Restricted until after publication.
Manuscript submitted for publication
to: GEOL SOC AUST

DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1975/7

GRAVITY TRENDS AND THE GROWTH OF AUSTRALIA

by

PETER WELLMAN

RECORD 1975/7

GRAVITY TRENDS AND THE GROWTH OF AUSTRALIA

by

PETER WELLMAN

ABSTRACT

Gravity anomalies of wavelength 20 to 100 km mainly reflect density variations in the non-sedimentary part of the crust. Elongate highs and lows of this wavelength can be used to divide the Australian continent into crustal blocks; within each block the elongate anomalies are subparallel. The relative age of deformation of adjacent blocks can be inferred, because a block with anomaly axes oblique to a block boundary is likely to antedate the formation of the boundary, while a block with anomaly axes parallel to the boundary is likely to postdate the boundary. The order of stabilization of Australian crustal blocks inferred using this procedure is consistent with the ages of the major deformation of cratonic areas inferred from geology and isotopic dating. In areas of sedimentary cover the positions of the crustal block boundaries are at present best defined by the gravity anomaly pattern.

INTRODUCTION

Continents are thought to change in size and shape throughout geological time because of splitting and fusing of continental fragments during continental drift episodes, the formation of new continental crust in marginal geosynclines, and possibly by the formation of orogenic zones across the centre of continents.

Continental growth has mainly been investigated by measuring the time of stabilization of the crust by isotopic dating (Goldich et al., 1966). With this technique the pattern of continental growth can generally be determined for areas of thin or no sediments; but in areas of widespread thick sedimentary cover the relative or absolute age of the crust cannot easily be determined.

Palaeomagnetic work combined with isotopic dating can be used to determine the relative positions of the crustal blocks in the past, so it is a powerful method for investigating continental growth (Piper et al., 1973). But only a few palaeomagnetic results are available for the Australian Precambrian rocks.

Large-scale trend patterns of the metamorphosed and crystalline part of the crust can also be used to investigate continental growth, because continental growth must have occurred in a way consistent with the crustal trend pattern. Trend patterns derived from geology or magnetic anomalies are detailed and very useful in non-sedimentary areas; but in areas of thick sediments these trends may reflect only non-relevant structures in the sedimentary cover. The trend pattern of gravity anomalies can be mapped over the whole of the Australian continent, and in almost all areas seems to reflect predominantly the density variation in the non-sedimentary part of the crust. Gravity trends can therefore be used to define crustal trends over the whole continent, and these can be used to investigate continental growth.

GRAVITY TREND PATTERN

A regional gravity survey of Australia is now complete. The density of gravity stations is one per 130 km^2 or greater; this density and the accuracy of the station anomalies are adequate to delineate 5 - milligal Bouguer anomaly contours. Figure 1 shows the trends (axes of elongate highs and lows) determined from the Bouguer gravity anomaly map of Australia (BMR, 1973). These trends are well defined over most of Australia except the northern part of the Northern Territory. The mapped trend lines are generally about 200 km long, and 20 to 100 km apart. They have only slight curvature. Adjacent lines are usually subparallel, but in some areas there are two trend directions.

Using the gravity trends pattern Australia has been divided into blocks, each containing an internally consistent set of subparallel trends (Fig. 1). Block boundaries bound discordant trend patterns; where discordant patterns become gradually concordant the block boundary has been extended parallel to the trends. Some of the block boundaries are obvious on the Bouguer gravity map of Australia, and these boundaries have been recognized by others (Darby & Vale, 1969; Fraser, 1973), but most of the block boundaries became clear only when the trend map was prepared.

ORDER OF DEFORMATION OF CRUSTAL BLOCKS

The relative age of deformation of adjacent blocks can be inferred where the trends on one side of the common block boundary are parallel to the boundary, and on the other side are oblique to the boundary. The deformation of a block with trends oblique to the boundary is likely to antedate the formation of the boundary, while the deformation of a block with trends parallel to the boundary is likely to postdate the boundary. The following order of deformation of crustal blocks (Fig. 2) is found by applying these rules to the gravity trend pattern.

The blocks with the oldest deformation are inferred to be the Yilgarn Block and a single block consisting of the Pilbara Block and Hamersley Basin. Adjacent blocks that appear to be deformed against these blocks are the Gascoyne Block, a block under the Albany-Fraser Domain and the Officer Basin, the Gawler Block, a block under the Warburton Basin, and a block that includes the Willyama Block.

Another area deformed at approximately this time consists of the crust under and between the Kimberley, McArthur, and Georgina Basins. Within this area the youngest deformation seems to be that beneath the southern part of the Georgina Basin.

Between these two large areas of early deformed crust there is now a band of crust consisting of the Canning and Amadeus Basins and the Musgrave and Arunta Blocks. The gravity trends in this band are parallel to its margins, so this band of crust is inferred to have been deformed later than the crust to the north and south. Two blocks farther east - a block containing the Mount Isa Geosyncline and a block containing the Georgetown and Coen Inliers - were subsequently deformed.

The order of deformation of the remaining crustal blocks in eastern Australia is apparently: first, the block under the Eromanga Basin and the block under the Murray Basin and the remainder of Victoria; then, in order, the two elongate blocks along the Eastern Highlands. In Western Australia a block under the Perth and Carnarvon Basins was deformed late.

The only block boundary with gravity trends inconsistent with this order of deformation is the boundary between the block under the Eromanga Basin and the block under the Warburton Basin.

COMPARISON WITH GEOLOGY

The gravity trends are expected to be due to folds, major faults, and elongate intrusions in the metamorphosed and crystalline part of the crust. This correlation is clear in areas of good non-sedimentary outcrop. Some areas of sedimentary rock have folds and faults in the same direction as the gravity trends, the mass distribution of the sediments accounting for some, but not all, of the gravity anomalies (e.g. Amadeus Basin). Other sedimentary rocks display minor or no structures related to the gravity trends, which must be due mainly to structures in the metamorphosed and crystalline crust underlying the sediments (e.g. Hamersley and Carpentaria Basins).

A block boundary defined by the gravity trend pattern is expected to be slightly displaced into the older crustal block from the boundary defined by geology. This is due to deformation of the margin of the older block at the time the younger block was deformed. Such displacement is found on the margins of the Yilgarn Block, and is probably present elsewhere.

The relative ages of deformation of crustal blocks inferred from gravity trends are very similar to the relative ages of deformation of orogenic domains inferred from geology and isotopic dating. In the 'Diagrammatic Relationships of Tectonic Units' on the Tectonic Map of Australia and New Guinea (Geol.Soc.Aust., 1971) the deformation of the major groups of crustal blocks extended to the following times: 3000 m.y. for Yilgarn and Pilbara Blocks, 1900 m.y. for the northern part of the Northern Territory, 1600 m.y. for the southern part of South Australia, 1300–1100 m.y. for the Arunta and Musgrave Blocks, and between 500 and 250 m.y. for most of eastern Australia.

These relative and absolute deformation ages may in all cases reflect the first deformation of a newly formed addition to the Australian Continent; if so the sequence of deformation would closely approximate the sequence of additions to the Australian continent. Alternatively, some of the deformation may be in relatively young rocks overlying relatively old crust with a different trend pattern. In this case the additions to the Australian continent occurred earlier and in a different sequence from that suggested by gravity trends, geology, and isotopic dating.

CROSS TRENDS

If a major rift crossed Australia it is likely to be intruded by igneous rocks and to be marked by a gravity trend. If a major transcurrent fault displaced parts of Australia then the sets of trend lines on the two sides of the fault would be displaced. A major rift is possibly represented by north-striking trends crossing the continent near longitude 127°E, near the Western Australia border. Transcurrent movement may be the cause of cross-cutting trend zones in northeast Queensland and the Eromanga Basin.

ACKNOWLEDGEMENTS

I am grateful for discussions with Mr K.A. Plumb, Dr R.W. Page and Mr H.F.Doutch during the preparation of this paper, which is published with the permission of the Director, Bureau of Mineral Resources.

REFERENCES

BMR, 1973 - Bouguer gravity anomaly map of Australia 1:2 534 400, Canberra, Bur.Miner.Resour.Aust.

DARBY, F., & VALE, K.R., 1969 - Progress of reconnaissance gravity survey of Australia. ECAFE Symp. Canberra, July 1969.

FRASER, A.R., 1973 - A discussion on the gravity anomalies of the Precambrian shield of Western Australia. Bur.Miner.Resour.Aust.Rec. 1973/105(unpubl).

GEOLOGICAL SOCIETY OF AUSTRALIA, 1971 - Tectonic Map of Australia and New Guinea, 1:5 000 000. Sydney.

GOLDICH, S.S., MUEHLBERGER, W.R., LIDIAK, E.G. & HEDGE, C.E., 1966 - Geochronology of the midcontinental region, United States. 1: Scope, methods and principles. J.Geophy.Res., 71, pp. 5375-5388.

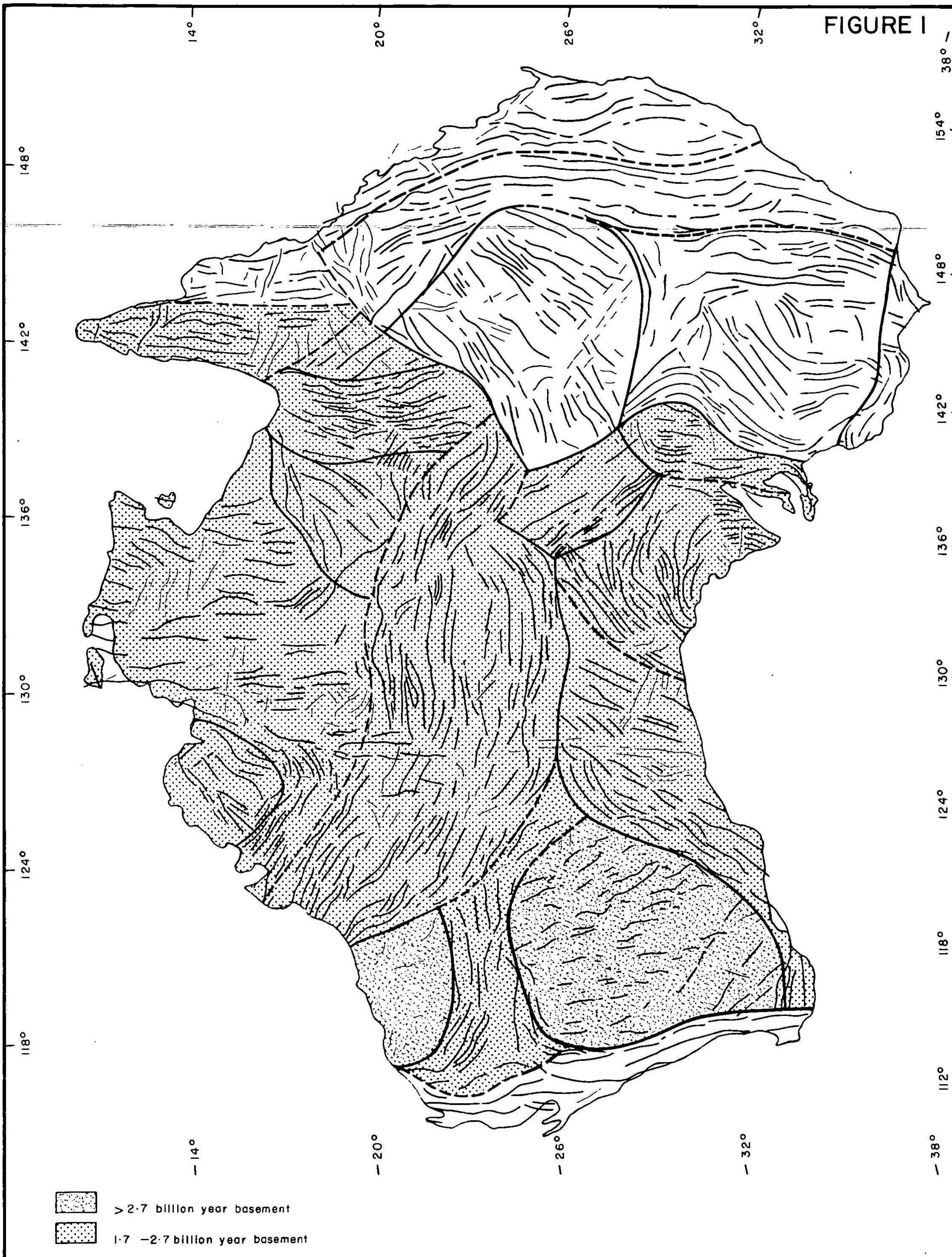
PIPER, J.D.A., BRIDEN, J.C., & LAMAX, K., 1973 - Precambrian Africa and South America as a single continent. Nature, London, 245 pp. 244-248.

CAPTIONS

Fig. 1. Gravity trends in Australia. Boundaries between crustal blocks defined by gravity trends are shown solid where well defined, and shown broken elsewhere. Areas of Archaean, Proterozoic, and Phanerozoic stabilization have been differentiated.

Fig. 2. Geological trends given in the Tectonic Map of Australia and New Guinea (Geol.Soc.Aust., 1971).

FIGURE I



AUSTRALIAN GRAVITY TRENDS

Record No. 1975-7

A/B2–104A

Record No. 1975/7

> 2·7 billion year basement

1·7 — 2·7 billion year basement

AUSTRALIAN GEOLOGY TRENDS

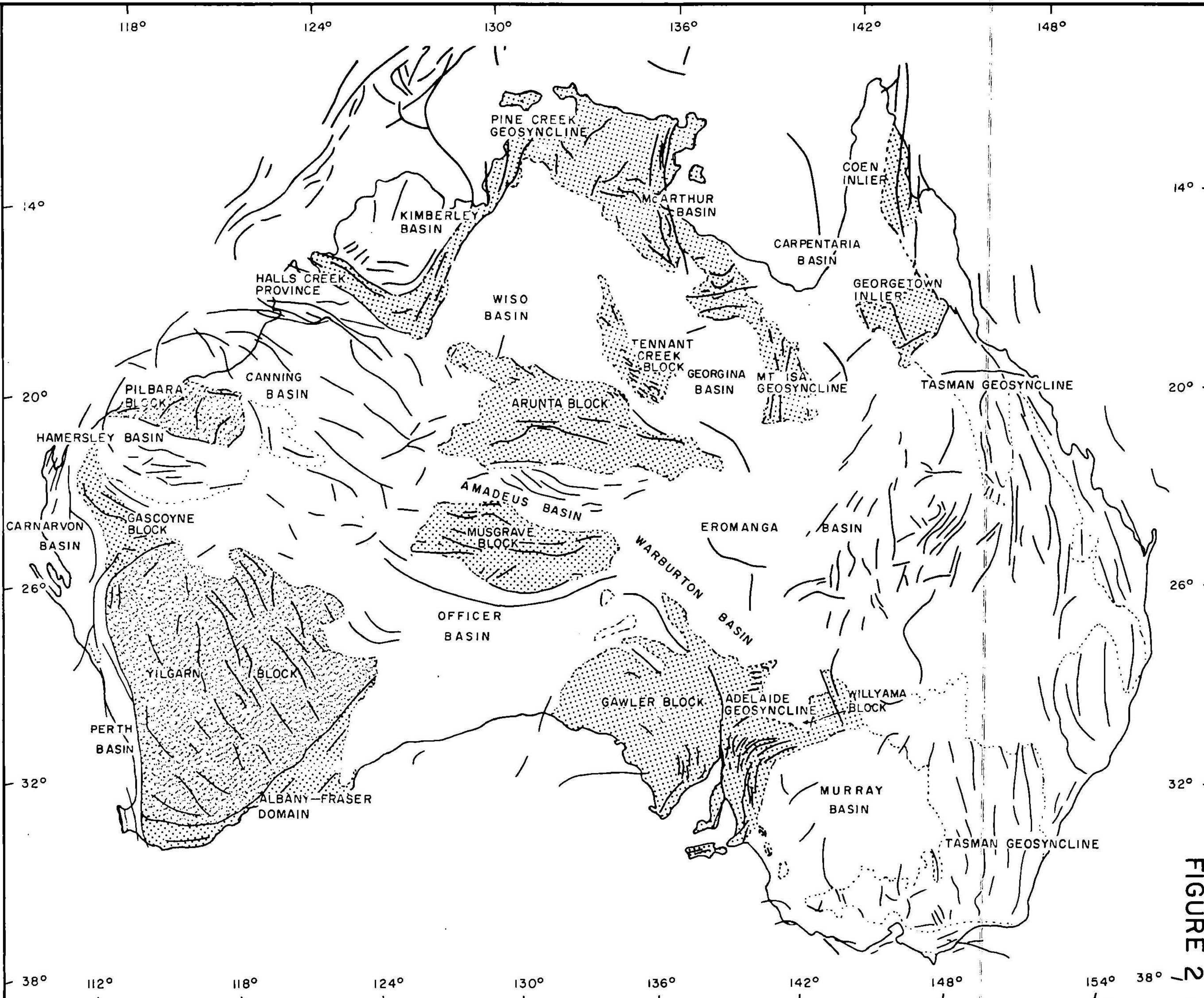


FIGURE 2

A/B2-105A