

Accuracy of Lu-Hf and Sm-Nd garnet dating

ROBERT ANCZKIEWICZ^{1*}, SUMIT CHAKRABORTY², SOMNATH DASGUPTA³, DILIP K MUKHOPADHYAY⁴

¹Polish Academy of Sciences, Kraków, Poland, ndanczki@cyf-kr.edu.pl (* presenting author)

²Ruhr Universität, Bochum, Germany

³Indian Institute of Science Education & Research-Kolkata, India

⁴Indian Institute of Technology Roorkee, Roorkee, India

Lu-Hf garnet dating provides high precision age information, which is competitive even for the most precise geochronometers. Accuracy of garnet geochronology, however, may suffer from several obstacles such as protracted garnet crystallization, resorption or different diffusivities of REE and Hf. In this study we demonstrate the potential of Lu-Hf system for high precision dating of metamorphism and deformation, and show the influence of the above mentioned obstacles on precision and accuracy of garnet geochronology. We compare bulk and high spatial resolution dating of metapelites from the inverted Barrovian metamorphic sequence of the Sikkim Himalaya in India, and migmatites from the Red River shear zone in Vietnam in the context of major and trace element distribution.

Lu-Hf bulk garnet dating of the inverted Barrovian sequence of the Lesser Himalaya in Sikkim yielded Lu-Hf dates from 10.6±0.2 to 14.6±0.1 Ma with uncertainty smaller than 2% achieved for all samples. Such high precision of bulk garnet dates may be significantly underestimated due to uncertainty about the duration of garnet growth. This was verified by chemically controlled, high spatial resolution dating of synkinematically grown garnet. Lu-Hf analyses did not show resolvable time difference between core and rim. Instead, all analysed fractions define an isochron age of 13.3±0.5 Ma, which points to fast crystallization and rather short lasting early deformation phase. Dating of the post-kinematic outer rim in the same crystal gave a 9.4±1.5 Ma age, which additionally brackets timing of deformation. All obtained ages reflect the time of prograde garnet crystallization, which is indicated by Rayleigh-like zonation profiles of Lu and Hf up to the silimanite zone.

Under migmatitic conditions garnets from the Red River shear zone display strongly disturbed Rayleigh zonation trends. Light REE, and to a lesser extent, heavy REE rim-to-rim zonation profiles show progressive flattening with the decreasing garnet size. Nd and Sm are completely homogenized in the smallest crystals, while Lu always preserves variable degree of core-to-rim concentration gradient. The observed REE patterns are interpreted as resulting from the combination of protracted garnet growth of progressively smaller crystals and intracrystalline diffusion. This had profound influence on Sm-Nd and Lu-Hf geochronology and resulted in a wide range of the obtained dates. The youngest age was obtained for a sample, where all garnet crystals are smaller than 2 mm and light REE profiles are completely or nearly completely homogenized. Very old apparent Lu-Hf ages are interpreted as being the consequence of variable degree of intracrystalline Lu diffusion and preservation of the original Hf distribution. Commonly observed back diffusion of Lu during resorption typically affected very narrow garnet rims and played subordinate role in modifying the isotope systematics.

The Influence of Recycling on Mantle 238U/235U?

M. B. ANDERSEN^{1*}, T. ELLIOTT¹

¹Bristol Isotope Group, School of Earth Sciences, University of Bristol, Wills Memorial Building, BS8 1RJ, United Kingdom (*morten.andersen@bristol.ac.uk)

The sub-chondritic Th/U (~2.5) of typical mid-ocean ridge basalts (MORB) is puzzling a much higher integrated Th/U (~3.8) evident from 208Pb/206Pb measurements [1,2]. A popular explanation of this problem has been to invoke recycling of U from the surface into the mantle since the Great Oxidation Event [e.g. 3]. It is intriguing that the lowering of Th/U seems concentrated in the upper mantle, such that MORB have lower Th/U than ocean island basalts (OIB), which are thought to be derived from deeper seated upwellings. This observation potentially informs on the style and vigour of mantle convection. Although an attractive hypothesis, it is uncertain if the recycled U fluxes over the last 2Ga are sufficient to lower the Th/U of MORB to 2.5 [4], despite recent improvements in estimates of modern recycling rates [5].

Mass-related variations in the natural 238U/235U ratio [6,7] offer a new means to test this model and we present new data that pertains to the problem. Variations in 238U/235U are related to low-temperature fractionation processes on Earth, with some of the largest variations observed in oceanic material (e.g. black shales). Thus, recycled material may have 238U/235U that deviates significantly from bulk Earth. We initially contrast the isotopic composition of seawater U, as might be quantitatively transferred to oceanic crust by high temperature alteration and Ocean Island basalts (OIB). Such measurements allow us to discern if we will be able to resolve 238U/235U differences between high Th/U OIB and low Th/U MORB as a result of recycling. We have measured the 238U/235U compositions of a suite of well-characterised OIB and related samples with high precision (±20, 2 SD). The measured OIBs include samples from La Palma, Azores and Iceland, spanning a wide range of U/Th compositions. The measured OIBs have identical 238U/235U compositions within ± 25 ppm (2 SD) and these are ~100 ppm heavier than modern seawater. Furthermore, preliminary measurements of hydrothermal altered MORB yields a weighted 238U/235U mean similar to seawater. This indicates that MORB should have 238U/235U ~50ppm lighter than the OIB if the recycling hypothesis is correct. We are currently undertaking the challenging task of making high precision 238U/235U measurements on MORB.

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