Re-examination of pressure difference based on geobarometry and its geological significance

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Conventional geobarometers contain, in general, uncertainty that exceeds 100 MPa. The uncertainty of 100 MPa corresponds to the uncertainty in depth of 3.6-3.7 km. These features have caused difficulty in deciphering precise thermobaric structures (isobaric lines) in a metamorphic region, as well as in employing them as constraints to evaluate the validity of any numerical models of crustal evolution. This study re-examined the formulation of conventional geobarometers and revealed that the difference in the estimated pressures based on the same geobarometer contains uncertainty that is smaller, in one order of magnitude, than that of the absolute pressure.

The uncertainty in pressure estimation of conventional geobarometers is derived from the uncertainties of enthalpy and entropy changes of the reaction, provided that volume change of the reaction, equilibrium constant and temperature were well-established. The uncertainties derived from the enthalpy change and entropy change represent similar magnitude at temperatures of most crustal conditions. For example, the geobarometers based on the reaction among garnet, clinopyroxene, plagioclase and quartz show uncertainty derived from enthalpy change of 120 MPa, that from entropy change of 120 MPa at 727 °C, and in total of 160 MPa.

In contrast, comparison of two samples based on the same pair of geothermobarometers provides uncertainty of pressure difference in which the uncertainty derived from enthalpy change disappears. Further the uncertainty of entropy change is multiplied by temperature difference but not by absolute temperature, the former is much smaller than the latter. As a result the geobarometers shown above represent uncertainty in pressure difference of 32 MPa at temperature difference of 200 °C. This indicates that we can determine the difference in depth precisely with uncertainty of c. 1.2 km.

As an example of geological application, we chose a high-temperature metamorphic complex in the Omuta area, northern Kyushu, SW Japan. The metamorphic complex is in contact with a Cretaceous granitic complex, which has raised a question whether the metamorphism was regional or thermal. Two examined samples are spatially 6.8 km distant (2.3 km perpendicular to the isograds) from each other, and show the pressure difference of 320 MPa with uncertainty of 10 MPa. This pressure difference corresponds to 11-12 km difference in depth with unceratainty of 0.3 km, and is significantly larger than the geographic distance. No fault with large separation is present between the localities. The result leads us to the conclusion that the significant crustal thinning took place during retrograde metamorphism, implying regional origin of the metamorphism.

Keywords: pressure difference, geothermobarometer, uncertainty

