Uranium incorporation in andraditic garnet

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Minerals of the garnet supergroup are widespread in, e.g., medium- to high-pressure metamorphic rocks, where they form an integral part of many well-established geobarometers and -thermometers. Since a few years, garnet U-Pb dating by (in-situ) LA-ICPMS is being developed. This method offers rapid analysis of a large set of samples with high spatial resolution and an age precision comparable to other geochronometers. However, the success rate of the method is hampered by our limited ability to predict the suitability of a particular sample for U-Pb dating. This limitation is due to current ambiguities regarding the incorporation of uranium (and Pb) in garnet.

In this study we investigate the incorporation of Uranium in (Ti-bearing) andraditic garnet, from alkaline igneous rocks and skarns. Previous studies on the incorporation of U into the garnet structure were restricted to elbrusite that contains U as a major component (up to 27 wt.%) in conjunction with Zr (Galuskina et al., 2010). Most natural andradite, however, contains only trace levels of U (typically 1–50 µg/g) and the substitution and incorporation mechanisms at this concentration level are unknown. Furthermore, previous studies even have claimed that U is not incorporated in garnet at all, and that the analysed U content is due to U-bearing inclusions (e.g., Lima et al., 2014). On our suite of five andradites, two of which originated from alkaline igneous rocks and three from skarn deposits, we completed a full chemical characterization. This included major and trace-element analyses and mapping by EPMA and LA-ICPMS, determination of the oxidation state of Fe by the EPMA flank method and by Mössbauer spectroscopy, and U-Pb dating by LA-ICPMS. Our results demonstrate that uranium concentrations strictly follow the oscillatory growth zoning of garnet, and one sample even exhibited sector zoning of U in garnet (Fig. 1). In general, U shows a positive correlation with Th and with Ce, and no correlation between U and Zr, showing that the elbrusite substitution vector does not (necessarily) operate at the trace-element level in andradite. Instead, U is likely incorporated in the dodecahedral site and charge compensated by octahedral divalent ions and/or tetrahedral Fe^{3+}.

Our results show that U, together with Th and the LREE, is indeed incorporated into the structure of garnet, as opposed to U being present only in submicroscopic inclusions. Also, the LREE abundance can be used as a proxy for U-enriched zones. Garnet U–Pb geochronology by LA-ICPMS on andraditic garnet will, thus, be able to reveal the age of the garnet crystallization itself, if U-rich inclusions are avoided. This conclusion agrees with mass-balance estimates presented by Millonig et al. (2020) for metamorphic garnet.

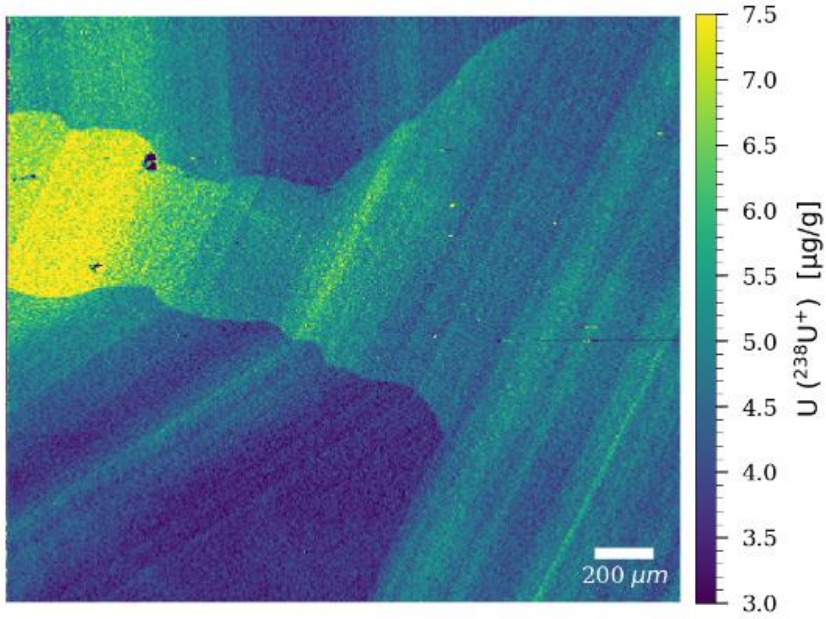

Figure 1. LA-ICP-QQQ-MS mapping of ^{238}U in a Ti-rich andradite from Magnet Cove, Arkansas. Notice the very distinct oscillatory and sector zoning.

Galuskina IO, Galuskin EV, Armbruster T, Lazic B, Kusz J, Dzierżanowski P, Gazeev VM, Pertsev NN, Prusik K, Zadov AE, Winiarski A, Wrzalik R, Gurbanov AG (2010): Elbrusite-(Zr)–A new uranian garnet from the Upper Chegem caldera, Kabardino-Balkaria, Northern Caucasus, Russia. - Amer Mineral 95, 1172-1181

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