Sulfide mineralogy and whole-rock sulfur isotope composition of high-grade metamorphic rocks from the Sør Rondane Mountains, East Antarctica

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The lower crustal rocks of the ca. 650-500 Ma continental collision zone are widely exposed in the Sør Rondane Mountains, East Antarctica. Bounded by the Main Tectonic Boundary (MTB), which is considered to be the collision boundary, granulite facies rocks are mainly distributed in the NE terrane and rocks below amphibolite facies to granulite facies grade are distributed in the SW terrane (Osanai et al., 2013). Recently, ultrahigh-temperature (UHT) metamorphic rock is newly found from the Balchenfjella area in the NE terrane (Higashino & Kawakami, 2022).

Among these metamorphic rocks, sulfide-rich lithologies are found mainly in the Brattnipene and Balchenfjella areas. The sulfides are mostly phyrrotite and pyrite, which often occur in an irregular form at grain boundaries in the rock matrix. In some samples, a small number of sulfides are also found as inclusions in garnet and clinopyroxene. In this study, we measured the whole-rock sulfur isotopic compositions (^{32}S, ^{33}S, ^{34}S, and ^{36}S) of samples containing the sulfides. Bulk rock powders were used to extract sulfur (see Banerjee et al., 2021 for further details on measurement procedures) and results likely reflect the sulfur isotopic composition of the sulfide minerals in the matrix. There is no record of sulfur with mass-independent isotope fractionation, hawever the felsic gneisses, such as garnet-biotite gneiss and garnet-sillimanite gneiss, gave a wide range of $\delta^{34}S_{(CDT)}$ values from -7.0 to +12.0 ‰. These values overlap with sulfur isotopic composition of modern sedimentary sulfides and granitoid rocks (Giacometti et al., 2014). On the other hand, the values for mafic gneisses such as garnet-orthopyroxene-biotite gneiss and garnet-hornblende gneiss ranged from -6.0 to +3.9 ‰, which is consistent with the values previously reported from basalts and gabbros, except for one sample. The mafic gneiss sample that gave a $\delta^{34}S$ value (+12.8 ‰) largely different from published basalt and gabbro values is the one from the Brattnipene area. This sample is a wall rock part of the garnet-orthopyroxene-hornblende gneiss that is discordantly cut by the garnet-hornblende selvage. Higashino et al. (2015, 2019a) found a diffusion profile of chlorine concentration around a garnet-hornblende selvage, which they interpreted to be the trace of saline fluid infiltration during the retrograde metamorphism. Detailed petrological study have shown that the wall rock around the selvage was also affected by saline fluid infiltration (Higashino et al., 2019a), so the sulfur isotopic compositions obtained in this study are likely traces of sulfur-bearing saline fluid infiltration that was involved in the formation of the garnet-hornblende selvage. The high $\delta^{34}S$ value (+12.8 ‰) is close to that indicated by sulfate in seawater or sedimentary sulfides and granitic rocks (e.g., Giacometti et al., 2014). Hornblende and biotite selgaves similar to the garnet-hornblende selvage that cut gneissose structures are widely distributed throughout the Sør Rondane Mountains, suggesting that saline fluid infiltration occurred during the retrograde metamorphism in the entire Sør Rondane Mountains. The results of this study indicate that these retrograde metamorphic saline fluids may be seawater or fluids released during the crystallization of granitoids or partial melts. In fact, in the matrix of felsic gneisses of the Brattnipene, for which high $\delta^{34}S$ values (+9.1 ‰) were obtained in this study, we observed microstructures in which garnet is replaced by mineral intergrowth containing sulfides + cordierite due to fluid influx during the retrograde metamorphism (Ikeda et al., 2021). Therefore, not only mafic gneisses but also some felsic gneisses with high $\delta^{34}S$ values may have been affected by the infiltration of saline fluids during the retrograde metamorphism, similar to the fluids involved in the formation of the garnet-hornblende selvage. Higashino et al. (2019b) studied the oxygen isotopic zoning of felsic gneisses from Barchenfjella and found that $\delta^{18}O$ is significantly lower in the garnet rim. Based on this, they infer that the fluid responsible for the formation of the chlorine-rich biotite included in the garnet rim has a low $\delta^{18}O_{(V\text{-}SMOW)}$ value, and therefore, the origin of the fluid is inferred to be mafic rocks. The $\delta^{34}S$ value of this sample was determined as +5.4 ‰ in this study. Therefore, as in the case of hornblende and biotite selvages that cut the gneissose structure, we can also consider the involvement of sulfur-containing fluids of seawater origin.

In summary, while the origin of fluids involved in the formation of chlorine-rich minerals from the Sør Rondane Mountains may vary by metamorphic stage, they may also be understood in a unified manner as an influx of sulfur-bearing fluids of seawater origin. Further evaluation of more samples with multiple isotopic systems is needed in the future studies.

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