Components and structure of the Yilgarn Craton, as interpreted from aeromagnetic data

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Existing geological models of the structure and evolution of the Yilgarn Craton are poorly constrained with extensive regolith (weathering and surficial cover) a significant factor in limiting understanding. Regional aeromagnetic data acquired with a ground clearance of 60 metres or greater are little effected by this regolith, and their interpretation provides a continuous model of the distribution of the Archaean rocks. Five distinct regionally distributed geophysical map units are defined (undivided gneiss-migmatite-granite, banded gneiss, granite plutons, sinuous gneiss, and greenstone) which in various proportions comprise eight large domains that may equate with geological provinces. The domain boundaries coincide with abrupt changes in magnetisation and or structural trends. Boundaries of geologically-based models commonly occur in areas where there is no geophysical evidence for changes in crustal structure or composition. Interlinking shears in the Norseman-Wiluna Belt define a craton scale shear zone with less deformed crust to the east and west.

Background

Gee et al. (1981) subdivided the Yilgarn Craton on geological grounds into four provinces, the Western Gneiss Terrane, and three granite-greenstone provinces to the east (Murchison, Southern Cross and the Eastern Goldfields Provinces). Subsequent zircon dating has yielded ages of 3.7 to 3.3 Ga for gneiss in the northern Western Gneiss Terrane, 3.00 to 2.70 Ga for greenstone deposition in the Murchison and Southern Cross Provinces, and 2.74 to 2.63 Ga for greenstone deposition and granite intrusion in the Eastern Goldfields Province. Despite ongoing geological investigations, the position and nature of the Province boundaries remain poorly defined.

Aeromagnetic data

This study is based largely on interpretation of aeromagnetic surveys with 1500m and 400m line spacing from the National Airborne Geophysical Database of the Australian Geological Survey Organisation. The 400 m line spaced data was acquired in joint projects with the Geological Survey of Western Australia and covers much of the central and northeastern Yilgarn Craton. The project also drew on Fugro Airborne Surveys Pty Ltd's 200 m flight line spaced data coverage of the Kalgoorlie greenstone belt. Interpretation was undertaken at 1:250 000 scale and delineated regionally distributed mappable units, compositional banding, dislocation structures and the extent of domains with apparent related crustal content and history.

Geophysical map units

Five main geophysical map units are defined from interpretation of the aeromagnetic data: gneiss-migmatite-granite, banded gneiss, granite plutons, sinuous gneiss, and greenstone. Rocks of granitic composition dominate the first three units where as greenstone and sinuous gneiss include a wide variety of lithologies giving rise to well developed compositional layering.

Extensive regions of moderately magnetised gneiss-migmatite-granite comprise more than 45% of the Yilgarn Craton. Within these regions, interpreted internal boundaries and compositional banding are sparse to rare. Cross cutting, poorly magnetised faults and shears, and moderate to highly magnetised dykes are the most notable features mapped within the unit. Gneiss-migmatite-granite encloses examples of most other units.

Moderately to highly magnetised, banded gneiss occurs in elongate belts up to 150 km in length and 5-15 km in width, in and along the margins of gneiss-migmatite-granite regions. Both internal compositional banding and elongation of the belts grossly parallel adjacent regional shears. The boundaries of banded gneiss with gneiss-migmatite-granite are irregular and poorly resolved. Banded gneiss frequently encloses greenstone pendants and amphibolite of uncertain origin.

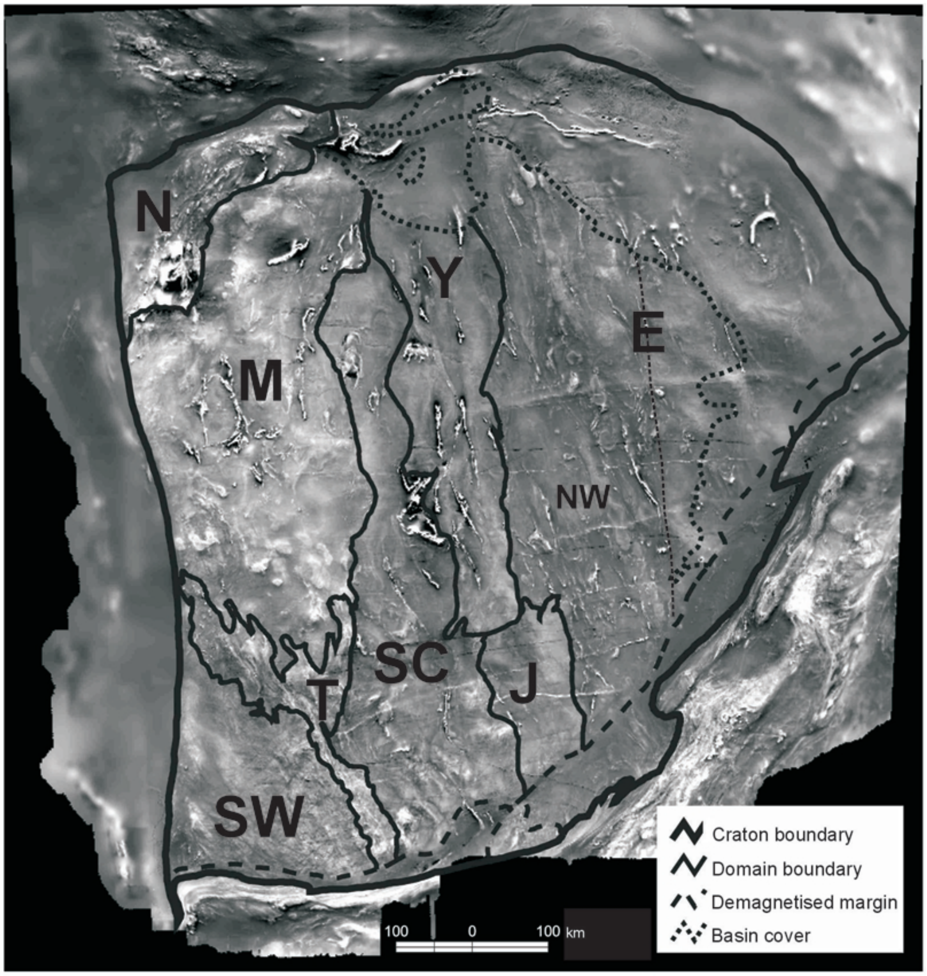

Figure 1. Total magnetic intensity image of the Yilgarn Craton – black to white represents low to high magnetisation. Geophysical domains are labelled N = Narryer, M = Murchison, T = Toodyay-Lake Grace, SW = Southwest, SC = Southern Cross, Y = Yeelirrie, J = Lake Johnston, E = Eastern Goldfields. NW in the west of the Eastern Goldfields domain correlates approximately with the Norseman-Wiluna Belt of Gee et al. (1981)

Circular to lensoidal granite plutons (<1 to >50 km) intrude all other mapped units and comprise approximately 15 % of the Yilgarn Craton. Plutons exhibit a wide range of magnetisation; some are zoned with more highly magnetised rims. Granite plutons are unevenly distributed across the Yilgarn Craton. High abundances and aligned spatial associations are particularly apparent in of the Norseman-Wiluna belt (NW in Fig.1, structurally defined here and a larger area than in Gee et al. 1981).

Sinuous gneiss is confined to the central and southwestern parts of the Yilgarn Craton. The gneiss occurs in elongate belts of variable magnetisation. Although compositional banding is well developed in these belts, it is much less coherent, less consistently aligned with regional trends, and inferred to result from a broader range of lithologies than for the banded gneiss.

Greenstone occurs in irregularly distributed elongate belts that account for approximately 20% of the Yilgarn Craton. The most extensive area of greenstone occurs in the Norseman-Wiluna belt. Greenstone is generally of low average magnetisation but includes highly magnetised banded iron-formation and ultramafic rocks which provide some detail of the internal structure of the belts. The margins of greenstone are commonly in apparent concordant contact with abutting gneiss-migmatite-granite and banded gneiss and are generally at higher metamorphic grade than greenstone more distant from these contacts (Binns et al. 1976, Williams & Whitaker 1993).

Other features mapped in the interpretation include granite and gneiss domes, layered intrusions, small intrusives (unassigned composition), shears and faults, and numerous dykes.

Shears and Faults

Poorly magnetised shear and fault zones are most apparent in areas of moderate to highly magnetised gneiss-migmatite-granite and banded gneiss (felsic crust) but delineated with difficulty in poorly magnetised greenstone.

The largest structures are the shear zones. They are commonly 50 to 250 km in length and 2 to 10 km in width. Shears zones are composed of overlapping en echelon lineaments or distended 'S' form curvilineaments. Where measured, apparent lateral movement is in the order of 30 to 50 km. Deformation associated with shears in felsic crust is inferred to have occurred in the brittle-ductile transition. By comparison, most faults are less than 50 km in length, occur as discrete to anastomosing zones of 300 m width or less, and are inferred to have dislocated brittle crust. Apparent lateral movement on faults is generally less than 5 km and they overprint, and therefore post date, shear zones in felsic crust.

Accretionary models developed in recent years to explain crustal growth have evoked craton crossing faults as terrane boundaries (e.g. Myers 1995). The aeromagnetic data, however, do not provide any support for craton-crossing faults. Such proposed faults either pass through felsic crust with no geophysical (or geological) evidence for their extent or continuity, or are coincident with shear zones across which the crust can be correlated.

Geophysical domains

The Yilgarn Craton is subdivided into eight province-sized geophysical domains (Fig. 1; Narryer, Murchison, Toodyay-Lake Grace, Southwest, Southern Cross, Yeelirrie, Lake Johnston and Eastern Goldfields), each of which contains two or more of the mappable units described above. Domain boundaries coincide with abrupt changes in average or variability of magnetisation, truncation of structural trends, or changes in the abundance of mappable units; i.e. reflecting inferred changes of crustal composition and/or history of the province boundaries cut geophysical domains in areas where there are no inferred changes in crustal composition or structure.

Regionally-aligned, compositionally-banded gneiss dominates the Narryer and Toodyay-Lake Grace domains in the west of the Yilgarn Craton. In comparison, the Murchison domain, which lies between these domains, is largely composed of gneiss-migmatite-granite with sparse compositional banding which shows little regional coherence. The Southwest and Lake Johnston domains contain little compositional banding attributed to gneiss, but where evident, banding is aligned north-northwest to north. Banded gneiss is particularly abundant in the Yeelirrie and western Eastern Goldfields domains and appears to be spatially associated with regional shear zones. The Eastern Goldfields domain occupies the eastern half of the Yilgan Craton and is subdivided into two main components: an eastern half with abundant gneiss-migmatite-granite, and sparse banded gneiss, greenstone, granite plutons and regional shears; and a western half, the Norseman-Wiluna belt, with abundant greenstone, banded gneiss, granite plutons and regional shears. Within the Norseman-Wiluna belt, interconnecting north-northwest and north oriented shear zones define deformed rhomb-shaped areas of granite and greenstone. Collectively, the structures of the Norseman-Wiluna belt are thought to comprise a craton-scale shear zone approximately 200 km in width with less deformed crust to the east and west.

The geophysical model of the Yilgarn Craton presented above provides a useful framework in which to assess the importance and nature of apparent boundaries in the crust and therefore tectonic models, and also to assimilate the results of a wide variety of geological studies.

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References

Binns R.A., Gunthorpe R.J. & Groves D.I., 1976, Metamorphic patterns and development of greenstone belts in the eastern Yilgarn Block, Western Australia, in *The Early History of the Earth*, Windley, B.F., ed, 303-313, Wiley, London.

Gee R.D., 1979, Structure and tectonic style of the Western Australian shield, Tectonophysics, 58, 327-369.

Gee R.D., Baxter J.L., Wilde S.A. & Williams I.R., 1981, Crustal development in the Archaean Yilgarn Block, Western Australia, Geol. Soc. Aust., Spec. Publ., 7, 43-56.

Myers J., 1995, The generation and assembly of an Archaean supercontinent: evidence from the Yilgarn Craton, Western Australia, in *Early Precambrian Processes*, Coward M.P. & Ries A.C., eds, Geol. Soc. London, Spec. Publ., 95, 143-154.

Williams P.R. & Whitaker A.J., 1993, Gneiss domes and extensional deformation in the Archaean Eastern Goldfields Province, Western Australia, Ore Geol. Rev., 8, 141-162.