Geochemistry of silica rocks in the Drummond Basin as a record of geothermal potential

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Silica is the most abundant mineral in the Earth's upper crust; yet its trace element composition has not been utilised routinely in the exploration of natural resources. Siliceous sinters are pristine rocks that precipitate at the surface from spring waters heated by deep-seated magma chambers. They can be useful indicators of hot radioactive magmatic basements in sedimentary basins. However, distinguishing silica sinters from other siliceous lithologies is often ambiguous because siliceous lithologies of various origins occur ubiquitously on the ground surface as rock chips or soil material eroded from deeper geological units. In this study, we characterise trace element compositions of silica sinters to provide geochemical criteria for exploration of geothermal energy sources. We investigated silica sinters and the associated hydrothermal quartz veins, volcanic rocks, silicified hydrothermal breccias, alteration minerals, and some soil samples from the Paleozoic Drummond Basin, Australia by ICP-MS trace element analysis.

Keywords: Sinter, quartz, geochemistry, geothermal, Drummond Basin, Galilee Basin

Sampling

Samples for this study were collected from the Twin Hills area hosting high-grade epithermal gold resource, 309 and Lone Sister (BMA compony report). Location 309 mine is a fault-bounded area characterised by the occurrence of a silicified breccia system capped by sinter deposits, whereas Lone Sister represents a rhyolite dome. The textual features of the sinters at 309 are very similar to those of sinters from other locations in the Drummond Basin (Cunneen and Sillitoe, 1989; White et al., 1989). They are well-laminated (from white through gray to orange-brown), consisting of dense and vitreous chalcedony.

Results and implications

The Drummond Basin sinters and quartz veins are unique in having anomalously enriched incompatible element (Cs, Li, Be, W, U, Th and rare earth elements) concentrations in comparison to hydrothermal quartz veins from various granitic-pegmatitic systems elsewhere in the world (Figure 1). Bonding factors such as ionic size and charge are the main factors controlling the distribution of elements in precipitating crystals. Large-ion lithophile elements (LILE, e.g. Rb, Cs), large highly charged cations (e.g. W^{6+}, U^{4+}) and small variable charged cations (e.g. Be, Li) are usually prevented from being incorporated into crystalline phases during early magmatic processes (Strong, 1981). Hence these incompatible elements tend to concentrate in residual melts with high concentrations of fluids and volatiles, which commonly occurs during pegmatitic stages of granite magmatism. It has long been recognised that that Cs, Li, Rb, Be (the alkali and alkaline earth elements) can be quite mobile during water/rock interaction (Nesbitt and Markovics, 1997; Nesbitt and Young, 1989). Tracing such elements can thus be used as a geochemical tool for locating areas of hydrothermal convection cells interacting with deep heat-producing granitic rocks. Alkali mobile element concentrations are divided by concentration of most immobile elements such as Lu to compare alkali element mobility (Fig. 2). The majority of sinter and quartz samples within or near the highly mineralised area (309 mine) are significantly more mobile for Cs, Li, Rb and Be than the sinters and silica deposits from areas distal to 309 (except the quartz vein from Off Limits) and the volcanic rocks (Fig. 2). Plotting all data set, a good correlation (R^2 =0.70, power regression) is evident between Cs/Lu and Be/Lu, with the highest ratios being for sinter samples from 309 (Fig. 2A). Considering only silica deposits in Fig. 8A (black filled symbols) a significantly better correlation (R^2 =0.79, power regression) would be obtained. Sinter and quartz samples from 309 have also high Rb/Lu and Li/Lu ratios, (Fig. 2B). A well-developed correlation (R^2 =0.77) between Rb/Lu and Li/Lu is evident among silica samples from the entire Twin Hills area (Fig. 2B). The interaction of hydrothermal waters with the late Carboniferous alkaline igneous rocks resulted in the breakdown of K-Feldspar releasing alkali elements, which were subsequently mobilised in these fluids. This process led to the generation of an evolved, fertile hydrothermal fluid system that carried precious metals (Au, Ag) as was the case at 309 and Lone Sister in the Twin Hills area.

U and Th content of silica and clay samples from the surface can also be used in evaluating hot dry rock geothermal potential of the igneous rock association buried by heat-insulating sediments in adjacent sedimentary basins. Compared to pegmatite quartz compiled from the literature (Götze et al., 2004), U and Th concentrations in

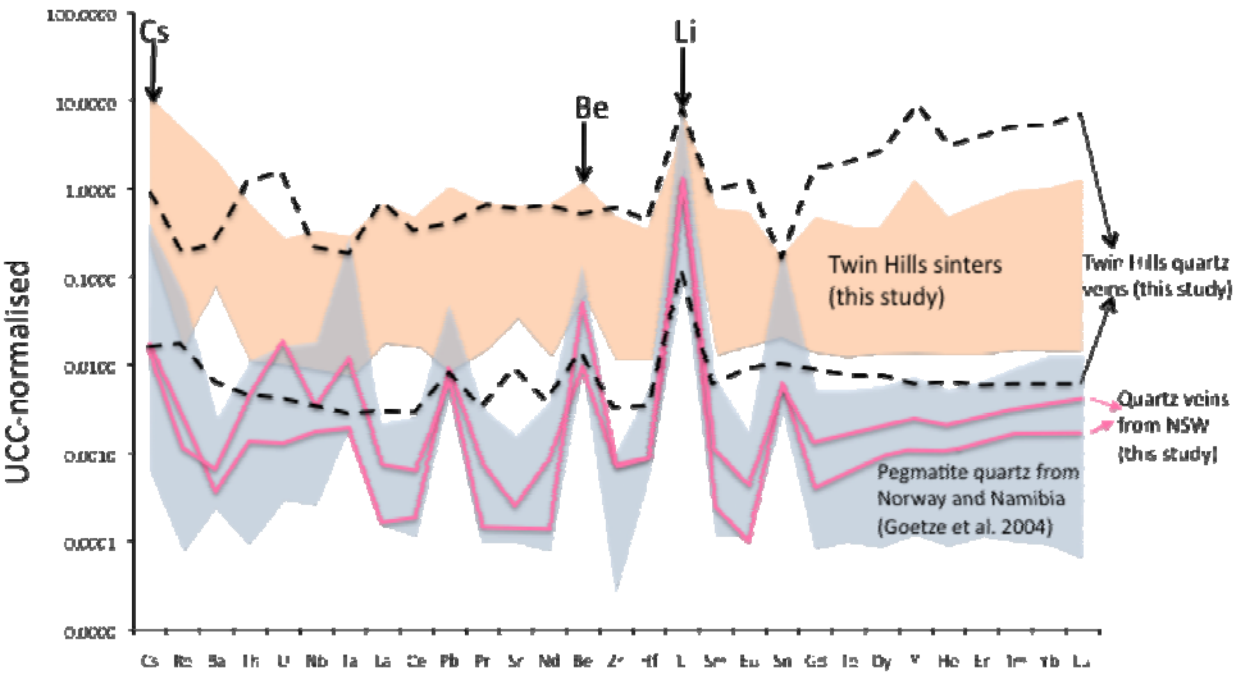

Figure 1: Upper continental crust (UCC) –normalised trace element concentration of the silica deposits from the Drummond Basin (Twin Hills area) in comparison to quartz from various granitic/pegmatitic environments.

sinter and quartz deposits from the Drummond Basin are significantly elevated (Fig. 3A-B). U and Th contents of the illitic clay minerals that formed in response to the interaction of hydrothermal fluids with host rocks are similarly high as those from the Cooper Basin. The latter represent a radiometric heat production from the basement granite (Middleton, 1979), whereas the clay concentrations for the Bowen Basin in Queensland and Paris Basin in Europe are similar to those of the upper continental crust (Fig. 6A-B).

Geothermal potential in the Galilee Basin

Igneous rocks of the Drummond Basin occur as the basement of the adjacent Galilee Basin of Upper Carboniferous to Middle Triassic age (Evans, 1980). The late Permian coal deposits and carbonaceous pelitic rocks in the Galilee Basin are ideal heat insulating sediments (Nun and Li, 2002) that would store the radioactive heat generation in the basement. Indeed, temperatures of about 80°C at 1000 m were measured in coal seam gas drilling boreholes in the Galilee Basin (pers. commun. with several coal seam gas companies) that indicate high heat flux from the basement. Furthermore, the vitrinite reflectance values measured on the coal cores throughout most of the Galilee Basin range between 0.63 and 0.73 %$R_o$max (Holland and Applegate, 2008), translating into reservoir temperatures of about 95°C - 110°C (Barker and Pawlewicz, 1986).

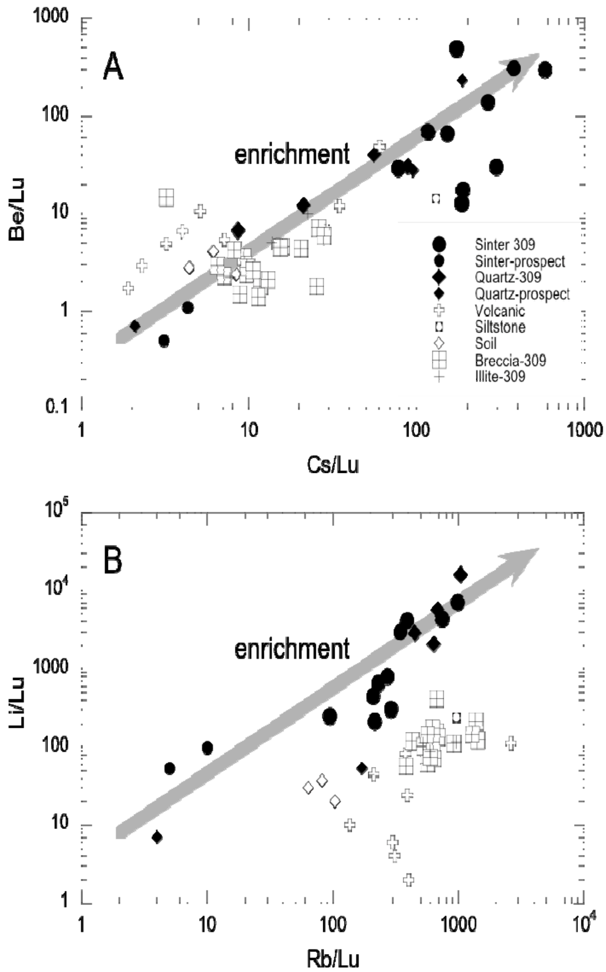

Figure 2. Alkali element mobility in the Twin Hills area.

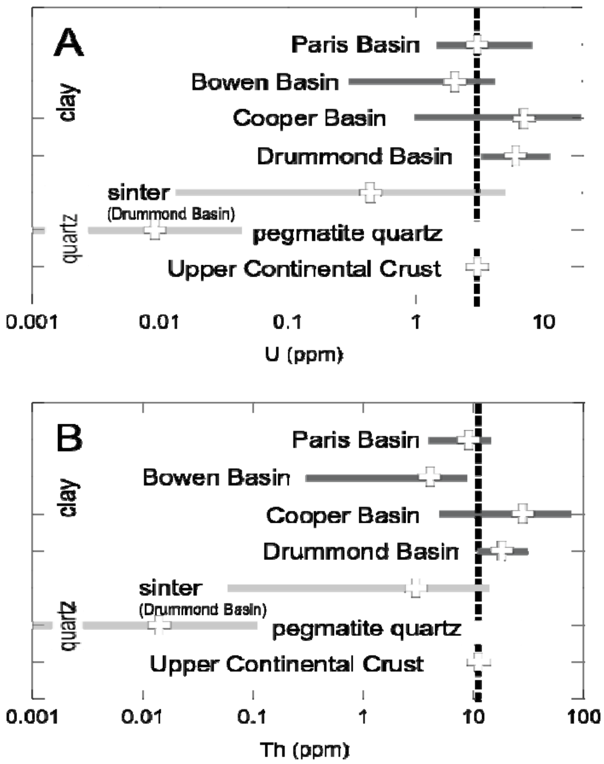

Figure 3. U – Th abundances of sinter and clay deposits from the Drummond Basin in comparison to those of other sedimentary basins. Pegmatite quartz from Götze et al. (2004).

Conclusion

The results of the pilot study suggest that trace element geochemistry of silica samples and the associated clay alteration can serve as a powerful tool in 1) discriminating between sinter and quartz veins from hydrothermal systems driven by granitic heat sources and other siliceous rock types (barren quartz/silica deposits) and 2) to be used in reconnaissance soil sampling to identify hydrothermal alteration zones associated with heat-producing granite plutons. Further work aimed at investigating similar samples from various settings with different ages will expand existing knowledge of how these techniques can be used to effectively discriminate areas with high geothermal potential from barren systems on a routine basis.

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