titanomagnetite, ilmenite and calcite (Hari et al., 1997). All these rocks are nepheline normative and are enriched in alkali, REE, Ba and Sr. However camptonite have low $Na_2O + K_2O$, ΣREE and Ce/Yb values than kersantite. None of the samples carry a primary magma signature. High alkali and trace element concentrations in these rocks indicate that source region is metasomatically enriched in these elements (Hari, 1997). Salite globules in the lamprophyres and in the matrix of carbonatites indicate silicate-carbonate immiscibility.

Dolerite is the third category of dyke noticeable in the present region. On the basis of mineralogy, these rocks are divided into (1) Olivine dolerite - Presence of olivine with other minerals (2) Dolerite - devoid of olivine. Augite labradorite (An_{52-60}), titanomagnetite, ilmenite, calcite and secondary glass are commonly noticeable in thin section. The 'Olivine dolerite' is olivine normative and contain high Mg values, Ni, Cr than that of 'Olivine free dolerite'. Negative Eu anomaly in (1) the chondrite normalized diagrams of both the olivine dolerite and olivine free dolerite indicate plagioclase fractionation. Low LREE concentration in olivine dolerite than that of the most 'primitive flow' in this area indicate that these rocks are not co-genetic.The dyke swarms warrant detailed studies in terms of their structural setting, petrology and geochemistry in elucidating the rift tectonics of the Indian sub-continent from the East Gondwana assembly.

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CORRESPONDENCE

The Ryoke Metamorphic Belt (Japan): An Excellent Example of Low-P/High-T Metamorphic Belt

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The Ryoke metamorphic belt is one of the typical low-pressure type metamorphic belts in the world (e.g. Miyashiro, 1994), that is not of Gondwana assembly, and is composed of Cretaceous Ryoke granitoids and associated metamorphic rocks of low-pressure facies series. This metamorphic belt can be now regarded to provide an excellent example of island arc or continental margin metamorphism, which might contribute to understand the formation and development of continental crust. The Ryoke granitoids are divided into sheet-like bodies (Older granitoids) and stock-like bodies (Younger granitoids). The Ryoke metamorphic rocks and Older granitoids in the Yanai district, southwestern Japan, show three different phases of ductile deformation (Okudaira, 1996b). During the first phase (D_1), a distinct foliation parallel to lithologic layering was formed under the thermal peak conditions of the low-pressure facies series metamorphism. The second phase deformation (D_2) led to the formation of mylonitic shear zones and nappes. Deformation of the third phase (D_3) was responsible for the

formation of the upright folds with E-W trending axes. The displacement of D_1 during and immediately before the intrusion of the Older Ryoke granitoids was of extension tectonics. After D_1, the nappes and upright folds of the metamorphic rocks and granitoids were formed during D_2 and D_3 probably under compressional stress field.

The regional Ryoke metamorphism has been divided into two phases, M_0 and M_1 (Okudaira et al., 1993). The metamorphism of M_0 was of nearly medium-pressure facies series (ca. 30°C / km) and that of M_1 was of low-pressure facies series (ca. 40-50°C / km). On the basis of the mineral assemblages crystallized under M_1, the Ryoke metamorphic rocks are divided into four metamorphic zones: biotite zone, cordierite zone (460-590°C, 250-350 MPa), sillimanite zone (630-690°C, 300-500 MPa), and garnet zone (730-770°C, 550-650 MPa).

The Older granitoids intruded concordantly into the high-grade metamorphic rocks without development of a contact metamorphic aureole, and the intrusion ages of the granitoids are similar to the ages of thermal peak of the M_1 metamorphism. It is suggested that the low-P Ryoke metamorphism resulted from the intrusion of the Older granitoids. A simple 1-D numerical model of conductive heat transfer was used to evaluate the thermal effects of emplacement of the Older granitoids (Okudaira, 1996b). Calculated temperature-time (T-t) paths are characterized by a rapid increase of metamorphic temperature and a relatively short-lived period of high temperature. For example, the T-t path at the 15km depth is characterized by a rapid average increase in temperature of 1.4×10^{-3} °C year^{-1} and high temperatures for < ca. 0.5 Ma. The calculated peak temperature for each depth is nearly equal to the petrologically estimated value for each correlated metamorphic zone. The results suggest that the magma-intrusion model is one possible thermal model for low-pressure facies series metamorphism.

Furthermore, to evaluate the thermal model, chemical zoning in garnet crystals were examined (Okudaira, 1996a). Garnet crystals from the rock of the sillimanite zone show several kinds of chemical zoning patterns that systematically vary with grain radius between ca. 0.1 and 0.5 mm. Large grains (> ca. 0.4 mm) show normal zoning and small grains (< ca. 0.4 mm) show unzoned or reversely zoned cores. Observations of the chemical zoning and of the spatial and size distributions of the garnet grains between ca. 0.1 and 0.5 mm in radius suggest that they were formed by continuous nucleation and diffusion-controlled growth. Chemical zoning of garnet grains with different radii simulated for the T-t path using a numerical model of continuous nucleation and diffusion-controlled growth, in combination with intracrystalline diffusion, compares well with the observed zoning patterns in garnet grains with different radii. This is, in spite of the fact that the simulated zoning patterns vary greatly, depending on subtle differences in the T-t history. Therefore, they suggest that the T-t path gives a good explanation for the low-pressure Ryoke metamorphism (M_1).

In conclusion, the Ryoke metamorphic rocks firstly were heated under medium-pressure facies conditions, and then they were further heated under low-pressure facies conditions caused by the intrusion of the Older Ryoke granitoids.

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