EMERALD AND OTHER GEM BERYL MINERALIZATION IN NORTHWESTERN CANADA

By Lee A. Groat and Heather L. Neufeld, Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, BC, Canada,
Daniel D. Marshall, Department of Earth Sciences, Simon Fraser University, Burnaby, BC, Canada
Hendrik Falck, C.S. Lord Northern Geoscience Centre, Yellowknife, NWT, Canada
and James K. Mortensen, Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, BC, Canada

INTRODUCTION

Emerald is green gem beryl ($Be_3Al_2Si_6O_{18}$), in which colour is related to minor amounts of contained Chromium (Cr) or Vanadium (V). Emerald is the third most valuable gemstone (after diamond and ruby) and can be worth more than US$100,000 per carat. Other gem varieties of beryl include aquamarine (blue), bixbite (red), goshenite (colourless), heliodor (yellow), morganite (pink), and rosterite (pink). Canada is not currently a producer of coloured gemstones, but this could change as a result of several exciting new discoveries in northwestern Canada. These, in turn, have prompted exploration expenditures of approximately $3 500 000 in 2003 in the Yukon Territory alone.

LENED

In 1997, an occurrence of V-dominant emerald was discovered near the mid-Cretaceous Lened pluton in the southwestern Northwest Territories. Pale to medium green emerald crystals up to 3 centimetres in length occur where quartz veins cut a garnet-diopside skarn developed from a limestone of the Rabbitkettle Formation that overlies V-rich (2070-3170 ppm) black shales of the Earn Group. The proximity of the granite suggests that it is the source of the Be, although the Be content is low (6 to 7.3 ppm), but the source of the V is undoubtedly the shale. A fluid inclusion study (Marshall *et al.*, 2004) suggests that the emerald crystals formed at temperatures of 250 to 550°C and pressures of less than 3700 bars. Questions remain about the relative timing of the skarn formation, vein emplacement, and thrust faulting.

REGAL RIDGE

In 1998 a major occurrence of emerald was discovered at Regal Ridge in the southeastern Yukon Territory in northwestern Canada. The mineralogy, geology, and origin of the occurrence are described in Groat *et al.* (2002). The mineralization is associated with quartz veins and aplite dikes that intrude metavolcanic rocks of the Yukon-Tanana Terrane. Green beryl crystals up to 4 centimetres in length are found in 12 mineralized zones within a 900 by 450 metres area. Cr averages 3208 ppm and is the predominant chromophore. Some of the smaller crystals, and sections of larger crystals, are gem-quality, and a number of small gems (up to about 2.4 carat) have been fashioned from the Regal Ridge samples.

The Yukon-Tanana Terrane in the Regal Ridge area is composed of mainly Devonian quartz-rich metaclastic rocks and carbonates, and Devonian and Mississippian metavolcanic and metaplutonic rocks that are inferred to have formed in continental magmatic arc (Mortensen and Jilson, 1985; Mortensen, 1992; Murphy and Piercey, 2000) and back-arc settings (Piercey *et al.*, 2000). The oldest rocks are in the Devonian to Mississippian Grass Lakes succession. The Fire Lake unit, a mafic metavolcanic unit composed mainly of chloritic phyllite (Murphy *et al.*, 2002), is the second-oldest unit within the succession. These rocks were thrust onto the North American miogeocline between late Triassic and earliest Cretaceous time. The Yukon-Tanana rocks are intruded by several ca. 112 Ma intrusions of the Cassiar-Anvil plutonic suite. The Tintina fault lies 14 kilometres southwest of the property.

The main host rock for the mineralization is a chlorite-plagioclase schist that is part of the Fire Lake unit (DF unit of Murphy *et al.*, 2002). Geochemical analyses show that the schist is a high-Ca boninite. The Cr in the emerald most likely came from the schist (average 960 ppm Cr). A leuco-gabbro unit (Dmi unit) is closely interfingered with the mafic schist. Variably-serpentinized ultramafic rocks occur in the western and northern parts of the map area. Murphy *et al.* (2002) suggest that these represent intrusive sills that fed the overlying DF rocks via gabbroic dikes (Dmi).

The occurrence is underlain at a depth of approximately 800 metres by a 112 Ma two-mica (biotite > muscovite) quartz monzonite, which outcrops to the east, south, and north. The intrusion, which is weakly foliated to unfoliated with shallowly dipping contacts, belongs to the Anvil plutonic suite (Mortensen *et al.*,

2000). This suite of 112-100 Ma felsic intrusions are typically rich in W, Mo, Au, and Bi. The proximity of the granite suggests that it is the source of the Be, although its Be content is low (12 to 13.2 ppm). Numerous aplite dikes from 40 centimetres to 10 metres in width occur on the property.

Quartz veins are abundant throughout the property, and the majority appears to be related to Cretaceous deformation. Early veins are typically thin, foliation-parallel, sulphide-rich, and tourmaline free. All the other quartz veins, including those that contain beryl and emerald, contain at least some tourmaline, either within the veins or in the vein selvages. The degree of alteration surrounding the veins varies from none to metre-wide rusty-weathering zones in the schist. This rustiness is likely due to weathering of finely disseminated sulphides (especially pyrrhotite) that are common in the alteration zones adjacent to the veins.

Emerald is associated with veins with several orientations. Mineralization appears to be particularly well developed where veins of the youngest generation intersect older, more deformed veins. Emeralds occur along the margins of quartz veins in highly-altered schist, as well as within the quartz veins themselves. The mineralizing event is interpreted to have occurred over a considerable period of time, but was mainly syn- to late-tectonic, and coincided with the waning stages of quartz monzonite intrusion. Late ductile deformation has also affected some of the emerald-bearing veins, as evidenced by the presence of healed fractures in emerald and micro-boudinage of tourmaline grains within vein quartz. At least two of the aplite dikes contain beryl or emerald, which confirms our hypothesis that there is a continuum from the quartz monzonite intrusion through aplite dikes to beryl-bearing quartz veins (Neufeld *et al.*, 2003).

RED MOUNTAIN

Crystals of V-dominant emerald were discovered in 1989 at Red Mountain, near Stewart on the central coast of British Columbia. The emerald occurs as small opaque crystals with numerous fractures in narrow quartz-calcite-pyrite veins that cut volcaniclastic rocks adjacent to a quartz-monzonite intrusion (Wilson, 1997). Electron microprobe analyses show 1612 ppm V and 1.04 wt.% FeO (average of six analyses), but no detectable Cr.

TRUE BLUE

The True Blue property, which is located in the Ketza-Seagull District of the southern Yukon Territory, occurs within the Cassiar Platform and southwest of the Tintina Fault. Beryl was discovered on the property in 1976, and gem beryl in 2003 (Rohtert *et al.*, 2003). The crystals occurs in a swarm of closely spaced quartz ± siderite ± fluorite ± tourmaline veins that fill tension gashes in a Mississippian-age (approximately 360 My) syenite stock. The veins range in thickness from 0.5 to 20 centimetres, and locally comprise up to 30% of the rock. The vein zone measures 700 by 200 metres in outcrop at the surface, and is exposed over an elevation range of 100 metres. Within this area, more than 100 individual occurrences have been discovered. The vein zone is developed near the upper contact of the syenite body with Lower Paleozoic pelitic and carbonate country rocks. The syenite is sodic in composition, with about 8 wt.% Na_2O, and contains moderately high concentrations of Be (up to 10 ppm) and F (up to 4000 ppm).

The beryl crystals range in size from a few millimetres to 5 by 2.5 centimetres, and in colour from pale to medium green, and from pale to dark blue. Some of the crystals, especially those occurring with tourmaline, show a blue core and a green rim. The dark blue material is noteworthy for its striking hue (which is maintained at very small sizes for aquamarine) and for its exceptionally strong dichroism. Electron microprobe analyses show high concentrations of Fe (to 5.81 wt.% FeO), Mg (to 3.27 wt.% MgO), and Na (to 2.51 wt.% Na_2O). The Fe content is among the highest ever reported for beryl. The colour is probably due to intervalence charge-transfer between Fe atoms, but the exact mechanism is unknown and is being studied.

OTHER BE AND BERYL OCCURRENCES IN NORTHWESTERN CANADA

A literature review of assessment reports and other published and unpublished reports shows numerous Be and beryl occurrences in southern Yukon and northern British Columbia. Analyses of a scapolite skarn with scheelite at the Myda claim (Yukon MINFILE 105G/071; www.geology.gov.yk.ca/minfile/, Deklerk, 2003), approximately 20 kilometres south of Regal Ridge, show 0.05 to 0.09 wt.% BeO, thought to be present in vesuvianite. Beryl has been reported from the Logtung W-Mo deposit (105B/039), the JC (Viola) Sn-bearing skarn claims (105B/040), and the Ice Lakes area (Groat *et al.*, 1995). All are just north of the British Columbian Yukon border. Beryl has also been reported from the following showings and prospects in northern British Columbia (listed west to east): Jennings River 104O/028, Ash Mountain (104O/021), Blue Light (104O/005), Gazoo (104O/045), Low Grade (104P/026), Haskins Mountain (104P/020), and Cassiar Beryl (Horseranch Range, also called Wilson (Simandl *et al.* 2000) (104P/024). The numbers are British Columbia MINFILE property reference numbers. For on-line information, see http://www.em.gov.bc.ca/mining/Geolsurv/minfile/).
Most of these prospects are associated with Cretaceous plutons, in particular the Cassiar batholith. The occurrences listed here (including Regal Ridge) define a Be-rich area approximately 265 (nortwest-southeast) by 125 kilometres (northeast-southwest) that straddles the

British Columbia-Yukon border and the Tintina Fault. Legun (2004) used data from assessment and other published reports to define a "beryl belt" extending from southeastern to northwestern British Columbia. Within the "beryl belt" he proposed a "principal area of emerald potential" which approximately coincides with this area.

Beryl has also been found at the Pluto property in the offset part of the Yukon-Tanana Terrane southwest of the Tintina Fault, close to Dawson City (116B/134). Other Be/beryl occurrences in northern British Columbia and the Yukon, and western Northwest Territories include Mount Foster (104/M14?), Kalzas (105M/066), Emerald Lake (115O/009), and the Little Nahanni Pegmatite Group (NORMIN.DB 105ISE0015, 25, 50-56; see www.nwtgeoscience.ca). At Mount Foster colourless to light blue aquamarine occurs in miarolitic cavities in granitic rocks (Wilson, 1997). Wilson has cut several stones from this locality; the largest are 8.63 and 2.99 carats, and although the 8.63 carat stone has many inclusions, stones that weigh less than two carats are virtually flawless (Wilson, 1997).

The discovery of emeralds at Regal Ridge and Lened, and gem beryl at True Blue, along with numerous reports of anomalous levels of Be and/or the presence of beryl in northwestern Canada, suggest the potential for more emerald and gem beryl occurrences in the Yukon, western Northwest Territories, and northern British Columbia. This area could represent one or more distinct beryl/emerald camp(s), as has been recognized at other places in the world.

SELECTED REFERENCES

Deklerk R. (2003): Yukon MINFILE 2003 - A database of mineral occurrences; *Yukon Geological Survey*, CD-ROM.

Groat, L.A., Ercit, T.S., Mortensen, J.K. & Mauthner, M.H.F. (1995): Granitic Pegmatites in the Canadian Cordillera: Yukon and Northwest Territories; Exploration and Geological Services Division, *Indian and Northern Affairs Canada*, Open File 1995-14, 40 pages.

Groat, L.A., Marshall, D.D., Giuliani, G., Murphy, D.C., Piercey, S.J., Jambor, J.L., Mortensen, J.K., Ercit, T.S., Gault, R.A., Mattey, D.P., Schwartz, D.P., Maluski, H., Wise, M.A., Wengzynowski, W. and Eaton, W.D. (2002): Mineralogical and geochemical study of the Regal Ridge showing emeralds, southeastern Yukon; *Canadian Mineralogist*, Volume 40, pages 1313-1338.

Legun, A. (2004): The potential for emeralds in B.C.; (poster), Mineral Exploration Roundup 2003.

Marshall, D.D., Groat, L.A., Falck, H. and Giuliani, G. (2004): The Lened emerald prospect, Northwest Territories, Canada: Insights from fluid inclusions and stable isotopes, with implications for northern Cordilleran emerald; *Canadian Mineralogist*, Volume 42 (in press).

Mortensen, J.K. and Jilson, G.A. (1985): Evolution of the Yukon-Tanana Terrane: Evidence from southeastern Yukon Territory; *Geology*, Volume 13, pages 806-810.

Mortensen, J.K. (1992): Pre-Mid-Mesozoic tectonic evolution of the Yukon-Tanana Terrane, Yukon and Alaska; *Tectonics*, Volume 11, pages 836-853.

Mortensen, J.K., Hart, C.J.R., Murphy, D.C. and Heffernan, S. (2000): Evolution of early and mid-Cretaceous magmatism in the Tintina Gold Belt; *In* J.L. Jambor, Editor, The Tintina Gold Belt: Concepts, Exploration, and Discoveries, *British Columbia and Yukon Chamber of Mines*, Volume 2, pages 49-57.

Murphy, D.C. and Piercey, S.J. (2000): Syn-mineralization faults and their re-activation, Finlayson Lake massive sulphide district, Yukon-Tanana Terrane, southeastern Yukon; *In* D.S. Emond and L.H. Weston, Editors, Yukon Exploration and Geology 1999, Exploration and Geological Services Division, Yukon, *Indian and Northern Affairs Canada*, pages 55-66.

Murphy, D.C., Colpron, M., Roots, C.F., Gordey, S.P. and Abbott, J.G. (2002): Finlayson Lake targeted geoscience initiative (southeastern Yukon), Part 1: Bedrock geology; *In* D.S. Emond, L.H. Weston and L.L. Lewis, Editors, Yukon Exploration and Geology 2001, Exploration and Geological Services Division, Yukon, *Indian and Northern Affairs Canada*, pages 189-207.

Neufeld, H.L.D., Groat, L.A. and Mortensen, J.K. (2003): Preliminary investigations of emerald mineralization in the Regal Ridge area, Finlayson Lake district, southeastern Yukon; *In* D.S. Emond and L.L. Lewis, Editors, Yukon Exploration and Geology 2002, Exploration and Geological Services Division, Yukon, *Indian and Northern Affairs Canada*, pages 281-284.

Piercey, S.J., Murphy, D.C., Mortensen, J.K. and Paradis, S.A. (2000): Arc-rifting and ensialic back-arc basin magmatism in the northern Canadian Cordillera: evidence from the Yukon-Tanana Terrane, Finlayson Lake region, Yukon; *Lithoprobe Report*, Volume 72, pages 129-138.

Rohtert, W.R., Quinn, E.P., Groat, L.A. and Rossman, G.R. (2003): Blue beryl discovery in Canada; *Gems and Gemology*, Volume 39, pages 327-329.

Wilson, B.S. (1997): Gemstone occurrences in British Columbia; *Canadian Gemologist*, Volume 18, pages 74-86.