# Progressive reactions and *P-T* conditions of the Ryoke metamorphism, SW Japan: Implication for thermobaric structure beneath continental margin

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The Ryoke metamorphic rocks in the Yanai district, SW Japan, upgrade from virtually non-metamorphic rocks to partially molten rocks. Change in mineral assemblages in pelitic rocks has been well explained by a series of progressive dehydration reactions. In addition, finding of orthopyroxene-bearing assemblages in metabasite in the highest-grade area suggests that the Ryoke metamorphism reached the granulite facies, contrary to the upper amphibolite facies as previously asserted. Pressure-temperature conditions of pelitic and siliceous rocks have been determined based on a conventional thermometer and an empirically calibrated barometer based on the following reaction in the assemblage, garnet + biotite + plagioclase + quartz,

pyrope + grossular + eastonite + quartz
= phlogopite + anorthite.

The thermobaric structure of the area shows that pressure increases up to 5-6 kbar with southward ascension of metamorphic temperature up to ca. 900 $^{o}$C. Towards further south, pressure is almost the same as that of the highest-grade zone and temperature decreases. These features suggest that the high-grade areas of the Ryoke metamorphism do not lie on a smoothly-curved field pressure-temperature curve, and that temperature increases northwards, that is, towards continental side at the mid-crustal level at time of the peak metamorphism.

# Magmatic Inclusions in Martian Meteorites

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Magmatic inclusions occur in most martian meteorite groups (chassignite gr., nakhlite gr., lherzolitic shergottite gr., and basaltic shergottite gr.). They are mainly included in some olivine or pyroxene grains of the host lithologies. They are several to a few hundreds of µm in diameter, and rounded to subrounded in shape.

During crystallization of martian magmas, the liquid of magmas was trapped as melt inclusions in crystallizing host minerals, which resulted in magmatic inclusions. The melt inclusions experienced closed-system crystallization in the host minerals, except for exchange diffusion of Mg and Fe between the melt inclusions and the host mineral. The melt inclusions show metastable crystallization sequences that are different from the stable sequence suggested by phase diagrams, indicating that crystallization of the melt inclusions differs from that of the host lithology that shows an open-system and stable crystallization sequence.

Primary trapped liquid (PTL) crystallizes first the “wall phase” surrounding the inclusions under a metastable condition. Thereofre, the chemical compositions of PTL are obtained from the compositions of magmatic inclusions mixed with a suitable amount of the wall phase. As magnesian martian meteorites contain cumulus minerals more or less, the whole rock compositions do not necessarily represent the martian magmas. Magmatic inclusions, however, give us direct information about the major element compositions of martian magmas.

In addition to magmatic inclusions, the chemical compositions of martian magmas have been obtained from interstitial liquid compositions for cumulus phase-bearing rocks and the whole rock compositions for cumulus phase-free rocks. Recently, new types of martian meteorites have been recovered from deserts and Antarctica, and the martian meteorites show a wide variety, forming a martian magma trend in compositional variation diagrams. This trend is mostly between the Hawaiian tholeiite trend and the lunar low-Ti basalt trend. The $P_2O_5$ and $TiO_2$ contents of the martian trend, however, are higher and lower than the latter two trends, respectively. The FeO contents of the martian trend are higher than the Hawaiian trend and similar to the lunar trend, although the $Al_2O_3$ contents are lower than the Hawaiian trend and again similar to the lunar trend. The martian magma trend is consistent with the composition of the martian mantle that was obtained by Wanke and Dreibus (1988).

## Reference

Wänke H. and Dreibus G., (1988), Phil. Trans. R. Lond. A325, 545-557.