超高温変成作用の指標鉱物たり得る Fe^{3+} を含むアーマルコライトの高温高圧合成の準備状況

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Preparation of high-pressure synthesis of Fe^{3+}-bearing armacolite as a possible key mineral of ultrahigh-temperature metamorphism

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Armalcolite is an Fe–Mg–Ti mineral found at Sea of Tranquillity on July 20, 1969. Previous experiments indicated that armalcolite is stable at low-pressure and high-temperature under low oxygen fugacity (cf. Anderson et al 1970; Kesson & Lindsley 1975; Friel et al 1977; see Figure 1). Recently, Miyake & Hokada (2013) reported Fe^{3+}-bearing armalcolite with an X_{Mg} of 0.136 and $Fe^{3+}/(Fe^{2+}+Fe^{3+})$ value of 0.327 included within quartz porphyroblasts in the garnet–orthopyroxene-bearing quartzo-feldspathic gneiss from Mt. Riiser-Larsen, Napier Complex, East Antarctica. The complex where the ultrahigh-teperature metamorphism underwent is characterized by the occurrence of the sapphirine–quartz paragenesis (Harley 1998). The peak metamorphic temperature of this rock was estimated as about 1060 °C at 0.8 GPa based on the ternary feldspar solvus thermometers (Hokada 2001). As shown by small circles on dotted curves at 0.8 GPa in Figure 1, a single armalcolite with 0.136 X_{Mg} and no ferric iron is only stable above 1345 °C. The assemblage of armalcolite + ilmenite + rutile is stable at temperatures between 1300 and 1345 °C. Armalcolite is no longer stable and breaks down to the two-phase assemblage of ilmenite + rutile below 1300 °C. These pressure–temperature constraints are improbable for regional-scale crustal metamorphism. This indicates that the stability temperature of ferric armalcolite from the Napier complex is likely to be about 240 °C lower than that derived from experiments conducted at reductive conditions. The stability temperature of armalcolite decreases with increasing oxygen fugacity, which is reflected the difference in f_{O_2} between our experiments (f_{O_2} at wüstite–magnetite buffer) and previous experiments (f_{O_2} at iron–wüstite buffer).

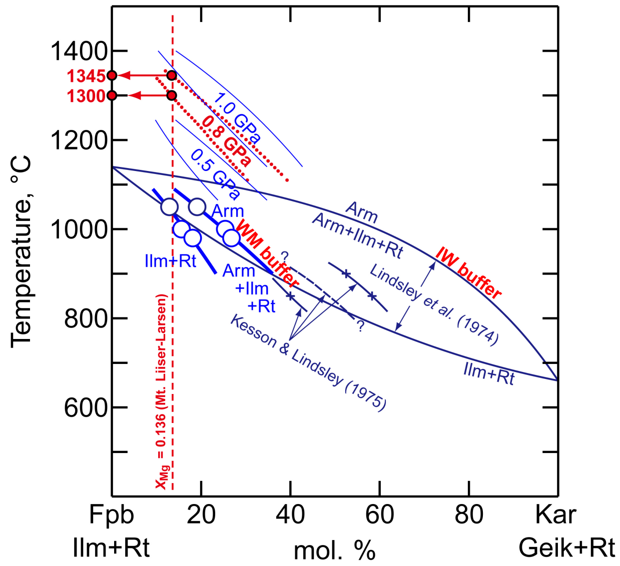

Fig. 1. Plot of chemical data of armalcolite (large circles) projected on the join $FeTi_2O_5$–$MgTi_2O_5$ and of ilmenite (large circles) plotted on the join $FeTiO_3$–$MgTiO_3$, as obtained from annealing experiments on quartz eclogite fragments at 1 atm (Kawasaki et al 2013). The boundaries between the stability fields of the assemblages armalcolite, armalcolite + ilmenite + rutile and ilmenite + rutile in the binary $FeTi_2O_5$–$MgTi_2O_5$ system are indicated by thin loops (Lindsley et al 1974). Experimental data by Kesson & Lindsley (1975) for $(Fe_{0.5}Mg_{0.5}Ti_2O_5)_{0.85}$–$(Ti_2^{3+}TiO_5)_{0.15}$ are shown by "+" on thin curves dividing the stability fields of armalcolite, armalcolite + ilmenite + rutile and ilmenite + rutile. The symbol "+" indicates the composition of coexisting armalcolite and ilmenite. Dashed curve with "?" divides the stability fields of armalcolite and armalcolite + ilmenite + rutile for the composition $(Fe_{0.5}Mg_{0.5}Ti_2O_5)_{0.84}$–$(Al_2Ti_5)_{0.04}(Cr_2Ti_5)_{0.03}(Ti_2^{3+}TiO_5)_{0.09}$, following Kesson & Lindsley (1975). Thin curves labelled "1.0 GPa" and "0.5 GPa," and dotted curves labelled "0.8 GPa" show the calculated phase boundaries between the stability fields of the assemblages armalcolite, armalcolite + ilmenite + rutile and ilmenite + rutile using the volume data and Friel et al's (1977) experimental data. Arm, armalcolite. Fpb, ferropseudobrookite $FeTi_2O_5$. Geik, geikielite $MgTiO_3$. Ilm, ilmenite $FeTiO_3$. Kar, karrooite $MgTi_2O_5$. Rt, rutile TiO_2.

I believe that armalcolite is a promising indicator of ultrahigh-temperature metamorphism. More work is needed before we can be used to make quantitative pressure–temperature etimates. High pressure experiments have been started to clarify the stability of armalcolite under high oxygen pressure. New high pressure assemblages have been designed to maintain high oxygen pressure as the first step of the experiments. I wolud like to report these eperimental approaches.

References

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Fig. 1 armalcolite