

A 4D Petrogenetic Model for the Uis Pegmatite Field

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As major sources of the world's lithium (Li), tin (Sn), and tantalum (Ta), Lithium-Caesium-Tantalum (LCT) type pegmatites are vital exploration targets. Yet, their ore forming processes remain heavily debated, with the specific roles of source composition, melting conditions, and magmatic fractionation in controlling whether a system becomes economically mineralised still unresolved.

To evaluate these competing models of LCT-type pegmatite formation, we present a study of the Uis Pegmatite Field in the Damara Orogen, Namibia. This region provides an exceptional setting to disentangle the drivers of mineralisation because it encompasses the Uis Li-Sn-Ta mine, well-exposed mineralised and unmineralised pegmatite suites, and three distinct regional granite suites (Salem, Grey, and leucogranite). By integrating fieldwork, petrography, and mineral-based microanalysis, including geochronology, we develop a 4D petrogenetic framework for the Uis Pegmatite Field.

Multi-mineral U-Pb geochronology has been necessary to untangle the age relations, and we use zircon, cassiterite, titanite, monazite, xenotime and apatite to provide a robust magmatic age framework for the region. The Uis pegmatites were emplaced in two phases at c.500 and c.490 Ma, consistent with late-tectonic intrusion into tension gash structures. Crucially, the majority of the surrounding granites predate the pegmatites by up to 50 Ma, ruling them out as parental magmas. While, Hf isotopes in zircon reveal these granites are derived from distinct sources. Reset apatite U-Pb ages of c. 490 Ma within these older granites record a widespread thermal event linked to pegmatite emplacement.

Mineral trace element analysis yields a record of progressive magmatic metal enrichment and demonstrates that the pegmatites and nearby leucogranites underwent separate paths of magmatic evolution. Our findings indicate that the Uis Pegmatites likely originated independently as small volume melts of a distinct protolith late in the orogenic cycle during a late, regional thermal event.