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Optimization of Age and Compositional Mapping of Zircon by single collector LA-ICP-MS: Methodology and application to Jack Hills Quartzite zircon

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The transformative impact of advancements in laser ablation, mass spectrometry, and data reduction systems has opened new frontiers for high-resolution geochronologic and compositional mapping of individual zircon grains. This study presents a novel technique that employs a Teledyne Photon Machines (Bozeman, MT, USA) Iridia laser ablation (LA) system coupled to a ThermoFisher (Bremen, Germany) Element 2 inductively coupled-mass spectrometer (ICP-MS) for the rapid generation of U-Pb age and trace element chemistry maps with a resolution of pixels 5x5-μm^2 . Teledyne's HDIP data reduction and analysis platform is used for U-Th-Pb geochronology and trace element concentration calibrations. Zircon from the Duluth Gabbro (FC-1) and Sri Lanka (SL) served as primary and secondary reference materials for geochronology, respectively, while trace elements were calibrated using glass standard NIST612, and zircon 91500, FC-1, and SL. To validate the method, we obtained maps of well-characterized natural zircon that span wide age and compositional range (i.e., OG-1, FC-1, 91500, SL, Plešovice, and GHR1) and treated them as unknowns during data acquisition and processing. Filtered average pixel ages reproduced published crystallization ages within 1 to 2 % and trace element concentrations fall within published ranges.

Once the method was optimized, we conducted a case study application to five Hadean zircon grains from the Jack Hills Quartzite. Jack Hill zircon were first analyzed by traditional U-Pb spot analysis to identify ages of interest (i.e., >4.0 Ga). For the five selected grains, we combined imaging techniques, including cathodoluminescence and micro-Raman mapping to correlate these with the age and trace element information acquired from LA-ICP-MS. The mapping results exhibit a close agreement between pixel averages and traditional U-Pb spot analysis for the same grain, confirming the technique's reliability for age determination, and additionally provide a comprehensive range of trace element concentrations that are comparable to existing datasets for Hadean Jack Hills zircon grains. The emergence of LA-ICP-MS U-Pb isotopic and elemental mapping techniques marks a significant advancement in zircon U-Pb geochronology, especially in combination with other micro-analytical techniques (e.g., Raman Spectroscopy) and offer a revolutionary approach to studying texturally complex zircons.