59062-DNI8: Combining data and models of the Centralian Superbasin to investigate cratonic basin formation

PI: Jacqueline Austermann, Lamont-Doherty Earth Observatory, Columbia University.

Project goals: The aim of this project is to understand the formation mechanism of a larger cratonic basin located in central Australia. The first part has been to develop models of the present-day lithospheric structure across the region. The second part will be to investigate models of sedimentary basin formation that are consistent with its present-day structure and subsidence history.

Summary of results at September 2019: Deformation of the lithosphere plays a fundamental role in the formation of sedimentary basins in continental interiors. Our study area is in central Australia and consists of the the Officer, Amadeus, Ngalia and Georgina sub-basins. These basins are located on thick cratonic lithosphere, and the first task of our project has been to map out variations in its lateral thickness and internal thermal structure at the present-day. To do this, we have been exploiting regional seismic tomography models that are created by inverting the time taken for acoustic energy generated by earthquakes to travel through the Earth to seismometers placed across the continent. These models are continuous maps of the variation of seismic velocity as a function of distance and depth. To convert them into temperature, we need to understand how seismic velocity varies as a function of temperature and pressure for rocks in the upper mantle.

Volcanic eruptions, including basaltic flows and kimberlites, carry lumps of mantle rock up to the Earths surface, which are known as xenoliths. The chemical composition of the individual mineral phases can be used to estimate the temperature and depth at which they were sourced. We have collated an inventory of 15 xenolith suites from different sites around Australia. Geochemical analyses indicate that the individual samples form linear arrays of increasing temperature with depth, which can be fitted using simple thermal modelling to constrain the geotherm (Figure 1). These locations can then be used as tie points to calibrate the mapping between seismic velocity and temperature as a function of depth, which allows us to investigate lithospheric structure at locations away from the xenolith samples.

The resulting map of lithospheric thickness reveals significant variations throughout the continent (Figure 2). Central and western areas are underlain by thick lithosphere of up to 250 km, whereas the eastern margin has significantly

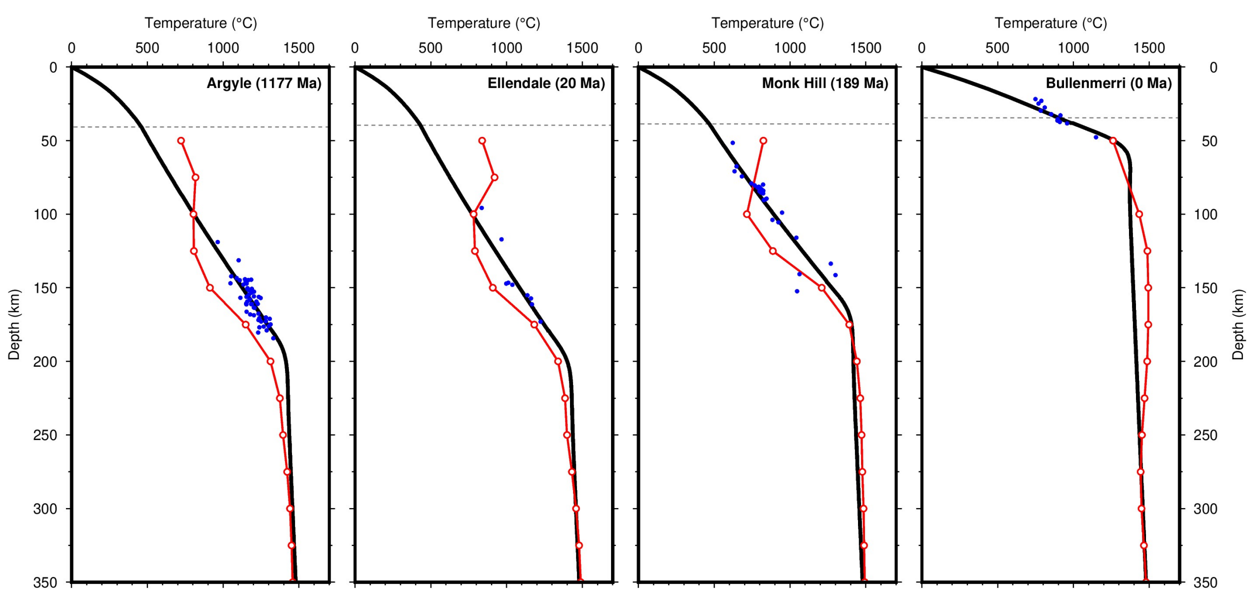

Figure 1: Example geotherms for sites with mantle xenoliths suites in Australian lithosphere. Blue circles = xenolith samples; black line = fitted geotherm; red line = tomographic geotherm.

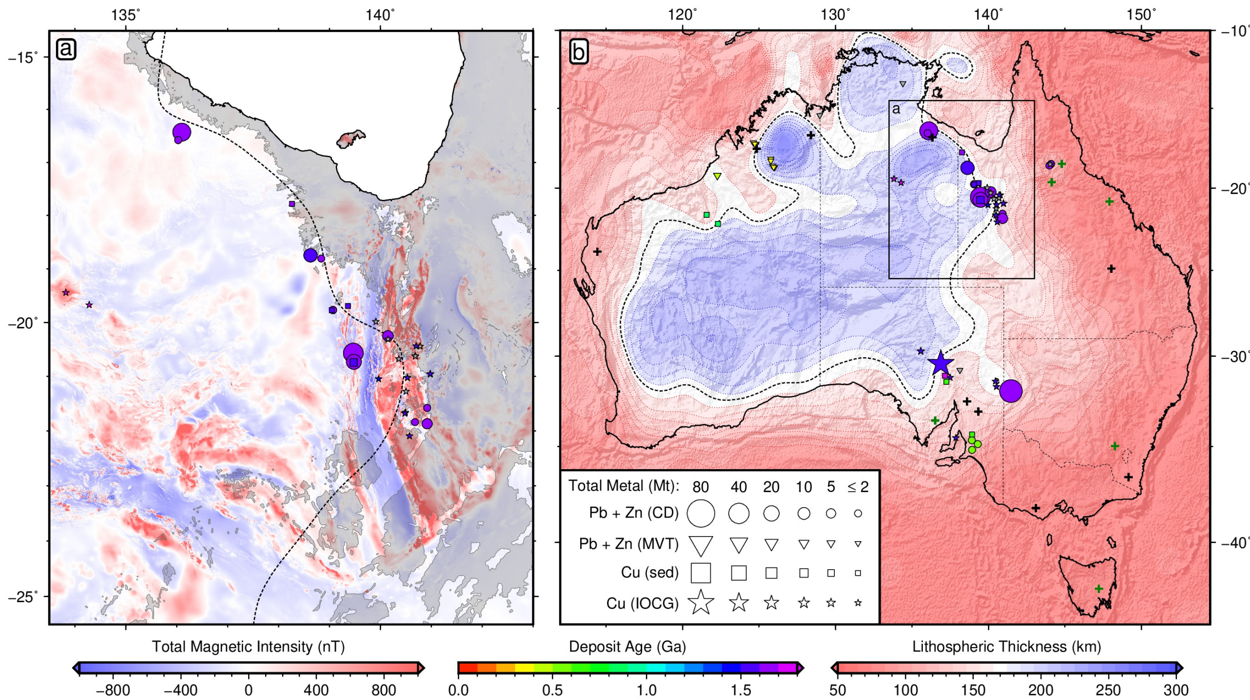

Figure 2: Present-day lithospheric thickness beneath Australia and relationship to base metal mineral deposits. (a) Zoom of the Carpentaria lead-zinc belt; red/blue = magnetic anomalies mapping crustal structure; grey polygon = Cretaceous marine sediments; symbols = mineral deposits; black dashed line = 170 km thickness contour. (b) Whole Australia map; crosses = locations of xenolith suites.

thinner lithosphere ($<$ 100 km). Interestingly, the map reveals a strong correlation between the location of large base metal deposits (copper, lead and zinc) and the transition from thick to thin lithosphere. This observation has led to a collaboration between the postdoctoral researcher and our collaborator at Geoscience Australia, Carol Czarnota, with one research paper currently in review (Czarnota et al., in rev.).

Next steps: Armed with knowledge of the present-day lithospheric structure, we have begun to explore models of basin formation including standard rifting and flexural loading. These models will be fitted to subsidence curves derived from well data in the basins of interest, in order to investigate their geological setting within the regional geodynamic framework.

Career impact of this research: The PRF DNI award has had a great impact on my career and the training and research of members of my research group. Funding from this grant has allowed me to recruit my first post-doctoral research associate, Mark Hoggard, who began work on the project in January 2019. The work on this project so far has allowed me to deepen my understanding of the thermochemical structure of the lithosphere and structure of sedimentary basins. Funding has also allowed me and the post-doctoral researcher to participate in a fieldtrip to Utah to advance our knowledge of sequence stratigraphy. Lastly, this work has allowed us to review the current understanding of how mantle flow affects Earth's surface, which led to a publication currently in review (Hoggard et al., in rev.).

Publications:

Czarnota, K., M. Hoggard, F. Richards, D. L. Huston, A. L. Jaques, Gigayear stability of cratonic edges controls global distribution of sediment-hosted metals, *Nature Geoscience*, in rev., www.eartharxiv.org/2kjvc

Hoggard, M., J. Austermann, C. Randel, S. Stephenson, Observing dynamic topography through space and time, *AGU Monograph*, in rev.