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Combined U-Pb and Sm-Nd Systematics of Early Archean Titanite

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In this study I use combined Sm-Nd and U-Pb isotopic systems in single titanite grains from early Archean rocks in an attempt to obtain initial Nd isotopic values that are independent of assumption about closed system behavior of whole rocks. Neodymium isotopic systematics of early Archean polymetamorphic rocks has long been a subject of controversy. The main problem is that the assumption of a closed system is hard to verify for whole rocks. Titanite is a common accessory mineral in early Archean felsic rocks and a major concentrator of REE and uranium. U-Pb in titanite may be used to monitor the integrity of the Sm-Nd system, in a similar way as U-Pb in zircon is used to interpret Lu-Hf data [1].

Extensive use of titanite from Neoarchean and younger rocks for dating metamorphism has shown that titanite populations are in many cases heterogeneous and form linear arrays on concordia diagrams between the timing of magmatism and metamorphism, or between two metamorphic episodes. To resolve the isotopic characteristics of old and young titanite populations, one has to analyze multiple, small fractions or single grains.

Titanite from three gneiss samples from West Greenland have been analyzed: a massive gray gneiss GGU-163254 from the Isua area; a dark "early" phase of a polyphase gneiss GGU-163263, collected south of the Isua supracrustal belt, and an Amitsoq augen gneiss GGU-163290 from the Nuuk area. Zircons from these samples were previously analyzed for U-Pb and Lu-Hf [1]. Titanite is abundant in all three samples. The gneisses 163254 and 163263 contain mainly pale-brown, anhedral titanite of variable clarity. Dark-brown grains make up less than 10 per cent of the populations. The titanite population of the gneiss 163290 consists of euhedral yellow grains of uniform appearance. Single titanite grains and multigrain fractions were spiked with ^{235}U-^{205}Pb and ^{149}Sm-^{150}Nd, and analyzed using a thermal ionization mass spectrometer.

U-Pb titanite ages were calculated from concordia intercepts of linear arrays on a conventional concordia diagram, and from 3-D plane regressions. Both methods yielded nearly identical results for multiple analyses of brown titanite grains from the gneiss 163263, with upper concordia intercepts of 3596-3597 Ma and lower concordia intercepts of 2662-2670 Ma. A Sm-Nd isochron for the same fractions yielded an age of 3601±170 Ma, identical to the upper intercept U-Pb age. This implies that the dark titanite crystallized at ca. 3600 Ma during early Archean metamorphism, and the downward shift along the discordia results from variable amount of Pb loss. Most brown grains have [Nd]>1000 ppm, and [U]>90 ppm. The ε_{Nd}(T) values calculated using ^{206}Pb/^{238}U ages are nearly uniform for titanite fractions with [Nd]>1000 ppm, while fractions with low [Nd] show variable ε_{Nd}(T). The data for five oldest grains give a robust estimate of ε_{Nd}(T)=+0.32±0.20 at 3600 Ma for the gneiss 163263. Extrapolation from this value to the crystallization age of 3710±20 Ma using an average crustal ^{147}Sm/^{144}Nd=0.12±0.04 yields ε_{Nd}(T)=+1.5±0.6 at the time of crystallization. Average zircon E_{Hf}(T) of this rock is +1.9±1.0.

The U-Pb data for pale-brown titanite fractions from the gneiss 163254 yield upper concordia intercept of 3543-3549 Ma and lower concordia intercepts of 2597-2646 Ma, very similar to those of the gneiss 163263. The Sm-Nd systematics are, however, very different: titanite grains have low Nd contents of 15-30 ppm, high ^{147}Sm/^{144}Nd of 0.25-0.45, and very radiogenic Nd (measured ^{143}Nd/^{144}Nd of 0.514-0.518), and do not form an isochron. This suggests recrystallization of titanite that was possibly accompanied by modification of the Sm-Nd system in the whole rock. No reliable initial Nd value has been obtained from this gneiss.

The U-Pb system in titanite from the gneiss 163290 is concordant at 2.56±0.06 Ga. The Sm-Nd analyses of four fractions yielded average ε_{Nd}(T)=-9.00±0.36. Extrapolation to the crystallization age of 3610±10 Ma using the average crustal ^{147}Sm/^{144}Nd=0.12±0.04 yields ε_{Nd}(T)=+1.8±5.4 at the time of crystallization. The large uncertainty is a result of extrapolation over a billion-year period between crystallization of zircon and titanite.

The results presented here show that precise and tenable initial Nd values for early Archean gneisses can be obtained from analyses of titanite grains formed during an early metamorphism and not disturbed later, even if these grains represent a small fraction of an otherwise young or altered titanite population.

Amelin Y, Lee D-C & Halliday AN, *Ninth Annual V.M.Goldschmidt Conference. LPI Contribution 971*, 8-9, (1999).