Lithos 198–199 (2014) 281–297

Contents lists available at ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

Origin of gem corundum in calcite marble: The Revelstoke occurrence in the Canadian Cordillera of British Columbia

Tashia J. Dzikowski [a,*], Jan Cempírek [a,b], Lee A. Groat [a], Gregory M. Dipple [a], Gaston Giuliani [c]

[a] Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, 2207 Main Mall, Vancouver, BC V6T 1Z4, Canada
[b] Department of Mineralogy, Moravian Museum, Zelný trh 6, Brno 61137, Czech Republic
[c] IRD et CRPG/CNRS, Centre de Recherches Pétrographiques et Géochimiques, 15 rue Notre Dame des Pauvres, Vandoeure-lés-Nancy 54501, France

ARTICLE INFO

Article history:
Received 30 July 2013
Accepted 31 March 2014
Available online 12 April 2014

Keywords:
Corundum
Muscovite
Calcite marble
Oxygen isotopes
Geochemistry
Metamorphism

ABSTRACT

The calcite marble-hosted gem corundum (ruby, sapphire) occurrence near Revelstoke, British Columbia, Canada, occurs in the Monashee Complex of the Omineca Belt of the Canadian Cordillera. Corundum occurs in thin, folded and stretched layers with green muscovite + Ba-bearing K-feldspar + anorthite ($An_{0.85-1}$) ± phlogopite ± Na-poor scapolite. Other silicate layers within the marble are composed of: (1) diopside + tremolite ± quartz and (2) garnet ($Alm_{0.7-0.5}Grs_{0.2-0.4}$) + Na-rich scapolite + diopside + tremolite + Na,K-amphiboles. Non-silicate layers in the marble are either magnetite- or graphite-bearing. Predominantly pink (locally red or purple) opaque to transparent corundum crystals have elevated Cr_2O_3 (≤0.21 wt.%) and variable amounts of TiO_2; rare blue rims on the corundum crystals contain higher amounts of TiO_2 (≤0.53 wt.%) and Fe_2O_3 (≤0.07 wt.%). The associated micas have elevated Cr, V, Ti, and Ba contents. Petrography of the silicate layers show that corundum formed from muscovite at the peak of metamorphism (~650–700 °C at 8.5–9 kbar). Because the marble is almost pure calcite (dolomite is very rare), the corundum was preserved because it did not react with dolomite to spinel + calcite during decompression. The scapolite-bearing assemblages formed during or after decompression of the rock at ~650 °C and 4–6 kbar. Gem-quality corundum crystals formed especially on borders of the mica-feldspar layers in an assemblage with calcite.

Whole rock geochemistry data show that the corundum-bearing silicate (mica-feldspar) layers formed by mechanical mixing of carbonate with the host gneiss protolith; the bulk composition of the silicate layers was modified by Si and Fe depletion during prograde metamorphism. High element mobility is supported by the homogenization of $\delta^{18}O$ and $\delta^{13}C$ values in carbonates and silicates for the marble and silicate layers. The silicate layers and the gneiss contain elevated contents of Cr and V due to the volcanoclastic component of their protolith.

1. Introduction

The origin of gem corundum (Al_2O_3), which includes ruby (red variety, Cr,V-bearing) and sapphire (blue and other colors), has recently been the subject of significant interest due to the growing economic potential of the gem corundum market, new deposits, and advances in understanding of their origin (e.g., reviews of Giuliani et al., 2007; Groat and Laurs, 2009; Simonet et al., 2008). Ruby and sapphire are arguably the world's most widely sold colored gemstones, accounting for approximately one-third of sales by value (BUZ Consulting 2009, in Shor and Weldon, 2009), and commanding some of the highest prices paid for any gem.

Corundum only forms in Al-rich assemblages deficient in Si; in order to form ruby and sapphire, chromophores such as Cr, V, Ti, and Fe must also be present. The enrichment in both Al and Cr is problematic because both are relatively insoluble and difficult to transport over large distances in aqueous solutions that are poor in Si (Manning, 2007). Several showings of gem corundum have been described in Canada (Fig. 1A), including: blue, yellow, and colorless sapphire near Kimmirut on Baffin Island (discovered in 2002; Gertzbein, 2005; LeCheminant et al., 2005); sapphire in southeastern Newfoundland (discovered in 1987; Wight, 1999); “low-grade ruby” near Sydney, Nova Scotia (discovered in 2004; Durstling, 2005); sapphire from eastern Ontario (Wight, 2004); and star sapphire from several localities near Passmore in south-central British Columbia (discovered in the early 1980s; Wilson, 2010).

A new carbonate-hosted gem corundum locality northwest of Revelstoke in British Columbia (at 51° 31.3′ N, 118° 46.7′ W, 82M/10; Fig. 1) was staked as the Goat claims by Bradley S. Wilson in 2002. Several gem-quality sapphires and rubies from this locality have been faceted with the largest under 0.5 ct. (Appendix A, Suppl. Fig. A1). In

* Corresponding author.
E-mail address: t.dzikowski@alumni.ubc.ca (T.J. Dzikowski).

http://dx.doi.org/10.1016/j.lithos.2014.03.030
0024-4937/

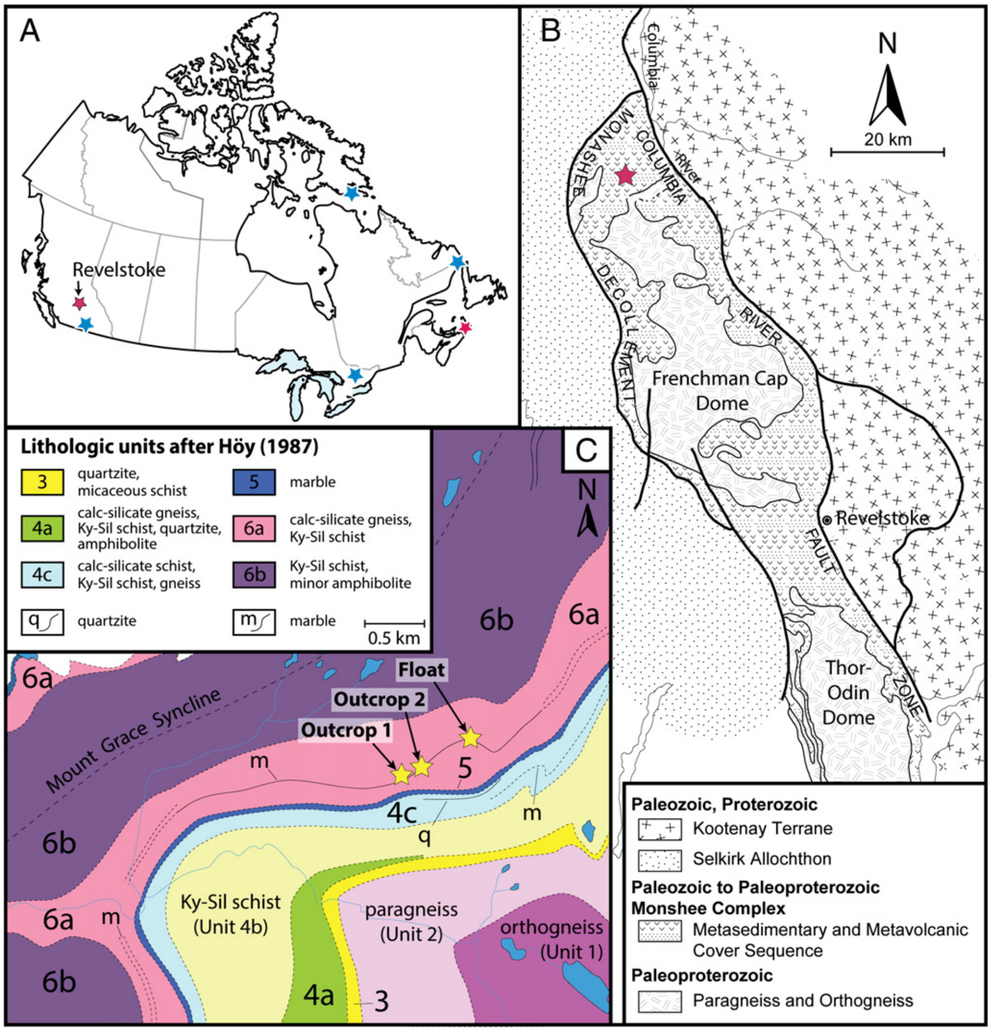

Fig. 1. Location and geology of the Revelstoke occurrence. A) Map showing Canadian gem-corundum localities. B) Tectonic assemblage of part of the Monashee complex. The studied area is marked with a star. C) Regional geological map of the Revelstoke occurrence (Units 1–6 are marked by numbers). The studied locations (from east to west: float, outcrop 1, outcrop 2) are marked with yellow stars.
Panel b is modified after Höy (2001). Panel c is modified after Höy (1987).

this contribution we characterize the geology, geochemistry, mineralogy, and fluid inclusions found in the corundum at the Revelstoke locality in order to draw conclusions about the genesis of this occurrence.

2. Geological setting

The Revelstoke occurrence is located in the Shuswap Metamorphic Core Complex (MCC), in the southern part of the Omineca Belt of the Canadian Cordillera in British Columbia. It is hosted in a marble layer within the Monashee Complex cover sequence northwest of the Frenchman Cap dome (Fig. 1). The Omineca Belt is a northwest trending uplifted region of metamorphic and plutonic rocks separating accreted terranes from the ancestral North America continental margin in the Canadian Cordillera (Johnson, 2006). Rocks within the Omineca Belt are typically highly deformed and variably metamorphosed. The Shuswap MCC is the most deeply exhumed part of the southern Omineca Belt in the core of the Canadian Cordillera (Johnson, 2006). The Monashee Complex is the lowest exposed part of the Shuswap MCC and is the largest exposure of Precambrian crystalline rocks in the Canadian Cordillera (Crowley, 1999). The Monashee Complex, which contains the Frenchman Cap dome to the north and the Thor–Odin dome to the south (Fig. 1B), is bounded by the Monashee décollement in the west and the Columbia River fault in the east (Brown, 1980; Brown et al., 1986; Crowley, 1999; Johnson, 2006; Journeay, 1986).

During the formation of the Frenchman Cap and Thor–Odin domes, initial compressional tectonism was succeeded by extension of the orogen along the Columbia River and Okanagan–Eagle River fault system following a path of isothermal decompression and isobaric cooling. The exact mechanism of decompression and uplift is discussed by Teyssier et al. (2005), Hinchey et al. (2006), Gervais et al. (2010), and Gervais and Brown (2011). All suggest similar P–T paths with peak metamorphic conditions of ca. 750–800 °C and 8–10 kbar followed by isothermal decompression to <5 kbar and isobaric cooling to 300–150 °C. The observed inverted metamorphic gradient in the northern part of the Frenchman Cap dome (Journeay, 1986) was explained by Crowley and Parrish (1999) as a juxtaposition of high-grade rocks over a lower-grade metapelitic rock sequence with regular metamorphic zonation. The Monashee décollement was active during both Mesozoic orogenesis (Read and Brown, 1981) and early Tertiary (~58 Ma) extension and uplift (Lane, 1984). Work by Crowley and Parrish (1999) shows that the pelitic schist, which borders the marble hosting the Revelstoke occurrence, has thermal peak U–Pb monazite and zircon ages that range from 57 to 51 Ma.