Diamondiferous units typically form discontinuous lenses or pockets within the upper mantle beneath stable, thick Archean cratons.

- Peridotitic and eclogitic diamonds occur in every known diamond deposits worldwide.
  - Peridotitic diamonds are more abundant than eclogitic diamonds.

- Diamond paragenesis is usually significantly older than the volcanic host rock, which transported the diamonds to the earth's surface.
  - Peridotitic diamonds predominantly form in chemically depleted peridotite near the base of the lithosphere (depth range 150-200 km)
    - Metasomatism in a Ti-poor, LREE, K and Rb enriched event.
    - Includes, in decreasing order of diamond potential: garnet harzburgite, chromite harzburgite and garnet lherzolite
  - Eclogitic diamonds show a range of ages apparently younger than the oldest Archean peridotitic diamonds (990-2700 m.y.).

- Transport to the surface must be rapid.

- Typically volatile, ultrapotassic, ultrabasic volcanic activity.

Characteristics of Kimberlites

- May be diamondiferous

- Commonly occur in clusters of < 50 pipes
  - Usually only one or two of the largest pipes in a cluster are economically viable
  - Areal extent of the cluster fields is variable
  - Pipes rarely occur at distances greater than 50km from the cluster field

- Ages range from Archean to Tertiary
  - Kimberlite emplacement of different ages may occur at the same location.

- Restricted to continental intraplate settings (based on information to date)

  - ♦ Commonly on cratons (more diamondiferous) and in the metamorphosed, younger belts accreted to the craton

- ♦ Diamond grades of economically viable pipes are extremely variable
  - ♦ Range from a minimum of 3 cts/100 tonnes (Frank Smith deposit in South Africa) to over 200 cts/100 tonnes
  - ♦ Location is important in defining economic grade
- ♦ Geometry of the kimberlite body depends on many factors and deviations from the classic "model" are typical.
  - ♦ Commonly form carrot-shaped pipes, dykes or sills
  - ♦ http://www.amnh.org/exhibitions/diamonds/how.html
  - ♦ Divided into three zones based on compositional variation:
    - ***Crater facies***
      - Surface expression of the intrusion
      - Geometry of the sides is irregular
      - Typically infilled with pyroclastics
      - Commonly eroded or reworked; may contain crater lakes
    - ***Diatreme facies***
      - Main body of the pipe with fewer phases of intrusion
      - Usually more regular in shape with steep contacts
      - Mainly tuffisitic kimberlites or tuffisitic kimberlite breccias
      - Pelletal lapilli are characterisic
      - Matrix usually contains serpentine and microlitic clinopyroxene
    - ***Hypabyssal facies*** (root zone, "blow", sills and dykes)
      - Rocks have crystallized from magmatic kimberlite and have hypabyssal textures.
      - Relatively coarse-grained xenocrysts incorporated into the magma.
      - Phenocrysts crystallized from the magma prior to emplacement.
      - Commonly contain primary carbonate and serpentinite
      - Sub-divided into kimberlite and kimberlite breccia based on xenolith content and on the modal abundances of the primary groundmass minerals
      - Roots are commonly irregular in geometry, typically formed by several intrusive pulses of kimberlite magma of varying composition.
  - ♦ Diamond grade varies between and within the various facies
  - ♦ Vertical flaring over 2 km

Characteristics of Lamproites

- ♦ May be diamondiferous (Argyle in Australia), but apparently only in the crater "facies"

- ♦ Classified based on modal mineralogy

- ♦ Ages are variable
  - ♦ Only economically diamondiferous bodies known to date are Proterozoic in age

- ♦ All known occurrences are found less than 0.5km deep

- ♦ Typically found along craton margins and adjacent mobile zones that have experienced younger and persistent faulting
  - ♦ May shown strong structural control with major fracture zones

- ♦ Geometry is distinctly different than that of a kimberlite
  - ♦ http://volcano.und.nodak.edu/vwdocs/volc_images/australia/argyle/argyle.html
  - ♦ http://www.amnh.org/exhibitions/diamonds/kimberlite.html
  - ♦ Lack of root and kimberlite-like diatreme development
  - ♦ Typically champagne-glass shaped craters with shallow, irregular, pipe-wall contacts
  - ♦ Often have magmatic lamproite intruding into the crater facies forming a lava lake
  - ♦ Areally, they can cover up to 124 hectares
  - ♦ Craters are infilled by volcaniclastic rocks dominated by primary pyroclastics (lapilli tuffs); material may be reworked

Diamond Indicator minerals

- ♦ Include minerals that have crystallized directly from a kimberlitic magma or are derived from the mantle and later incorporated into kimberlitic magma.

- ♦ Used to assess the presence of and diamond potential of kimberlites.

- ♦ Most common minerals used are: picroilmenite, titanium and magnesium rich chromite, chrome diospide, magnesium rich olivine, pyrope and eclogitic garnets.

- ♦ The number of diamond indicator minerals found is not necessarily an indication of diamond grade.
  - ♦ Most diamondiferous unit of Argyle yielded only 3 eclogitic garnets and 3 peridotitic garnets from a 32 kg sample

Garnets
- ♦ Peridotitic paragenesis
  - ♦ Classified based on position in the diamond stability field (amount of calcium depletion)
  - ♦ G10 → from garnet harzburgite (85% of the samples fall into this category)

    - G9 → from lherzolitic garnet rocks

- Eclogitic paragenesis
    - G3, G4, G5 and G6 (as defined by Gurney and Moore, 1993)
    - Enrichment in Na (0.06 to 0.7 wt%)
    - Moderate to high levels of TiO_2
    - Lamproites often contain G5, relatively iron-rich garnets

Chromite

- From chromite harzburgite
- Average chrome content (>60 wt% Cr_2O_3) with moderate to high levels of magnesium (12-16 wt% MgO)
- Characterized by very low TiO_2 (gen. <0.3 wt%, but may reach in rare cases 0.6 wt%)
- In diamondiferous lamproites they are often rounded, spherical and disc-shaped, exhibiting regular, polycentric stepped development and resorption sculpturing of octahedral cleavage faces.

Orthopyroxene

- Chrome-diopsides (bright green)
- Generally do not survive transportation except in certain circumstances (ie. Glacial and some fluvial regimes)
- Wide range of composition even within diamondiferous samples
- Diamondiferous kimberlites → generally between 80-96 wt% MgO; between 0.2 to 2 wt% Al_2O_3
- Diamondiferous lamproites → generally between 92-95 wt% MgO; between 0.6 – 5.5 wt% Al_2O_3

Olivine

- Not really distinguishable based on composition due to the overlap
- However, their presence is significant due to their poor preservation tendencies
- May be useful for lamproites

Tourmaline, Zircons and Nb-rutile

- Have been somewhat successful in lamproite exploration (ie. Australia)
- Significant overlap in the compositional fields and difficult to apply elsewhere
- More data is needed to better refine their use

Commonly Used Exploration Methods

Geophysical Surveying (Airborne and Ground)

- Looking for irregularities in the data compared to background, such as ovoid or circular shaped isolated points
- Some economic kimberlites have subtle geophysical signatures that may be difficult to discern.
- Cultural interference can often produce anomalies similar to those produced by kimberlites
- Several methods: high resolution aeromagnetic (HRAM), ground magnetics, very low frequency electromagnetic (VLF-EM), gravity

Magnetics (Ground and HRAM)

- Measure magnetic susceptibility
- Pipes often occur as semi- to circular magnetic highs or lows
- Some pipes may have no obvious magnetic signature
- Magnetism depends on the remnant magnetism in the pipe and the host rock, and the mineralogy involved
- May detect a pipe, but not the diamondiferous phases of it

EM and VLF-EM

- Measure electrical resistivity of the material at or near the Earth's surface.
- Works well for pipes containing well developed, weathered, conductive, clay-altered upper portions.
- Need good contrast with the surrounding material for detection

Gravity

- Looking for a specific gravity signature that is less than the surrounding host rock
- Is useful is delineating the size and shape of a pipe.

Surface Sampling

- Includes a variety of sampling medium (till, stream sediment, plant tissue, soil, rock grab)
- Basic principle is to look for and define dispersion patterns for anomalous chemical elements or mineral grains
- Basic concept is to follow the dispersal "train" to its source.
- Requires some knowledge of the geological history of the region including any glacial or alluvial activity the may have occurred since the deposition or emplacement of the unit of interest (ex. Pipe emplacement).

Soils and Plant Tissue

- Soils over kimberlites are often enriched in trace elements such as Niobium, Phosphorus, Nickel and Chromium
- Halos are generally closely restricted to within a few 10's of metres of the pipe
- Higher clay content of altered kimberlites often causes vegetation changes over the kimberlite due to higher water retention rates.
- Vegetation anomalies may be visible on airphotos

Heavy Mineral Concentrates

- Oldest and most widely used technique in the world
- Collect 'Resistant" heavy minerals often associated with kimberlitic units: garnet, chromite, ilmenite, chrome diopside, olivine, picro-ilmenite
- Samples are collected from till, stream sediments, beach sands, eskers, frost boils, etc.
- Also look at mineral grain appearance: fresh vs. weathered; rounded vs. angular to determine mode of transport and probable distance to source.
- In areas where fluvial, aeolian or glacial processes may have played a part in transport of the material → must know the history of the region to properly assess the information.