

## Emerald in Canada

L.A. GROAT AND H.L.D. NEUFELD

University of British Columbia, Vancouver, Canada  
(lgroat@eos.ubc.ca; hneufeld@eos.ubc.ca)

Four emerald localities have been described in Canada to date. At the Taylor 2 occurrence, near Dryden, Ontario, beryl occurs in a "zone of mixing" between two limbs of a pegmatite dike consisting of relict K-feldspar crystals in a matrix of albite, biotite, and tourmaline. The beryl occurs as euhedral crystals up to  $2.3 \times 1.8$  cm in size proximal to the relict feldspar crystals. Most are opaque white to pale green, but approximately 10% of the crystals are emerald green in colour. EMP analyses show up to 0.47 wt.%  $\text{Cr}_2\text{O}_3$ , 0.05 wt.%  $\text{V}_2\text{O}_5$ , and 0.50 wt.% FeO.

Crystals of deep-green emerald have been described from Red Mountain near Stewart in British Columbia. These occur as small opaque crystals with numerous fractures in narrow quartz-calcite-pyrite veins cutting volcanoclastic rocks adjacent to a quartz-monzonite intrusion. EMP analyses show 1612 ppm V, 1.04 wt.% FeO, and no detectable Cr.

At the Tsa Da Glisza property in the southern Yukon Territory, emerald mineralization is associated with quartz-tourmaline veins and aplite dikes which intrude mafic metavolcanic rocks. Pale to dark green beryl crystals up to 4 cm in length occur in 12 zones within a  $\sim 1$  km<sup>2</sup> area. Some of the smaller crystals, and sections of larger crystals, are gem-quality. The Cr in the emerald (average 3208 ppm) is from the schist, which has an average Cr content of 960 ppm. The source of the Be is a two-mica S-type granite pluton with 9.8-13.2 ppm Be which underlies the occurrence.

At the Lened property in the western NWT pale to dark green emerald crystals typically 2 cm  $\times$  3 mm occur in quartz-carbonate veins which extend perpendicularly from a thrust fault and cut a skarn assemblage. EMP analyses of the emeralds show up to 0.5 wt.%  $\text{V}_2\text{O}_5$  and 0.04 wt.%  $\text{Cr}_2\text{O}_3$ . The probable source of Be is the Lened stock with up to  $\sim 8$  ppm Be, and the source of the V is the black shale footwall unit, with  $>3,000$  ppm V.

## Distribution and geochemistry of gem tourmaline-bearing pegmatites in western Maine

M.A. WISE

Department of Mineral Sciences, Smithsonian Institution,  
Washington, D.C. 20560 (wise.michael@nmnh.si.edu)

Since the discovery of tourmaline in North America in 1820, Maine has been one of two primary sources of gem-quality tourmaline in the United States. These gemstones are found in granitic pegmatites of the LCT (*Li, Cs, Ta*) affinity believed to have been derived from S-type granites of Devonian to Permian age. The Rumford and Sebago pegmatite groups of the Oxford pegmatite field contain differentiated pegmatite bodies that carry significant gem-quality tourmaline. Gem grade tourmaline typically occurs in pegmatites with marginal to significant Li mineralization (i.e., spodumene, petalite or lepidolite) and is found largely in cavities within cleavelandite-rich intermediate zones or replacement units. Gem tourmaline crystals are typically shades of green, although locally some pink varieties do occur. In the Rumford pegmatite group, only the Newry pegmatite swarm is well-known for green, pink, and occasionally watermelon variety of gemmy tourmaline. By comparison, gem tourmaline is more common in the eastern and northeastern portions of the Sebago pegmatite group, but absent in the western part.

EMPA data for green and pink tourmalines show compositions that are predominantly elbaite, but with a minor rossmanite component. Overall, X-site vacancies range from 0.06-0.48 apfu for elbaite. Na is always greater than Ca in all tourmalines examined and most contain almost no Ca. Most gem tourmaline contain low Mg, moderate to low Fe and Mn, and high F contents. Chemical data for rock forming and accessory minerals in the gem-bearing pegmatites demonstrate moderate to high degrees of fractionation: e.g., K-feldspar [*K/Rb* 19-146]; muscovite [*K/Rb* 10-82]; beryl [*Na/Li* 0.8-6.6]; garnet [*Mn/(Mn+Fe)* 0.14-0.69] and columbite-tantalite [*Ta/(Ta+Nb)* 0.04-0.93]. The level of rare element enrichment observed in the Maine gem pegmatites is consistent with similar pegmatites hosting gem tourmaline found in other parts of the world.

## A new geochemical tool to separate basaltic from metamorphic blue sapphires

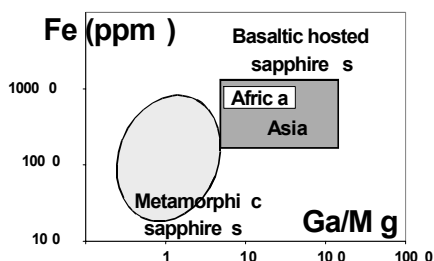
J.J. PEUCAT<sup>1</sup>, P. RUFFAULT<sup>1</sup>, E. FRITSCH<sup>2</sup>, C. SIMONET<sup>2</sup>,  
B. LASNIER<sup>2</sup> AND M. BOUHNİK-LE COZ<sup>1</sup>

<sup>1</sup>Géosciences Rennes, 35042 Rennes Cedex, France  
(peucat@univ-rennes1.fr)

<sup>2</sup>IMN Université de Nantes, 44322 Nantes Cedex 3, France  
(fritsch@cnrns-imm.fr)

Attempts to separate metamorphic from basaltic blue sapphires have been done so far combining five elements : Fe, Ti, Cr, V and Ga. We demonstrate that magnesium (determined by ICPMS-LA) in combination with iron and gallium, is a more efficient discriminant (Fig. 1). Blue-sapphires from alkali-basalts are medium-rich to rich in Fe (2000 to 11000 ppm) and Ga (100 to 300 ppm) and low in Mg (generally < 10 ppm), with Ga/Mg ratios often >10. Metamorphic blue-sapphires have variable iron contents (300 to 5000 ppm), low Ga contents (<100 ppm), but high Mg values (30 to 250 ppm) with Ga/Mg ratios <3.

Figure 1: Fields representing basaltic and metamorphic blue sapphires in the Fe vs Ga/Mg diagram.



## Painite (CaZrBa<sub>9</sub>O<sub>18</sub>): A second source in Myanmar and Metasomatic Origins

G.R. ROSSMAN<sup>1</sup>, S. NAUNG<sup>2</sup>, G.E. HARLOW<sup>3</sup>  
AND J. HUNT<sup>1,3,4</sup>

<sup>1</sup>Div. Geological & Planetary Sciences, California Institute  
Tech., Pasadena, CA 91125-2500 (grr@gps.caltech.edu)

<sup>2</sup>Mogok, Myanmar (drsaw@myanmar.com.mm)

<sup>3</sup>Dept. Earth & Planetary Sciences, Amer. Museum Natural  
History, NY, NY 10024-5192 gharlow@amnh.org

<sup>4</sup>Earth & Space Sciences, University of California, Los  
Angeles (jhunt@ess.ucla.edu)

Painite, CaZrBa<sub>9</sub>O<sub>18</sub>, is a rare mineral that was previously known only as crystals from the vicinity of Ongaing village in the Mogok Stone Tract, Mandalay district, northern Myanmar. Specimens of the orange-red to brownish-red painite from Ongaing number at least thirteen. It has now been found as slightly water worn crystals among alluvial spinel, corundum and zircon from Namya (Nanyaseik), Kachin State, some 300 km to the northwest of Mogok. Minor elements observed in EMP and XRF analyses of all painites include Ti, V, Cr, Fe and Hf. Inclusions within painite include liquid CO<sub>2</sub>, srilankaite [(Ti,Zr)O<sub>2</sub>], baddeleyite (ZrO<sub>2</sub>), a CaAl-silicate, and calcite.

The new crystals purchased in Namya, 50 km NW of Mogaung, are pale pink and dichroic from pale orangish-pink to nearly colorless. Painite from Namya is fluorescent under UV light. CL shows both planar and irregular growth zoning on a scale of <10 μm banding.

Cr and V control the red to brown coloration in all samples and produce optical absorption bands near 398, 455 and 550 nm. The Namya material analyzed to date contains nearly an order of magnitude lower concentration of these elements and is proportionally less intensely colored. Crystals from both localities share a distinctive Raman spectrum.

The Mogok and Namya deposits, known for rubies (corundum), are sourced from the marbles of the Mogok Belt, interpreted as late Proterozoic limestones that have experienced various metamorphic events as late as Oligocene intrusions and metasomatism. The corundum's origin is ascribed either to paleosols that were Fe<sup>2+</sup>-depleted by metasomatism or to Si-depletion metasomatism followed by Ca-reaction metasomatism. Painite is consistent with these models that yield refractory oxides and calc-silicate overgrowths.

## Geochemical study of the Kimmirut sapphire occurrence, Baffin Island, Canada

A.M. CADE, G.M. DIPPLE, AND L.A. GROAT

Dept. of Earth & Ocean Sciences, UBC, 6339 Stores Road,  
Vancouver, BC V6T 1Z4 Canada (acade@eos.ubc.ca)

In 2002 gem-quality corundum (sapphire) was found 1.5 km to the southwest of Kimmirut, Nunavut, on Baffin Island. The sapphire is hosted by calc-silicate lenses within the Paleoproterozoic Lake Harbour Marble unit. The sapphire appears to have formed in one of two ways; isochemically from retrograde alteration of the protolith minerals or during hydrothermal alteration of the assemblage. Constraining the method of formation will aid with formulation of guidelines for further exploration.

Change-of basis analyses were performed on whole rock geochemical data from 5 samples using MatLab to identify valid prograde metamorphic assemblages (protolith) and retrograde metamorphic assemblages (alteration) and to determine if corundum could be formed isochemically during these reactions. The results indicate that isochemical formation of corundum is valid with a protolith assemblage of diopside, calcite, phlogopite, anorthite, albite and KNa-1 exchange reacting to form an alteration assemblage of diopside, meionite, marialite, nepheline, kalsilite and corundum. Further petrographic and geochemical examination will help to further our understanding of this occurrence.

## Toward a geochemistry of opals

E. GAILLOU<sup>1</sup>, B. RONDEAU<sup>2</sup>, E. FRITSCH<sup>1</sup>, M. BOUHNİK –  
LE COZ<sup>3</sup>, G. CORNEN<sup>4</sup> AND M. OSTROUMOV<sup>5</sup>

<sup>1</sup>Institut des Matériaux Jean Rouxel (I.M.N.), L.P.M.N., 2 rue de la Houssinière, B.P. 32229, F-44322 Nantes Cedex 3, France (Emmanuel.Fritsch@cnsr-imm.fr)

<sup>2</sup>Museum National d'Histoire Naturelle, Laboratoire de Minéralogie, 61 rue Bouffon, F-75005 Paris, France (rondeau@mnhn.fr)

<sup>3</sup>Laboratoire de Géochimie, Bâtiment 14B C.A.R.E.N. Géoscience Rennes, av. du GI Leclerc, F-35042 Rennes, France Cedex (martine.bouhnik-le-coz@univ-rennes1.fr)

<sup>4</sup>Laboratoire de Planétologie et Géodynamique, U.F.R. des Sciences et des Techniques, 2 rue de la Houssinière, B.P. 92208, F-43222 Nantes Cedex 3, France (Guy.Cornen@sciences.univ-nantes.fr)

<sup>5</sup>Universidad de Michoacan de San Nicolas de Hidalgo, Ciudad universitaria, Apartado postal 52B, C.P. 58000 Morelia, Michoacan, Mexico (ostroum@zeus.umich.mx)

Opal, in particular gem opal, is a geological marker of certain specific sedimentary and volcanic environments. It has a great variety of appearance and of micro- and nanostructures. Physical properties have been investigated in detail but the role of impurities and trace elements has not been much tackled, although opal is a fairly common form of silica. The aim of this study is to investigate what those elements could teach us about the way opals form, and if they have an influence on certain physical properties, such as vibrational or luminescence characteristics. 47 opals coming from 20 mines in 7 countries (Mexico, Brazil, Peru, Honduras, Ethiopia, Slovakia and Australia) have been analysed by ICPMS in order to determine impurities and trace elements. They range from common to play-of-color opals, opal-A to -CT, and sedimentary to volcanic opals. Impurities are essentially Al, with minor amount of Fe, Na, Mg, K or Ca. Trace elements found are essentially Mn, Zn, Rb, Sr, Y, Ba, Pb, Th, U, Ni and REE. There is a greater variety and concentration of trace elements in colored opals than in colorless ones. The yellow to "chocolate brown" color is correlated with Fe concentration. The REE spectrum is representative of each locality (anomalies, enrichment, or depletion). REE concentrations are variable from one deposit to the next, and span from 100 times less, to 500 times more than chondritic values. This range of REE concentration is very unusual for a mineral. This sample survey seems to be very promising in the identification of the geographical/geochemical origin of opal deposits because of the differences in geochemical profile among deposit.

## Asterism in the Idaho star garnet

MICKEY E. GUNTER<sup>1</sup>, WILLIAM L. MABBUTT<sup>2</sup>,  
ELIZABETH H. MIURA<sup>3</sup> AND GEORGE R. ROSSMAN<sup>3</sup>

<sup>1</sup>Department of Geological Sciences, University of Idaho,  
Moscow, Idaho 83844-3022, U.S.A.  
(mgunter@uidaho.edu)

<sup>2</sup>Gem State Crystals, 404 South Main Street, Moscow, Idaho  
83843, U.S.A.

<sup>3</sup>Division of Geological and Planetary Sciences, California  
Institute of Technology, Pasadena, California 91125-2500,  
U.S.A.

The Idaho star garnet occurs 40 miles northeast of Moscow and is the state gemstone of Idaho. The cause of asterism in this unique gemstone is not thoroughly understood. Figure 1 shows photographs of a 40 cm polished sphere of star garnet in different orientations: (A) shows a 6-ray star observed down a 2-fold axis and (B) shows a 4-ray star observed down a 4-fold axis. We found the asterism was produced by linear inclusions aligned along the four [111] directions (Figure 2).

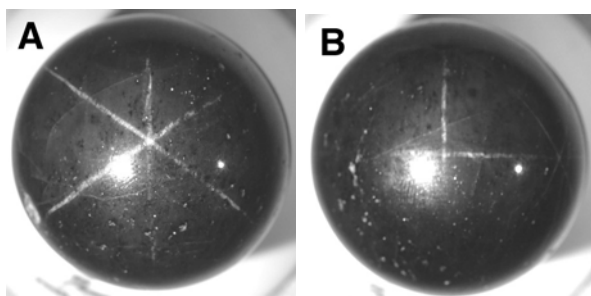


Figure 1.

Figure 2 shows photomicrographs (approximate field of view 10 microns) of inclusions matching the orientations in Figure 1. Two of the inclusions in Figure 2A are in the plane of projection, while the horizontal one is inclined to it, as are both of the inclusions in Figure 2B. These inclined inclusions produce weaker asterism, as shown in Figure 1.

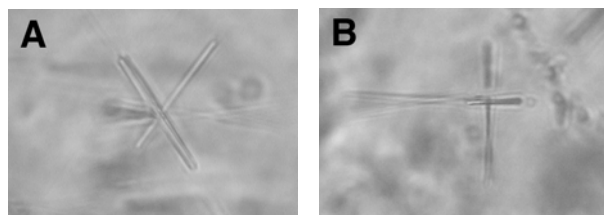


Figure 2.

Raman spectroscopy revealed some of the inclusions are voids and others are rutile.

## Sapphires from Kimmirut, Baffin Island, Nunavut, Canada

A.N. LECHEMINANT<sup>1</sup>, L.A. GROAT<sup>2</sup>, J.K. MORTENSEN<sup>2</sup>,  
P. GERTZBEIN<sup>3</sup>, AND W. ROHTERT<sup>4</sup>

<sup>1</sup>Petrogen Consultants, Manotick, Ontario, Canada  
(tony\_lecheminant@rogers.com)

<sup>2</sup>University of British Columbia, Vancouver, Canada  
(lgroat@eos.ubc.ca; jmortensen@eos.ubc.ca)

<sup>3</sup>Department of Indian Affairs and Northern Development,  
Iqaluit, Nunavut, Canada (gertzbeinp@inac-ainc.gc.ca)

<sup>4</sup>True North Gems Inc., Vancouver, British Columbia, Canada  
(william.rohert@gte.net)

Recently, gem-quality blue and yellow sapphires were discovered near Kimmirut on the south coast of Baffin Island. The original "Beluga" occurrence contains deep blue sapphires with violet overtones. Single crystals up to 7.7 x 2.1 cm have been recovered. Most sapphires are color-zoned, and may display concentric, irregular, or end-to-end variations in hue. EMP analyses of 10 sapphires yielded maximum TiO<sub>2</sub> and FeO values of 0.13 and 0.30 wt.%, respectively. The dominant chromophore in yellow sapphires from "Beluga South" is iron, with up to 0.04 wt.% FeO.

Sapphires are hosted by calc-silicate lenses in a marble unit of the metasedimentary Lake Harbour Group, near a major terrane boundary within the 1.8 Ga Trans-Hudson Orogen. Beluga sapphires occur with plagioclase, clinopyroxene, phlogopite, muscovite, calcite, graphite, nepheline and scapolite. Accessory minerals are apatite, rutile, titanite, and zircon, and rare phases include chlorite, dravite, monazite, sanbornite, thorianite, and uraninite. This diverse mineral suite formed during retrograde metamorphism accompanied by multi-stage fluid infiltration. A U-Pb zircon age of 1783 Ma indicates P-T conditions during zircon formation were < 710°C and 6 kbar, the regional P-T conditions at the end of terminal continental collision in Trans-Hudson Orogen at 1795 Ma. The tectonic setting is analogous to gem-producing areas within the India-Asia collision zone. South Baffin also hosts other gem minerals in complexly deformed, high-grade metamorphic rocks. These include diopside, pargasite, garnet, spinel, scapolite, tourmaline, apatite, zircon, moonstone, and lapis lazuli.

## Trace element geochemistry of gem beryl

C.E. MCMANUS<sup>1</sup>, F. DE LUCIA<sup>2</sup>, R. HARMON<sup>2</sup>,  
N.J. MCMILLAN<sup>1</sup> AND R. WHITMORE<sup>3</sup>

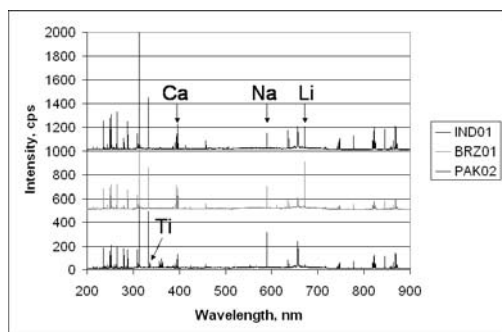
<sup>1</sup>Geological Sciences, New Mexico State University, BOX 3001, MSC 3AB, Las Cruces, NM 88003

<sup>2</sup>Weapons and Materials Research Directorate, U.S. Army Research Laboratory, Aberdeen Proving Ground, Aberdeen, MD 21005

<sup>3</sup>Palermo Mining Company, Weare, NH 03281

Trace element concentrations of minerals are a reflection of fluid source (e.g. magma, metamorphic, hydrothermal, or sea water). This pilot study examines the use of trace element variation of gem beryl to determine gem provenance.

Trace element variations of gem beryl from four zones of two pegmatites from the Palermo district, North Groton, New Hampshire, USA, are compared to each other and to nine other gem beryl localities worldwide (Afghanistan, Antarctica, Brazil, China, India, Mozambique, Namibia, New Mexico, Pakistan). LIBS (Laser Induced Breakdown Spectroscopy) and LA-ICP-MS analyses provide complementary data. LIBS is a simple, real-time, and potentially portable analysis tool that requires no sample preparation. In LIBS, a pulsed laser is used to generate a high-temperature plasma on a sample surface; the visible emission spectrum from the plasma is captured and resolved. In this study, qualitative LIBS spectra are calibrated by quantitative ICP-MS analyses.



Trace element variations in beryl are complex and unique to locality, as seen in the three LIBS spectra below (aquamarines from India, Brazil, and Pakistan).

## Mineralogical and geochemical study of the True Blue aquamarine showing, Shark property, southern Yukon

DAVID J. TURNER<sup>1</sup>, LEE A. GROAT<sup>1</sup> AND  
WILLIAM WENGZYNOWSKI<sup>2</sup>

<sup>1</sup>Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, British Columbia V6T 1Z4 (dturner@eos.ubc.ca, lgroat@eos.ubc.ca)

<sup>2</sup>Archer, Cathro & Associates (1981) Limited, 1016 - 510 West Hastings Street, Vancouver, B.C. V6B 1L8

The True Blue aquamarine occurrence in the Quiet Lake area of southern Yukon is underlain by Paleozoic Cassiar Platform miogeoclinal clastic and carbonate rocks, a Mississippian syenite stock, and Mississippian felsic metavolcanic rocks (Pelly Mountain Volcanic Belt). Evolved Cretaceous granite bodies are regionally present; however none have been recognized within the property limits. Beryl occurs in quartz veins and tension gashes and is restricted to those that cut the syenite. Accessory minerals in the quartz veins include varying amounts of fluorite, siderite, calcite, allanite and ilmenite. Mineralization has been dated as Mid-Jurassic ( $172 \pm 5$  Ma) using the Sm-Nd system on fluorite from several veins. This age suggests that mineralization is unrelated to the intrusion of the Mississippian syenite and a buried Cretaceous intrusion should not be invoked to explain the beryl mineralization. Previous studies have constrained major regional thrusting in the Pelly Mountains to have occurred between Late-Triassic and Late-Cretaceous, suggesting a link between beryl mineralization and metamorphic fluids. Aquamarine discovered on the property is distinctive because of its deep blue colour and high  $\text{Fe}^{+2}$  concentration, up to 5.92 wt.% FeO.

## $\delta^{13}\text{C}$ of carbon dioxide in ancient air from ice core samples

J.V. LAVRIC<sup>1</sup>, J.-M. BARNOLA<sup>1</sup>, J. CHAPPELLAZ<sup>1</sup>,  
M.C. LEUNBERGER<sup>2</sup>, H. FISCHER<sup>3</sup> AND D. RAYNAUD<sup>1</sup>

<sup>1</sup> Laboratoire de Glaciologie et Géophysique de  
l'Environnement (LGGE), CNRS-UJF, BP96, FR-38402  
Saint Martin d'Hères Cedex, France  
(lavric@lgge.obs.ujf-grenoble.fr)

<sup>2</sup> Climate and Environmental Physics, Physics Institute,  
University of Bern, Sidlerstrasse 5, CH-3012 Bern,  
Switzerland

<sup>3</sup> Alfred Wegener Institute for Polar and Marine Research  
(AWI), Columbustrasse, DE-27515 Bremerhaven,  
Germany

The concentration and stable carbon isotope composition ( $\delta^{13}\text{CO}_2$ ) of carbon dioxide ( $\text{CO}_2$ ) trapped in ancient ice are essential for the reconstruction of the paleo record of greenhouse gases, the study of the global carbon cycle, and the prediction of the future climatic evolution.

At present, high-resolution ice core  $\delta^{13}\text{CO}_2$  data for larger time spans are scarce. New analytical methods are being developed with the objective to increase the time resolution (smaller sample size), to improve the accuracy of the measurements, and, particularly in clathrate ice, to optimize the extraction efficiency. The recent analytical improvements include different continuous flow setups (LGGE, University of Bern) and off-line extraction by sublimation (AWI). Thus obtained higher sensitivity to changes in the  $\delta^{13}\text{CO}_2$  record is important in view of the small variations of few tens of a per mill observed in previous studies.

The ongoing measurements are performed primarily on ice from two Antarctic drilling sites, the EPICA Dome Concordia (EDC) and Dronning Maud Land (EDML). We will present the status of  $\delta^{13}\text{CO}_2$  and associated  $\text{CO}_2$  concentrations data from ice cores with a focus on the Holocene and the recent glacial–interglacial transitions, and discuss the available constraints that they provide on the global carbon system and its past variations.