Application of new-age clinopyroxene and garnet thermobarometry techniques in diamond exploration

Herman Grütter
BHP Billiton World Exploration
Workshop 3: Indicator Mineral Methods
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New-age thermobarometry techniques

- The association of indicator minerals with diamond **or** graphite implies pressure (P) and temperature (T) information must be obtained from indicator grains recovered during exploration
- The relevant "new-age" P-T approaches for garnet and clinopyroxene are:
  - T-Ni & P-Cr for G10 or G9 garnets (Ryan et al, 1996)
  - T-Mn for G10 or G9 garnets (Grütter et al, 1999)
  - P and T for Cr-diopside (Nimis & Taylor, 2000)
  - P_{38} for G10 or G9 garnets (Grütter et al, 2006)
- P and T are used to constrain the geotherm for the exploration project and hence the extent of the "diamond window"
- Applications discussed: West Greenland & Northern Ontario

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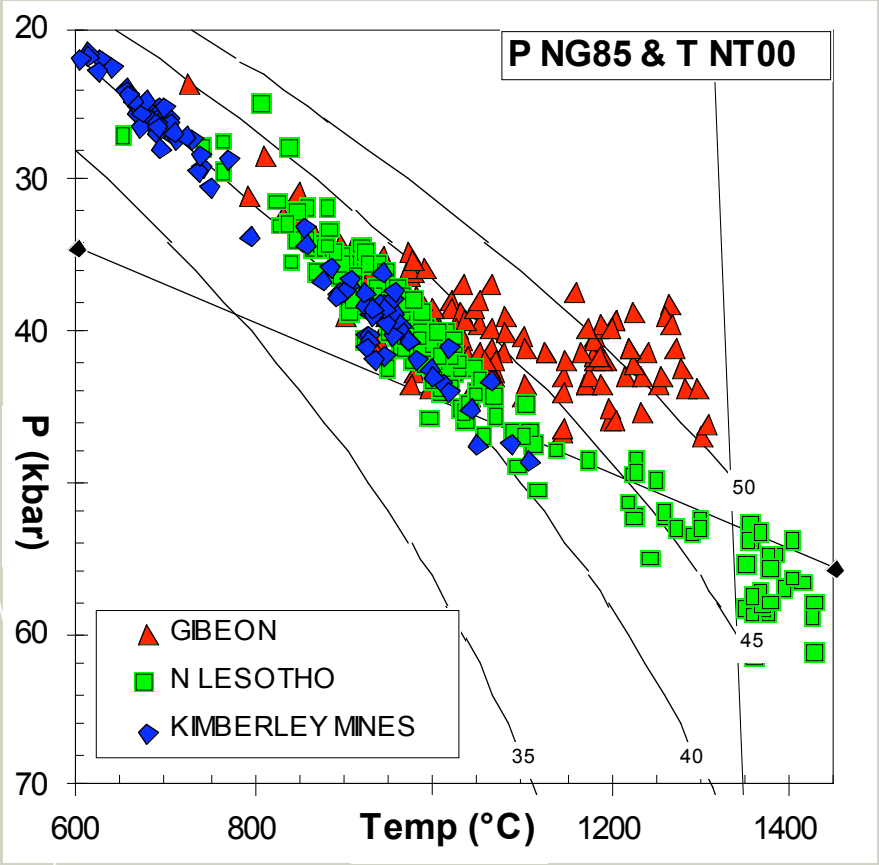
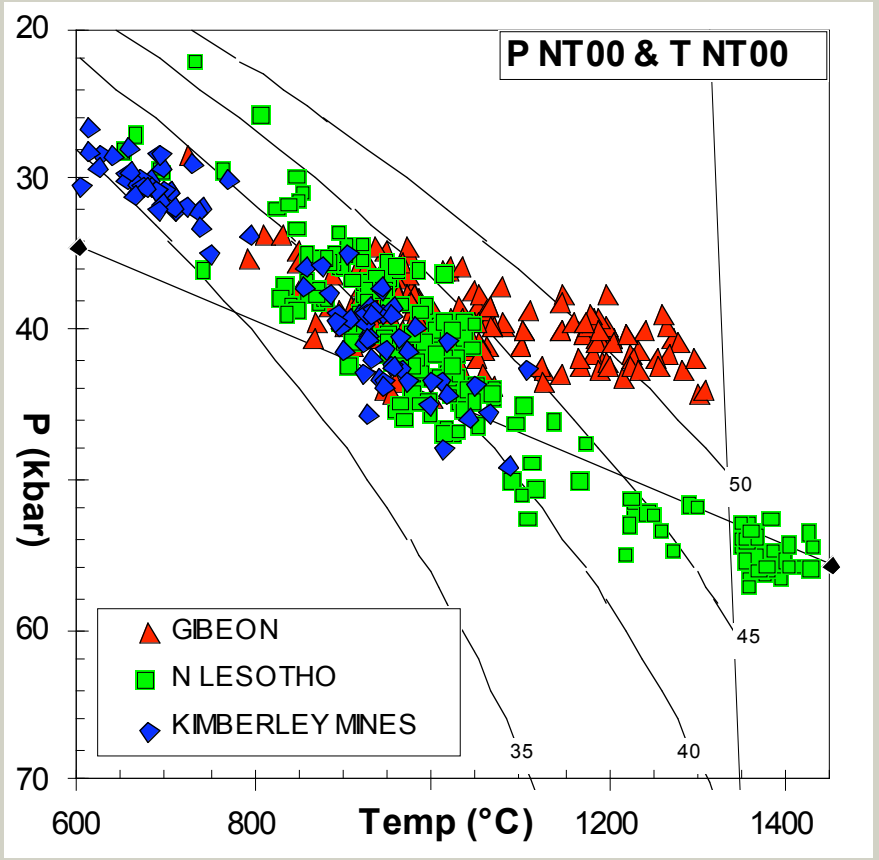
Pyroxene thermobarometry: Kaapvaal

Grutter and Moore (2003) 8IKC Ext Abs 272





Xenolith P-T: Opx + Cpx + Gt

Cpx single-grain P-T

- Little variability from "classic" 40 mW/m^2 geotherm for Kaapvaal Grp1 kimberlites

- Very similar P-T results from Cpx, but with larger scatter

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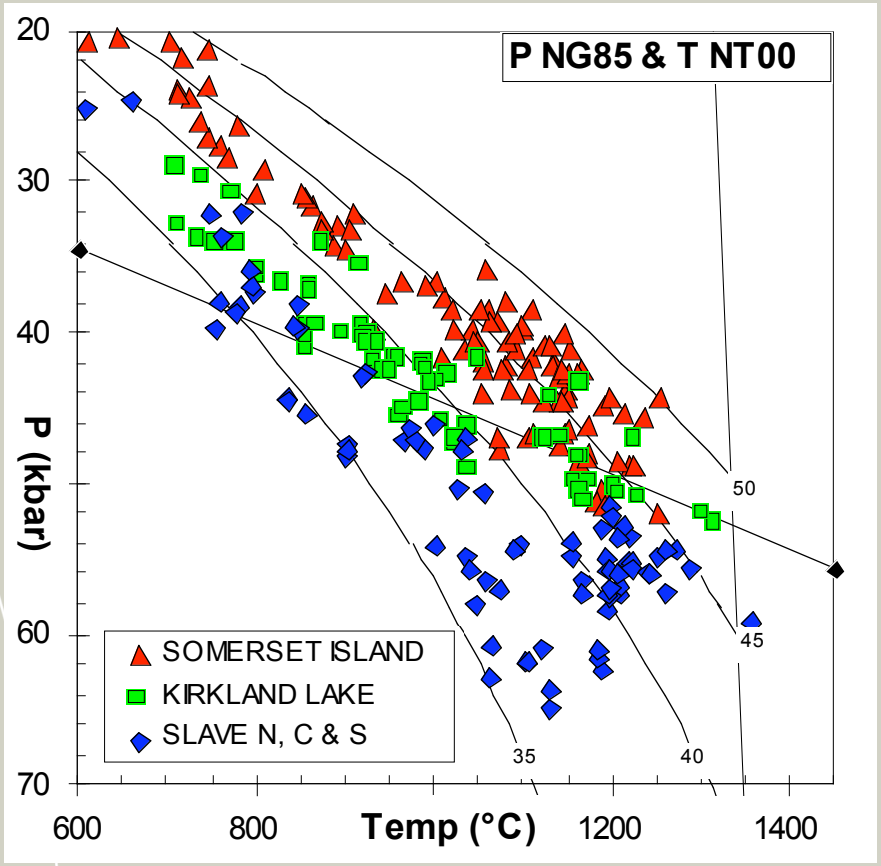
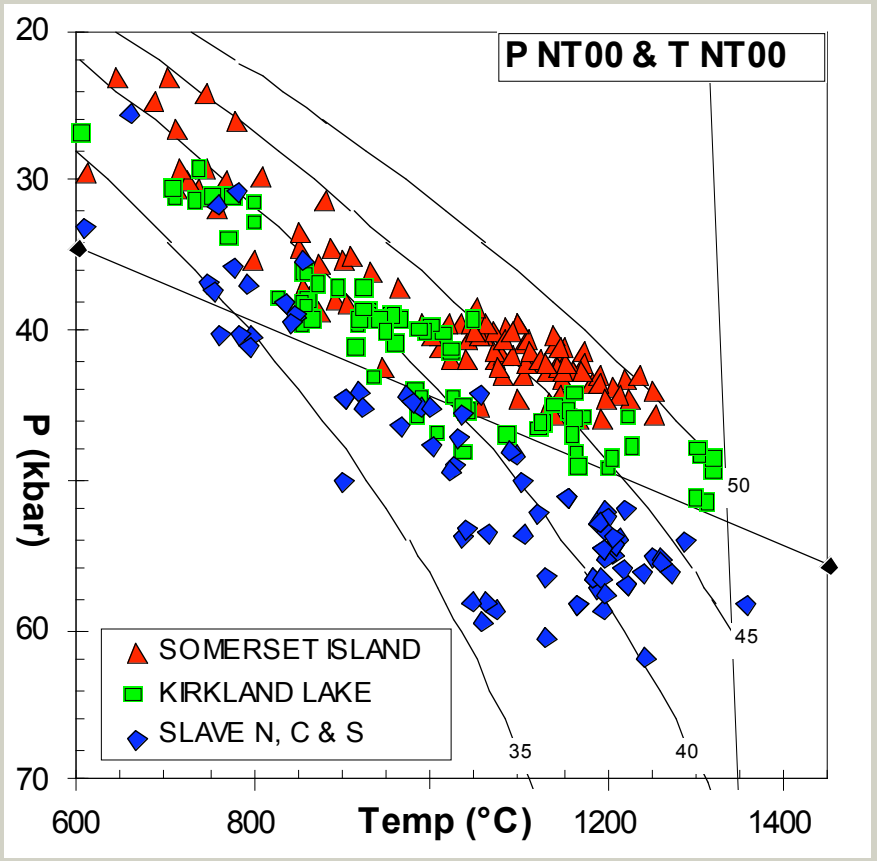
Pyroxene thermobarometry: Canada

Grutter and Moore (2003) 8IKC Ext Abs 272





Xenolith P-T: Opx + Cpx + Gt

Cpx single-grain P-T

- Canadian geotherms are separated: cold, normal and hot (36, 40 and 43 mW/m2)
- Separated P-T arrays also obtained using Cpx, with slightly larger scatter
- Cpx geotherms appear flatter

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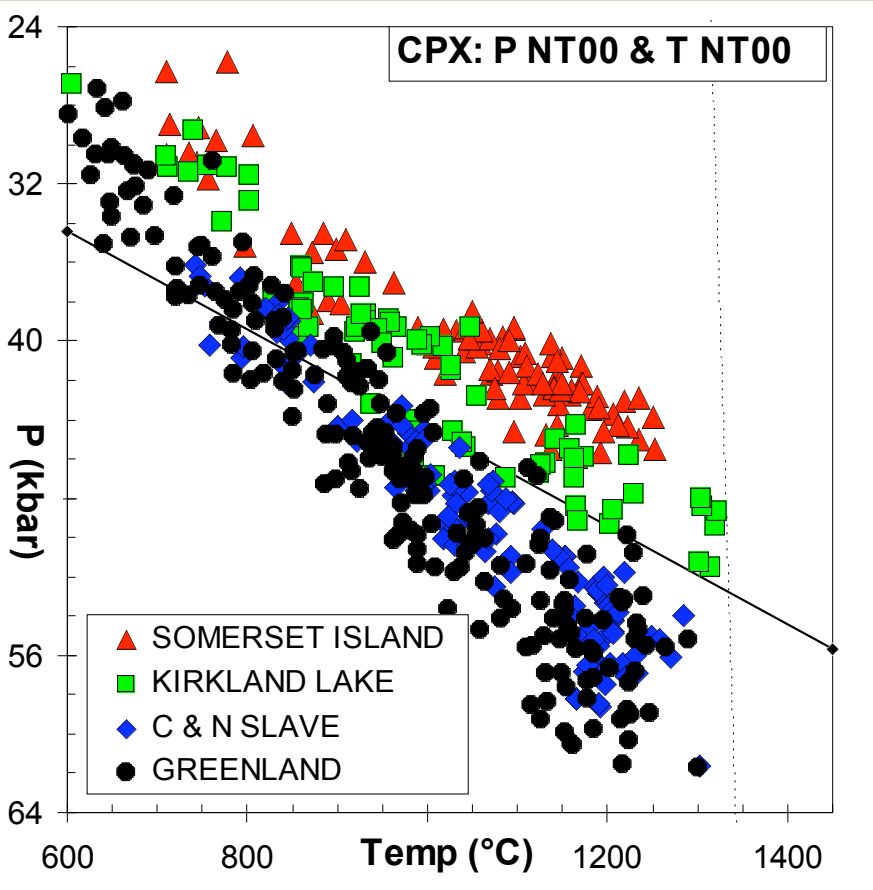
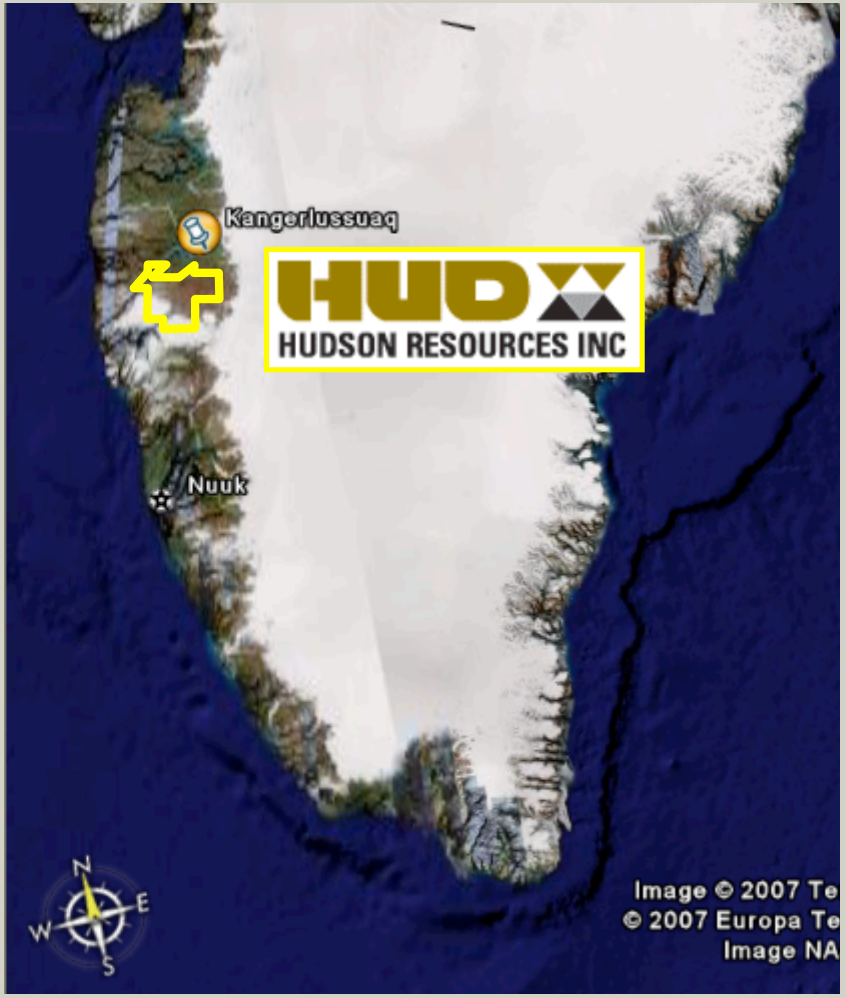
Cpx geotherm – Safartoq (Kangerlussuaq), West Greenland



Data from Jensen et al (2004) GEUS Report 2004/117



Cpx from till samples

- Safartoq geotherm is cold (~ 36 mW/m^2)

- Inside diamond field at T > 850 to 900°C

- Whole mantle section sampled by kimberlite sources

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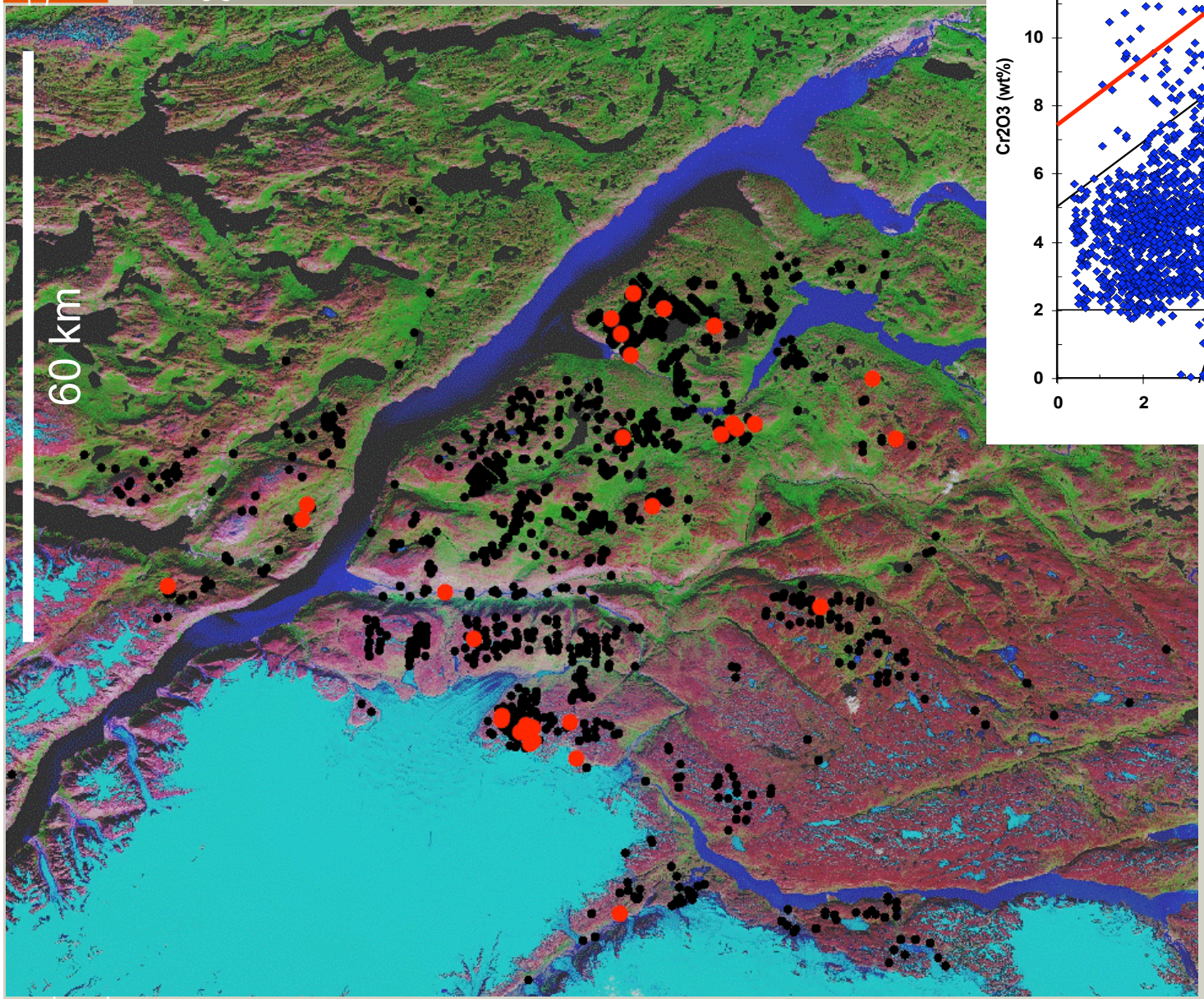
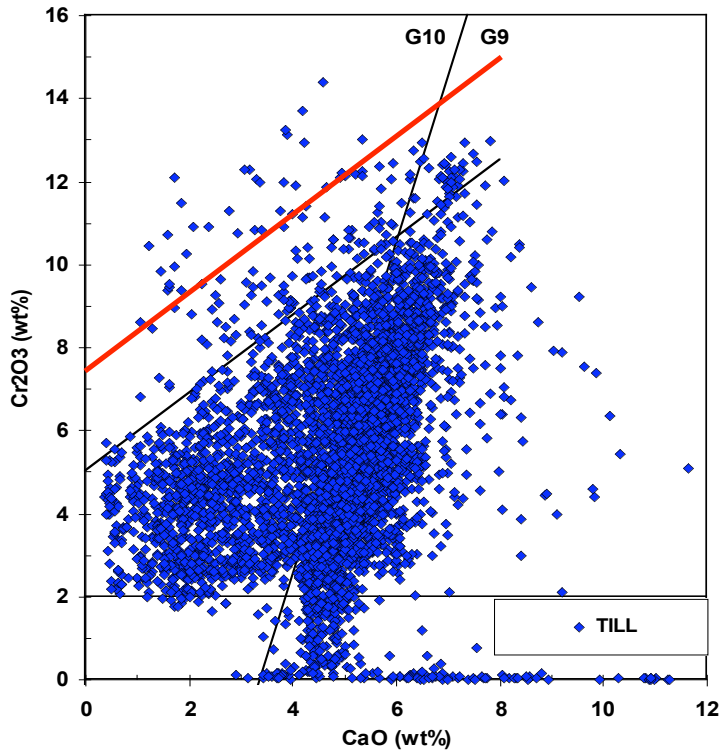
High pressure G10D garnets in till (P_{38} ≥ 51 kbar)





1568 samples

5921 garnets

32% are G10 n=1906

11% are G10D n=627

0.6% have P_{38} ≥ 51

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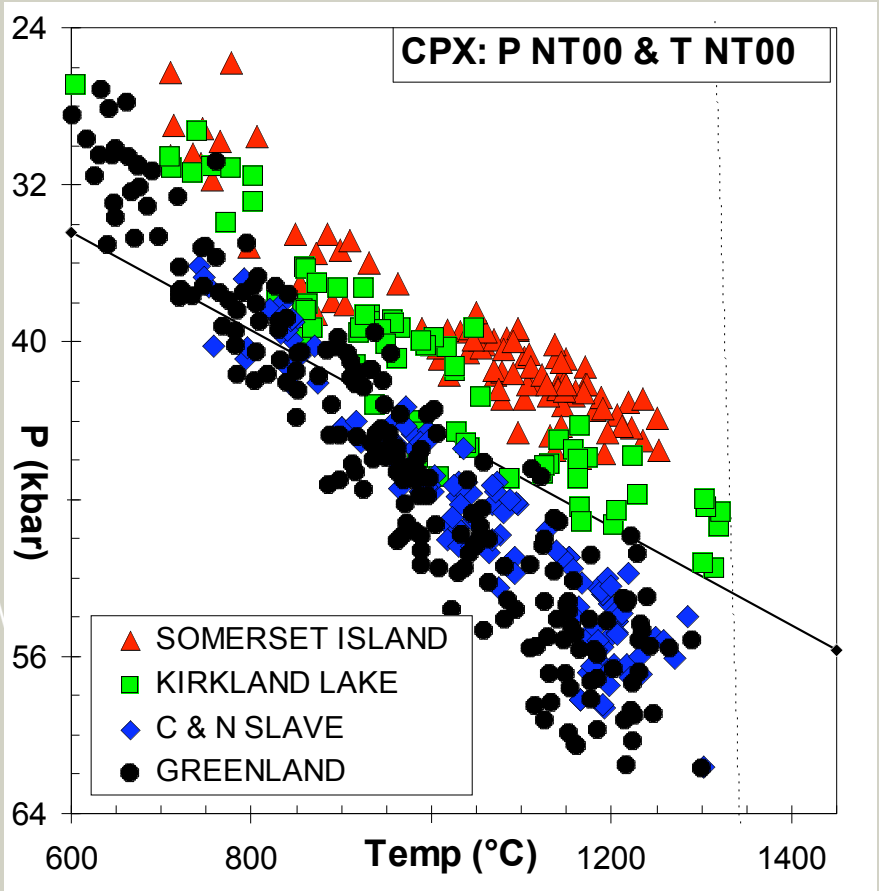
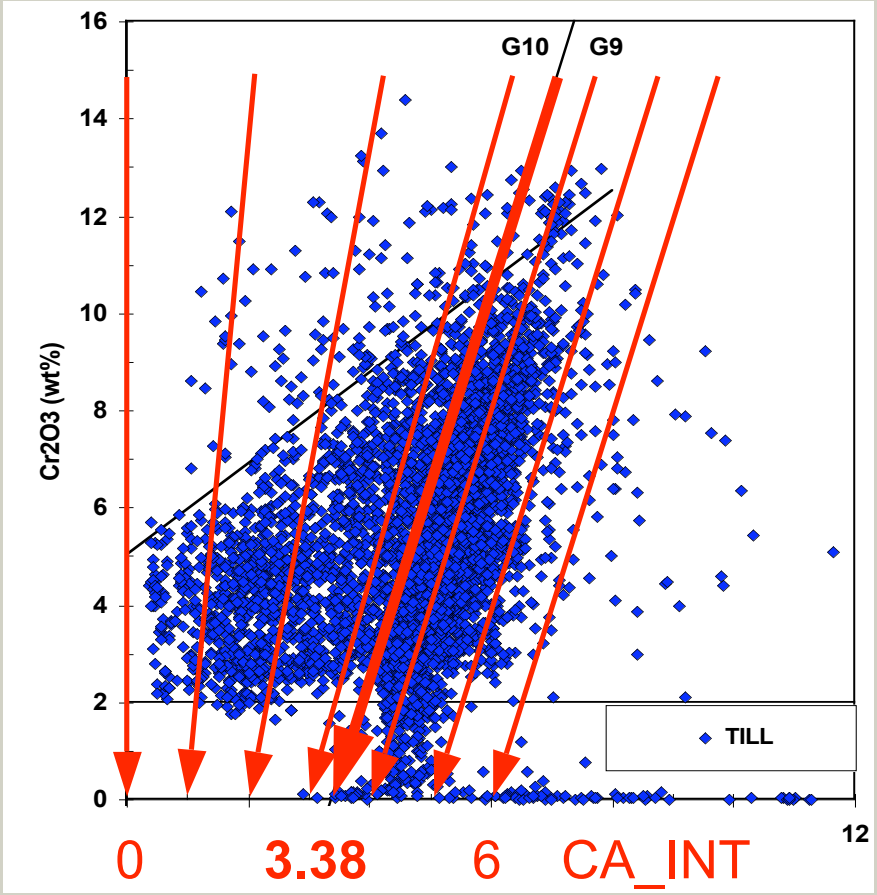
Merging cpx P-T with garnet compositions





CPX: P-T space

No compositional information

GAR: Compositional space (Cr-Ca)

No P-T information

Data from Jensen et al (2004) GEUS Report 2004/117

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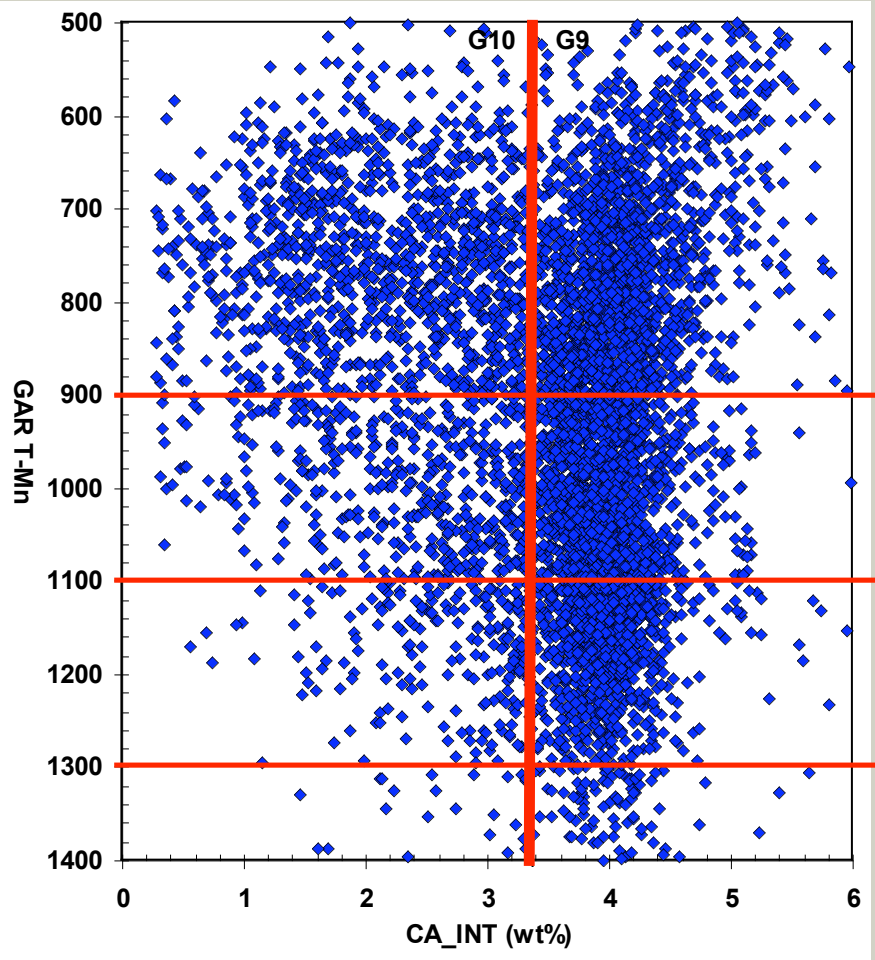
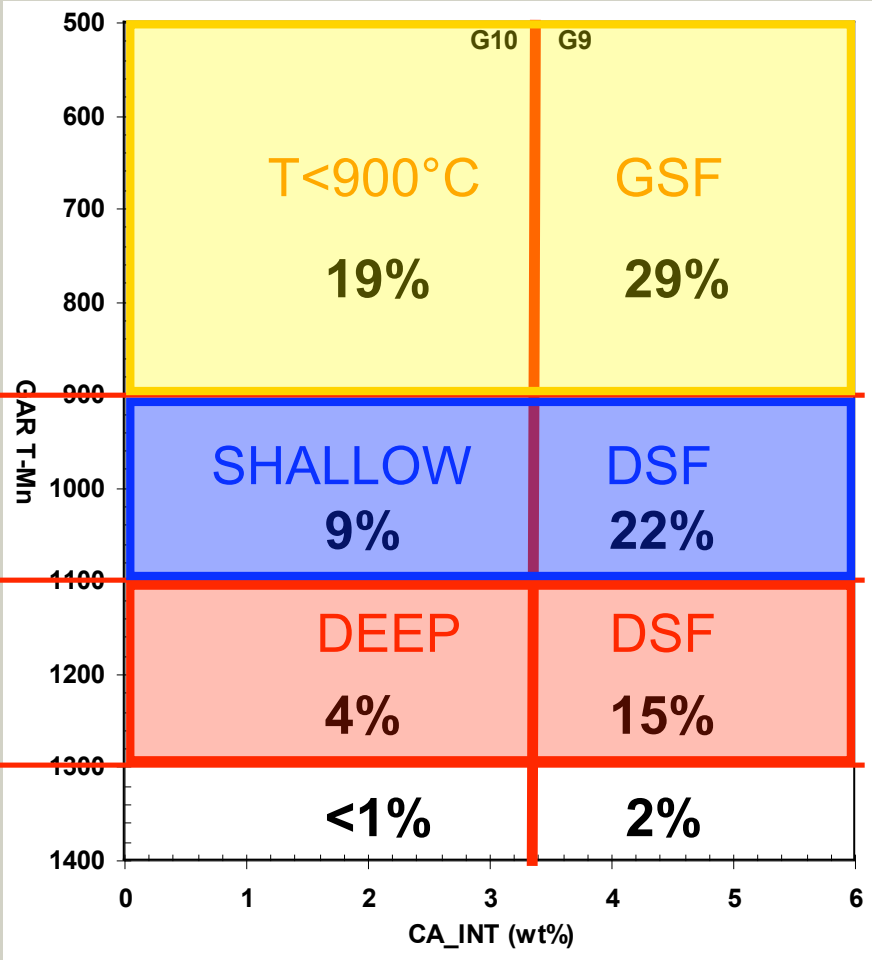
Apply T-Mn to Cr-pyrope garnet to obtain mantle section

T-Mn from Grutter et al (1999) 7IKC Proc V2: 307





GAR T-X section

n = 5921

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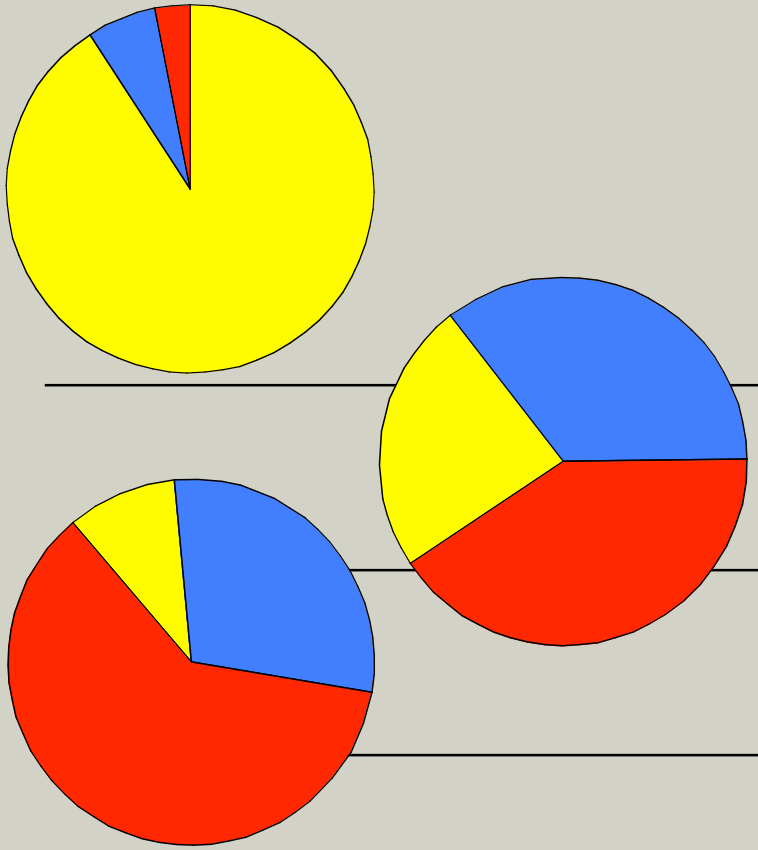
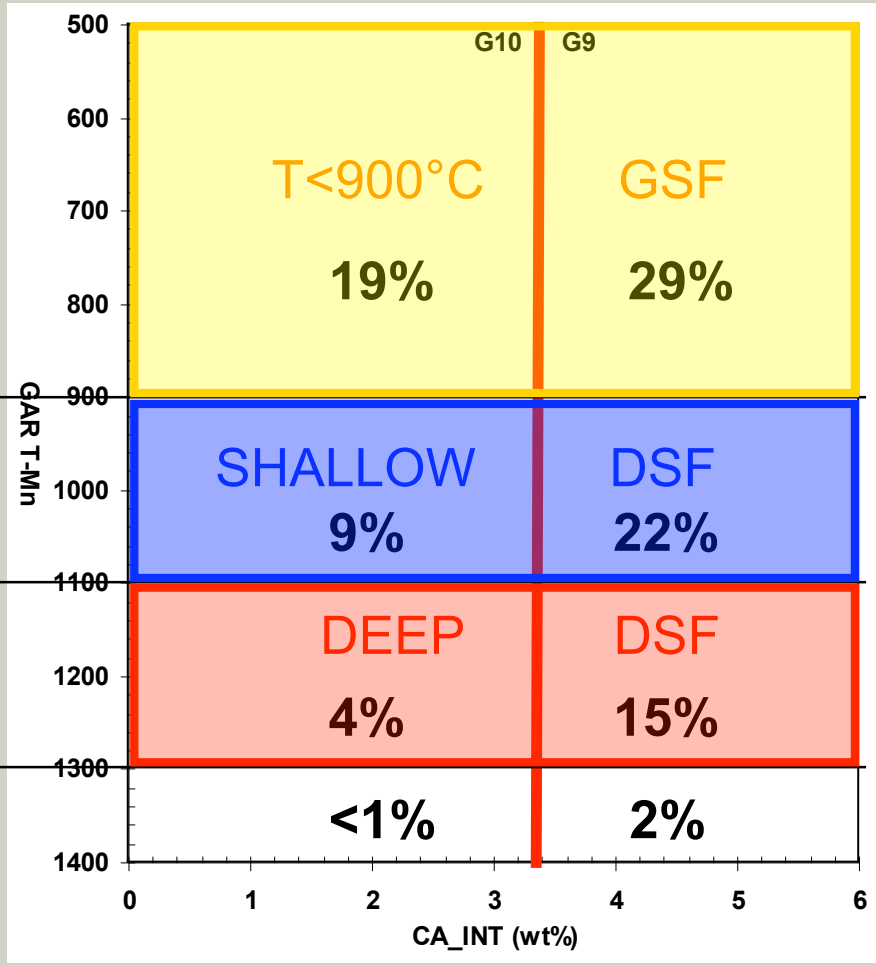
Representation as mapped data elements



- GSF (T<900)
- Sh DSF (T 900-1100)
- Dp DSF (T 1100-1300)



32% 68%

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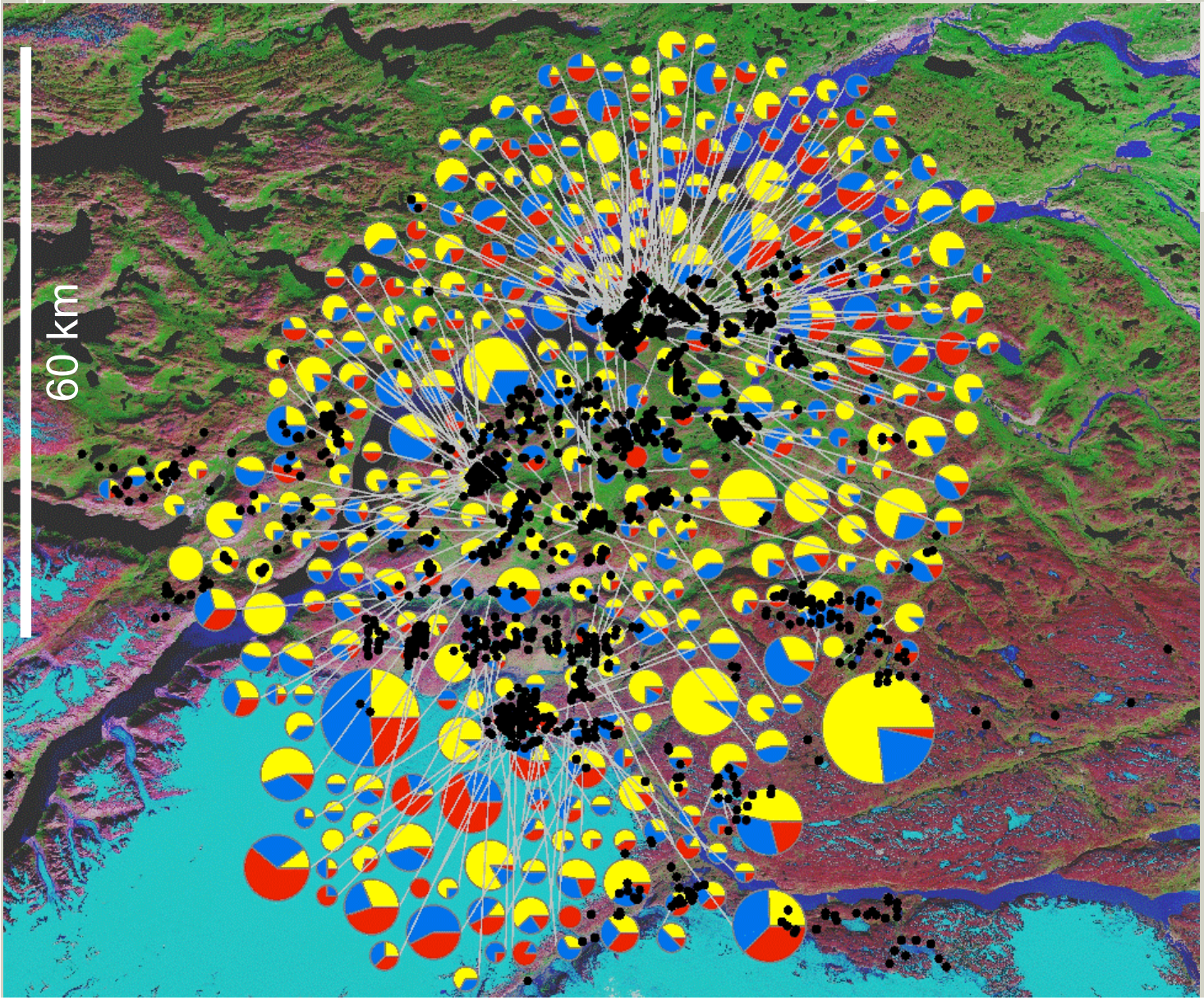
Safartoq till samples; 4 or more garnets / sample



Pie diagrams

- do not overlap

- spatial relations preserved

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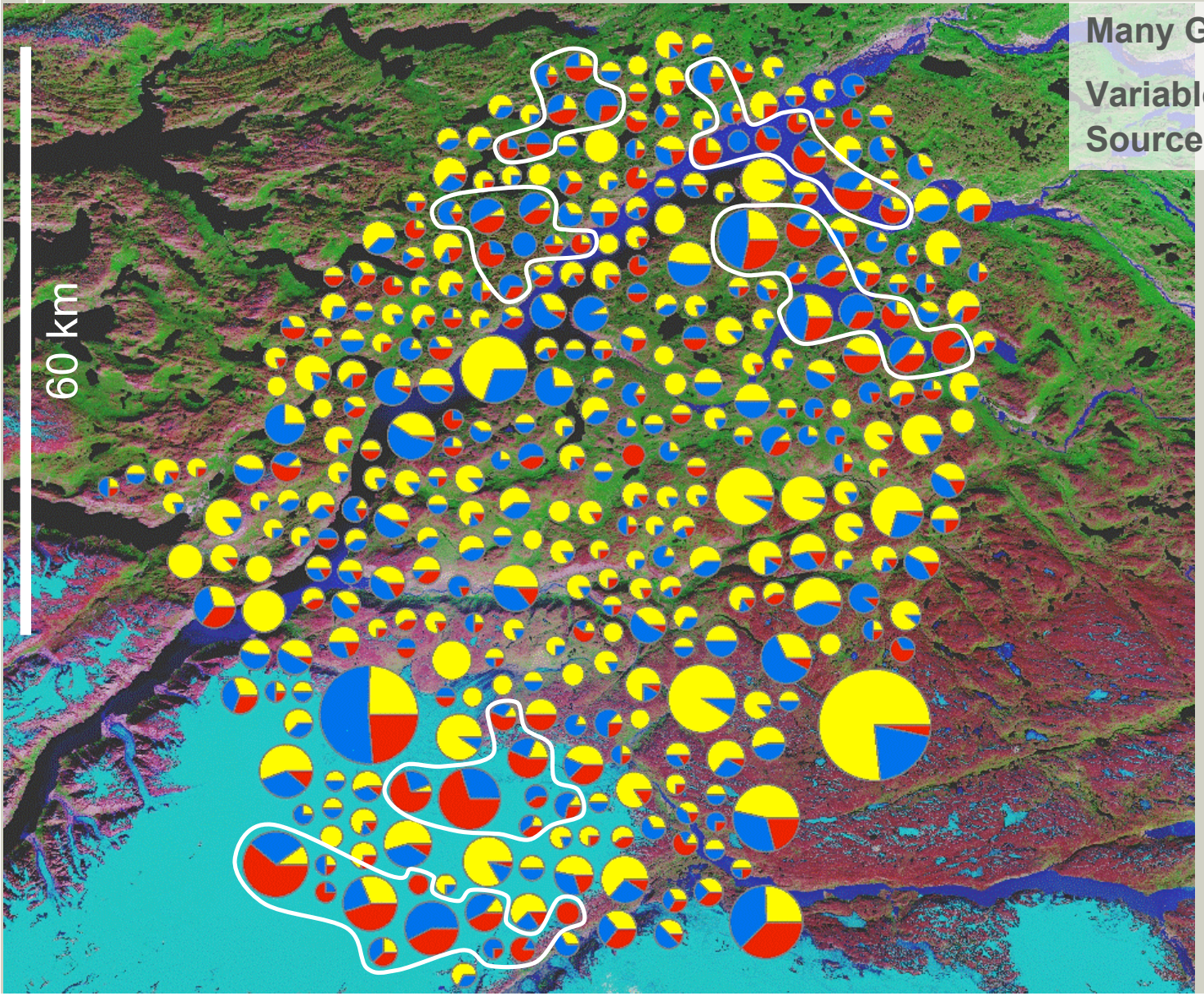
Safartoq deep mantle tenure; ≥ 4 garnets / sample



Many GSF grains (yellow)

Variable deep mantle tenure
Source-specific ♦ potential

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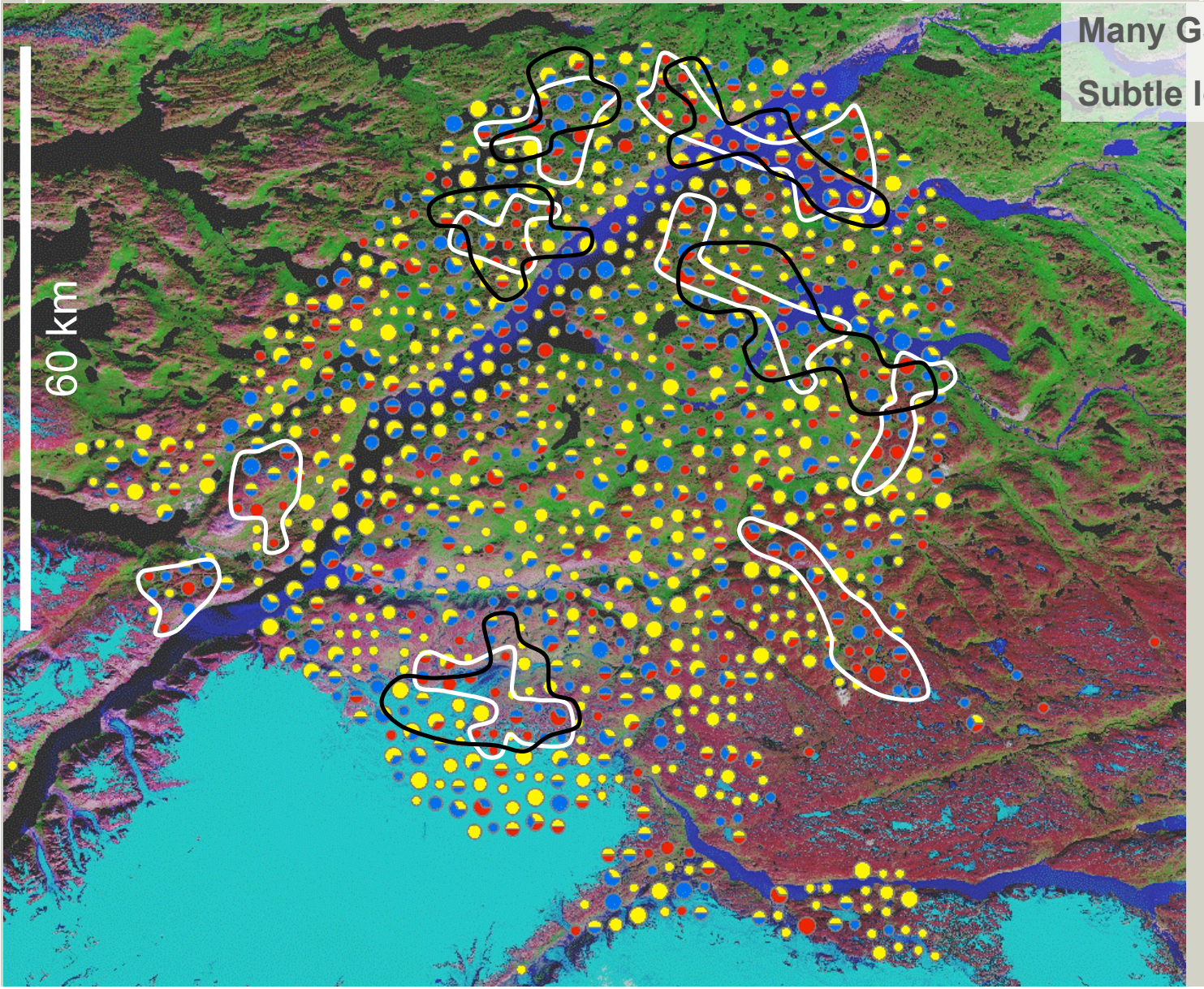
Safartoq deep mantle tenure; ≤ 3 garnets / sample



Many GSF grains (yellow)

Subtle low-count anomalies

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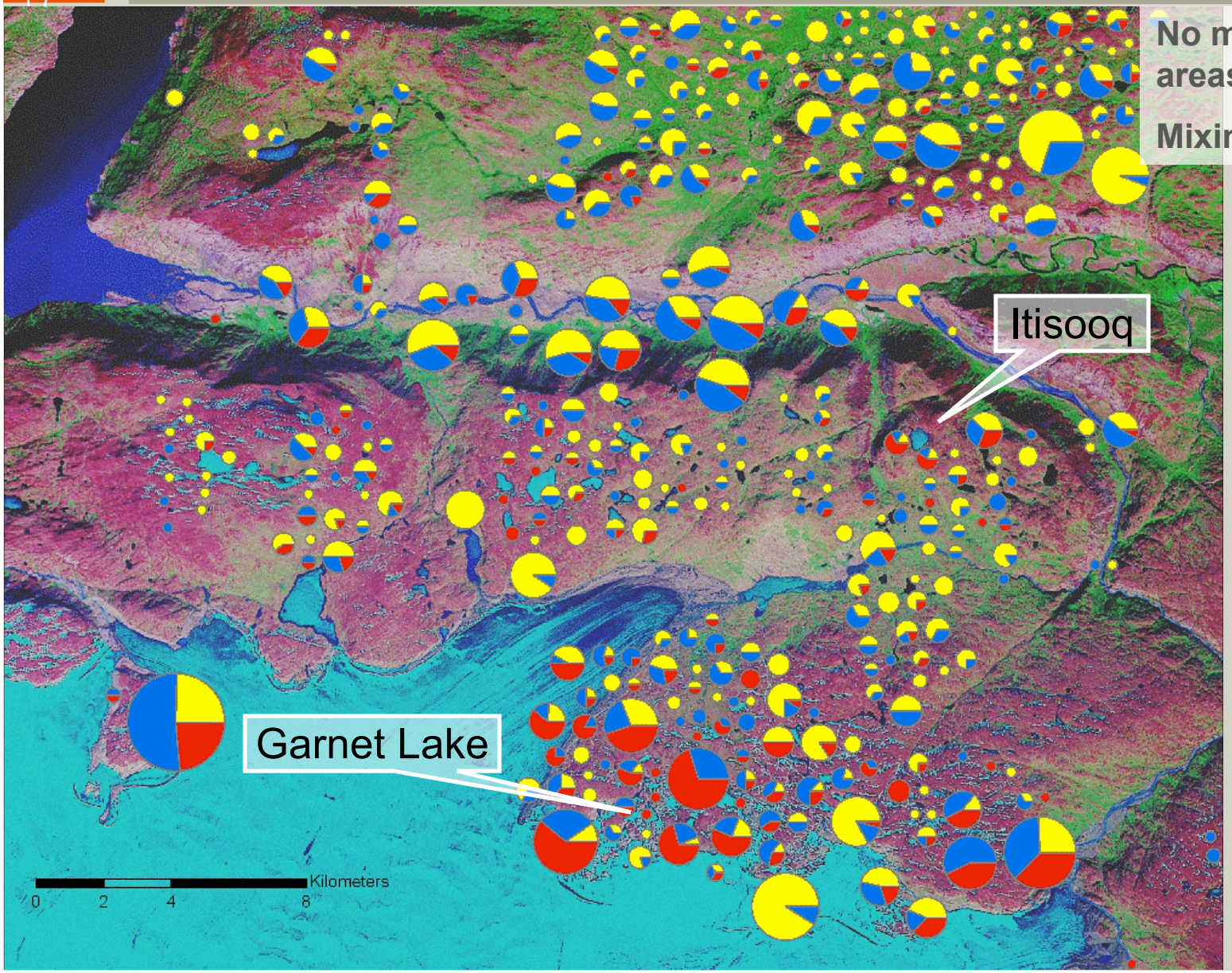
Garnet Lake focus area



No mixing in elevated areas of felsenmeer

Mixing into valleys

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Summary: Safartoq

- Cpx and garnet well preserved in cold climate
- New-age P-T techniques easily applied to high quality probe data
- ~ 6000 garnets in ~ 1500 samples sufficient to pinpoint diamond potential across property (1st phase follow-up data set)
- T-Mn applied to G10 and G9 garnets provides statistical leverage
- Very high % G10 garnets. Most are graphite-facies on a cold geotherm (T < 900°C) => substantial shallow mantle sampling
- Diamond potential related to deep mantle sampling of G10D grains
- Microdiamond results reflect highly variable diamond potential
- Bulk sampling of Garnet Lake locality (Hudson Resources)

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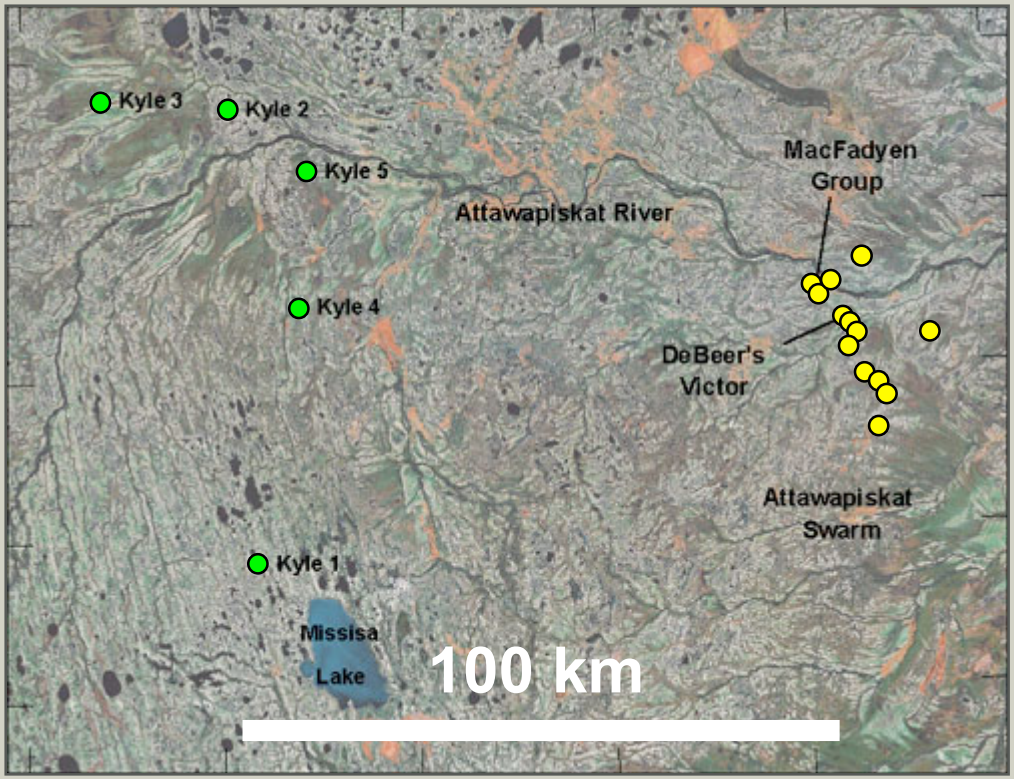
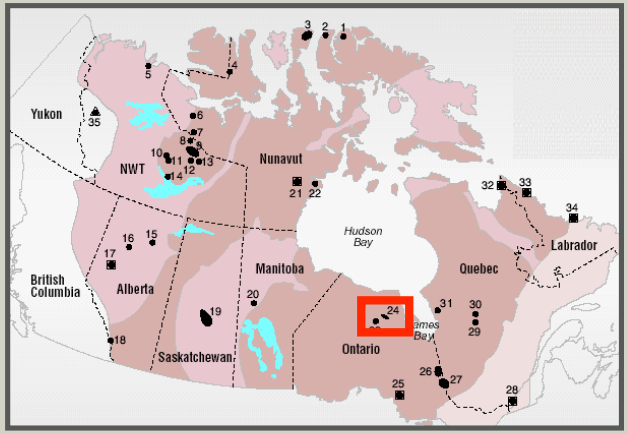
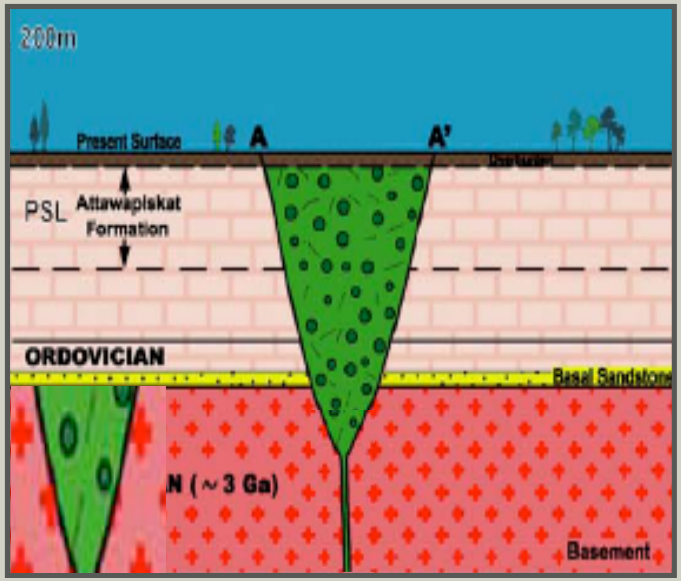
Northern Ontario kimberlites







Kimberlite Province	Rb-Sr age (Ma)	U-Pb age (Ma)
Attawapiskat	156	175-180
Kyle Lake	1123	1076

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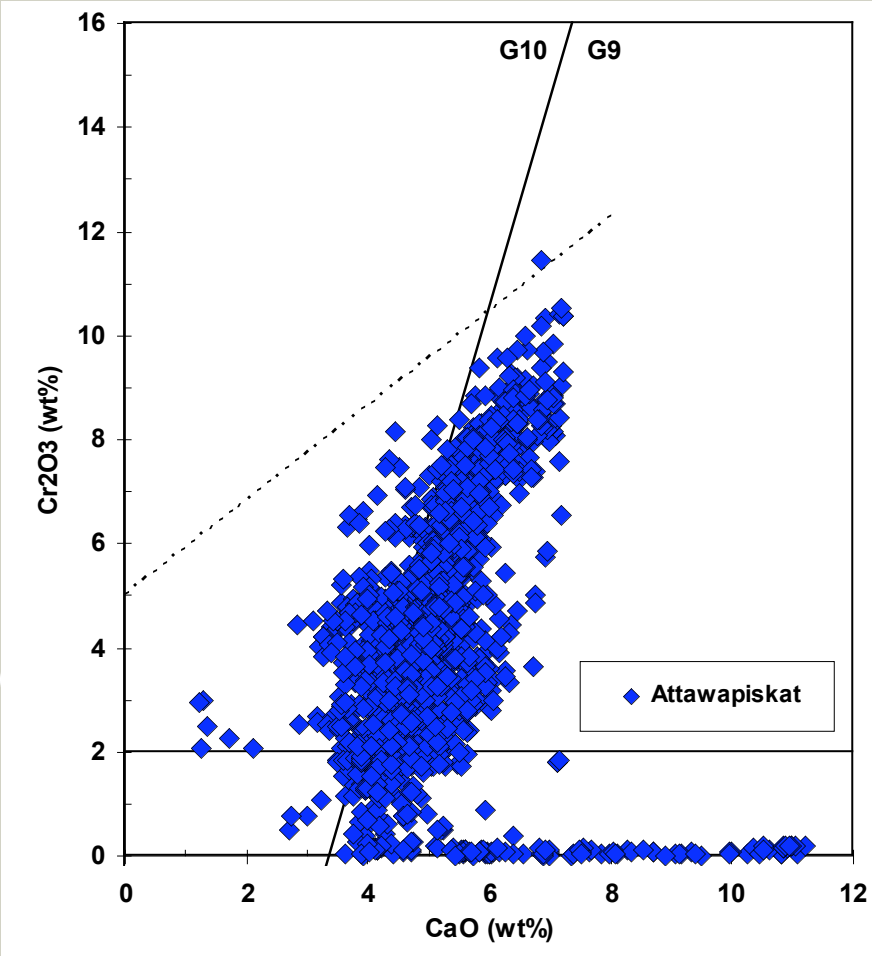
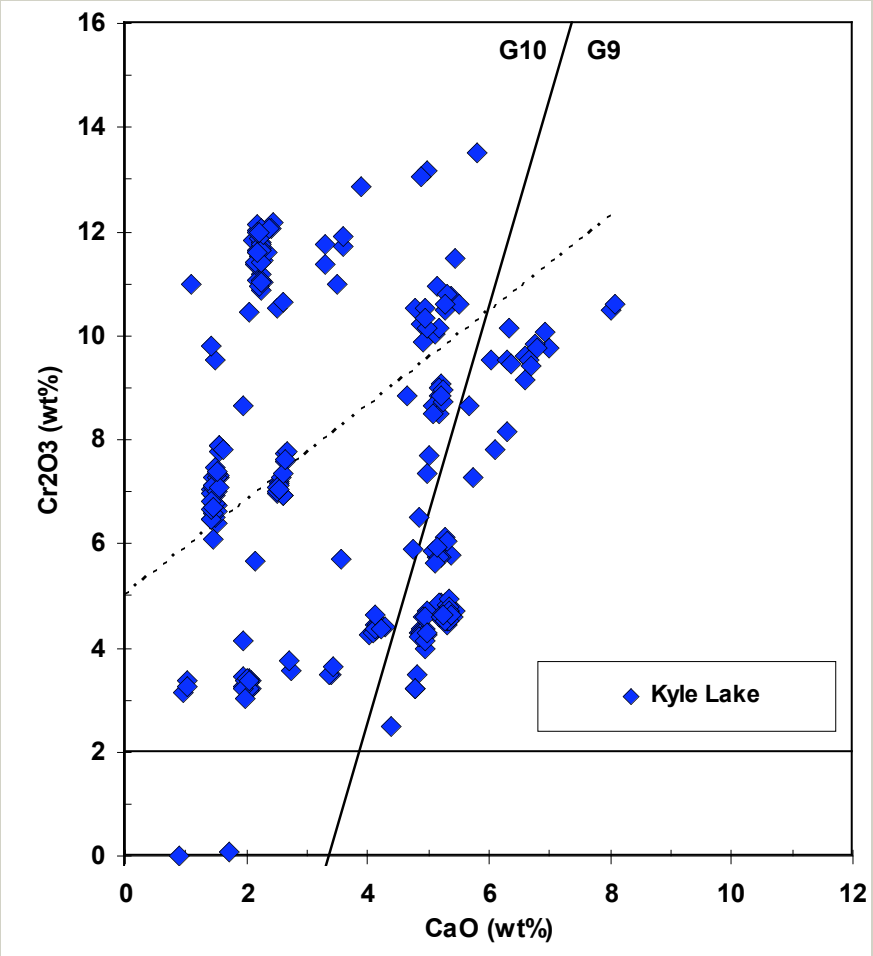
Which do you prefer ?





Attawapiskat province n = 3664

Kyle Lake 1&2 n = 250

Data from Sage (2000) OGS Open File Report 6019

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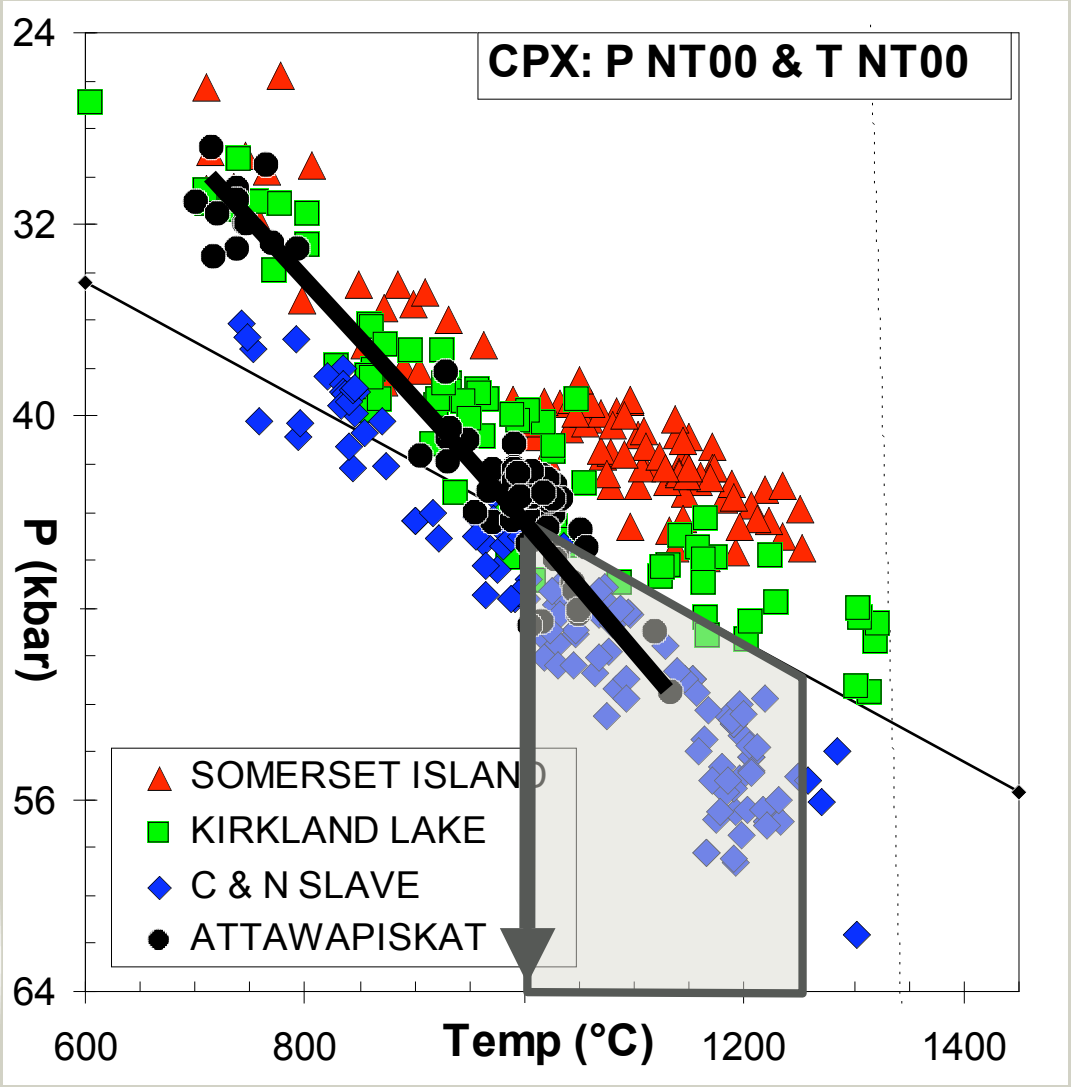
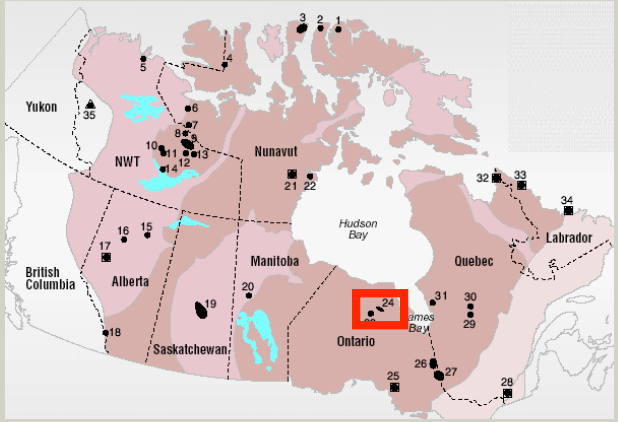
Cpx P-T: Attawapiskat, Ontario





Cpx from Victor, Charlie, Gulf & X-Ray

Geotherm is "normal" and enters DSF at T ~ 1000°C, like Kaapvaal craton

Data from Sage (2000) OGS Open File Report 6019

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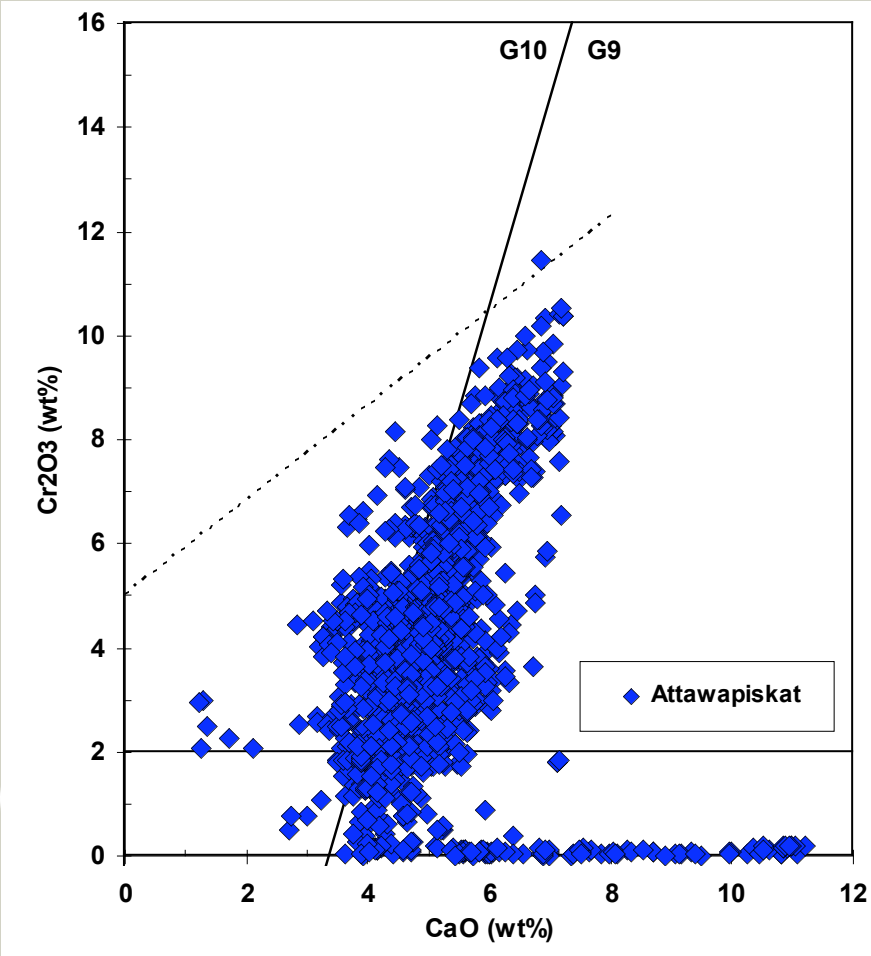
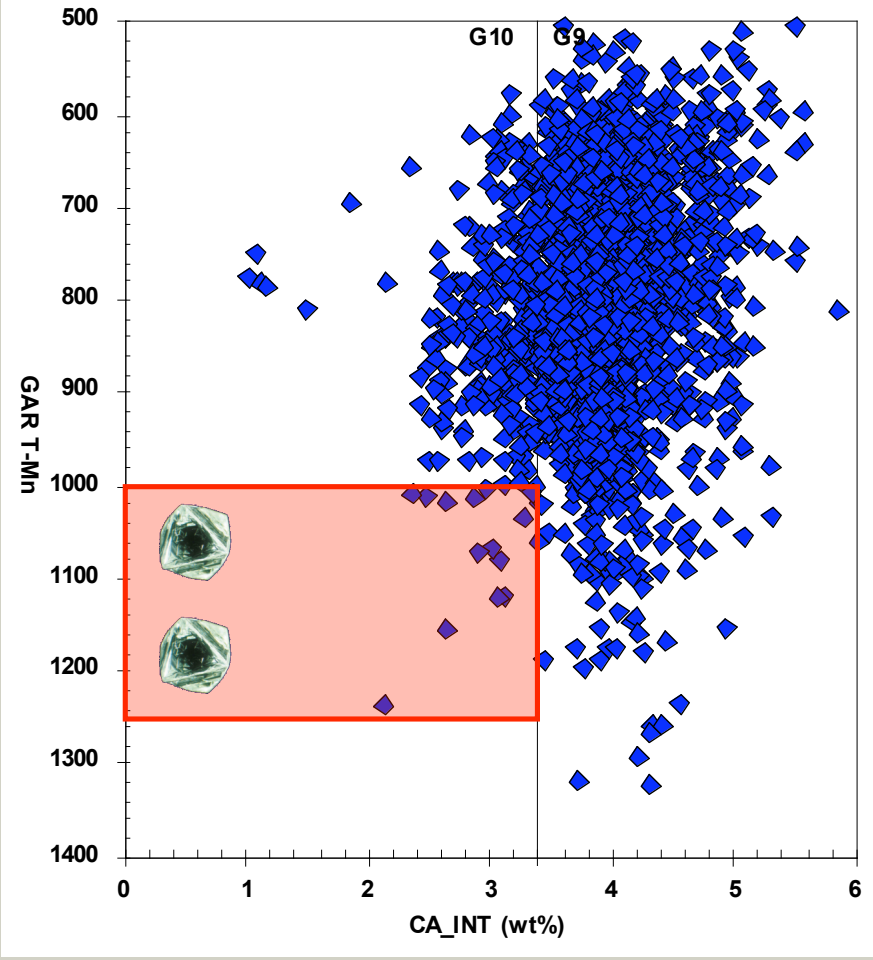
Attawapiskat garnet Cr-Ca & T-Mn





Data from Sage (2000) OGS Open File Report 6019

Normal geotherm, but very limited diamond-facies mantle sampling profile

Diamond potential decoupled from G10 grains ? - check low-Cr garnets

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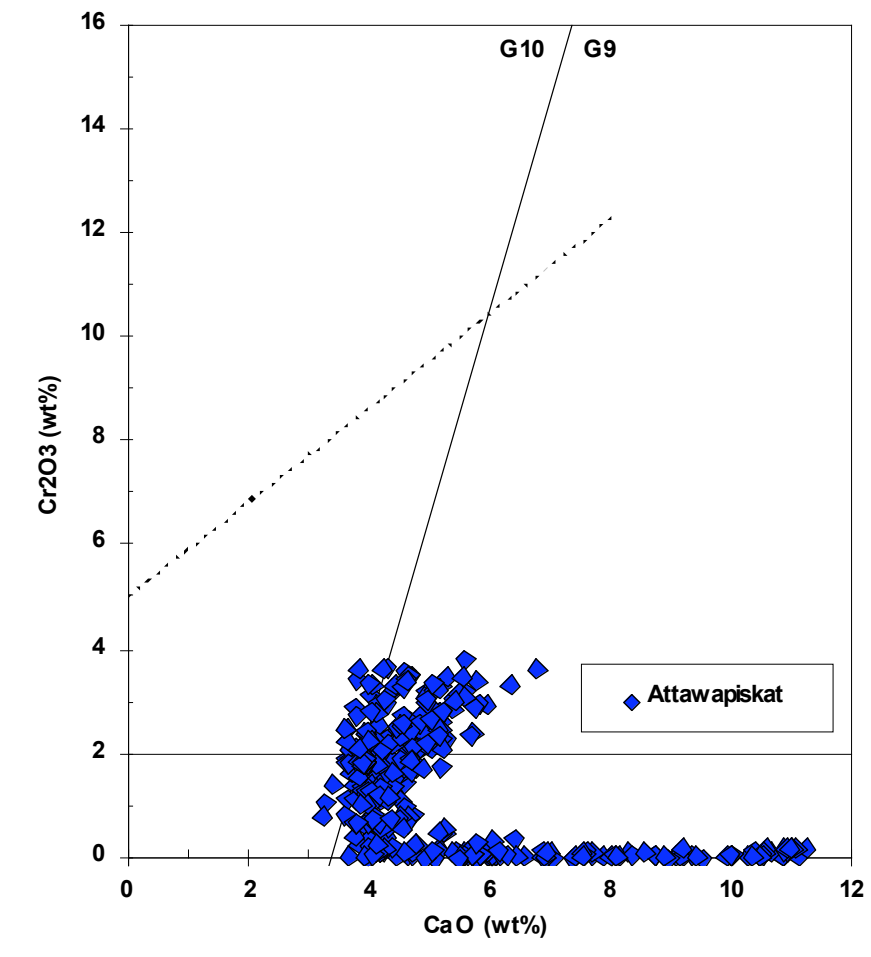
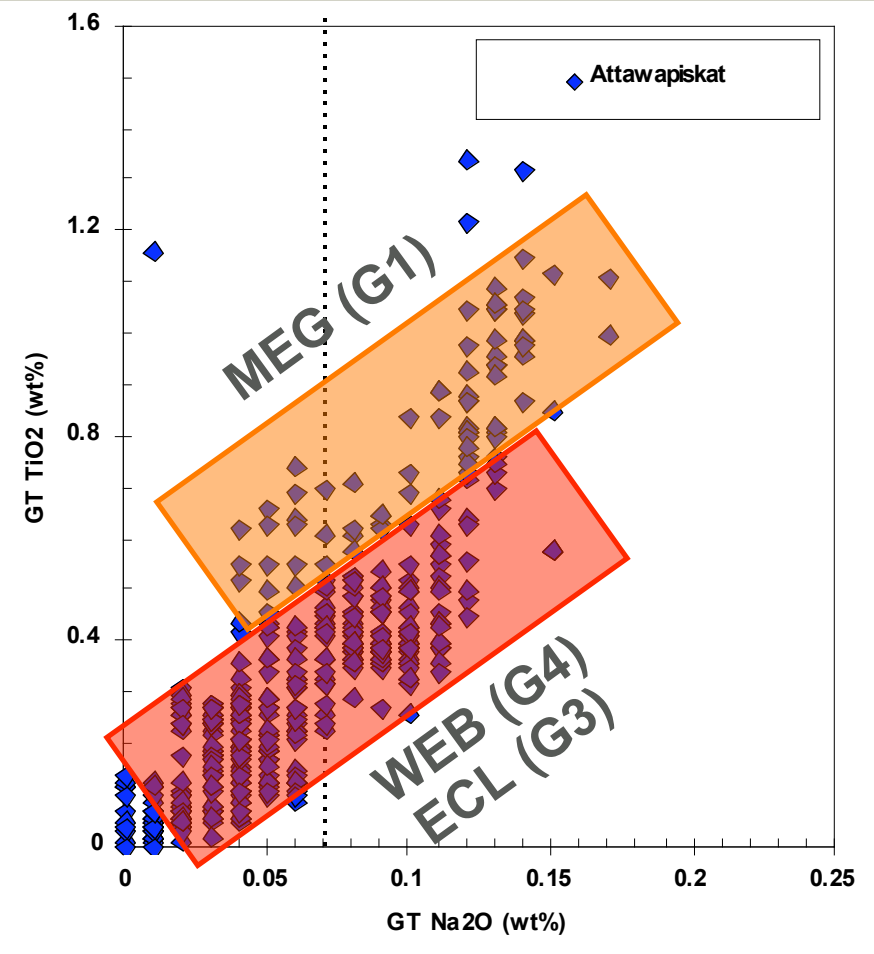
Attawapiskat low-Cr garnets





Data from Sage (2000) OGS Open File Report 6019

Diamond potential related to low-Cr eclogitic / websteritic grains
- see AT-56 interpretation (Armstrong et al. 8IKC Proc., 2004)

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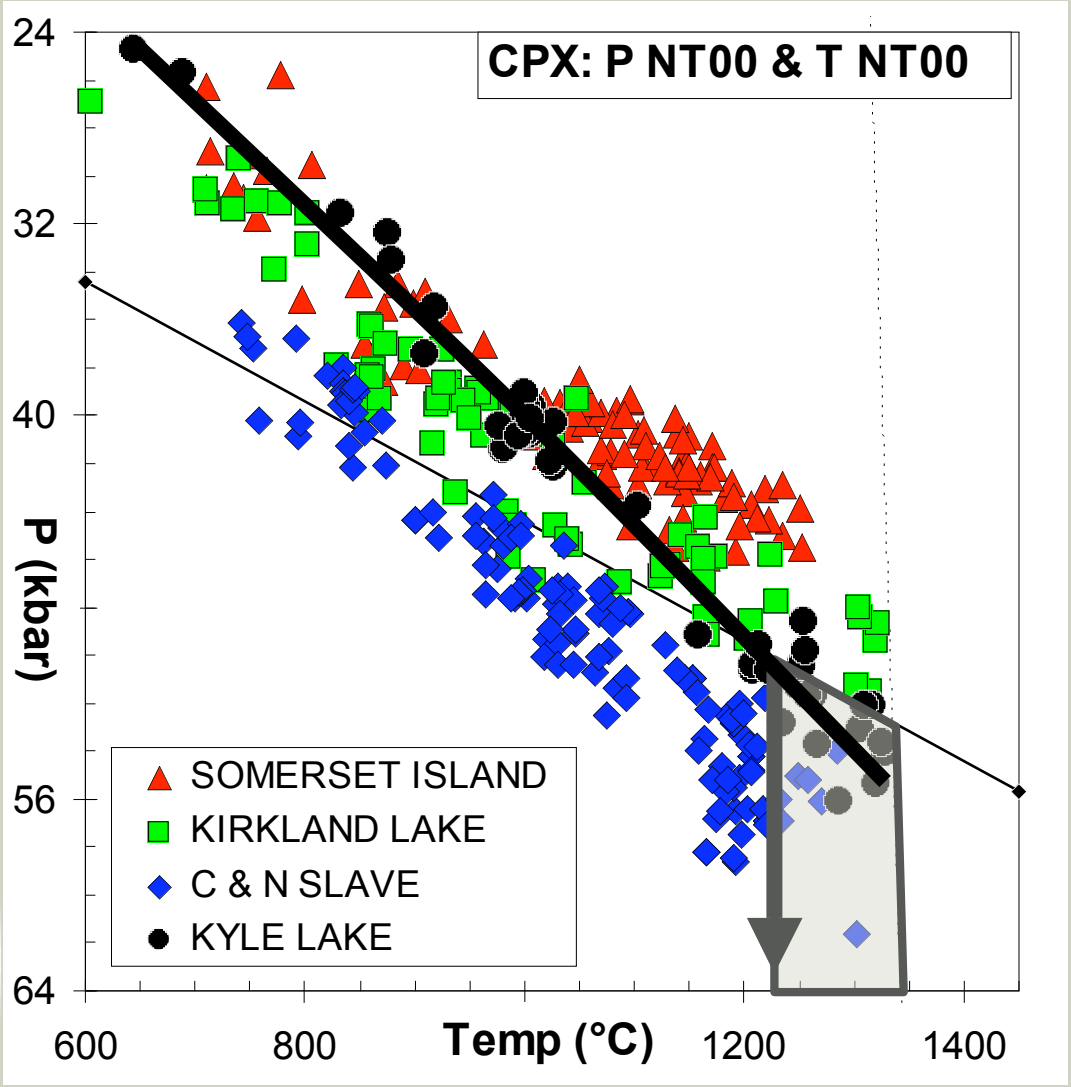
Attawapiskat summary

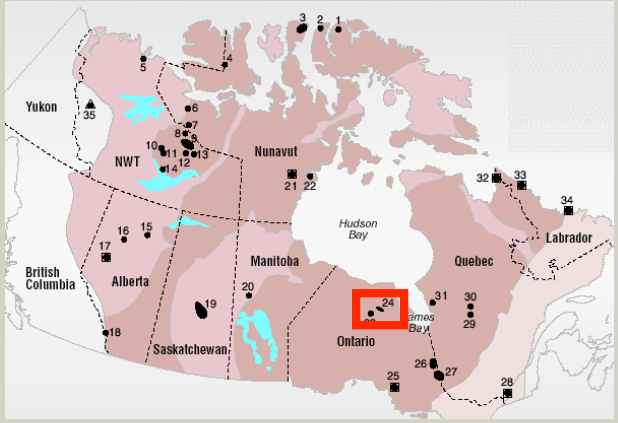
- Jurassic kimberlites cutting carbonate host rocks
- “Normal” cratonic geotherm
- “Normal” diamond window (1000 - 1250°C)
- Low % G10 garnets and most are graphite-facies
- Significant content of G3 (ECL) & G4 (WEB) garnets, with high Na_2O content – probable source of high-quality, coarse diamonds


Victor rough diamonds

Background image courtesy of De Beers Canada (with permission)

Cpx P-T: Kyle Lake, Ontario





Cpx from core samples

Elevated geotherm enters DSF at T ~ 1220°C

What is the impact of an elevated geotherm ?

Data from Sage (2000) OGS Open File Report 6019

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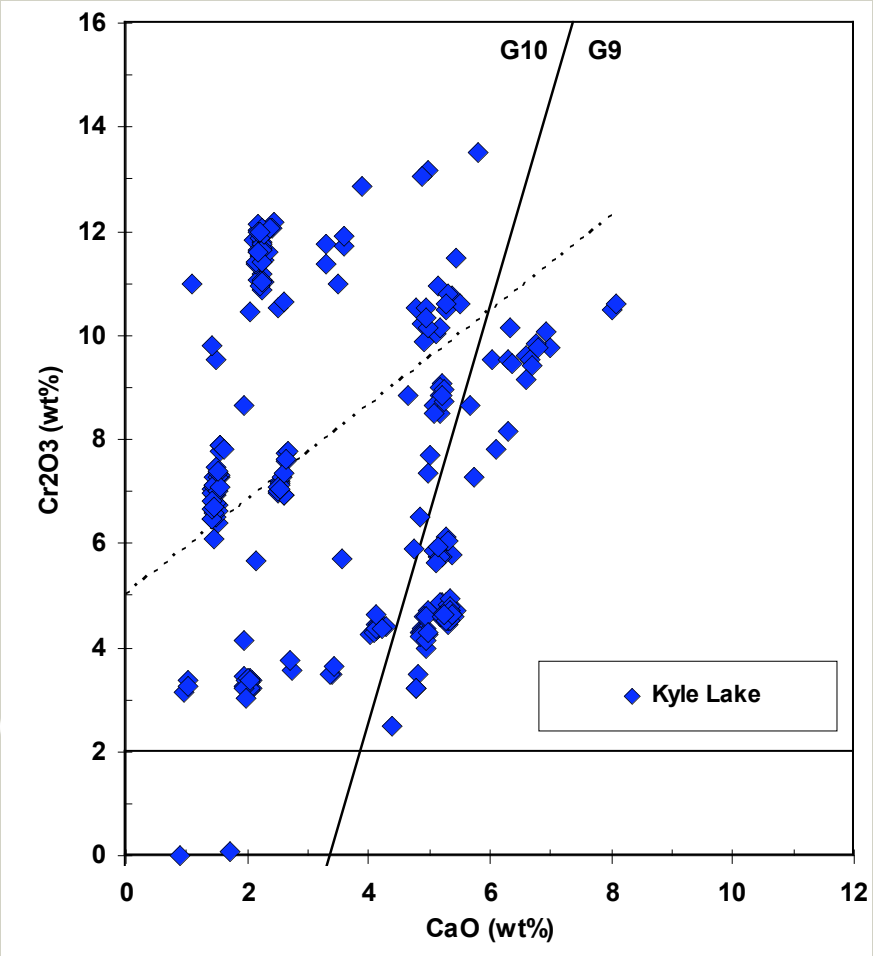
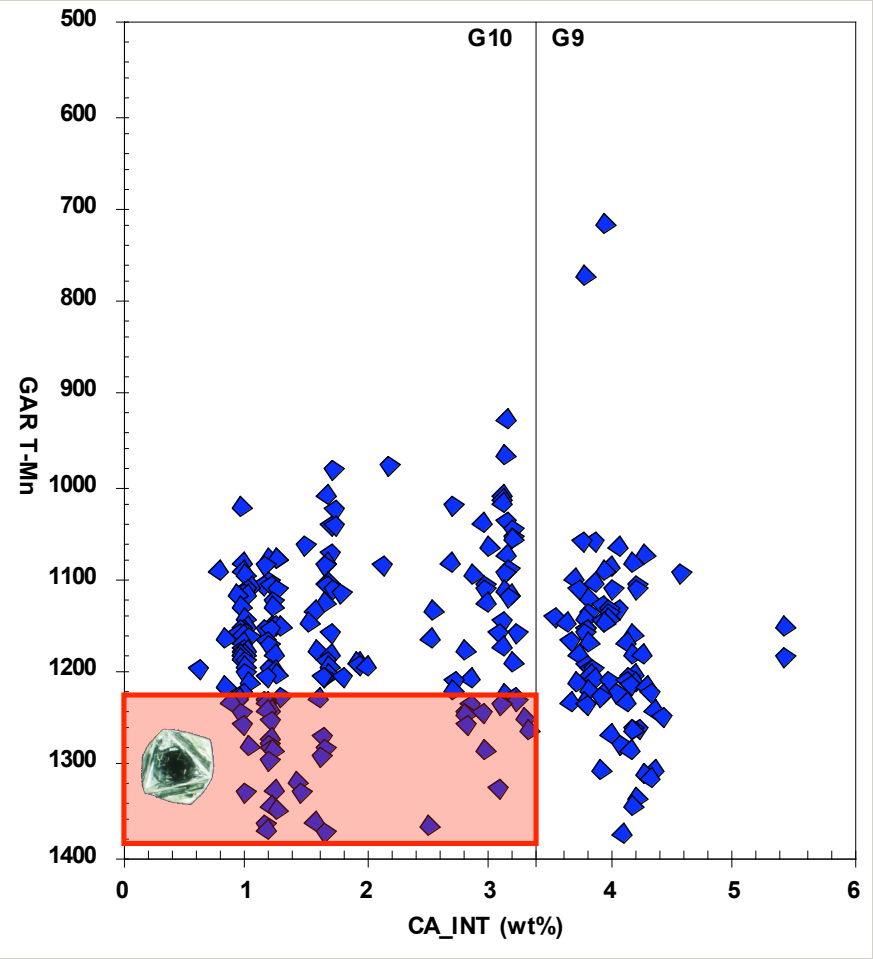
Kyle Lake garnet Cr-Ca & T-Mn





Data from Sage (2000) OGS Open File Report 6019

Deep mantle sampling profile for G10 and G9 grains

Elevated geotherm restricts diamond window

Deep eclogite could make a big difference – no low-Cr garnet data

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Summary: Kyle Lake

- Mid-Proterozoic kimberlites underlying Ordovician carbonates
- Very high % G10 garnets; all would fall inside diamond window on a normal geotherm
- Cpx data show an elevated geotherm and define a restricted, high-T diamond window (1220 - 1350°C)
- Content of low-Cr G3, G4 & G5 garnets unknown
- Microdiamonds are present
- Macrodiamond content being tested (Metalex Ventures / KWG)

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Conclusions

New-age clinopyroxene and garnet thermobarometry techniques

- Permit prioritization of indicator source(s) prior to discovery. Integrate the data streams to simplify the message
- Bring into sharp focus the mantle sampling profile and thus the likely presence / absence of diamond
- Constrain the G10-related diamond tenure. Hence highlights the relative importance of eclogitic diamonds (low-Cr association)

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Thank You
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