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The dynamics of granite-greenstone belts

1. Background

Today, plate tectonics dominates the tectonic deformation of the Earth's surface, in which processes like seafloor spreading, subduction, continental collision are responsible for phenomena such as mountain building, arc volcanism, and the division into oceanic and continental lithosphere. But it is very unlikely that plate tectonics always existed (van Hunen and Moyen, 2012), and one of the major open geodynamical questions is 'Which kind of tectonics dominated the Earth before the onset of plate tectonics?' (Sizova et al., 2015).

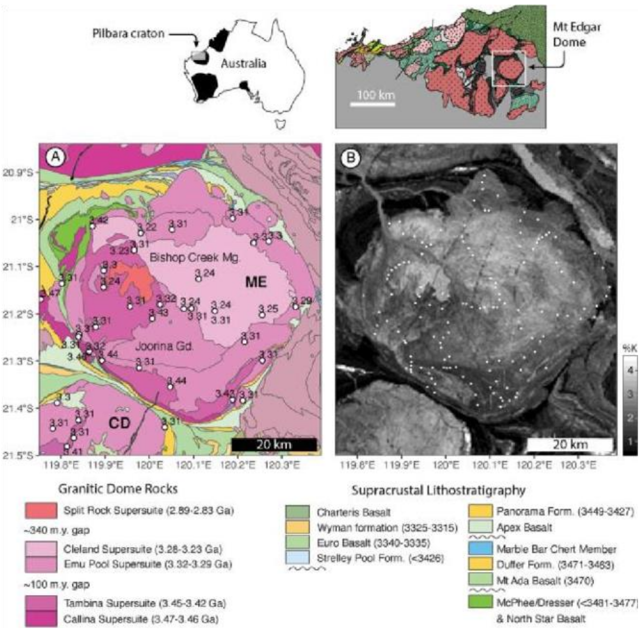

Fig. 1. Geologic map of the Mt Edgar dome, Pilbara, W-Australia. A) Interpreted bedrock geology of the Mt Edgar dome (ME). Labeled white dots are UPb zircon SHRIMP ages (Ga). B) Potassium content map. (From Roberts & Tikoff (2021)).

While plate tectonics is widely recognized in the rock record, some of the oldest terranes on Earth lack any obvious signs of plate tectonics, and, instead, have been interpreted to exhibit different tectonic styles that may have been dominated the Earth before plate tectonics initiated.
For example, geological structures in East Pilbara (western Australia) lack the typical plate tectonic rock record features, such as linear sutures or other fossil subduction zone features. Instead, it shows oval-shaped felsic gneiss terranes surrounded by more mafic 'greenstone belts' (Figure 1).

These so-called 'dome-and-keel' structures lack typical plate tectonic characteristics (Zegers and van Keken, 2001; van Kranendonk et al., 2002; Nijman et al., 2017). Crustal large-scale diapirism has been proposed (e.g. Peschler et al., 2004), although the applicability of this model is widely debated, and the 'domes' are made up of smaller terranes that together span a wide age range from

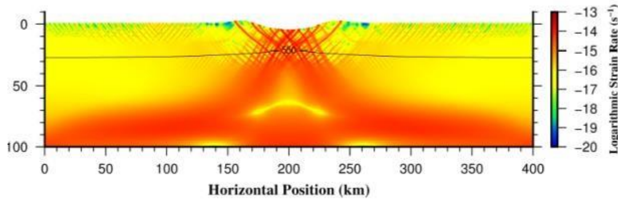

Figure 2) Example of lithospheric deformation modelling using ASPECT, illustrating features relevant for this project, including surface deformation, strain localisation, and brittle + viscous deformation. From Bangerth et al. (2018).

3.5-2.9 Ga, i.e. 600 Myrs (Roberts and Tikoff, 2021; Figure 1). Others advocate a more prominent role for the various regional extensional and compressional events in the area (Nijman et al., 2017).

Understanding the tectonic and environmental conditions of these early formations is crucial, as this phase of early crust formation has played a major role in the thermal and compositional evolution of the Earth, and these terranes provide records the most ancient life on Earth.

This project aims to use numerical models to investigate the specific conditions under which those granite-greenstone belts were shaped. How did those 'domes' form? How mobile was the early Earth lithosphere for this process to take place? What was the role of the observed syntectonic extension or compression? At which pressure-temperature conditions were they likely to have taken place? Modelling this poorly understood phenomenon of the Earth's ancient past will not only provide a more quantitative assessment of this process, but also provides valuable insight in the effective properties (strength, thermal regime, mobility) of the oldest

systems. The project is an opportunity for the student to become proficient in computer programming and modelling, with support from an enthusiastic modelling community.

ASPECT is open source with an importance placed on member participation in development (which is done in the open here), allowing for worldwide collaboration and education (e.g., through hackathons and public meetings).

continents on Earth at the time of their formation.

2. Methodology

Geodynamical modelling in this project will be done with the state-of-the-art communitysupported code ASPECT. This code has been designed for regional and global geodynamical problems (Figure 2; Bangerth et al., 2018; Heister et al., 2017), uses cutting-edge numerical techniques for optimal performance, is very well documented, and is extensible to tailor for individual needs. By combining these geodynamical models with observational data sets from the rock record, we aim to understand and constrain the dynamics of the formation of these tectonic events of the Earth's distant past.

3. Training

The student will become part of a vibrant research culture in the department of Earth Sciences, in which ~70 postgraduate students work on a wide range of Earth Science research projects. In particular, the student will closely collaborate with the academic staff, postdoctoral researchers and fellows, and postgraduate students in the geodynamics, tectonics, and geophysics research groups.

Further training will be provided in geodynamical modelling (programming, code development, model setup, and usage) as well as usage and data management of high-performance computing

Experience or affinity with numerical modelling, tectonics and magmatism will be an advantage for the project.

For any questions, please contact Prof. Jeroen van Hunen at Jeroen.van-hunen@durham.ac.uk.

References & Reading

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