AGSO has released for sale this month an innovative full-colour map of ‘Australian crustal elements’ at 1:5 million scale. This map delineates upper-crustal elements, primarily based on composite geophysical domains, each of which shows a distinctive pattern of magnetic and gravity anomalies. These elements generally relate to the basement, rather than the sedimentary

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Fig. 1. Simplified crustal elements map of Australia, 1995. (See text for an explanation of letter symbols.)
basins, which tend to mask or distort — rather than define — the magnetic and gravity characteristics. Boundaries between these elements are interpreted to mark crustal-scale changes in composition or structure, both composition and structural pattern. Where feasible, these boundaries are chosen to emphasise their correlation with the outcropping boundaries of geological provinces. The elements are categorized secondarily according to their magnetic character, in a way which places them in a tectonic context. Finally, a tentative relative timescale emphasises the range of time over which the geophysical features, normally the magnetic patterns, were imposed.

Existing tectonic maps of Australia have the limitation that they do not tell us what basement units underlie the sedimentary basins; nor do they give us much information about the third dimension (depth). We have compiled an innovative type of map, inspired by the virtual completion of gravity and magnetic maps for the continent (Morse et al. 1992; ‘Gravity anomaly map of Australia’, scale 1:5 000 000, AGSO; Tarlowski et al. 1995: ‘Magnetic anomaly map of Australia’, scale 1:5 000 000, AGSO). This dual coverage allows a more integrated interpretation of basement crustal elements than was previously possible. Our map builds on an earlier analysis of crustal-scale gravity anomalies (e.g., Wellman 1978: BMJ Journal of Australian Geology & Geophysics, 3, 153–162), and on other regional studies of gravity and magnetic anomalies. It places a geophysical perspective on earlier evolutionary models based on geological data (e.g., Plumb 1978: Earth Science Reviews, 14, 205–249). The map uses the magnetic signature of composite magnetic and gravity domains to provide links to the outcropping geology. It goes farther by using structural relationships, deduced from the geophysical trends, and links to the geology to reveal the relative time implied by the combined geological and geophysical data sets.

The objective of this map is to present a new model — based on geophysical interpretation — of the tectonic framework of the Australian continent. In doing so, we hope to provide a starting position for the examination or re-examination of evolutionary tectonic models. The map presents the 'big picture': it encourages the user to consider how the continent might have evolved into its present configuration, and to make predictions about the distribution, relative ages, and nature of the crustal blocks. This kind of predictive ability should be helpful in targeting new areas for frontier petroleum and mineral exploration, or revealing problem areas for future research.

Principles of the map
In attempting to build our model for the tectonic framework of the continent, we began by looking for coherence between gravity and magnetic data sets so that we could delineate composite geophysical domains. After analysing several portrayals of amalgamated magnetic and gravity data sets (e.g., Fig. 2), we erected compositional and structural province-scale boundaries that correlate where possible with geological features. Such boundaries can then be extrapolated under the sedimentary basins. To give the map an added tectonic flavour, we characterised the domains according to their magnetic and gravity character, in a way that reflects the tectonic significance of their magnetic responses. We enhanced the tectonic significance of the map by deducing relative ages, mainly according to geophysical evidence derived from two sources: we deduced the relative ages of the domains from the structural relationships between adjoining domains; and then we assigned the age-range for the sources of the dominant magnetic and gravity signals. The two methods of interpretation were used to construct an age-box for each domain. This approach has enabled us to express the evolution of the continent as a sequence of relative age slices on the map sheet. A simplified version of the map and the age-boxes is shown in Figure 1.

Three classes of crustal elements are identified in Figure 1:

- standard — not modified by any geophysical overprinting;
- highly magnetic — dominated by magnetic and gravity highs, which imply gross modification of the upper crust; and
- geophysically overprinted.

We emphasise that the magnetic and gravity boundaries shown on the 1:5 million map are not always coincident for the crustal elements, unlike typical geophysical domains. Where there is some mismatch, the crustal boundary favoured is that which most closely corresponds to an established geological boundary. Also unlike typical geophysical domains, the crustal elements have relative age range as an attribute.

We emphasise too that the crustal elements are not geologically defined features, because they have been defined primarily from magnetic and gravity data sets, which largely monitor the overall properties of the upper crust. The crustal elements represent upper-crustal segments showing some overall commonality of geophysical properties. In contrast, basement provinces are defined on the basis of geological criteria derived from outcrop mapping, event stratigraphy, and the isotopic dating of events. Such geologically defined provinces are three-dimensional bodies that have a definite thickness and represent time-rock units whose maximum and minimum ages are generally, but not always, well established. Some of the crustal elements could represent a set of overlying or overlapping basement provinces resting on pre-existing crust.

We chose to refer to the various elements by symbols (groups of letters), rather than by giving them names. We did this because the history of naming such features shows that new names tend to be short-lived and to require constant refinement with the incoming of new data and fresh interpretations.

The crustal elements have a distinctive geo-
physical character and show unique structural relationships with their neighbours, suggesting that the MI (Mount Isa) element is younger than the elements to its east and west, as it truncates structures to the east and west (cf. Wellman 1992: BMR (AGSO) Bulletin, 232, 15–27); it is interpreted from geology to be a region of complex extensional structures with three periods of rifting along a north-south axis.

The mega-elements

The general picture that has emerged from the new map is of a continent made up of eight coherent mega-elements. These represent groups of crustal elements having similar geological and geophysical characteristics, and lying within a common set of boundaries (Fig. 3).

Boundaries between mega-elements

The boundaries between mega-elements and between many of the crustal elements are commonly associated with two broad classes of geophysical anomaly type. One is a major change in mean density or mean apparent susceptibility of the crust, which gives rise to paired high and low gravity or magnetic anomalies along the boundary — dipole anomalies. The other is that generated as a result of interaction processes at the boundary; anomalies within this class include three main types:

- zones of geophysical overprinting, commonly associated with shearing, where trends of one element replace those of another;
- zones of overprinting characterised by extensional magnetic lows generated as a result of processes such as denudation associated with heating of the older element when the younger element was emplaced against it; and
- zones characterised by major gravity and magnetic highs — the so-called highly magnetic zones — formed alongside the boundary, or uplift of the lower crust by overthrusting along the boundary.

Significance of the boundaries between mega-elements

Mega-element boundaries are well illustrated by the overprinting zone at the boundary between elements WA (Western Australia) and SA (South Australia; Fig. 3), which separates the element labelled Y (Yilgarn) from element AF (Albany-Fraser; Fig. 1). This zone (YMR in Fig. 1) is characterised by a drop in magnetic history. Thus, overprinting and discordant relationships in geophysical anomalies show that the MI (Mount Isa) element is younger than the elements to its east and west, as it truncates structures to the east and west (cf. Wellman 1988: Precambrian Research, 40/41, 89–100). This zone (YMR in Fig. 1) is characterised by a drop in magnetic intensity (demagnetisation) and the progressive disruption of the magnetic pattern of element Y. The demagnetisation is the result of Mesoproterozoic deformation and high-grade metamorphism of the Archaean gneisses and greenstones (Yilgarn) during convergence of the elements (Beeston et al. 1988: Precambrian Research, 40/41, 117–136). This overprinted zone, YMR, is adjacent immediately to the west by a highly magnetic zone, the 40–200-km wide element AF (Albany–Fraser). It correlates with a complex orogenic belt of orthogneiss, dolerite and gabbro that was extensively intruded by granite at about 1150 Ma (Myers 1990: Geology, 18, 537–540). Zone YMR and the western margin of the magnetic element corresponding to element AF are overlain by major gravity highs and lows — a gravity dipole. At this complex boundary (corresponding to the WA–SA mega-element boundary), the gravity anomaly reflects change in crustal density across the boundary, and the magnetic anomaly reflects the crustal effect of processes acting at the crustal-element boundaries.

The mega-element CA (central Australia; Fig. 3) is a complex zone separating simpler and more coherent mega-elements. It comprises an assembly of long narrow crustal elements, more-equidimensional elements, and relatively small elements. These include several highly magnetic zones and overprinted zones, similar to those described above. The geophysical evidence indicates that mega-element CA corresponds to a wide region of interaction between, on the one hand, the more cratonic mega-element NA (north Australia) and, on the other, WA and SA, which are even more cratonic in character. Geological evidence suggests that mega-element CA evolved between 1900 Ma and 1100 Ma (Collins & Shaw 1995: Precambrian Research, 71, 315–346).

Major discordant boundaries within mega-element CA (Fig. 3) imply large strike-slip displacements. These include the discordant boundary where element ASR (Fig. 1; a highly magnetic zone that borders the Redbank Thrust Zone, in the central Arunta Block) truncates element M (Musgrave). Another markedly discordant boundary is that marked by the zone of overprinting BD (Bright Jowns). This zone truncates element MI (Mount Isa), and swings from southwest to northwest to merge with the boundary between mega-elements CA and NA (TN and MD) at the overprinted zones. The tectonic significance of these discontinuous boundaries and elements can be assessed by their degree of discordance and whether they mark abrupt changes in crustal composition. Studies in Canada (Gibb et al. 1983: Precambrian Research, 19, 249–284), west Africa, and Brazil (Lesguer et al. 1984: Tectonics, 110, 9–26) suggest that many discordant boundaries showing abrupt changes in mean crustal composition can represent geometries between previously separated lithospheric plates.

Conclusion

Our new map of Australian crustal elements delineates and classifies the geophysical domains in a way that sheds new light on the tectonic development of the continent. The map recognises many abrupt or discordant boundaries in the upper crust, some of which may be plate or subplate boundaries that have been active at various stages in the continent’s history.

The release date for the 1:5 000 000-scale ‘Australian crustal elements’ map is 17 November 1995, coinciding with the project-presentation seminar of AGSO’s Division of Regional Geology & Minerals.

A reality and a winner — automated AF demagnetisation comes of age in palaeomagnetic methodology at AGSO

John Giddings

In the current funding environment, in which scientific projects — like tubes of toothpaste — are being squeezed to get the most out for the funds in, it has to be good news when a labour-intensive routine data-acquisition task is fully automated, and yields data quality superior to that of the procedure it replaces. Such is the case at the Black Mountain palaeomagnetic laboratory, where state-of-the-art automated alternating-field (AF) demagnetisation of rock specimens has recently become a reality with the commissioning of AF control software, and the resolution of problems inherent in the AF method. As a measure of the time savings involved, a demagnetisation task on eight specimens, which previously consumed a day, now requires only twenty minutes of operator intervention, and saves a cumulative walk, to tend equipment, of one kilometre.

Why demagnetise rocks?

We may regard the natural magnetic remanence of a rock as a palaeomagnetic signature of...