Gem zircon and sapphire age dating and application of origin determination: A study from New England sapphire fields, New South Wales, Australia

Ahmadjan Abduryim[1,2], Frederick Lin Sutherland[3], Terry Coldham[4], Elena Belousova[5]

[1] Tokyo Gem Science LLC; tgs@gemscience.tokyo

[2] GSTV Gemological Laboratory

[3] Australian Museum

[4] Gemmological Association of Australia

[5] Department of Earth and Planetary Sciences, Macquarie University

Abstract

Chemical composition and U-Pb age determined by laser ablation (LA) ICP-MS are presented for zircon megacrysts found in alluvial gem corundum deposits associated with alkali basalts in the Inverell district in New England, New South Wales, eastern Australia. The three mine localities, Kings Plains, Swan Brook, and Mary Anne Gully, produce gem-quality brown to yellow zircon megacrysts characterized by relative enrichment in Hf and REE. We observed no differences in relative concentrations of transition metals in relation to color. Chemical homogeneity within the single zircon crystals indicates stable crystallization conditions. The 206Pb/238U age of zircon megacrysts from these three localities fall into two groups, an older group of about 174-216 Ma and a younger group of about 37.7-45 Ma, respectively. Based on our data, the zircons in the New England alluvial gem deposits may be related to two formation episodes, one in the Upper Triassic-Lower Jurassic and one in the Eocene (late Oligocene). Most originated from the lithospheric mantle, and later hosted basaltic magmas brought up. Gem quality blue sapphires are also directly collected from these mines, and zircon inclusions in Kings Plains and Mary Anne Gully sapphires gave U-Pb ages of about 35 to 37 Ma which fall within the range of basalt K-Ar ages of 19 to 38 Ma and close to the younger group of zircon megacrysts (37.7-45 Ma) thus indicating the timing of volcanism of the Inverell district-New England field.

Introduction

Zircon megacrysts are common within eluvial, paleo-alluvial, and alluvial sapphire/ruby deposits derived from basaltic sequences, with gem properties suitable for cutting as an accessory gemstone. Such zircons and sapphires/rubies are widely distributed along eastern Australia (Figure 1). The largest gem field in New England, New South Wales, has a limited systematic spread of U-Pb ages (Coenraads *et al.*, 1990; Sutherland & Fanning 2001; Sutherland *et al.*, 2002; Zaw *et al.*, 2006; Abduriyim *et al.*, 2012). In 2010, the authors visited sapphire mines in Kings Plains, Mary Ann Gully, and Swan Brook and investigated the geological distribution and mining at each deposit. This study presents U-Pb age dating of zircon megacryst and zircon inclusion in host sapphire from the Inverell district in the New England gem field. These data are used to characterize and discuss the crystallization ages and source affinities (or genesis) of gem-quality zircon and sapphire megacrysts from a world-class basaltic gem field.

Figure 1. Distribution of sapphire/ruby and zircon in eastern Australia, showing mining locations of the New England, New South Wales, Anakie and the Lava Plains gem fields in Central and Northern Queensland, other sapphire/Ruby gem fields in Victoria and Tasmania.

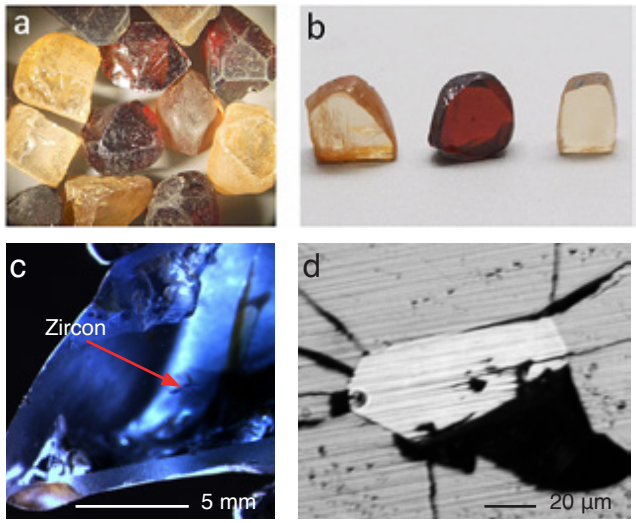

Figure 2. Zircon megacryst concentrate (a: left top) from Kings Plains mine. Zircon megacryst color range with polished surface for analysis (b: right top, sample weight, 2.46~4.11cts).
(c) Blue sapphire from Mary Anne Gully (sample S-MA-0001) with a small zircon inclusion surrounded by tension cracks.
(d) Zircon inclusion in sapphire (sample S-MA-0001) which was carefully polished to expose the zircon to the surface for LA-ICP-MS analysis.

Materials and Methods

Zircons from the Inverell district-New England gem deposits selected for analysis included 7 brown and yellow zircon megacrysts collected from the alluvial corundum mine in Kings Plains, 3 from the Mary Anne Gully mine and a color range of 5 faceted megacrysts from Swan Brook (Figure 2a and b).

125 samples of blue and greenish blue sapphire megacrysts were collected from the exact three mine locations. They show a glossy natural surface which is typical as a result of magmatic dissolution and etching. Two blue sapphire samples contained several large transparent euhedral zircon inclusions, and these sapphires were carefully orientated and polished to expose the zircon inclusion to the surface of the sapphire (Figure 2c and d). Their size (100 and 80 µm in length), was suitable for dating with conventional LA-ICP-MS (Agilent 7700 ICP-MS with 213nm YAG laser).

Results and Discussions

Chemical Composition: Zircon megacrysts from the Inverell district are significantly HREE-enriched over LREE (Figure 3). The chondrite-normalized REE patterns are moderately fractionated and show a positive Ce anomaly. Only a few samples show negligible Eu anomalies. The total content of LREE in the Inverell zircons is 0.01 to 0.3 (La) up to 20 to 300 (Dy) chondrite units. HREE content ranges from 30 to 500 (Ho) to 100 to 1250 (Lu) chondrite units. The REE patterns of the zircons from three localities in the Inverell district sapphire mine field have similar profiles, indicating related origins.

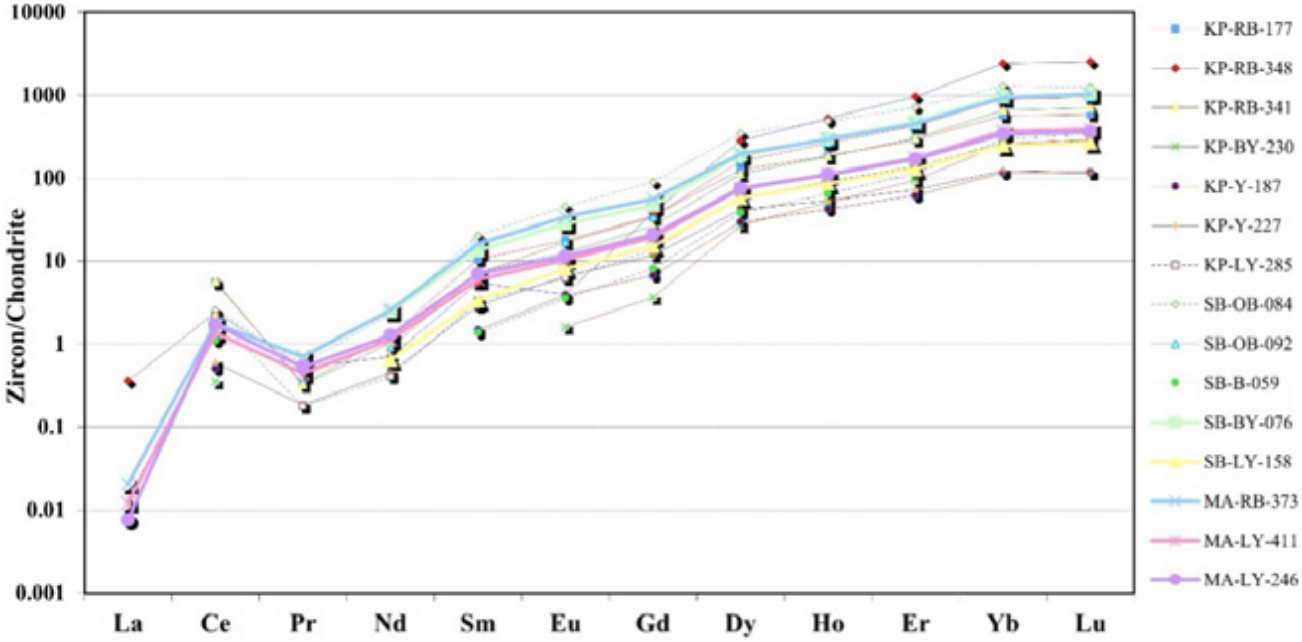

Figure 3. Chondrite-normalized REE patterns of zircon megacrysts from Kings Plains, Swan Brook, and Mary Anne Gully in the Inverell district, New England gem field, Australia.

The blue, yellow-blue (parti-color type) and greenish blue sapphires from three mine locations in Inverell district show relatively high Ga (> 120 ppm), low Mg (< 18 ppm) and low Cr (< 10 ppm), features that typify magmatic sapphires. The blue sapphire group, however, shows lower Fe, V, and Mg and higher Ti than the greenish blue group. Other minor trace elements such as Ni, Sn, and Ta values are mostly <1 ppm in blue and yellow-blue sapphires and below detection in greenish blue sapphires.

Geochronology: Six samples among the 7 zircon samples from Kings Plains reveal older ages, from the U-Pb concordance of 206Pb/238U age around 188.9 ± 4.5 Ma, 185.9 ± 3.3 Ma, 208 ± 4 Ma, 176 ± 6.1 Ma, 174 ± 7 Ma, and 207 ± 17 Ma at the 95% confidence level. One zircon gave a younger 45 ± 0.52 Ma age (Figure 4). Based on these results we assume that the deposits may represent two different volcanic activity periods, one in the upper Triassic and later in the late Oligocene.

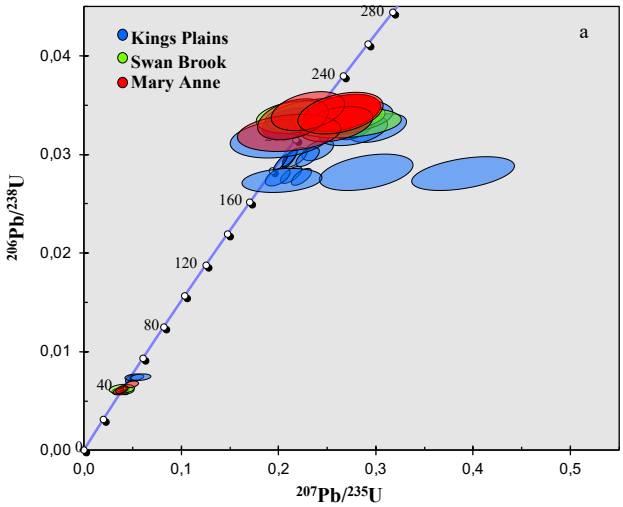

Figure 4. Concordia diagram showing U-Pb age data of zircons from Kings Plains, Swan Brook and Mary Anne Gully from the Inverell district, NSW, Australia.

Four samples among the 5 Swan Brook zircons show a younger concordant age around 37.94 ± 0.34 Ma, 37.22 ± 0.28 Ma, 36.2 ± 6.4 Ma, 37.66 ± 0.35 Ma at the 95% confidence level, except one zircon grain with an older U-Pb age of 215 ± 2 Ma.

This trend of two age groups is also found in zircons from the Mary Anne Gully alluvial deposit. Two samples resulted in a concordant age of 206 ± 11 Ma and 216±5.7 Ma, while one zircon shows a concordant age of 37.7 ± 0.9 Ma.

Most of the zircons from the Kings Plains alluvial deposits belong to the older age group (the weighted mean 206Pb/238U age of 174 Ma to 216 Ma) and suggest its main volcanic eruption episode was in Triassic to Jurassic, but Swan Brook zircons are dominantly the younger age group (37.7 Ma to 45 Ma), relating them to the Eocene Maybole volcano eruptions.

In the blue sapphire sample from Kings Plains, two spot analyses were obtained on the zircon inclusion carefully polished to be exposed at the surface. The U-Pb concordant ages of this zircon inclusion were 37.2 ± 1.9 and 36.9 ± 1.6 Ma (Figure 5). Another zircon inclusion in the Mary Anne Gully sapphire gave similar concordant ages of 35.7 ± 2.1 and 34.9 ± 1.4 Ma, revealing that there is no significant difference between these two mine locations in terms of formation ages. These results show that the sapphires originated during the Eocene volcanism in the Inverell district. In addition, the age of the zircon inclusions in sapphires fully overlaps with the young age of the zircon megacrysts from the same locations, indicating that the zircon inclusions probably formed together with the sapphires or shortly before. Based on literature and our data, it is assumed that the sapphires formed from strongly evolved magmas in the deep crust or upper mantle and that they were carried up in large quantities within alkali basaltic magmas during volatile-rich and explosive volcanic eruptions.

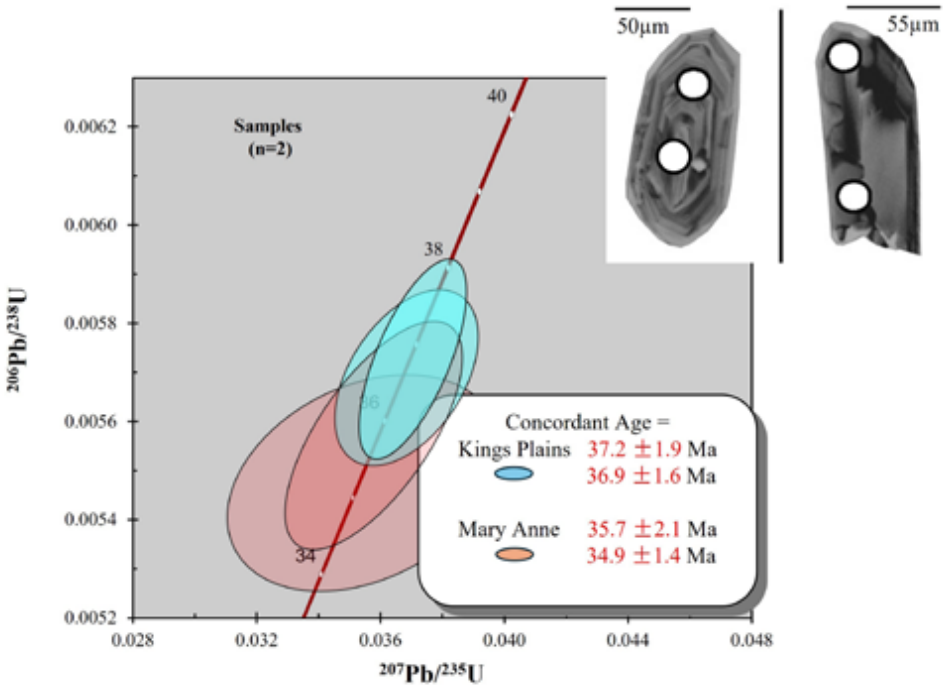

Figure 5. Concordia diagram for the zircon inclusion in sapphires from Kings Plains and Mary Anne Gully.