Faculty of Science and Engineering

2020 Australian Government Research Training Program Scholarships

Strategic Project Profile

PROJECT TITLE: Nanogeochronology of Earth's oldest rocks

FIELD OF RESEARCH CODE: 0403

PROJECT SYNOPSIS:

Our ability to precisely date rocks and minerals by radiometric methods underpins the most significant advances in geoscience research and provides the basis for understanding the geological evolution of Earth’s crust. A fundamental assumption of radiometric dating is that the original parent isotope and the radiogenic daughter isotope remain captured, and coupled, within the analysed volume of material. However, micrometre-sized heterogeneous concentrations of radiogenic Pb in ancient zircon ($ZrSiO4$), yielding U-Pb dates that are up to 300 million years older than the estimated time of crystallization, have recently been discovered. This heterogeneity is a critical issue for geoscientists because we can no longer tell if ages obtained by conventional dating techniques are correct or not. This fundamentally undermines our understanding of natural processes, the rates at which they occur, and the evolution of the early Earth. Furthermore, there is no clear understanding or consensus of the mechanisms responsible for microscale variations in concentrations and isotopic compositions of Pb, and there is no consensus on how to deal with this issue. Such understanding is critical if we are to correctly interpret zircon U-Pb data collected from analytical volumes by modern ion beam and laser techniques, and confidently derive the timing of geological events.

Nowhere is this problem more significant than in the world's oldest populations of zircon grains, which represent the oldest vestiges of Earth's crust (~4.0 billion years ago). The compositions of these zircons reflect events and conditions that occurred shortly after Earth formed and, as such, they provide a unique record of early Earth evolution. Utilizing these data to constrain planetary development requires a well-characterized temporal framework. However, the recent discovery of micrometre-scale, Pb isotopic variations in ancient zircon casts doubt on the robustness of interpreted dates, and questions the reliability of the established temporal framework of early Earth evolution.

Establishing the mechanisms of Pb mobility in zircon, and the geochronological implications, has recently become a tractable scientific problem due to the geological application of atom probe tomography, a development largely instigated by the principal supervisors. In this project, we will use Curtin Geoscience Atom Probe facility, and associated correlative characterisation and analytical techniques, to analyse zircon grains from Earth's oldest preserved crust (the Acasta Gneiss of Canada) and determine the mechanisms and potential drivers of nanoscale Pb mobility (e.g. radiation damage, defect formation, defect mobility, fluids and thermal history). We target Earth's oldest crust, rather than the slightly older detrital zircon populations from Jack Hills, because Acasta zircons are still preserved in their original host rock, and therefore have a better-constrained thermal and deformation history that is essential to interpret the nanoscale geochemical processes operating within zircon. These samples also have the potential to yield information on Earth's early meteorite bombardment history, something that has not been possible with Jack Hill detrital zircons. In addition, we have recently collected Acasta samples so material for study is already available.

This project addresses a fundamental issue that threatens the future development of geochronology and needs critical attention. Such knowledge will increase our ability to determine robust and reliable ages from zircon, at the scale that is routinely used for geochronological analysis by SIMS and laser techniques, thereby providing a framework for geochronologists to correctly interpret the ages of geological events. Additional outcomes will be the development of new geological applications of nanoscale zircon geochemistry and geochronology, for example, establishing the timing, intensity and duration of cryptic igneous and metamorphic events, as well as processes active on the early Earth. In developing the general protocols and procedures for studying trace element mobility and parent-daughter isotopic decoupling in zircon, we will develop a framework that can be applied to a broad range of minerals and mineral chronometers. This new knowledge will provide the framework for investigating the evolution of the Australian crust; a strategic research priority for Australia.

FEASIBILITY AND RESOURCING – DESCRIPTION OF THE SUPPORT THIS PROJECT WILL RECEIVE:

The project is entirely feasible and is supported research infrastructure housed at Curtin. The project complements and builds on Dr. Fougerouse's current DECRA on Nanogeochronology and analytical costs for the project will be met from this grant. The project will provide mentorship to ECR Fougerouse around research and PhD supervision. The project will utilise new SEM and ToF-SIMS facilities awarded in 2019 via ARC LIEF totalling close to $2M.

WHAT MINIMAL ATTRIBUTES AND SKILLS EXPECTED BY THE CANDIDATE BE COMPETITIVE:

A BSc Hons (first class) or Masters (preferably by research) in Geoscience by the time of appointment
Ability to work with a broad range of people from varying research backgrounds and evidence of strong oral and written communication skills
Demonstrated ability to work independently while contributing to overall team performance and proven ability to meet performance deadlines during the course of a project
Demonstrated commitment to publish the results of research in scientific journals
High competency in relevant scientific disciplines as required by project (e.g. mineralogy/petrology/geochemistry/geochronology) desirable

Demonstrated experience in a research environment/laboratory or research team would be beneficial
Evidence of academic awards and academic publications/presentations at conferences desirable

THE SIGNIFICANCE OF THE PROJECT/ PROGRAM FOR THE ENROLLING SCHOOL OR INSTITUTION:

Zircon geochronology is a key area of research in Earth and Planetary Sciences, is a major focus of research infrastructure in the JDLC, and is a significant contributor to Geoscience ERA outcomes. In targeting the world's oldest crustal rocks, the project will have significance to the evolution of Earth's crust and the role of meteoritic bombardment in its evolution - it is therefore relevant to both TIGeR and SSTC. This project targets a fundamental scientific problem that threatens our ability to extract meaningful geologic ages from the world's most widely used geochronometer. The Geoscience Atom Probe Facility is currently the only facility of its kind in the world and we lead the international field in the growing discipline of nanoscale geochemistry. This project will build on this success and will contribute to the growing international reputation of this Facility.

Students are advised to contact the Project Lead listed below prior to submission of their scholarship application to discuss their suitability to be involved in this strategic project.

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