Disequilibrium Sm-Nd and O isotope systems in garnet peridotite during UHP metamorphism

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In the isotopic geochronology of metamorphic rocks, an critical question is whether radiometric systems of mineral isochron have achieved thermodynamic equilibrium during a given metamorphic event and preserved the equilibrium afterwards. A garnet peridotite at Zhimafang in the Sulu terrane of eastern China shows decoupled Sm-Nd, Rb-Sr and U-Pb systems when making radiometric dating. Two samples of mineral Sm-Nd isochron yield ages of 376±14Ma and 378±24Ma, respectively. Mineral Rb-Sr isochron dating gives consistent ages of 201±4Ma and 205±4Ma for the same two samples. SHRIMP zircon U-Pb dating gives discordant ages of 216 to 233Ma, but an isochron age of 224±8Ma. Sm-Nd isotope disequilibrium is suggested among the minerals if the Triassic UHP metamorphic event is assumed for the garnet peridotite. This is confirmed by petrological textures and the state of oxygen isotope equilibrium or disequilibrium among the constituent minerals in the garnet peridotite.

Oxygen isotope disequilibria are observed among most minerals. In particular, garnet is not in oxygen isotope equilibrium with any other of the analysed minerals. The degree of oxygen isotope disequilibria between the other minerals varies from pair to pair. Oxygen isotope equilibrium is only observed between orthopyroxene and olivine for both samples and between phlogopite and clinopyroxene for one sample. The $\delta^{18}O$ values of both single minerals and whole-rock for the two isochron samples fall within the $\delta^{18}O$ range of 5.7±0.5‰ for the normal mantle, indicating that the garnet peridotite was not significantly affected either by meteoric-hydrothermal alteration before plate subduction like the UHP eclogites in this region.

This combined study of U-Pb, Rb-Sr, Sm-Nd and O isotope systems demonstrates that the duration of the UHP metamorphism and subsequent HP eclogite-facies recrystallization was not long enough for the reequilibration of the Sm-Nd and O isotope systems in the garnet peridotite, but just long enough for the reequilibration of the Rb-Sr isotope systems. The timescale of the Rb-Sr reequilibration is thus shorter than that of the Sm-Nd and O isotope reequilibration at mantle and deep-crustal depths. Therefore, the rates of Sr isotope reequilibration between the mafic minerals are constrained to be faster than those of Sm-Nd and O isotope reequilibration between the same minerals at the mantle and deep-crustal conditions.

Oxygen isotope mapping of UHP metamorphic rocks in the Dabie-Sulu orogen of China

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Metamorphic devolatilization is very common during subduction of oceanic crusts because of the presence of fluid-rich marine sediments. However, it is a question whether subduction of a continental crust also produces a great deal of volatiles during prograde metamorphism. Occurrence of diamond and coesite in supracrustal rocks in the Dabie-Sulu orogen provides an important target to study fluid mobility during UHP metamorphism of the Yangtze continental plate.

Oxygen isotope mapping was accomplished for various types of HP and UHP rocks, including eclogite, granulite, paragneiss and granitic orthogneiss, over an outcrop area of about 15,000km^2 in the Dabie-Sulu orogen. Despite a large variation in $\delta^{18}O$ value from −10 to +10‰ for the UHP rocks, ^{18}O depletion relative to the normal mantle is discovered in most regions of this orogen. Most of the samples have preserved oxygen isotope equilibrium fractionations between quartz and the other minerals, suggesting that these rocks acquired the low $\delta^{18}O$ signature before plate subduction.

Heterogeneous $\delta^{18}O$ distribution in the eclogites and gneisses is observed not only in the regional scale (−8 to +10‰ in the Shuanghe area of eastern Dabie, and −10 to +5‰ in the Donghai area of western Sulu) but also in outcrop scales (for instance, at Bixiling in eastern Dabie and at Qinglongshan in western Sulu). While a small variation in $\delta^{18}O$ from −11.1 to −10.1‰ is observed for garnet within 5 to 6m distances from kyanite-bearing eclogite at the western outcrop of Qinglongshan, there are large $\delta^{18}O$ variations from −5.5 to −1.6‰ for garnet within 2 to 3m distances from the epidote-bearing eclogite at the eastern outcrop of Qinglongshan and from −1.8 to +3.8‰ for garnet within 200m outcrop from the Bixiling eclogite. In some localities, oxygen isotope homogenization between different rock types was limited to distances of 10cm, and little or no effective isotopic transport took place over distances greater than 1m.

The present study demonstrates very small mobility of fluids during UHP metamorphism of the continental crust. The UHP metamorphism is characterized by channelized fluid flux; slab fluids originate from the metamorphosed supracrustal rocks whose protoliths were hydrothermally altered by the fluid of meteoric water origin; oxygen isotope composition of the fluid is heterogeneous within the subducted slab; the fluid flux is low during the prograde and peak UHP metamorphism. Therefore, the extremely ^{18}O-depleted signature of pre-subduction fluid-rock interactions is not only well preserved in the UHP rocks but also carried into the Earth's interior by broken off slab.