Triple dating of a metapelite from Menipa, Sør Rondane Mountains, East Antarctica based on U–Pb isotopic systems of garnet, titanite, and apatite

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Age analysis from multiple minerals reflecting each metamorphic stage is important to unveil complicated metamorphic histories (e.g. [1]). To do this, discussion based on the direct linkage between *in situ* age determinations and petrological observations is highly desired. Despite the importance, practical applications of *in situ* dating methods have been retarded mainly due to lack in the elemental sensitivity of analytical techniques, and thus, the U-Pb dating was mainly focused on specific minerals, especially U-bearing minerals such as zircon or monazite (e.g. [2]).

Among the metamorphic minerals, garnet is important for constraining both metamorphic environments and the timing of metamorphic events (e.g. [3]). Despite the significance of garnet, the limited number of *in situ* age determinations were reported on garnet, mainly due to the low U concentration. However, owing to the developments of a multiple-spot femtosecond laser ablation (msfsLA) system [4] and a multiple-collector ICP-MS (MC-ICP-MS) [5, 6] at our research group, *in situ* U-Pb dating of metamorphic grossular (Grs) garnet can be conducted [7].

In this study, for determining the timing of prograde and subsequent retrograde metamorphic events, garnet and minerals in its decomposition texture such as titanite and apatite were measured by the U-Pb dating method using msfsLA-MC-ICP-MS. The samples analyzed here were two thin sections (TK2019121301F03 and TK2019121301T01; renamed MNP1 and MNP2 hereafter for simplicity) of metapelites containing vanadium-bearing green Grs collected from Menipa, Sør Rondane Mountains (SRM), East Antarctica, which is a high-temperature metamorphic terrain. The green Grs with the lower V_2O_3 content (~0.5-1.0 wt%; Type 1) is surrounded by a kelyphitic rim, which is the decomposition product of the garnet with quartz, plagioclase, clinopyroxene, and graphite [8]. The kelyphitic rim contains V_2O_3-enriched garnet (up to 21.2 wt%; Type 2 and Type 3) [8].

The Type 1 Grs is a coarse-grained porphyroblast with the U concentration of 1-3 $\mu g\ g^{-1}$. The resulting U-Pb ages were 593 ±8 Ma and 586 ±9 Ma for MNP1 and MNP2, respectively. In the kelyphitic rim of the Type 1 Grs, the Type 2 Grs occurred as fine-grained crystals constituting the kelyphytic rim. The Type 2 Grs hardly contained U while U was concentrated in coexisting titanite (U: 100-1000 $\mu g\ g^{-1}$) in the kelyphite. The U-Pb age of the titanite ranged from 550 to 500 Ma for the MNP1 and was 548 ±7 Ma for the MNP2. The Type 3 garnet (goldmanite) is found in the outermost kelyphitic rim of the MNP1. The Type 3 garnet also barely contained U and a coexisting apatite was a U-bearing mineral (U: 50-90 $\mu g\ g^{-1}$). The U-Pb age of the apatite was 496 ±9 Ma.

The obtained U-Pb ages of the Type 1 Grs (ca. 590 Ma) correspond to the reported timing of the prograde metamorphism in the SRM [9]. The titanite U-Pb age in the MNP2 (ca. 550 Ma) records the timing of the subsequent retrograde metamorphism. For the MNP1 with the outermost rim, the dispersion of the titanite U-Pb ages (550-500 Ma) and the coincidence of U-Pb ages between apatite and the youngest titanite (ca. 500 Ma) can be attributed to the resetting of the U-Pb system by a possible fluid activity driven by a magmatic activity [10]. Based on the data presented here, the important conclusion is that the timings of the prograde metamorphism and two retrograde metamorphic events in the SRM were constrained, and thus, *in situ* dating of garnet and its decomposition products can be a powerful tool for elucidating multiple metamorphic events.

References

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