LAMPROITE-HOSTED DIAMONDS N03

by Jennifer Pell[1]

IDENTIFICATION

SYNONYMS: None.

COMMODITY: Diamonds.

EXAMPLES (British Columbia (MINFILE #) - *Canada/International*): No B.C. examples; *Argyle, Ellendale (Western Australia), Prairie Creek (Crater of Diamonds, Arkansas, USA), Bobi (Côte d'Ivoire), Kapamba (Zambia), Majhgawan (India).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Diamonds occur as sparse xenocrysts and in mantle xenoliths within olivine lamproite pyroclastic rocks and dikes. Many deposits are found within funnel-shaped volcanic vents or craters. Lamproites are ultrapotassic mafic rocks characterized by the presence of olivine, leucite, richterite, diopside or sanidine.

TECTONIC SETTING: Most olivine lamproites are post-tectonic and occur close to the margins of Archean cratons, either within the craton or in adjacent accreted Proterozoic mobile belts.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Olivine lamproites are derived from metasomatized lithospheric mantle. They are generally emplaced in high-level, shallow "maar-type" craters crosscutting crustal rocks of all types.

AGE OF MINERALIZATION: Any age except Archean. Diamondiferous lamproites range from Proterozoic to Miocene in age.

HOST/ASSOCIATED ROCK TYPES: Olivine lamproite pyroclastic rocks and dikes commonly host mineralization while lava flows sampled to date are barren. Diamonds are rarely found in the magmatic equivalents. Lamproites are peralkaline and typically ultrapotassic (6 to 8% K_2O). They are characterized by the presence of one or more of the following primary phenocryst and/or groundmass constituents: forsteritic olivine; Ti-rich, Al-poor phlogopite and tetraferriphlogopite; Fe-rich leucite; Ti, K-richterite; diopside; and Fe-rich sanidine. Minor and accessory phases include priderite, apatite, wadeite, perovskite, spinel, ilmenite, armalcolite, shcherbakovite and jeppeite. Glass and mantle derived xenocrysts of olivine, pyrope garnet and chromite may also be present.

DEPOSIT FORM: Most lamproites occur in craters which are irregular, asymmetric, and generally rather shallow (often the shape of a champagne glass), often less than 300 metres in depth. Crater diameters range from a few hundred metres to 1500 metres. Diamond concentrations vary between lamproite phases, and as such, ore zones will reflect the shape of the unit (can be pipes or funnel-shaped). The volcaniclastic rocks in many, but not all, lamproite craters are intruded by a magmatic phase that forms lava lakes or domes.

TEXTURE/STRUCTURE: Diamonds occur as discrete grains of xenocrystic origin that are sparsely and randomly distributed in the matrix of lamproites and some mantle xenoliths.

ORE MINERALOGY: Diamond.

GANGUE MINERALOGY (Principal and *subordinate*): Olivine, phlogopite, richterite, diopside, sanidine; *priderite, wadeite, ilmenite, chromite, perovskite, spinel, apatite, pyrope garnet.*

[1] Consulting Geologist, Ottawa, Canada.

ALTERATION MINERALOGY: Alteration to talc ± carbonate ± sulphide or serpentine -septechlorite + magnetite has been described from Argyle (Jacques *et al.*, 1986). According Scott Smith (1996), alteration to analcime, barite, quartz, zeolite, carbonate and other minerals may also occur. Diamonds can undergo graphitization or resorption.

WEATHERING: Clays, predominantly smectite, are the predominant weathering product of lamproites.

ORE CONTROLS: Lamproites are small-volume magmas which are confined to continental regions. There are relatively few lamproites known world wide, less than 20 geological provinces, of which only seven are diamondiferous. Only olivine lamproites are diamondiferous, other varieties, such as leucite lamproites presumably did not originate deep enough in the mantle to contain diamonds. Even within the olivine lamproites, few contain diamonds in economic concentrations. Controls on the differences in diamond content between intrusions are not completely understood. They may be due to: different depths of origin of the magmas (above or below the diamond stability field); differences in the diamond content of the mantle sampled by the lamproite magma; differences in degrees of resorption of diamonds during transport; or some combination of these factors.

GENETIC MODEL: Lamproites form from a small amount of partial melting in metasomatized lithospheric mantle at depths generally in excess of 150 km (i.e., within or beneath the diamond stability field). The magma ascends rapidly to the surface, entraining fragments of the mantle and crust en route. Diamonds do not crystallize from the lamproite 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 in situ. If a lamproite magma passes through diamondiferous portions of the mantle, it may sample them and bring diamonds to the surface provided they are not resorbed during ascent.

ASSOCIATED DEPOSIT TYPES: Diamonds can be concentrated by weathering to produce residual concentrations or by erosion and transport to create placer deposits (C01, C02, C03). Kimberlite-hosted diamond deposits (N02) form in a similar manner, but the magmas are of different origin.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Lamproites can have associated Ni, Co, Ba and Nb anomalies in overlying residual soils. However, these may be restricted in extent since lamproites weather readily and commonly occur in depressions and dispersion is limited. Caution must be exercised as other alkaline rocks can give similar geochemical signatures.

GEOPHYSICAL SIGNATURE: Geophysical techniques are used to locate lamproites, but give no indication as to their diamond content. Ground and airborne magnetometer surveys are commonly used; weathered or crater-facies lamproites commonly form negative magnetic anomalies or dipole anomalies. Some lamproites, however, have no magnetic contrast with surrounding rocks. Various electrical methods (EM, VLF, resistivity) in airborne or ground surveys are excellent tools for detecting lamproites, given the correct weathering environment and contrasts with country rocks. In general, clays, particularly smectite, produced during the weathering of lamproites are conductive; and hence, produce strong negative resistivity anomalies.

OTHER EXPLORATION GUIDES: Heavy indicator minerals are used in the search for diamondiferous lamproites, although they are usually not as abundant as with kimberlites. Commonly, chromite is the most useful heavy indicator because it is the most common species and has distinctive chemistry. To a lesser extent, diamond, pyrope and eclogitic garnet, chrome spinel, Ti-rich phlogopite, K-Ti-richterite, low-Al diopside, forsterite and perovskite can be used as lamproite indicator minerals. Priderite, wadeite and shcherbakovite are also highly diagnostic of lamproites, although very rare.

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 to thousands of $/carat depending on their quality (evaluated on the size, colour and clarity of the stone). Argyle is currently the only major lamproite-hosted diamond mine. It contains at least 75 million tonnes, grading between 6 and 7 carats of diamonds per tonne (1.2 to 1.4 grams/tonne). The Prairie Creek mine produced approximately 100 000 carats and graded 0.13 c/t. Typical reported grades for diamond-bearing lamproites of <0.01 to .3 carats per tonne are not economic (Kjarsgaard, 1995). The average value of the diamonds at Argyle is approximately $US 7/carat; therefore, the average value of a tonne of ore is approximately $US 45.50 and the value of total reserves in the ground is in excess of $US 3.4 billion.

END USES: Gemstones; industrial uses such as abrasives.

IMPORTANCE: Olivine lamproites have only been recognized as diamond host rocks for approximately the last 20 years as they were previously classified as kimberlites based solely on the presence of diamonds. Most diamonds are still produced from kimberlites; however, the Argyle pipe produces more carats per annum (approximately 38,000 in 1995), by far, than any other single primary diamond source. Approximately 5% of the diamonds are good quality gemstones.

SELECTED BIBLIOGRAPHY

Atkinson, W.J. (1988): Diamond Exploration Philosophy, Practice, and Promises: a Review; *in* Proceedings of the Fourth International Kimberlite Conference, Kimberlites and Related Rocks, Volume 2, Their Mantle/Crust Setting, Diamonds and Diamond Exploration, J. Ross, Editor, *Geological Society of Australia*, Special Publication 14, pages 1075-1107.

Bergman, S.C. (1987): Lamproites and other Potassium-rich Igneous Rocks: a Review of their Occurrence, Mineralogy and Geochemistry; *in* Alkaline Igneous Rocks, J.G. Fitton and B. Upton, Editors, *Geological Society of London*, Special Publication 30, pages 103-190.

Fipke, C.E., Gurney, J.J. and Moore, R.O. (1995): Diamond Exploration Techniques Emphasizing Indicator Mineral Geochemistry and Canadian Examples; *Geological Survey of Canada*, Bulletin 423, 86 pages.

Griffin, W.L. and Ryan, C.G. (1995): Trace Elements in Indicator Minerals: Area Selection and Target Evaluation in Diamond Exploration; *Journal of Geochemical Exploration*, Volume 53, pages 311-337.

Haggerty, S.E. (1986): Diamond Genesis in a Multiply-constrained Model; *Nature*, Volume 320, pages 34-37.

Helmstaedt, H.H. (1995): "Primary" Diamond Deposits What Controls their Size, Grade and Location?; in Giant Ore Deposits, B.H. Whiting, C.J. Hodgson and R. Mason, Editors, Society of Economic Geologists, Special Publication Number 2, pages 13-80.

Jacques, A.L., Boxer, G., Lucas, H. and Haggerty, S.E. (1986): Mineralogy and Petrology of the Argyle Lamproite Pipe, Western Australia; *in* Fourth International Kimberlite Conference, Perth, Western Autralia, Extended Abstracts, pages 48-50.

Jennings, C.M.H. (1995): The Exploration Context for Diamonds; *Journal of Geochemical Exploration*, Volume 53, pages 113-124.

Kjarsgaard, B.A. (1996): Lamproite-hosted Diamond; *in* Geology of Canadian Mineral Deposit Types, O.R. Eckstrand, W.D. Sinclair and R.I. Thorpe, Editors, *Geological Survey of Canada*, Geology of Canada, Number 8, pages 568-572.

Levinson, A.A., Gurney, J.G. and Kirkley, M.B. (1992): Diamond Sources and Production: Past, Present, and Future; *Gems and Gemmology*, Volume 28, Number 4, pages 234-254.

Macnae, J. (1995): Applications of Geophysics for the Detection and Exploration of Kimberlites and Lamproites; *Journal of Geochemical Exploration*, Volume 53, pages 213-243.

Mitchell, R.H. (1991): Kimberlites and Lamproites: Primary Sources of Diamond; *Geoscience Canada*, Volume 18, Number 1, pages 1-16.

Mitchell, R.H. and Bergman, S.C. (1991): Petrology of Lamproites; *Plenum Press*, New York, 447 pages.

Nixon, P.H. (1995): The Morphology and Nature of Primary Diamondiferous Occurrences; *Journal of Geochemical Exploration*, Volume 53, pages 41-71.

Scott Smith, B.H. (1992): Contrasting Kimberlites and Lamproites; *Exploration and Mining Geology*, Volume 1, Number 4, pages 371-381.

Scott Smith, B.H. (1996): Lamproites; *in* Undersaturated Alkaline Rocks: Mineralogy, Petrogenesis and Economic Potential, R.H. Mitchell, Editor, *Mineralogical Association of Canada*, Short Course 24, pages 259-270.

Scott Smith, B.H. and Skinner, E.M.W. (1984): Diamondiferous Lamproites; *Journal of Geology*, Volume 92, pages 433-438.

Draft # 2a Dec. 15 1997