Morphology and Chemistry of Diamonds from the Lynx Kimberlite Dyke Complex, Northern Otish Mountains, Quebec

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Introduction

The Lynx complex, discovered in 2003 in the northern Otish Mountains, Quebec, is a series of roughly en echelon dykes striking north-northwest over nearly four kilometers with a maximum thickness of ~3 meters (Figure 1). Although only two kilometers west of the 630-645 Ma Renard kimberlite cluster, Lynx is 100 Myr younger with an age of 522+/-30 Ma from a U-Pb groundmass ilmenite isochron (after Noyes et al., 2008). In 2005, a trenching program recovered a total of 700 commercial-sized diamonds (~42 carats) from 34 tonnes of hypabyssal kimberlite. In 2007, additional trenching of 494 tonnes of Lynx kimberlite resulted in the recovery of an additional 5,898 diamonds (~529 carats), including the largest diamond recovered from Quebec to date, a 22 carat brown octahedron. An assessment of the physical and chemical characteristics of these Lynx diamonds and their inclusions is the topic of this study.

Diamond Morphology and Surface Features

Morphological characteristics were obtained from examination of whole diamonds from the 2007 sampling exercise. All stones above 0.65 carats were examined, and unbiased splits were taken for diamonds in the +3 to +11 DTC sieve categories (>1.47mm to 3.45 mm, ~0.03 to 0.32 carats/stone). A total of 442 diamonds were physically examined to assess the Lynx diamond population.

In the +3 to +11 DTC sieve categories the Lynx diamonds consist of 86% single crystal forms and 14% twins plus aggregates. The single crystals consist of 30% octahedra and 56% tetrahexahedroida (i.e., rounded dodecahedra), roughly double the number of octahedra observed in the nearby Renard bodies for a similar size range. Twin and aggregate crystals are dominantly octahedral macles, compared to abundant tetrahexahedroidal aggregates in the Renard 2 body for a similar size range (see Hunt et al., this conference). For larger diamonds exceeding 0.66 carats/stone, 68% are single crystals consisting of 37% octahedra and 31% tetrahexahedroida, and 32% are twins and aggregates of which 22% are tetrahexahedroidal forms. Light brown to brown coloration comprises 93% of the diamonds >0.66 carats, dropping to 52% for diamonds in the 0.03 to 0.65 carat range.

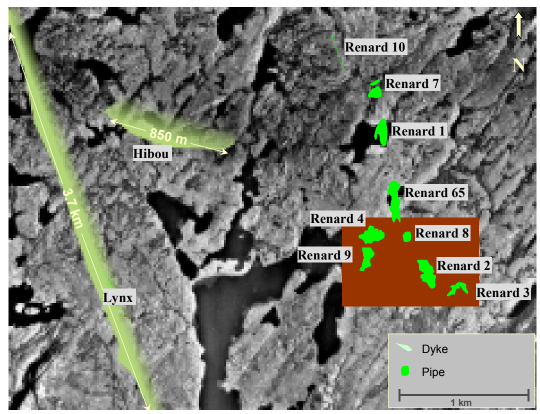

Figure 1: Location map of the Lynx dyke complex, relative to the Renard kimberlite pipes and the Hibou dyke system.

Shield and serrate laminae are the most common octahedral surface features, and fine to coarse hillocks dominate the tetrahexahedroidal surfaces. Uneven resorption (i.e., pseudohemimorphism of Robinson et al., 1989), a feature suggesting incomplete liberation of the diamond from its parent rock during resorption, is present on 15% of the >0.66 carat diamonds and on 43% of the diamonds in the 0.03 to 0.65 carat size range.

Inclusions in Lynx Diamonds

From the collection of 700 diamonds recovered in 2005, a suite of 45 were identified as having visual inclusions large enough for analysis, from which a subset of 21 were selected. The 21 stones range in mass from 0.03 to 0.45 carats, and are roughly representative of the larger 2007 diamond population, being 52% single crystals, 33% twins and aggregates, with 14% of irregular shape. With respect to resorption the subset has 43% octahedra and 43% tetrahexahedroida, and only 19% are colorless.

Inclusions in the diamonds were prepared for analysis by careful cutting of the diamond and polishing of the surface in order to expose the inclusions in situ relative to their diamond host. Cathode luminescence (CL) and carbon isotopic analysis is also anticipated for the host diamonds. To date, inclusions in six brown-colored diamonds have undergone microprobe analysis for major and minor elements and rudimentary CL imaging. The CL images suggest that simple growth to complex growth and resorption processes are recorded in the Lynx diamonds (Figure 2).

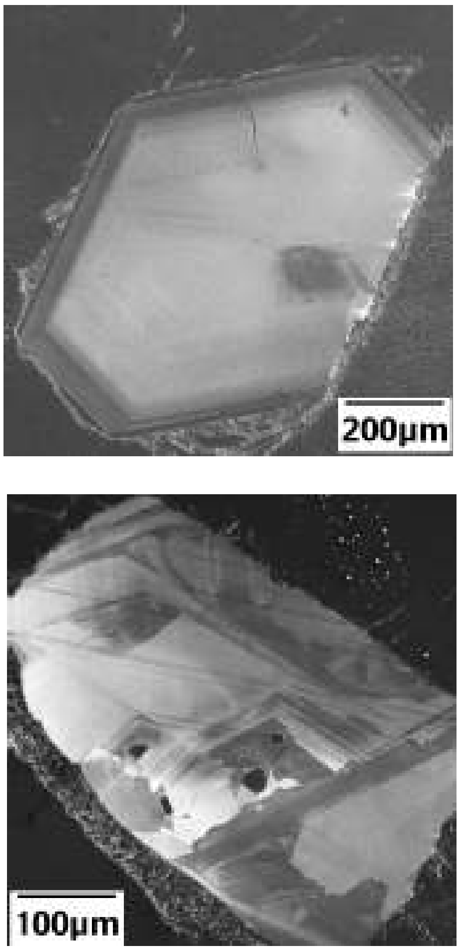

Fig.2 CL image of diamond 20 (top) and 8 (bottom) showing simple and complex zoning relations, respectively.

Although the polishing was highly successful in exposing numerous inclusions on a single analytical plane, only single-phase inclusions were analyzed in each of the six diamonds. Two diamonds contained single G10 pyrope garnet from which multiple analyses were possible. Average Mg# and Cr_2O_3 contents differ noticeably between grains at 87.4 vs 83.2 and 12.4 wt% vs 8.87 wt% respectively (Table 1). Multiple analyses points in each pyrope demonstrated that within-grain heterogeneities also exist. In contrast, multiple inclusions of forsterite in three diamonds are similar within each diamond and between diamonds, with Mg# from 93.1-93.3 mole% and NiO from 0.32-0.36 wt% (Table 1).

In one diamond, six chromian clinopyroxene inclusions were exposed for analysis. The clinopyroxenes exhibit some chemical variability between grains, particularly for MgO and Na_2O (Table 1), but otherwise are chemically consistent with derivation from a lherzolitic parent rock. The six lherzolitic clinopyroxenes allow for calculation of P-T using the thermobarometer of Nimis and Taylor (2000). Resultant values ranging from 57.5-59.9 kb and 1251-1276°C place the diamond roughly on a 42 mWm-2 geotherm at the time of encapsulation of the clinopyroxene inclusions. Geothermometry can be applied to the pyrope-bearing diamonds using MnO after Grutter et al., (1999) and give temperatures of 1167°C and 1395°C. Projecting these temperatures to the 42 mWm^{-2} geotherm gives pressures of formation for the diamonds of ~50 kb and ~70 kb, respectively (Figure 3).

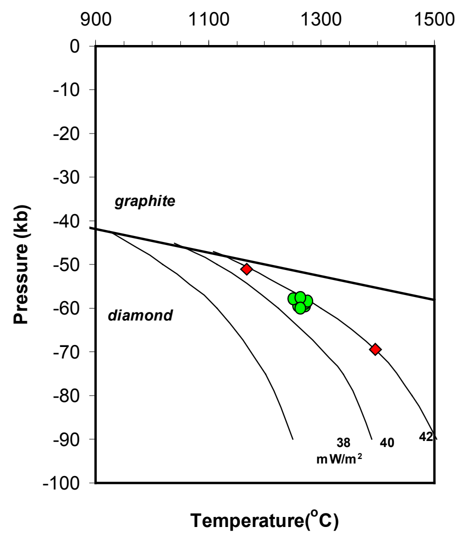

Fig. 3 P-T plot of chromian clinopyroxene inclusions in a single diamond (circles) and projection of pyrope inclusion Mn-geothermometer values to roughly a 42 mWm^{-2} geotherm.

Conclusions

The Lynx diamonds exhibit a typical range in morphology and surface features for kimberlitic diamonds, containing nearly equal amounts of resorbed and octahedral diamonds throughout the commercial-size range. The relative proportion of octahedral to tetrahexahedroidal forms differs relative to the nearby Renard kimberlites, as does the diamond color

Table 1. Microprobe analyses for inclusions from selected Lynx diamonds. Averages (Av.) and standard deviations are given for some analyses.

Sample	Lynx6-Av.	Lynx6-SD.	Lynx20-Av.	Lynx20-SD.
Mineral	Gnt	Gnt	Gnt	Gnt
SiO2	41.7	0.2	42.6	0.1
TiO2	0.11	0.03	0.04	0.02
Al2O3	13.8	0.1	15.1	0.1
Cr2O3	12.4	0.1	8.87	0.10
FeO	5.6	0.1	7.43	0.12
MnO	0.24	0.03	0.33	0.03
MgO	21.9	0.2	20.6	0.1
CaO	4.24	0.09	5.79	0.09
Na2O	0.01	0.01	0.03	0.00
Total	99.9	0.3	100.7	0.3
Mg#	87.4	0.3	83.2	0.2
Cr/(Cr+Al)	0.377	0.004	0.283	0.003

Sample	Lynx24-1	Lynx24-2	Lynx24-3	Lynx24-4
Mineral	CPX	CPX	CPX	CPX
Paragenesis	P	P	P	P
SiO2	55.4	55.4	55.6	55.3
TiO2	0.02	0.04	0.04	0.04
Al2O3	1.68	1.68	1.71	1.73
Cr2O3	2.23	2.26	2.32	2.33
FeO	2.87	2.88	2.84	2.83
MnO	0.12	0.13	0.12	0.11
MgO	18.41	18.44	18.26	18.25
CaO	16.7	16.7	16.8	16.9
Na2O	1.96	1.95	2.05	2.03
K2O	0.04	0.04	0.03	0.03
NiO	0.08	0.07	0.05	0.10
Total	99.5	99.5	99.8	99.7
Mg#	91.9	91.9	92.0	92.0

Sample	Lynx24-5	Lynx24-6	Lynx24-7	Lynx24-Av.	Lynx24-SD.
Mineral	CPX	CPX	CPX	CPX	CPX
Paragenesis	P	P	P	P	P
SiO2	55.4	55.3	55.5	55.4	0.1
TiO2	0.03	0.06	0.02	0.04	0.01
Al2O3	1.70	1.76	1.74	1.71	0.03
Cr2O3	2.24	2.32	2.29	2.28	0.04
FeO	2.86	2.78	2.82	2.84	0.03
MnO	0.12	0.11	0.10	0.12	0.01
MgO	18.46	18.28	18.34	18.35	0.09
CaO	16.7	16.7	16.7	16.7	0.1
Na2O	1.94	2.02	2.07	1.99	0.05
K2O	0.03	0.02	0.03	0.03	0.01
NiO	0.04	0.07	0.09	0.07	0.02
Total	99.5	99.4	99.8	99.6	0.2
Mg#	92.0	92.1	92.1	92.0	0.1

Sample	Lynx15-1	Lynx15-2	Lynx15-3	Lynx18-1
Mineral	Fo	Fo	Fo	Fo
SiO2	41.4	41.4	41.3	41.5
Cr2O3	0.05	0.05	0.05	0.09
FeO	6.64	6.68	6.71	6.81
MnO	0.10	0.09	0.10	0.10
MgO	51.7	51.6	51.6	51.5
CaO	0.02	0.02	0.02	0.03
NiO	0.33	0.33	0.32	0.35
Total	100.3	100.2	100.1	100.3
Mg#	93.3	93.2	93.2	93.1

Sample	Lynx8-1	Lynx8-2	Lynx8-3	Lynx8-4
Mineral	Fo	Fo	Fo	Fo
SiO2	41.7	41.8	41.6	41.6
Cr2O3	0.10	0.11	0.08	0.09
FeO	6.61	6.62	6.62	6.63
MnO	0.08	0.09	0.09	0.09
MgO	51.9	50.2	52.0	51.9
CaO	0.02	0.02	0.02	0.02
NiO	0.35	0.36	0.35	0.35
Total	100.8	99.1	100.7	100.7
Mg#	93.3	93.1	93.3	93.3

with variations of brown being dominant at Lynx. Uneven resorption is a regular feature of Lynx diamonds, suggesting that they were still partially enclosed in their parent rock throughout much of the resorption process. Inclusions in diamonds analyzed thus far are all peridotitic in nature, but only brown diamonds have been assessed. Pressure and temperature constraints from chromian clinopyroxene inclusions suggest that some lherzolitic diamonds have formed at conditions consistent with an elevated geotherm relative to diamond-bearing Archean lithosphere elsewhere in the world.

References

Grutter, H.S., Apter, D.B. and Kong, J., 1999. Crust-mantle coupling: evidence from mantle-derived xenocrystic garnets. In: Gurney, J.J., Gurney, J.L., Pascoe, M.D., Richardson, S.H. (Eds.), Proceedings of the 7th International Kimberlite Conference, Red Roof Desigh, Cape Town, 307-313.

Hunt, L., Stachel, T., and McCandless, T.E. 2008. Diamonds from the Renard kimberlites, Quebec. Extended Abstract, 9th International Kimberlite Conference, Frankfurt, Germany.

Nimis P. and Taylor, W.R. 2000. Single clinopyroxene thermobarometry for garnet peridotites. Part I. Calibration and testing of a Cr-in-Cpx barometer and an enstatite-in-Cpx thermometer. Contrib. Mineral. Petrol. 139: 541-554.

Noyes, A.K., Heaman, L.M., and Creaser, R.A. (2008). A comparison of chronometers applied to Monastery kimberlite and the feasibility of U-Pb ilmenite geochronology. Chemical Geology (submitted).

Robinson, D.N., Scott, J.N., van Niekerk, A., and Anderson, V.G., 1989. The sequence of events reflected in the diamonds of some southern African kimberlites. Geol. Soc. Australia, Sp. Pub. 14, 990-999.