Fluid flow and stable isotopic alteration along out-of-sequence thrust: The Northern Chichibu accretionary complex, western Shikoku, Japan

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Fluid flow related out-of-sequence thrust were investigated in the low-grade metamorphosed Jurassic Northern Chichibu accretionary complex in the Kanogawa area, western Shikoku, Japan, based on accretionary geology, metamorphic petrology and stable isotope geochemistry of host rocks and veins.

The Northern Chichibu Belt in the Kanogawa area, western Shikoku, is divided into two units, Kanogawa and Hijikawa, on the basis of their lithologies, geologic structure and metamorphic grades. The Hijikawa unit tectonically overlies the Kanogawa unit by the out-of-sequence thrust. The Hijikawa unit is composed mainly of pelitic, psammitic and basic semischists, and chert, metamorphosed under the middle grade of the pumpellyite-actinolite facies. The Hijikawa basic semischist were metasomatically altered. The Kanogawa unit consists mainly of alternation of sandstone and shale, and pelitic melange including blocks of green rocks, chert and limestone. It metamorphosed under the prehnite-pumpellyite facies.

In the Kanogawa unit, pelitic and psammitic rocks have $\delta^{18}O_{host\ rock}$ values of 12.7 to 15.6 per mil and 11.2 to 12.6 per mil, respectively. In the pelitic rocks, quartz and calcite in veins have $\delta^{18}O_{quartz}$ of 16.9 to 19.8, $\delta^{18}O_{calcite}$ of 15.9, and $\delta^{13}C_{calcite}$ of -4.7 to 4.8 per mil. In the basic rocks, calcite in veins have $\delta^{18}O_{calcite}$ of 15.3 to 20.1 and $\delta^{3}C_{calcite}$ of -7.7 to 2.6. In the Hijikawa unit, pelitic and psammitic rocks, and basic rocks rocks have $\delta^{18}O_{host\ rock}$ of 14.8 to 18.4 per mil and 12.7 to 18.2 per mil, respectively. In the pelitic and psammitic rocks, quartz and calcite in veins have $\delta^{18}O_{quartz}$ of 18.7-20.8, $\delta^{18}O_{calcite}$ of 17.3-20.9, and $\delta^{13}C_{calcite}$ of -6.9 to 0.1 per mil. In the Hijikawa basic rocks, calcite in veins have $\delta^{18}O_{calcite}$ of 18.0 to 20.2 and $\delta^{13}C_{calcite}$ of 0.6 to 4.6.

$\delta^{18}O_{quartz}$, $\delta^{18}O_{calcite}$ and $\delta^{18}O_{host\ rock}$ values show the large discontinuity at the out-of-sequence thrust between the Hijikawa and Kanogawa units. At the Hijikawa unit adjacent to the thrust, strongly channelized fluid flow requires a high permeability contrast between the sheared melange zone and other rocks. The stable isotopic alteration in the Hijikawa unit reflect up-dip flow of H_2O released at deeper part of accretionary prism.

Oxygen Isotope Geothermometry of Skarn Developed in Ichinotake Limestone, North Kyushu, Japan

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The Ichinotake skarns are located at Kawara Town in North Kyushu, Japan, and occur as veins invading Palaeozoic limestone-marble, which are sporadically found at the quarrying bench. They are 1 to 5 m wide at the benches. The veins are mineralogically zoned, and are classified into two types; Type 1: clinopyroxene-garnet-magnetite (Cpx-Gt-Mt), and Type 2: clinopyroxene-garnet-wollastonite (Cpx-Gt-Wo). Both types show different chemical compositions of Cpx and Gt; Type 1: $Di_{38}Hd_{62}$-$Di_{7}Hd_{93}$ and $Ad_{70}Gr_{30}$-$Ad_{99}Gr_{1}$, Type 2: $Di_{64}Hd_{36}$ -$Di_{51}Hd_{49}$ and $Ad_{88}Gr_{12}$-$Ad_{94}Gr_{6}$.

The purpose of this study is to clarify the P-T conditions of the vein-formed skarn by means of clinopyroxene (Cpx: Di/Hd = $CaMgSi_2O_6/CaFeSi_2O_6$) - garnet (Gt: Ad/Gr = $Ca_3Fe_2Si_3O_{12}/Ca_3Al_2Si_3O_{12}$) oxygen isotope geothermometry.

Each mineral in the skarn vein was carefully separated under the binoculars, and the oxygen was liberated by the BrF_5 fluorination technique (Clayton and Mayeda, 1963). Oxygen isotope ratios were measured by PRISM mass spectrometer at the Institute for Study of the Earth's Interior, Okayama University. The equilibrium oxygen isotope geothermometer between Di and Gr was constructed from the experimental results of Chiba et al. (1989) and Rosenbaum and Mattey (1995). Though no oxygen isotope geothermometer has been developed experimentally for andradite, experimental study of Matthews et al. (1983) suggests that the divalent cation substitution of Cpx does not change the oxygen isotope fractionation among chemically substituted Cpxs. Thus, we constructed the oxygen isotope geothermometer for the Cpx-Ad/Gr pair based on a combination of results of Chiba et al. (1989), Rosenbaum and Mattey (1995) and Kieffer (1982). The equation obtained is as follows:

$$1000\ ln\ \alpha_{Cpx\text{-}Ad/Gr} = \delta^{18}O_{Cpx} - \delta^{18}O_{Ad/Gr} = (0.30 + 0.50X_{Ad}) \times 10^6/T^2$$

where X_{Ad} is andradite mole fraction in garnet and T in Kelvin.

The oxygen isotope compositions measured for three Cpxs and eight Gts are in the range of 11.0 - 12.4 ‰ and 8.1 - 14.1 ‰, respectively. The differences of small-delta^{18}O between the paired minerals of Types 1 and 2 are 1.8 ‰ and 1.3 - 1.8 ‰, respectively. Using the equation shown above, the equilibrium oxygen isotope temperatures were calculated to be 395(±59) degrees centigrade for Type 1, and 385 - 484(±99) degrees centigrade for Type 2. These results will be discussed in comparison with fluid inclusion geothermometry.