Petrography of V and Zn-rich gahnite-sillimanite-muscovite gneiss from Menipa, Sør Rondane Mountains, East Antarctica

Tatsuro Adahi[1], Tetsuo Kawakami[2], Fumiko Higashino[2], Masaoki Uno[3]
[1]*Kyushu University,* [2]*Kyoto University,* [3]*Tohoku Universtiy*

The Sør Rondane Mountains, East Antarctica, are composed of high-grade metamorphic rocks and later intrusive rocks which were formed during orogeny associated with the formation of the Gondwana supercontinent (Shiraishi, 1997). The metamorphic rocks are divided into several units based on metamorphic *P-T-t* paths and age distribution of detrital zircons. Based on these observations, it has been suggested that there were two stages of crustal collision events that occurred at ca. 650-600 Ma and at ca. 570-550 Ma, respectively (Osanai, et al., 2013; Adachi et al., 2023a). The Menipa area is located in the central part of the mountains, where pelitic gneisses from structurally higher level underwent metamorphism during 620-560 Ma, while quartzo-feldspathic gneisses from lower structural level recorded metamorphism at 570-550 Ma (Adachi et al., 2022; Kawakami et al., 2022). These data imply that a collision boundary which was formed at 570-550 Ma also exists in this area (Adachi et al., 2023b).

The vanadium- and zinc-rich gahnite-sillimanite-muscovite gneiss occur as lenses about 30 cm thick in pelitic gneisses from structurally higher level of Menipa. Vanadium and zinc contents of the whole rock are about 2000 ppm and 4000 ppm, respectively. The surrounding pelitic gneisses (sillimanite-biotite-garnet gneiss and graphite-bearing sillimanite-biotite gneiss) have been reported to record a clockwise *P-T-t* path of prograde metamorphism between about 600-560 Ma, peak metamorphism of ca. 800 °C and 1.0 GPa at ca. 560 Ma, and subsequent decompression (Kawakami et al., 2022). Vanadium-bearing grossular with a diameter of more than 10 cm occur in the graphite-bearing sillimanite-biotite gneiss, suggesting that COH fluid may be involved in their coarsening (Kawakami et al., 2023).

The constituent minerals of the gahnite-sillimanite-muscovite gneiss are quartz, graphite, sillimanite (V_2O_3 = 0.33-1.46 wt%), gahnite (V_2O_3 = 1.70-2.10 wt%; Cr_2O_3 = 1.89-3.00 wt%), plagioclase (An = 24-30), K-feldspar (BaO = 1.54-1.82 wt%), with muscovite and chlorite as secondary minerals, and apatite, rutile, zircon, and monazite as accessory minerals. The sillimanite and muscovite are light green in color, giving the rock a greenish appearance. The gahnite contains very fine-grained sphalerite and is surrounded by fine-grained muscovite (V_2O_3 = 1.16-2.02 wt%; Cr_2O_3 = 0.84-3.59 wt%) and chlorite (V_2O_3 = 0.29-0.42 wt%; Cr_2O_3 = 3.03-3.34 wt%). Sillimanite is also surrounded by fine-grained muscovite (V_2O_3 = 0.63-1.62 wt%; Cr_2O_3 = 0.19-0.84 wt%) aggregates. Graphite is often associated with muscovite along gneissosity, suggesting the involvement of COH fluid in this rock. Rutile is found in two types of grains: those surrounded by sillimanite (V_2O_3=3.7 wt%, Zr=932-1088 ppm) and those in contact with muscovite in the matrix (V_2O_3=1.33-1.74 wt%, Zr=362-703 ppm). Based on the microstructures and mineralogical compositions, this rock was formed under conditions where sillimanite and gahnite coexisted and then they were replaced by muscovite and chlorite during COH fluid-associated retrograde hydration.

Graphite-bearing vanadium-rich rocks have been reported along possible collision boundaries associated with the formation of the Gondwana supercontinent (e.g., Kenya, Suwa et al. 1996; Madagascar, Ci Cecco et al., 2018). Concentrations of vanadium require a reducing environment and their protoliths are thought to be black shales in these regions. It indicates that graphite bearing vanadium-rich rocks may be environmental indicators of the Mozambique Ocean that existed prior to the formation of the Gondwana supercontinent.

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