Nb-Ta fractionation in peraluminous granites: A marker of the magmatic-hydrothermal transition

Alekandr S. Stepanov1, Sebastien Meffre1, John Mavrogenes2, and Jeff Steadman1
1ARC Centre of Excellence in Ore Deposits (CODES), School of Physical Sciences, University of Tasmania, Private Bag 79, Tas 7001, Australia
2Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia

On the basis of geochemical and mineralogical features, Ballouard et al. (2016) argue that magmatic fractionation alone cannot explain the formation of leucogranites with low Nb/Ta ratios. Instead, they propose that low ratios are better explained by post-magmatic interaction with F-bearing fluids. Although fluids may certainly play an important role in the formation of rare metal leucogranites, the model proposed by Ballouard et al. lacks key details. We contend that the principal features they attribute to magmatic-hydrothermal processes are better explained by the magmatic fractionation model.

Ballouard et al. propose greater mobilization of Nb than Ta during post-magmatic alteration. Although fluid removal of Nb may decrease Nb/Ta ratios, it does not explain the high Ta concentrations in leucogranites, which vary from crustal values (≤1 ppm) to >100 ppm in the most evolved leucogranites (Stepanov et al., 2014; Ballouard et al., 2016, their figure 1B). In fluid-driven models, Ta enrichment in leucogranites may either be attributed to removal of silicate component (the removal scenario) or to addition of Ta by the fluid (the addition scenario). The removal scenario requires the extraction of 90 wt% of the silicates from the rock mass for a tenfold enrichment in Ta, which is not feasible. The Ta addition scenario is equivalent to the formation of Ta mineralization by hydrothermal processes. However, Ta-rich granites have igneous contacts with their host rocks, and do not display textures typical for hydrothermal ores (e.g., London, 2008).

Stepanov et al. (2014) demonstrated that the fractionation of micas and ilmenite have an opposite effect that is not explained by the high Nb/Ta ratios. Ballouard et al. take this argument too far by proposing that effect of mica fractionation can be counterbalanced by the fractionation of 0.5 wt% of ilmenite. However, peraluminous granites evolving to low Nb/Ta ratios can be explained by Ti contents much lower than 0.26 wt% TiO2, which is equivalent to 0.5 wt% of ilmenite (Stepanov et al., 2014; Ballouard et al., 2016). Moreover, biotite and muscovite have significant hosts of Ti, and their presence further reduces the amount of produced ilmenite. Therefore, peraluminous granites evolving to low Nb/Ta contain insufficient ilmenite to counteract the decrease in Nb/Ta due to fractionation of mica.

Leucogranites with low Nb/Ta also contain low concentrations of Fe, Mg, Zr, light rare earth elements (LREEs) and Ti (Stepanov et al., 2014). If this were due to post-magmatic alteration, as proposed by Ballouard et al., fluid removal of all these “immobile” elements and simultaneous enrichment in “mobile” elements (e.g., Sn, Li, Cs, and F) would be required. By contrast, the magmatic differentiation model explains decreasing concentrations of Fe, Mg, Zr, LREEs, and Ti through the fractionation of minor and accessory minerals present in granites (London, 2008; Stepanov et al., 2014), while enrichments of Sn, Li, Cs, and F are attributed to incompatible behavior during crystallization.

The metallogenic arguments put forward by Ballouard et al. are also problematic. Whereas Li, Cs, Rb, and Be can be transported by fluids, the highest concentrations of these elements are found in magmatic intrusions of pegmatites and leucogranites, and are commonly associated with elevated Ta (London, 2008). On the other hand, granite-related hydrothermal Sn and W deposits are not known to be significant sources of Li, Cs, Rb, Be, and Ta. Ballouard et al. argue that negative correlations of Sn contents with Nb/Ta ratios in granites are “markers of magmatic–hydrothermal alteration.” However, Lehmann (1990) demonstrated that magmatic fractionation of tin granites increases Sn content, while fluid loss and alteration decreases Sn concentrations in granites, contrary to the proposal by Ballouard et al.

Ballouard et al. further argue that the correlation of decreasing Nb/Ta with increasing alteration of micas supports Nb-Ta fractionation by hydrothermal fluids. However, magmatic fractionation increases the concentrations of water and F in the melt. Upon exsolution, these components impose increasing post-magmatic alteration of fractionated leucogranites. Therefore, both decreased Nb/Ta and post-magmatic alteration can be the result of magmatic evolution.

Tantalite overgrowths on columbite in ongonite grains (Dostal et al., 2015) are cited by Ballouard et al. as an example of Ta hydrothermal transport. This contradicts their statement that Nb is more mobile than Ta in hydrothermal fluids. Zonation with an increasing Ta from core to rim of tantalite-columbite grains is common in leucogranites and pegmatites, and this zonation is best explained by the lower solubility of columbite relative to tantalite in melts (Linnen, 1998).

Extreme granite fractionation is required to explain the genesis of rare metal pegmatites (London, 2008) and Sn granites (Lehmann, 1982). Occam’s razor demands that the simplest explanation should be preferred. That magmatic processes explain most features of rare metal leucogranites and pegmatites suggests that hydrothermal processes may not be required to fractionate Nb from Ta, although there are still many unknowns regarding the origin of rare metal granites.

REFERENCES CITED


