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Metamictization and chemical durability of detrital zircon

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ABSTRACT

We have investigated the effect that metamictization has on the weathering of zircon in detrital continental sediments and tropical soils of the Amazon basin, Brazil. The degree of radiation damage in the near-surface region of the zircon grains was determined by Raman microprobe. In each of the four series investigated (i.e., sediment, podzol, topsoil, and subsoil horizons of lateritic soil), the degree of radiation damage ranges from less than 10^{14} to ~3.5×10^{15} α–decay/mg. The maximum degree of radiation damage coincides with the first percolation threshold of the metamictization process at ~3.5×10^{15} α-decay/mg. Below this threshold, amorphous volumes in the structure of damaged zircon are not connected to each other. The ranges of U, Th, and Pb contents (in ppm) measured by proton induced X-ray emission (PIXE) microanalysis are $100 < U < 7000$, $100 < Th < 18000$, and $100 < Pb < 1300$. Chemical ages, assessed from U, Th, and total-Pb, range between 0.15 Ga and 2.8 Ga. This range is roughly consistent with the ages reported for the Precambrian shields of the Amazon basin (0.45–3.5 Ga). Corresponding radiation doses range between $<2 \times 10^{15}$ and 3×10^{16} α-decay/mg. Comparison of calculated doses with the degree of structural damage indicates that most of the zircon grains have experienced significant annealing. However, the degree of annealing differs from one grain to another. Thus, the acute maximum limit observed for the degree of radiation damage of the whole zircon series is better explained by low-temperature alteration or weathering processes than by thermal resetting. Following this interpretation, our results provide evidence for a dramatic decrease in the chemical durability of zircon in natural weathering environments when the radiation dose exceeds 3.5×10^{15} α-decay/mg. Below the first percolation threshold, the zircon population survives the soil formation intact, but more damaged zircons are dissolved during weathering/alteration processes.