Lu-Hf dating of eclogite from the Sanbagawa belt, Japan

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The results of phengite Ar and zircon fission-track dating have established a cooling history for the Sanbagawa metamorphic belt from around 450°C to 250°C during the period between 85 Ma to 65 Ma. However, the timing of the peak of metamorphism has been much more elusive; a problem common to many metamorphic terranes. The peak age of metamorphism is important to relate metamorphism to large-scale tectonic events and to constrain rates of orogenic processes. Determining this age is, therefore, an important goal in studies of orogenic belts. Garnet is a common mineral in medium to high-grade metamorphic rocks and commonly preserves prograde chemical zoning. These features make garnet a suitable target mineral for dating projects designed to establish an older limit on the age of peak metamorphism. Sm-Nd dating is a widely applied garnet-dating technique. However, in many cases Sm-Nd dating does not produce well-defined isochrons. One of the main reasons for this is the common presence of inclusions within the garnet such as epidote and sphene that can contain high amounts of both Sm and Nd and which can dominate their budget. This problem is compounded by the very similar chemical behaviour of Sm and Nd which restricts the amount of spread likely to develop in Sm/Nd ratios. Despite several attempts, Sm-Nd dating has failed to give a clear age for garnet growth in the Sanbagawa belt. Lu-Hf dating is an alternative and more effective method particularly well-suited to dating eclogite. The elements Lu and Hf have contrasting chemical behaviour with Lu strongly partitioned into garnet resulting in a wide spread of Lu/Hf ratios and high-quality isochrons with low associated errors. Application of this method to Sanbagawa rocks gives high-precision age determination for eclogite formation and fills a major gap in understanding of the tecontics of the Cretaceous east Asian convergent margin.

Prograde P-T paths of the subduction-type Sanbagawa belt and thermal modeling studies suggest the metamorphism represents unusually warm conditions due to the approach of a spreading ridge and that these conditions were attained a few million years before the arrival of the ridge at the convergent margin. In addition, kinematic and radiometric age data from the Sanbagawa belt suggest the associated plate movement vector had a large sinistral oblique component with respect to the Cretaceous East Asian convergent margin. A re-examination of plate reconstructions for the Cretaceous to Tertiary for this region shows that the only plausible candidate plate compatible with such motion is the Izanagi plate. Plate reconstructions imply that progressively younger sections of the Izanagi plate were subducted beneath the Cretaceous East Asian convergent margin: this period is one of ridge approach. This implies the approach of a spreading ridge that continued until the remaining part of the plate became fused to the Pacific plate and ceased to move independently at 85 – 83 Ma. This period represents a major reorganization of plates and associated changes in movement vectors in the Pacific realm and is likely to be the age of large-scale interaction between the ridge and convergent margin. Thermal modelling of P-T conditions and P-T paths predicts that the peak metamorphism should be a few million years older than the age of ridge interaction. Lu-Hf dating of garnet and omphacite from eclogite gives ages of 88 - 89 Ma in excellent agreement with the model prediction. Combining this estimate for the peak age of metamorphism with published thermochronological results implies vertical exhumation rates of cm/yr. This high rate of exhumation can explain the lack of a significant thermal overprint in the Sanbagawa belt during subduction of the ridge.