Geochemistry and genetic significance of melt inclusions in corundum from the Bo Ploi sapphire deposits, Thailand

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Abstract. Rare silicate melt inclusions trapped in corundum from the Bo Ploi Deposit, Thailand were analysed in order to determine the genesis of corundum (in particular those gem quality) in basaltic terrains. The approximate compositions of melt inclusions are 58-65 wt% SiO_2, 25-33 wt%Al_2O_3, 3-7 wt% Na_2O, 3-6 wt% K_2O, up to 1 wt% CaO, and small amount of FeO, MnO, and MgO, which are consistent with trachyandesite to trachyte compositions. The discovery of melt inclusions with such compositions confirms a magmatic origin and strengthens the xenocrystic hypothesis for corundum from this locality.

Keywords: melt inclusions, sapphire, Kanchanaburi, Thailand

1. Introduction

The genesis of gem-quality corundum associated with basaltic rocks is still open to debate. To date, the general consensus is that they originated as xenocrystic phases carried to the surface via eruptions of basalt (Guo, *et al.,* 1996, Sutherland, 1998, Armour and Linnen, 1999, Srithai and Rankin, 1999, Limtrakun, *et al*., 2001, Yui, *et al*., 2003). However, the primary crystallisation processes of corundum, whether due metamorphism/metasomatism or magmatism, remain uncertain.

Fluid and melt inclusion studies can help resolve this uncertainty. Here we report on the results of a microthermometric and geochemical study of primary, melt inclusions in corundum from the Bo Ploi deposit, Kanchanaburi, Thailand, which is one of the best known examples of a “basaltic” gem corundum occurrence, supplying blue sapphire and black spinel to both domestic and international jewellery markets.

2. Method

Doubly polished sapphire wafers (c.1-2mm. thick) were used to study the melt and associated inclusions previously reported by Srithai and Rankin (1999). The rare melt inclusions were examined in detail under the microscope and their identity confirmed using a Renishaw Laser Raman Microprobe (LRM), equipped with an Ar-laser and operated in confocal mode. Phase changes on heating selected melt inclusions containing vapour bubbles were observed up to 1350°C using a Linkam TH1500 heating stage. Finally, melt inclusions in *samples quenched after heating* were carefully polished until exposed on the surface and then analysed using a JEOL-733 Superprobe equipped with a Link Systems EDS.

3. Results

3.1 Microthermometric study

Melt inclusions occur as isolated rounded anhedral to subhedral crystalline/glassey phases with various proportions of vapour bubbles. On the basis of their size and distribution, a primary (P) or pseudosecondary (PS) origin may be assigned to these inclusions. Their typical size ranges from 10-50 µm. But rarer, larger inclusions (70 to 120 µm) were used in heating experiments. Some melt inclusions contain daughter minerals, which completely dissolved on heating. None of the melt inclusions could be homogenised even after being held at 1350°C for 24 hours. Phase changes began at 750-800°C, at which point vapour bubbles, became mobilised in the melt/fluid.

3.2 Composition of melt inclusions

The chemical compositions of quenched P and PS melt inclusions are slightly variable but are typically within the following ranges: 58-65 wt% SiO_2, 25-33 wt% Al_2O_3, 3-7 wt% Na_2O, 3-6 wt% K_2O, upto 1 wt% CaO, 0.2-0.8 wt% FeO, upto 0.4 wt% MnO, 0.1-0.9 wt% MgO, and 7-10 wt% total alkali content. The relationship between total alkali content and SiO_2 content is shown in Fig. 1.

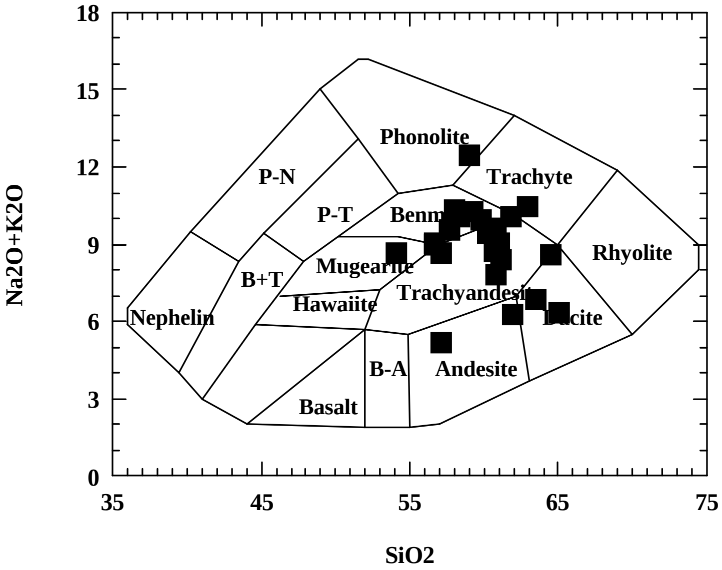

Figure 1 Plots of SiO_2 content *vs.* total alkali content of melt inclusions trapped in corundum from Bo Ploi deposit (after Cox *et al.*, 1979)

4. Discussion

The trapped melts show alkali intermediate to alkali felsic affinties. Most show trachyandesite/trachyte (equivalent to syenodiorite/syenite) compositions, with a scatter of results suggesting phonolite/nepheline syenite compositions. The high Al_2O_3, low CaO, MgO, and MnO contents suggest a more complicated process of melt formation than by normal fractional crystallisation processes. Major contamination of Al_2O_3 from the host corundum during analysis can be essentially ruled out on the basis of small electron beam size (2 μm) relative to the much larger size of the inclusions. Hence we believe that the observed negative correlation of Al_2O_3 with the increasing of SiO_2 is real and indicates the compatible nature and the uptake of Al_2O_3 to form alumina-bearing minerals.

Fractionation of intermediate melts to crystallise corundum is not a simple model, although it is generally agreed that felsic alkaline magmas can be generated from fractionation of basaltic magmas (Bowen and Schairer, 1938). The initial phases that fractionate from such melts are olivine, clinopyroxene, concurrent with plagioclase and magnetite. The separation of these mafic minerals would cause the residual melt to become more felsic. The Al_2O_3 contents of the trachyandesite/trachyte melts are higher than those reported in literature (Baker, *et al.*, 1977, Wolff, *et al.*, 2000). Such high levels would be required to promote alumina crystallization in the melt. The most likely caused of high alumina is from Al-bearing country rocks in contact with the melt during propagation. Aluminous sedimentary and metamorphic rocks e.g. shale, phyllite, gneiss, and biotite schist are common throughout the study area (Bunopas and

Bunjitradulaya, 1975) and provide field evidence supporting the possibility of crustal assimilation in the trachyandesite/trachyte melt. In addition, the $\delta^{18}O$ of the corundum from this deposit is in the range of 6.5 to 9.6 ‰ (V-SMOW) and such $\delta^{18}O$ values reflect oxygen from both crustal and mantle sources (Srithai, unpublished data).

Armour and Linnen (1999) reported melt compositions trapped in corundum from the Bo Ploi deposit, which they interpreted as nepheline syenite. Homogenization was also not achieved in their study even after holding the temperature of heating experiments at 1200-1300°C for 5 hours. The partial compositions of these trapped melt inclusion were characteristically: SiO_2 51%, Al_2O_3 28%, 9% Na_2O, 5% K_2O. Most of major oxides are consistent with our own studies, but their lower SiO_2 contents and higher total alkali contents are different. It is possible that the longer duration of our heating experiments prior to quenching may affect Na mobility and hence alkali content. But other possible reasons will also be discussed

The genesis of corundum from the Bo Ploi deposits can be envisaged as being due to magmatic evolution from an alkali basic to an alkali intermediate composition through fractionation processes. The melt became contaminated with alumina-rich country rocks during ascent, leading to crystallization of corundum and other mineral assemblages, e.g. spinel and augite. The estimated trapping temperature of fluid and melt inclusion ranges from 800 to 1000°C (Srithai and Rankin, 1999). Based on geothermal gradient estimates from mantle peridotites trapped in the Bo Ploi basalt (Srithai, 2005), a lower crust to upper mantle source region (40 to 50 km) is indicated.

The absence of outcrops of trachyandesite/trachyte in the study area is noteworthy but can be explained by the processes described above.

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