Mobility and fractionation of Zr-Hf, Nd-Ta and Y-Ho due to extreme and overprinting weathering events

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The mobility and fractionation of high field strength elements (HFSE; Zr, Hf, Nb, Ta, Th, U, Ti) under low temperature conditions is well reported but remains fundamentally enigmatic and unproven.

Zircon is a very stable and robust mineral that conserves Zr/Hf ratios through most weathering conditions, transport, diagenesis and metamorphism. However, trace-element fractionation in zircons can record different environments of growth. The Zr/Hf ratio of most crustal rocks is ≈37. Granitic rocks, primitive mantle and mid-oceanic ridge basalts have a narrow modal range of Zr/Hf ratios from ≈35 to ≈40. However, erratic Zr/Hf ratios up to 1300 have been reported for hydrothermal and low temperature authigenic conditions, suggesting extreme low temperature fractionation [1] and [2]. In comparison, Nb-Ta and Y-Ho behave coherently during most geological processes; the Nb/Ta ratio remains ≈12 in the sedimentary budget, and the primitive mantle, post Archaean Australian shale and upper continental crust all have Y/Ho = 25.

In the northeast of the Albany-Fraser Orogen in Western Australia, abundant pedogenic silcretes occur as duricrust capping a residual regolith dominated by ferruginous and kaolinitic saprolite. Rare earth element patterns in the saprolite are controlled by zircon and anatase (Fig. 1), which are highly concentrated in the silcrete as QAZ (quartz-anatase-zircon) cement [3]. Weathering has partially dissolved zoned, metamict zircons, leaving skeletal remnants. Zr/Hf and Nb/Ta ratio values in the silcrete span from ≈40 to ≈55, and from ≈7 to ≈15, respectively, coupled with Y/Ho values from ≈20 to ≈40. Original ilmenite has been altered to anatase.

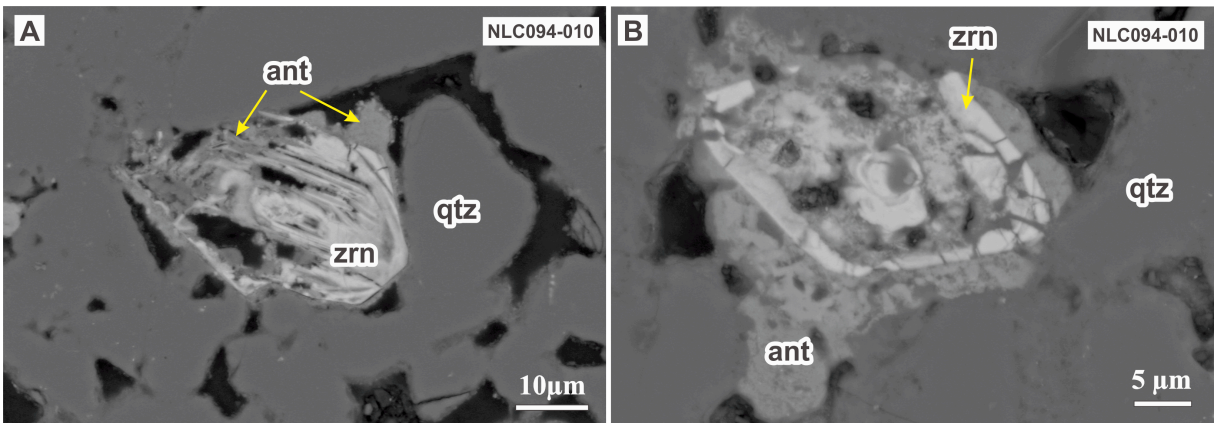

Figure 1: (A) and (B) Examples of two weathered zircons in the silcrete duricrust displaying significant alteration and voids are partly filled with authigenic anatase. (ant = anatase; zrn = zircon; qtz = quartz).

These erratic ratio values in the silcrete are interpreted as stemming from HFSE mobility due to extreme weathering or weathering overprinting events. These have resulted in differential behaviour of Zr-Hf, Nd-Ta and Y-Ho after partial dissolution and/or precipitation or replacement on resistant zircon, or some combination of these processes (Fig. 1).

References:

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