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The stability of sapphirine + quartz in magnetite-bearing high oxygen fugacity granulites: a case study of the Madurai Block (Southern India) and the Inner Mongolia Suture Zone (North China)

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Sapphirine has been the focus of many petrological investigations for the last two decades as the mineral often occurs in Mg-Al rich and pelitic rocks formed at high temperature to ultrahigh temperature (UHT). Particularly, sapphirine coexisting with quartz is considered as one of the most diagnostic mineral assemblages of UHT metamorphism. It is also known that sapphirine often occurs in magnetite-bearing high oxygen fugacity rocks, and, in such cases, the mineral can incorporate considerable quantity of ferric iron as well as Fe2+. It is therefore important to evaluate the effect of Fe3+ content on the stability of sapphirine-bearing assemblages for estimating peak conditions as well as constructing P-T paths. In this study, we evaluated the stability of sapphirine + quartz in magnetite-bearing high-oxygen fugacity rocks in UHT granulites from India (Madurai Block in the southern granulite terrane) and China (Inner Mongolia Suture Zone) using mineral equilibrium modeling technique, and constructed P-T paths of the areas. The calculations have been done in NCKFMASHTO system using THERMOCALC 3.33 with an updated version of the internally consistent data set.

The Madurai Block is the largest granulite block in the Southern Granulite Terrane, India, which was formed by collisional orogeny related to the assembly of the Gondwana Supercontinent. The block contains granulites with various UHT mineral assemblages including sapphirine + quartz, orthopyroxene + sillimanite + quartz, and Al-rich orthopyroxene. Quartzo-feldspathic garnet-sillimanite granulites from Rajapalaiyam area in the southern part of the block, for example, contain sapphirine + quartz inclusion in garnet as a stable mineral assemblage at the peak of metamorphism. The calculated T-X pseudosections suggest that the stability temperature of sapphirine + quartz is lowered from 1000°C at reduced condition ($XFe2O_3$ = 0.02) to 910°C at oxidized condition ($XFe2O_3$ = 1.0).

The Inner Mongolia Suture Zone within the North China Block rarely contains sapphirine-bearing UHT granulites. Tuguiwula area within the suture zone contains coarse-grained sapphirine granulites. Although both sapphirine and quartz occur quartzo-feldspathic layers of the rocks, the two minerals are separated by thin film of sillimanite. This indicates sapphirine was in equilibrium with quartz at prograde or peak metamorphic conditions and separated during retrograde metamorphism. The T-X pseudosection of the rocks indicate that the stability field of sapphirine + quartz lowered in more oxidized condition (T > 1050°C at $XFe2O_3$ = 0.1 to T > 920°C at $XFe2O_3$ = 0.9).

The results of this study demonstrated that the occurrence of sapphirine + quartz in UHT rocks is strongly controlled by the oxidation state of the rocks. Lowering of the stability field of sapphirine + quartz by increasing $XFe2O_3$ ratio was also confirmed for UHT granulites from the Madurai Block and the Inner Mongolia Suture Zone.