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Integrated Pb isotope and textural analysis of impact-shocked granite alkali feldspar elucidates grain-scale hydrothermal alteration

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Despite their abundance in rocks of the continental crust, feldspar group minerals appear somewhat underutilized in hypervelocity impact studies. Here, we present laser ablation inductively coupled plasma and thermal ionization mass spectrometry analysis of Pb isotopes in alkali feldspar from shocked monzogranite target rocks from the Paleoproterozoic Yarrabubba impact structure (2229 ± 5 Ma) in Western Australia. The spatial coverage by laser ablation spot grids on alkali feldspar grains allows linking Pb isotopic data with textural information for individual analyses. Feldspar textures are investigated through electron backscatter diffraction (EBSD), cathodoluminescence (CL), and time of flight secondary ion mass spectrometry imaging. Alkali feldspar microstructures such as sub-planar and irregular fractures, sets of planar deformation bands with relative misorientations of up to ~20°, sets of damage lamellae, and broad domains of lattice damage that have only ever been reported from impact-shocked feldspar are documented. Analyses from areas with high crystallographic ordering (from EBSD analysis) and high luminescence (from CL images) in the alkali feldspar show Pb model ages approximating the granite crystallization age of ~2650 Ma. By contrast, Pb isotope compositions collected from zones with lattice damage in alkali feldspar yield significantly younger Pb model ages. The rejuvenated Pb isotopic signatures are likely driven by Pb mixing through the partial ablation of monazite and Fe oxide (magnetite and/or hematite) micro-inclusions that align with the orientation of shock microstructures in many places. These observations are best explained by impact-generated hydrothermal fluid infiltration into damaged zones in alkali feldspar, followed by the precipitation of secondary minerals enriched in radiogenic elements. Hydrothermal modification is otherwise relatively obscure and superficial in the monzogranite target rocks. Evidence for U mobilization in the Paleoproterozoic at ~2229 Ma is interesting in the context of the Great Oxidation Event, since it would have required oxidizing hydrothermal fluids.