10IKC-079

# EXPLORATION AND GEOLOGY OF THE QILALUGAQ KIMBERLITES, RAE ISTHMUS, NUNAVUT, CANADA

**Kupsch B.G. and Armstrong J.P.**
*Stornoway Diamond Corporation, North Vancouver, Canada*

## INTRODUCTION

Kimberlites of the Qilaluqaq cluster were first discovered in 2003 approximately 10 kilometres (km) to the NE of the Hamlet of Repulse Bay on the Rae Isthmus, southern Melville Peninsula, Nunavut. The discoveries followed a regional exploration program that was part of an extensive staking and ground acquisition rush within the eastern arctic of Canada. The Qilalugaq Project, N 66° W 86°, is located on the Rae Isthmus which lies north of the Arctic Circle and connects the Melville Peninsula to eastern mainland Nunavut and sits between Committee Bay and Repulse Bay (Fig. 1). The Rae Isthmus is underlain by granitoids and gneisses of the Rae Craton within the Churchill Structural Province. Kimberlite emplacement occurred at ca. 546 Ma and is characterized by narrow hypabyssal (HK) dykes and root zone hypabyssal to diatreme (tuffisitic) kimberlite pipes. The HK dykes are preferentially emplaced along WNW trending structures. Several kimberlite pipes occur at the intersection of WNW trending lineaments with north-trending features. Kimberlites situated in the eastern portion of the cluster are defined by ilmenite–rich glacial dispersions and are barren to poorly diamondiferous. The central diamondiferous kimberlites (Q1-4 complex) are defined by glacial dispersions with a greater proportion of garnet lherzolite and sub-ordinate low Cr harzburgitic garnet, and return average diamond contents of up to 39 carats per hundred tonnes (cpht). Hypabyssal dykes on the western portion of the field have a signature defined by garnet-chromite-ilmenite.

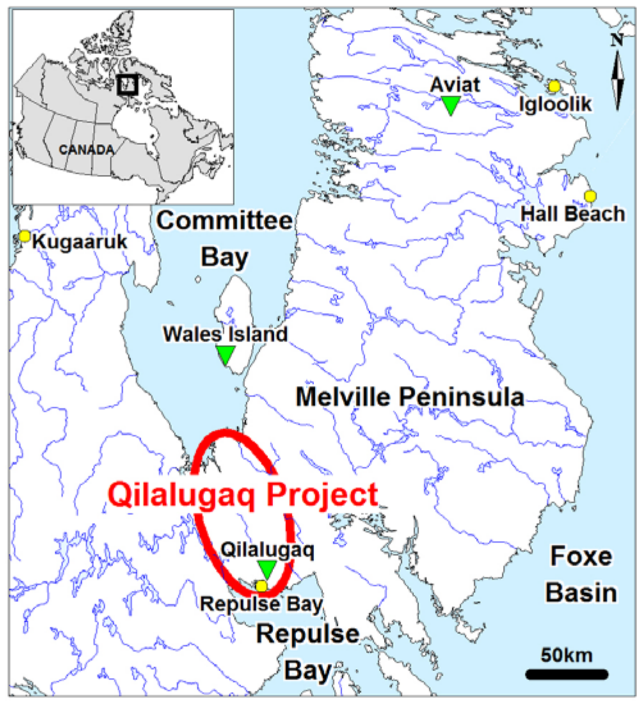


**Fig. 1.** Location of the Qilalugaq project, Rae Isthmus, Nunavut, Canada. Kimberlite clusters are shown as green triangles.

## GEOLOGICAL SETTING

### Bedrock

The project area is underlain by granitoid gneiss, paragneiss, schist, and granite rocks of the Precambrian Rae Province/Craton of the Churchill Structural Province, flanked by Paleozoic sedimentary rocks (Schau, 1993). The country rock adjacent to the kimberlite bodies consists mainly of fine- to coarse-grained fresh pink to grey granitoid gneiss and biotite-rich granitoid gneiss. They range from more massive weakly banded granitoid gneiss to strongly banded biotite-rich granitiotid gneiss with localized pegmatite veins. There are some zones of pink unfoliated fine-grained granite. The most common rocks of the region are Archean granitoid gneiss and schist which intrude the Prince Albert Group. The Prince Albert Group are Archean in age and are the oldest rocks in the Rae Isthmus, located in the central eastern side (Frisch, 1982), comprised of predominantly metasedimentary rocks, chiefly paragneiss, and metavolcanic rocks, with some distinct banded iron formations, ultramafic lavas and amphibolites. Within the central portion of the Rae Isthmus the basement rocks of undifferentiated granitoid gneiss and schist are unconformably overlain by the Aphebian-aged Penrhyn Group of metasedimentary rocks, chiefly paragneiss and marble, but also includes some schist, amphibolite, and quartzite (Henderson, 1988). Extensive NW-trending diabase dykes in the central area cross cut older rocks (Fahrig et al., 1971). The down-dropped fault blocks which flank the Rae Isthmus and the Melville Peninsula consist of flat-lying Ordovician carbonate rocks (Bolton et al., 1977). Kimberlite hosted lower crustal xenoliths of mafic and felsic granulite composition have zircons with cores returning minimum ages between 3.5 to 2.6 Ga and metamorphic zircon rims yielding ages of ca. 1.80 to 1.65 Ga (Petts et al., 2011)

**Surficial**

The Rae Isthmus lies within the Foxe sector of the Laurentide Ice Sheet where the latest glaciation began with accumulation on the plateaus of central and southern Melville Peninsula (Dredge, 2002). This ice was later subsumed by, and incorporated into, an ice dome underlain by limestone and centered in the Foxe Basin to the east. The main ice flow was westward, but a subsidiary ice divide on the central and southern plateaus caused the main Foxe ice to flow around the uplands of southern Melville, and eventually NNW through the Rae Isthmus (Dredge, 2001).

The southern Melville Peninsula started to experience deglaciation about 8600 years ago, and ice streamed northward through the Rae Isthmus towards the calving margin in Committee Bay, generating a distinctive carbonate dispersal train (Dredge, 2002). Following breakup of the Foxe ice about 6900 years ago, the Rae Isthmus was rapidly deglaciated and inundated by the sea to a level of about 150 metres (m) above current sea level, submerging the majority of the Rae Isthmus (Dredge, 2001). Remnant ice caps remained active on the uplands of the Melville Peninsula flowing radially towards low areas and the coast, and retreated from the coast between 6400 and 6100 years ago (Dredge, 2002).

Within the project area are extensive lowlands below 200 m elevation, and the surficial geology is dominated by till blankets, till veneer, glaciomarine deposits and till reworked by marine action, with numerous raised beaches closer to coastal areas. Predominant striations on glacially scoured outcrop trend NW to north and streamlined rock forms, roches mountonnees and craig-and-tail forms are found in a NW orientation across the Rae Isthmus (Dredge, 2002). Regionally the kimberlite dispersion plume has a northwesterly orientation. However, on a local scale, kimberlite indicator mineral dispersion trains within the eastern portion of the project area have a SSE attitude, and south directed indicator mineral dispersion trains are present within the central portion of the project area. Mapping of striations has yielded south directed ice flow, supporting the interpretation from indicator dispersions, and indicating that the remnant ice caps on the SW side of the Melville (i.e. Haviland Reminant) reached farther SW to the coast than previously interpreted.

## EXPLORATION HISTORY

The Rae Isthmus and southern portion of the Melville Peninsula was the focus of extensive exploration work by BHP Billiton Diamonds Inc. (BHP) from 2000 to 2005. Reconnaissance scale sampling of beach, streams and glaciofluvial material for kimberlite indicator minerals (KIMs) began in 2000 within the regional drainage catchment of the Foxe Basin, and identified the Repulse Bay area as prospective for diamonds. Follow-up regional till sampling programs across the Rae Isthmus in 2001 and 2002 yielded mantle derived garnet, ilmenite, chromite and rare clinopyroxene leading to ground acquisition starting in 2002. A regional 150 x 25 km area of anomalous indicator grains hosting numerous discrete indicator dispersions with variable indicator mineral abundances and chemical signatures was defined by the approximately 7000 reconnaissance and follow-up glacial sediment samples.

Airborne geophysical surveys consisting of 56000 line-km of combined fixed-wing magnetic and helicopter magnetic/electromagnetic surveys and 19000 line-km of fixed-wing gravity surveys were flown by BHP between 2002 and 2004. In general, anomalies associated with the kimberlites are magnetic lows with an accompanying electromagnetic response. Discovery phase core drilling was conducted in 2003 and resulted in the discovery of nine kimberlite pipes. Additional discovery phase core drilling in 2004-05 resulted in the discovery of two additional kimberlite pipes. Delineation drilling, HQ diamond drill hole (ddh) core sampling and reverse circulation (RC) mini-bulk sampling of the 14 hectare (ha) Q1-4 complex was completed in 2003-04. Approximately 229 tonnes (t) of kimberlite was collected during the HQ ddh and RC sampling.

Exploration was continued by Stornoway Diamond Corporation (Stornoway) through an option agreement with BHP. Exploration between 2006 and 2010 consisted of additional till sampling, ground geophysical surveys and prospecting in numerous unsourced indicator dispersion trains throughout the central core area. This resulted in the discovery of eight kimberlite dykes.

Ilmenite-dominated, south directed indicator trains with restricted (1-2 km) extents define the eastern cluster of kimberlites (Fig. 2). The central portion of the property

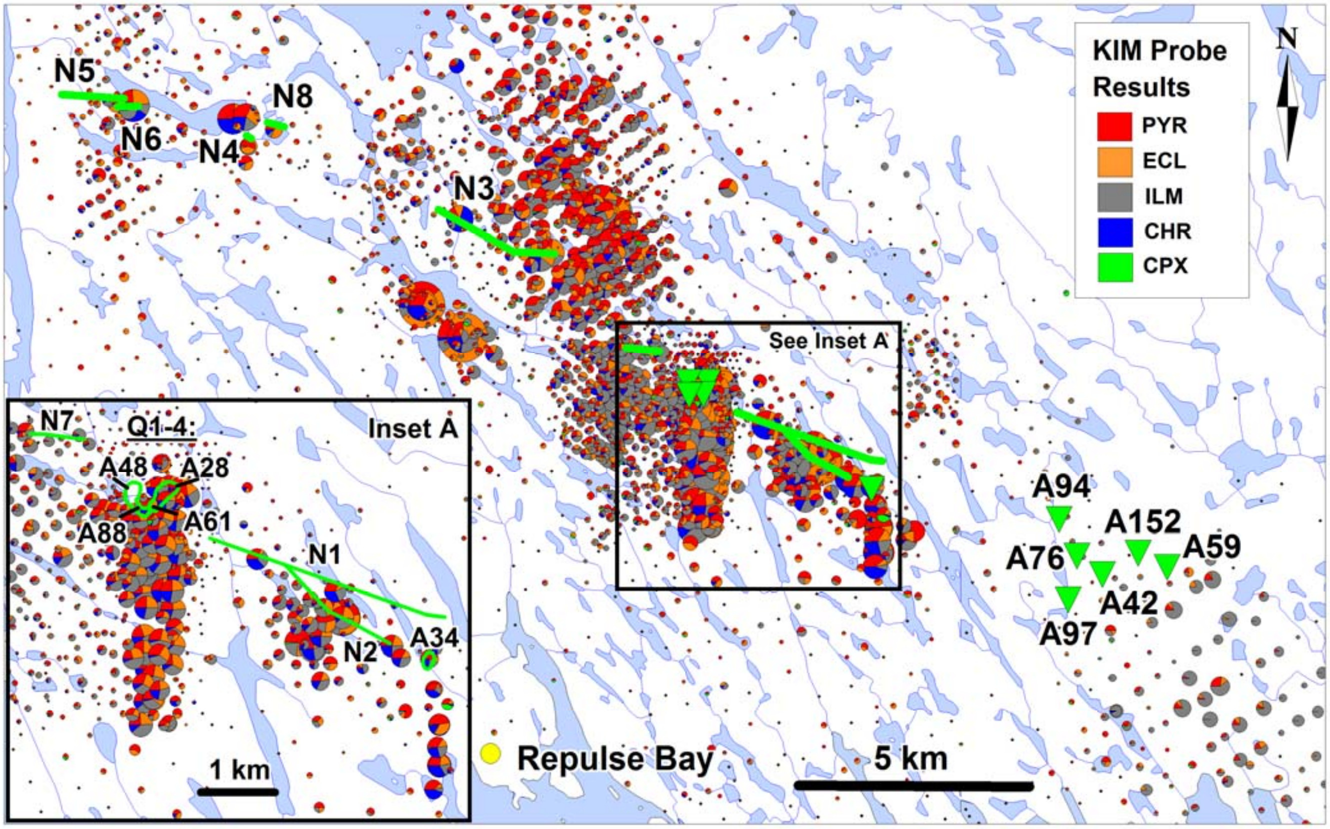


**Fig. 2.** Probe confirmed results of KIM grains from till samples collected on the Qilalugaq property. Qilalugaq kimberlites pipes are shown as green triangles and kimberlite dykes as green lines. The kimberlite dykes are abbreviated to N, eg. Naujaat 1 = N1. The eastern kimberlites have SSE directed dispersion trains dominated by ilmenite. The central kimberlites have variably oriented dispersion trains both to the N and S – with S prevailing - and are dominated by garnet>ilmenite. The western kimberlites have variably oriented dispersion trains both to the N and S and are dominated by garnet>ilmenite.

hosts a regional NW directed dispersion of pyrope ± eclogite ± spinel ± ilmenite and south directed trains of much shorter extent (~2 km) shed from a set of kimberlite pipes and sheets, including the Q1-4 complex. Prospecting at the north end of unsourced dispersions within the central and western portion of the property resulted in the discovery of eight dyke–like bodies.

## KIMBERLITE

The Qilalugaq kimberlite field occurs within a WNW trending corridor measuring 25 km long and approximately 5 km wide, parallel to significant regional lineaments (Fig. 2, Table 1).

**Table 1.** Summary of all kimberlites discovered on the property divided into three zones– east, central and west.

| Qilalugaq Kimberlites | KIM Dispersions | Rock Type | Diamond Recovery |
|---|---|---|---|
| Eastern (A42, A59, A76, A94, A97, A152) | ilm > grnt >> chrm | TK - HK | micro |
| Central (Q1-4, N1, N2, A34) | grnt > ilm > chrm | TK - HK | micro / macro |
| Western (N3, N4, N5, N6, N7, N8) | grnt > ilm > chrm | HK | micro |

A total of 57 exploration diamond drill holes completed between 2003 and 2005 confirmed 11 kimberlite pipes. The Q1-4 complex comprised of four coalescing pipes (A28, A48, A61, and A88) is the most significant intrusion and is interpreted as a multi-phase kimberlite complex having a lobate surface area of approximately 14 ha. The remaining kimberlite pipes (A34, A42, A59, A76, A94, A95, and A152) have surface expressions from 0.6 ha up to 11 ha based on drilling and interpretation of geophysical data. Ten of the 11 pipes have been tested for microdiamonds and are shown to be diamondiferous. Eleven delineation ddh, six HQ ddh and 18 RC holes were used to define the Q1-4 complex. In 2006 and 2007, Stornoway collected approximately 24.5 t of kimberlite from surface pits in A28 (Q1-4 eastern lobe) to confirm the macrodiamond data collected by BHP. The Q1-4 complex is the most significantly diamondiferous body discovered to date with mini-bulk sample diamond contents of up to 39 cpht (Table 2).

The textural varieties of kimberlite present within the pipes include tuffisitic kimberlite breccia (TKB) to hypabyssal kimberlite (HK); country rock dilution is variable and occurs in all units. Rocks that display textures gradational

**Table 2.** Summary of Q1-4 complex drilling and diamond results.

| Q1-4 Kimberlite Complex | Drilling | | Sampling* (tonnes) | Diamond content* (cpht) |
|---|---|---|---|---|
| | Core (m) | RC (m) | | |
| A28 | 2431 | - | 24.5 | 30.5 |
| A48 | 1159 | 1085.5 | 68.5 | 14 |
| A61 | 713 | 706.2 | 48.0 | 39 |
| A88 | 830 | 922.5 | 103.9 | 28 |

between these two end members HK and TKB are common and can represent one to multiple phases. The three main dominant mineralogical rock types are carbonate serpentine phlogopite kimberlite, serpentine carbonate phlogopite kimberlite and serpentine phlogopite kimberlite. Drilling suggests that Q1-4 is steep sided, irregular to complex in shape and possibly represents the root to diatreme zone of a Class I kimberlite pipe (Field and Scott Smith, 1999). The external pipe shapes and details of internal geology for the seven remaining pipes are hampered by limited drill hole data.

The Naujaat 1 through Naujaat 8 (N1 to N8) kimberlite dykes were discovered between 2006 and 2010 by prospecting in the vicinity of unsourced anomalous KIM grains and glacial dispersal trains within the western and central portions of the cluster. They appear to be preferentially emplaced along WNW structurally controlled corridors and lie on the south side of NW-SE and east-west trending structures. The average width of the N1 to N8 structures, where bounded by outcrop, is estimated between 1.5 to 4.5 m. The true width, nature, and continuity of the N1 to N8 kimberlites is currently unknown, although it is believed to be dyke-like in character as prospecting has identified discontinuous exposures of kimberlite float/boulders and subcrop extending over strike lengths between 0.1 to 3.16 km. From 40 to 1700 kilograms (kg) of kimberlite float or subcrop from each of the dykes, excluding N5, has been collected for microdiamond analyses and all seven have proven to be diamondiferous.

## MANTLE SAMPLE

KIMs of mantle provenance have been recovered from both surface sediment samples and kimberlites of the various discoveries. The suite of indicators present is dominated by garnet, clinopyroxene, chromite, olivine and kimberlite-derived ilmenite. The recovered garnets include significant proportions of both high-Cr and low-Cr types (Fig. 3a). The high-Cr (>2 wt.% $Cr_2O_3$) population is dominated by lherzolitic garnets with maximum $Cr_2O_3$ contents of approximately 13% and the trend is offset slightly to the low-CaO side of the G9/G10 divide. A subordinate population of harzburgitic garnets is also present. Within the G10 garnet data there is a small subpopulation that lies on the high $Cr_2O_3$ side of the diamond graphite line as defined by Grütter and Sweeney (2000) and Grütter et al. (2006) with minimum pressure estimations of 60 Kbar. The greatest proportion of G10 garnets lie below the diamond graphite constraint, defining a lower pressure origin for the harzburgitic component. There is also a population of Ti-enriched megacrystic garnets present in all kimberlites. A significant proportion of till and kimberlite sourced chromites (with >0.7 wt.% $TiO_2$) display increasing $TiO_2$ contents with decreasing $Cr_2O_3$, indicative of the phenocryst suite of chromites. The kimberlites host a very small proportion of chromites with < 0.7 wt.% $TiO_2$ and >59<69 wt.% $Cr_2O_3$. Pressure-temperature (P-T) estimations for garnet peridotite sourced clinopyroxene grains (Fig. 3b) recovered from the Q1-4 complex have a P-T range of 35-61 Kbar and 850°-1200°C trending from the graphite stability field into the diamond stability and define a relatively warm geotherm of 38-40 mW/m$^2$ (calculated according to Nimis and Taylor (2000)). Till-derived clinopyroxenes from the eastern portion of the property lie along a similar geothermal gradient but are sourced from a lower P/T environment within the graphite stability field. Ilmenite chemistry is similar for all intrusions and till dispersions (Fig. 3c).

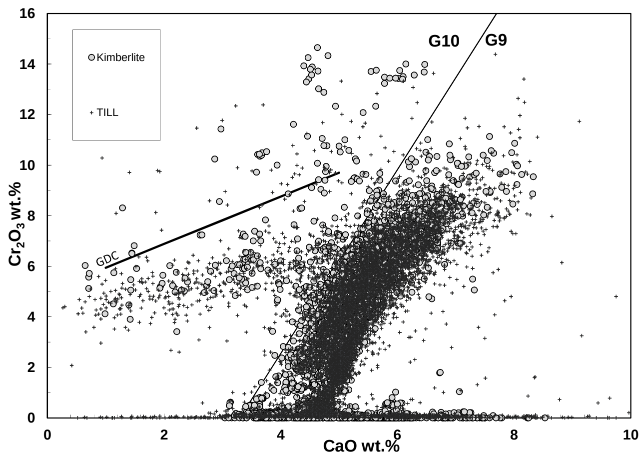


**Fig. 3a.** Discriminate plot of Qilalugaq kimberlite and till derived garnet.

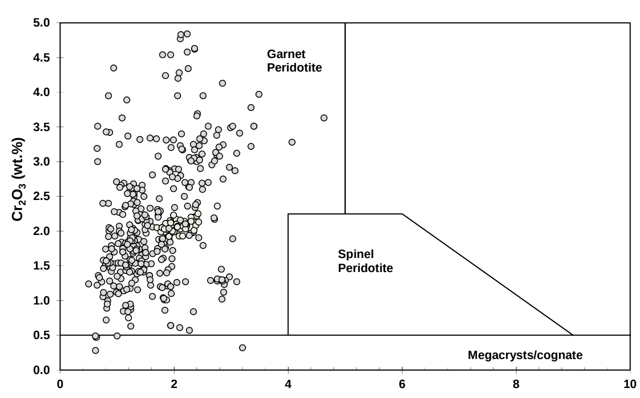


**Fig. 3b.** Discriminate plot of Qilalugaq kimberlite derived clinopyroxene.

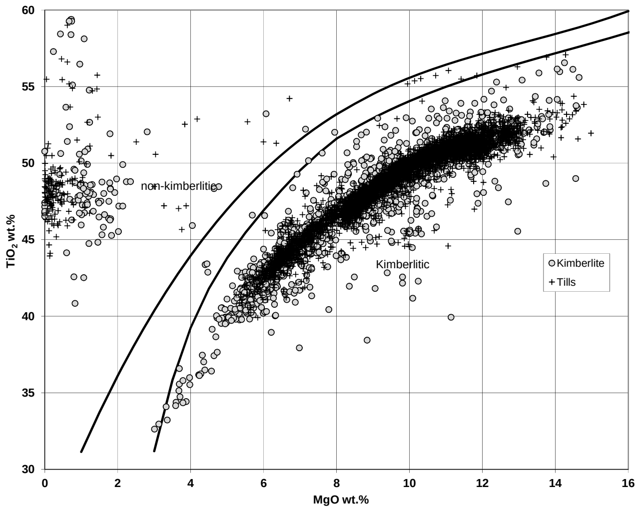


**Fig. 3c.** Discriminate plot of Qilalugaq kimberlite and till derived ilmenite (After Wyatt et al., 2004).

Microdiamonds have been recovered from all kimberlites submitted for analysis. Partially based upon the microdiamond abundance and distributions, larger mini-bulk samples have been extracted from the Q1-4 complex through large diameter core drilling, RC drilling and surface pitting (Table 2). Calculated sample grades range from 14 to 39 cpht.

## CONCLUSIONS

Emplacement age, host rock associations and kimberlite geology are analogous to the Aviat intrusions to the north of Qilalugaq (Armstrong et al., 2008) and other deep-diatreme to root zone kimberlite pipes located in southern Africa and the Slave Craton (i.e. Gahcho Kué; Field and Scott Smith, 1999; Hetman et al., 2004). The Qilalugaq kimberlite field was intruded into the Archean Rae Craton circa 546 Ma and represents a root zone to diatreme facies cluster. These diamondiferous kimberlites contain a mantle sample dominated by lherzolite with a sub-ordinate amount of low chrome harzburgite, likely derived from a lower pressure, shallower regime predominantly within the graphite stability field.

## REFERENCES

Armstrong, J.P., Stubley M.P., and Chang, F.Y. (2008) Geology and exploration history of the Aviat kimberlite cluster, Northern Rae Craton, Melville Peninsula, Nunavut, Canada. 9th International Kimberlite Conference, Frankfurt Germany, Extended Abstract 0266.

Bolton, T., Sanford, B., Copeland, M., Barnes, C., and Rigby, J. (1977) Geology of Ordovician Rocks, Melville Peninsula and region, southeastern District of Franklin. Geological Survey of Canada, Bulletin 269, 137 p.

Dredge, L.A. (2001) Late Pleistocene and Holocene glaciation and deglaciation of Melville Peninsula, northern Laurentide Ice Sheet. Geographie physique et quaternaire, v. 55, pp. 159-170.

Dredge, L.A. (2002) Quaternary geology of southern Melville Peninsula, Nunavut. Geological Survey of Canada, bulletin 561, 110 p.

Fahrig, W.F., Irving, E., and Jackson, G.D. (1971) Paleomagnetism of the Franklin diabases. Canadian Journal of Earth Sciences, v. 8, pp. 455-467.

Field, M., and Scott Smith, B. (1999) Contrasting geology and near-surface emplacement of kimberlite pipes in southern Africa and Canada. In: Proceedings of the 7th International Kimberlite Conference (J.J. Gurney, J. L. Gurney, M. D. Pascoe, S. H. Richardson, Eds.), Red Roof Design, Cape Town, v. 1, pp. 214– 237.

Frisch, T. (1982) Precambrian geology of the Prince Albert Hills, western Melville Peninsula, N.W.T. Geological Survey of Canada, Bulletin 346, 70 p.

Grütter, H.S. and Sweeney, R.J. (2000) Tests and constraints on single grain Cr-pyrope barometer models: some initial results. Extended Abstracts, GeoCanada 2000: The Millenium Geoscience Summit, 29 May–2 June 2000, Calgary, Abstract 772, 4 p.

Grütter, H.S.; Latti, D., and Menzies, A (2006) Cr-saturation arrays in concentrate garnet compositions from kimberlite and their use in mantle barometry. Journal of Petrology, 47, pp. 801-820.

Henderson, J.R. (1988) Geology, southeastern Melville Peninsula. Geological Survey of Canada, Map 1655A, scale 1:100 000, 2 sheets.

Hetman, C.M., Scott Smith, B.H., Paul, J.L.,Winter, F.W. (2004) Geology of the Gahcho Kue kimberlite pipes, NWT, Canada: root to diatreme transition zones. Proceedings of the 8th International Kimberlite Conference, Lithos 76, pp. 183-200.

Nimis, P. and Taylor, W.R. (2000) Single pyroxene thermobarometry for garnet peridotites. Part I. Calibration and evaluation of the Cr-in-pyroxene barometer and enstatite solvus thermometer. Contributions to Mineralogy and Petrology, v. 139, pp. 541-554.

Petts, D.C , Moser, D.E., Davis, W.J. and Longstaffe, F.J. (2011) Evolution of the lithosphere beneath the western Churchill province: U-Pb geochronology of zircon from kimberlite-hosted lower crustal xenoliths. Geological Association of Canada/Mineralogical Association of Canada Abstract volume.

Schau, M. (1993) Northern Melville Peninsula. Geological Survey of Canada, Open File 2594, scale 1:500,000.

Wyatt, B.A., Baumgartner, M., Anckar, E., and Grütter, H. (2004) Compositional classification of "kimberlitic" and "non-kimberlitic" ilmenite. Lithos, vol 77, pp. 819-840.