

Crustal evolution of the Gawler Craton, South Australia: Application of the TerraneChron® technique to detrital zircon from modern stream sediments

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ABSTRACT

This report presents the results of a TerraneChron® study of detrital zircons from modern stream sediments of the Gawler Craton. The TerraneChron® approach involves obtaining U-Pb ages, Hf isotope composition and trace element data from single zircon grains, which provide an insight into the age, source rock evolution and source rock type on the analysed zircons. In this study we collected zircons from surface sediment within widely spaced drainage networks across the Gawler Craton in order to evaluate the crustal evolution. The results indicate that major zircon growth periods correspond to the Late Archaean (2540–2450 Ma), Palaeoproterozoic (ca 2000–1700 Ma) and Mesoproterozoic (ca 1600–1500 Ma). A significant age peak in the detrital zircon age record at ca 1170 Ma is likely to represent transported material from the Musgrave Province. Magmatism during the late Archaean to Mesoproterozoic was dominated by crustal recycling of Archaean (ca 3.2–3.5 Ga) crust, with Hf isotopes indicating predominantly evolved compositions ($\epsilon_{\text{Hf}} < 0$). Three periods of juvenile mantle input are recognised: ca 2540 Ma, 1850 Ma and 1595 Ma, however, only a minor proportion of the zircons formed during this time appear to be strongly juvenile in origin ($\epsilon_{\text{Hf}} < 4$) thus a mixture of crustal reworking with mantle input is indicated. There is an apparent trend towards increasing juvenile contribution towards the south-eastern parts of the Gawler Craton.

INTRODUCTION

The Gawler Craton preserves a record of late Archaean to Mesoproterozoic crustal evolution and occupies a large portion of central South Australia (Fig. 1). Despite containing one of the worlds largest orebodies at Olympic Dam (Cu-Au-U-REE) and a host of other significant deposits, including Prominent Hill (Au), Challenger (Au) and the Middleback Ranges (FeO), mineral exploration expenditure within the craton—although growing steadily—remains low in comparison with other Australian terrains of late Archaean and/or Palaeoproterozoic age (e.g. Yilgarn Craton, North Australian Craton).

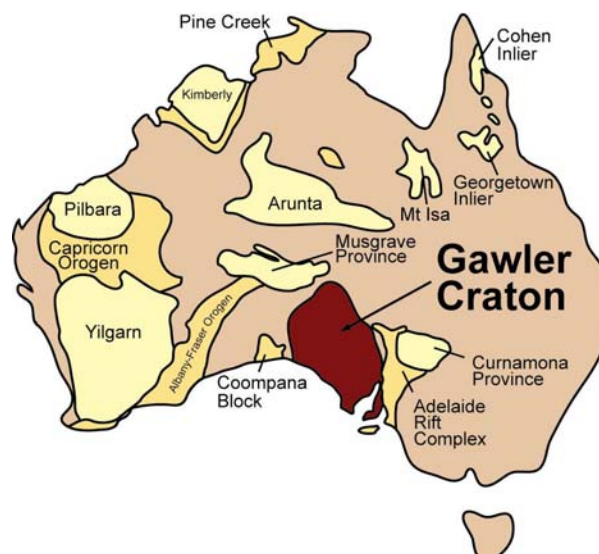


Figure 1 Location of the Gawler Craton relative to other Australian Archaean to Proterozoic provinces

Two main reasons for this low exploration activity can be highlighted: (1) a lack of outcrop—less than 15% of basement is exposed—which increases the cost of exploration through a reliance on drilling to directly sample the basement subcrop, and (2) limitations in our understanding of the geological framework.

Project aims

The aim of this project is to develop a framework for the crustal evolution of the Gawler Craton of South Australia through application of the TerraneChron[®] technique. In particular this project sought to investigate:

1. the timing and spatial distribution of tectono-magmatic events within the craton through U-Pb zircon age dating, and
2. the geochemical source affinities of these tectono-magmatic events through Hf isotope and trace element analyses, thereby enabling identification of relative crust and mantle contributions to specific magmatic episodes.

In this report we present a detailed description of the results of these analyses and, based on this, a new synopsis of the crustal evolution of the Gawler Craton.

METHODS

An outline of the TerraneChron[®] technique

The TerraneChron[®] concept has been developed through collaboration between GEMOC and Advantage Geochemical Solutions Pty Ltd for studying crustal evolution and evaluating the metallogenic potential of terranes. It is based on the integrated *in situ* analysis of zircons for U-Pb age, Hf-isotopic composition and trace-element composition.

1. **U-Pb age dating** of individual grains via laser-ablation-microprobe (LAM) inductively coupled plasma mass spectrometry (ICPMS). Analysis of large numbers of grains obtained from detrital concentrates generates age spectra that can be used to characterise fundamental terrane-scale events - sedimentary provenance, magmatic episodes, metamorphism and hydrothermal activity (Belousova et al., 2001; Griffin et al., 2004; Jackson et al., 2004).
2. ***In situ* analysis of Hf isotopes** in previously dated zircons via LAM-Multi-Collector (MC) ICPMS. This offers information on crustal evolution, analogous to that derived from whole-rock Sm-Nd systematics, in that it provides information on the source of the magmatic parent rock to each zircon. Hf isotopic data thus enables discrimination of mantle-derived magmatic input (a “juvenile” source), from crustal reworking, a source comprised purely of pre-existing crust, or the combination of these processes (Griffin et al., 2000; 2004; 2006).
3. **Trace elements** provide information about the composition of the magmatic rock that precipitated the zircon (Belousova, 2002). Hf and Y are measured on individual zircons via the electron microprobe (EMP), and U, Th, Yb and Lu concentrations are acquired during U-Pb and Hf-isotope analyses.

Establishing a geochronological framework is an important component in characterising terrane evolution and correlating events. This can include key metallogenic events or recognition of ‘fertile’ crustal histories of direct interest for terrane assessment in regional mineral exploration. Recent advances in laser ablation microprobe ICPMS (LAM-ICPMS) make it possible to obtain *in situ* U-Pb age data comparable in quality with ion microprobe analyses. These data are generated quickly (3-5 minutes/grain) and at relatively low unit cost, making it feasible to analyse large numbers of grains.

The TerraneChron[®] concept is based on LAM-ICPMS analyses of large zircon populations obtained from sampling stream sediment for the heavy mineral component. While the specific origin of individual zircons is lost using detrital concentrates, the broad spectrum of ages and events from large areas of composite geology within a given catchment system is generally well represented (Griffin et al., 2004).