Geophysical Data Sets Over Continental Australia

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Introduction

Magnetic, gamma-ray and gravity data sets provide vital information for mineral and petroleum explorers as well as researchers studying the geology of the Australian continent and for environmental management issues. Commonwealth, State and Territory governments have devoted considerable resources to acquiring these data sets and making them available to encourage exploration. Geoscience Australia's (GA) geophysical databases contain data acquired by governments, private industry and universities and this report summarises coverages over Australia of these data.

On the occasion of the centenary issue of Preview, it is worth reflecting on the advances in the coverage of publicly available magnetic, gamma-ray and gravity data over Australia since the first edition of Preview in February 1986. Since then the areas and resolution of coverages have increased dramatically. Quality of the data through better acquisition and processing techniques has also improved, and new types of data sets added to the explorers' supplies.

Magnetic data

Figure 1 shows the present state of coverage of magnetic data over Australia at various line spacings, and Figure 2 the situation in February 1986. The most noticeable difference is the improvement in coverage of 400/500m line-spaced data. However, even though coverage is now complete, large areas have only substandard coverage.

The tables below, showing the percent coverages of magnetic data over onshore Australia, and the distances surveyed onshore and offshore Australia by 2002 and 1986, quantify the situation.

Table 1: Line spacing of airborne magnetic data over onshore Australia, 2002 and 1986

	Coverage (%)	
Line spacing (m)	*2002*	*1986*
<= 500	53.4	3.7
501 - 1 600	34.7	48.6
3 000 - 3 200	12.8	29.6
>3 200	7.6	11.7
No coverage		6.4

NB: The coverage statistics for 2002 in Table 1 add up to more than 100% as some survey areas have been reflown at a higher resolution than when data was first acquired in the area.

Table 2: Distances of airborne magnetic data over Australia, 2002 and 1986

	Distance (km)	
Line spacing (m)	*2002*	*1986*
<= 500	10 888 482	621 124
501 - 1 600	4 170 909	2 736 756
3 000 - 3 200	1 182 317	861 941
>3 200	212 909	176 838
Total	16 454 617*	4 398 523*

* The database holds a small percentage of surveys with undefined line distances, which have not been included. These surveys are estimated to total 300 000 line km.

Gamma-ray data

Figure 3 shows the present state of coverage of gamma-ray data over Australia at various line spacings, and Figure 4 the situation in February 1986. As with the magnetics, the most noticeable difference is the improvement in coverage of 400/500m line-spaced data. However, the gamma-ray coverage is not complete.

The tables below show the percent coverages of gamma-ray data over onshore Australia, and the distances surveyed onshore and offshore Australia by 2002 and 1986.

Table 3: Line spacing of airborne gamma-ray data over onshore Australia, 2002 and 1986

	Coverage (%)	
Line spacing (m)	*2002*	*1986*
<= 500	52.5	2.8
501 - 1 600	24.2	22.8
3 000 - 3 200	3.8	9.7
>3 200	1.2	4.5
No coverage	18.3	60.2

Table 4: Distances of airborne gamma-ray data over Australia, 2002 and 1986

	Distance (km)	
Line spacing (m)	*2002*	*1986*
<= 500	10 456 686	536 018
501 - 1 600	2 464 124	1 724 051
3 000 - 3 200	347 421	319 125
>3 200	43 117	43 117
Total	13 311 348*	2 622 311*

Elevation

As a consequence of using GPS for flight path recovery, elevation of the Earth's surface above sea-level is now easy to calculate from data collected during airborne geophysical surveys. Elevation data are now a standard product from airborne geophysical surveys. In 1986, the GA databases held practically no elevation data. In June 2002 the coverage was as tabulated below, and as shown in Figure 5.

Table 5: Coverage of elevation data from airborne surveys over Australia, 2002

Line spacing (m)	*Coverage (%)*	*Distance (km)*
<= 500	34.9	7 094 873
501 - 1 600	0.4	22 970

A 250-m grid of elevations over all of onshore Australia derived from point elevations (spot heights), gravity survey station elevations and airborne geophysical survey elevation data is available from GA.

Accumulation of data into airborne geophysical databases

Figure 6 shows the yearly and cumulative acquisitions of airborne geophysical data into GA's airborne geophysical databases from 1951 to the present. The rapid accumulation of data, which occurred over the 1990s due to Commonwealth and State/Territory Government exploration initiatives, appears to be tapering off.

Gravity

Figure 7 shows the present state of coverage of gravity data over onshore Australia at various station spacings, and Figure 8 the situation in February 1986. The table below quantifies the situation.

Table 6: Coverage of gravity data from over Australia, 2002 and 1986

	2002		*1986*	
Station spacing	*Coverage (%)*	*Stations*	*Coverage (%)*	*Stations*
<= 1 km	0.9	8 688	0.3	1 436
2 - 3 km	14.2	135 197	7.6	44 351
4 - 6 km	25.6	244 783	9.7	56 778
7 km	11.0	105 331	10.8	63 076
11 km	48.3	461 673	71.7	419 259
Total		955 672		584 900

Although there is essentially full gravity coverage over onshore Australia, most is at a very coarse station spacing and much of the data are aliassed. There are no airborne gravity or gravity gradiometry data in the GA databases.

Figure 9 shows the acquisitions of gravity data into GA's gravity database from 1947 to the present. Although accumulation of data accelerated in the 1990s, the increase of gravity data was not as dramatic as the increase in airborne geophysical data.

Data availability

Data owned by the Commonwealth in the National Airborne Geophysical Databases are available at cost of transfer from GA. Data owned solely by State and Territory governments are available from the relevant State or Territory department.

New Commonwealth policy on data pricing and access

Publicly available digital data from Geoscience Australia's airborne geophysics and gravity databases are now available under the Commonwealth Government's new spatial data pricing and access policy. Some data, such as the Gravity database and the gravity and magnetic grids of Australia, are available for free download from GA's website (www.ga.gov.au). Almost all released data are available on CDs at a cost of A$99 per CD (including GST).

Data from most semi-detailed airborne geophysical surveys are provided on one CD per survey. For surveys larger than 69,000 line kilometres (at say 400 m line spacing) the data are contained on two or more CDs for each survey (up to a maximum of 7 CDs). Data from several 1 500-m line spaced surveys fit on a CD. The GA website has a list of available airborne geophysics data by survey. The grid of the Magnetic Map of Australia (at 15 second ~ 400 metre cell size) is on a single CD. The gravity database and the gravity grid (at 30 second ~ 800 metre cell size) of Australia are on a single CD.

Improvements in quality of data

As well as improvements in the coverage of data since 1986, data quality has markedly improved from advances in acquisition and processing techniques. Some of these are described below.

Location of measurement points

In 1986 most airborne geophysical surveys used a combination of aerial photographs with Doppler navigation systems for aircraft navigation and flight path recovery. In the late 1980s radio-navigation systems were introduced and in the early 1990s Global Positioning System (GPS) navigation systems were beginning to provide navigation and flight path recovery information. Today, GPS navigation systems are the standard for airborne geophysical survey navigation and flight path recovery. Flight lines are straighter and more precisely located than in 1986. Positions are to within 5m, compared to typically 70 m from aerial photographs.

GPS has improved the accuracy of gravity surveys. In 1986 many survey stations were levelled using barometers and horizontally located using aerial photographs because the alternative of surveying was too costly and slow. Height data recorded with barometers typically had errors of 1 m for digital barometers to 10 m or more for aneroid barometers, resulting in uncertainties of 3 to 30 μms^{-2}. Appropriate GPS height data now gives heights to better than 5 cm. Locations from aerial photographs could have had uncertainties of 200 m (equivalent to 1 μms^{-2}).

Magnetometers

Proton precession magnetometers were the standard sensor in 1986. These measured the total magnetic field to a resolution of 0.1 nT. Magnetic data were recorded at 1 second intervals with a noise envelope of 1 nT. Currently, caesium and helium vapour magnetometers are the industry standard. Both types of magnetometer can be sampled at 0.1 second intervals or closer, with resolutions of 0.001 nT, and noise envelopes of less than 0.01 nT.

Improvements in base station magnetometer instrumentation have followed a similar pattern to developments with the airborne magnetic sensor. Progress has seen the standard base station magnetometers change from a proton precession magnetometer in 1986 to high sensitivity helium base stations in 2002.

Compensation

In 1986 the effects of airborne magnetic survey aircraft were compensated by adjusting the currents flowing through three mutually orthogonal coils. This procedure was time consuming at the best of times and often took one - two days before a satisfactory result was obtained. Typically, manoeuvre noise was less than ±0.5 nT with a heading error of less than ±1 nT. The Automatic Aeromagnetic Digital Compensator (AADC) revolutionised the magnetic compensation procedure. The whole procedure could be completed in one - two hours with manoeuvre noise less than ±0.15 nT and a heading error less than ±0.25 nT.

Gamma-ray spectrometer systems and processing

In 1986 the standard crystal volume in the aircraft was typically16.8 l, sometimes with 4.2 l of upward crystal. Now 33 l is standard, giving a $\sqrt{2}$ improvement in noise levels.

Spectrometer calibration was difficult in 1986. The crystal packs and photomultiplier tubes (PMT) had to be maintained at a constant temperature to achieve thermal stability. The spectrometer system required regular calibration to maintain the resolution of the data. Drift was common, degrading data. Spectrometers are now self-calibrating spectrometers that don't require temperature stabilisation of crystal packs or PMTs

Whereas 4 channels of data were typically recorded in 1986, a minimum of 256 channels are now recorded. The increase in the number of recorded channels has enabled improved background estimation, and noise adjusted singular value decomposition (NASVD) or minimum noise fraction (MNF) processing to reduce noise. Systems are now regularly calibrated over calibration ranges so that final results are expressed as apparent ground concentrations, or dose rate. In 1986 results were usually expressed in counts per second, and easy comparison of results from different systems was not possible.

Gravity Meters

There are now several meters such as the Scintrex CG-5 and LaCoste and Romberg Graviton-EG meters that take readings automatically and store the data for downloading direct to a computer, decreasing the problems of reading and input errors. One factor often overlooked for the LaCoste and Romberg G meters is that they can become more stable over time, thus a meter from the seventies or eighties may give better results because of better drift characteristics than newer more automated instruments.

Improvements in gravity meters in recent years have made taking gravity observations easier and less prone to operator error. These improvements mean that less time is spent taking observations resulting in increased production.

Concluding remarks

Considerable improvements have occurred in geophysical coverages of Australia since 1986, both in the extent and quality of data. State and Commonwealth initiatives fuelled rapid increases in magnetic, gamma-ray and elevation data during the 1990s. The completion of first pass magnetic coverage and the introduction of GPS systems have encouraged the reduction in line spacing of the airborne coverages. Quality of airborne geophysical data has improved due to GPS, better magnetometers and compensation systems, multi-channel gamma-ray data acquisition, and improved processing. Coverage of gravity data has steadily improved and data quality have improved, largely due to the introduction of GPS. Presentation of data has also improved with the now routine use of image processing, and the use of derivatives and other manipulations of data. Maps can now be generated much easier and faster than in 1986.

Figures 10 and 11 demonstrate some of the improvements in coverage for magnetic data from 1986 to now. Figure 10 shows the Magnetic Map of Australia which was available in 1986 as a contour map generated by BMR in 1976. Figure 11 shows the 1999 edition of the Magnetic Map of Australia (Milligan et al) which is available as a pixel image map. Not only has the area of data coverage increased markedly, but also the quality of presentation of the map has improved, making it far more interpretable. Due to improvements in processing and visualisation techniques GA released three editions of the Magnetic Anomaly Map of Australia dur ring the 1990s whereas prior to 1990 only one edition of this map had been published.

Despite the recent improvements, large areas of Australia have poor quality of coverage. About 45% of onshore Australia has airborne magnetic coverage with line spacings of 1 500 m or more, and 18% has no coverage of gamma-ray data. Almost half of onshore Australia has gravity data at 11 km station spacings; only 15% has coverage at 3km or closer station spacings.

Acknowledgements

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Milligan, P.R. and Tarlowski, C., 1999, Magnetic Anomaly Map of Australia (Third Ed.), scale 1:5 000 000. *Australian Geological Survey Organisation.*

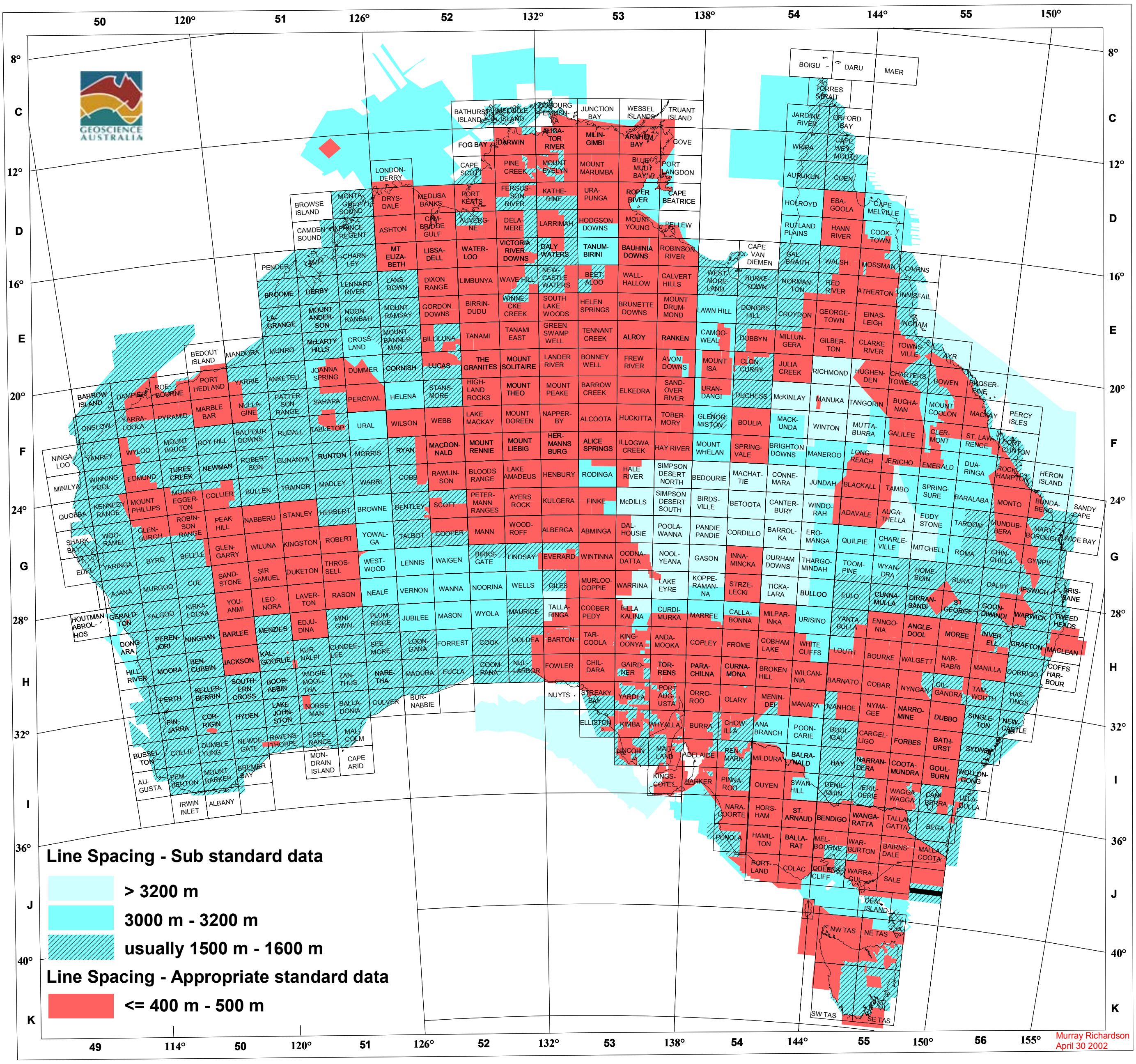

Figure 1: April 2002 - Airborne Magnetic Coverage of Australia - Line Spacing. Map Scale 1:25 000 000

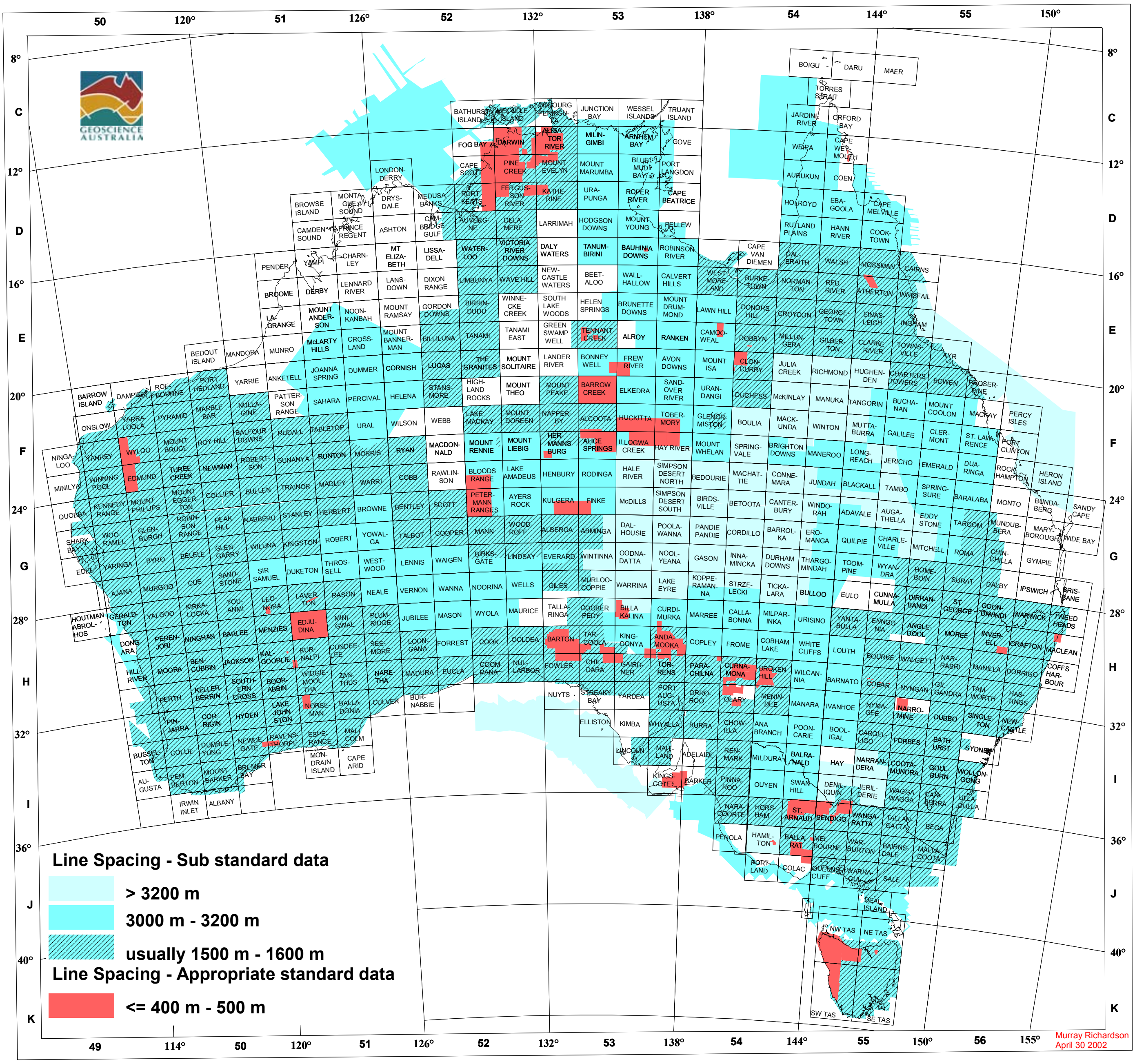

Figure 2: January 1986 - Airborne Magnetic Coverage of Australia - Line Spacing. Map Scale 1:25 000 000

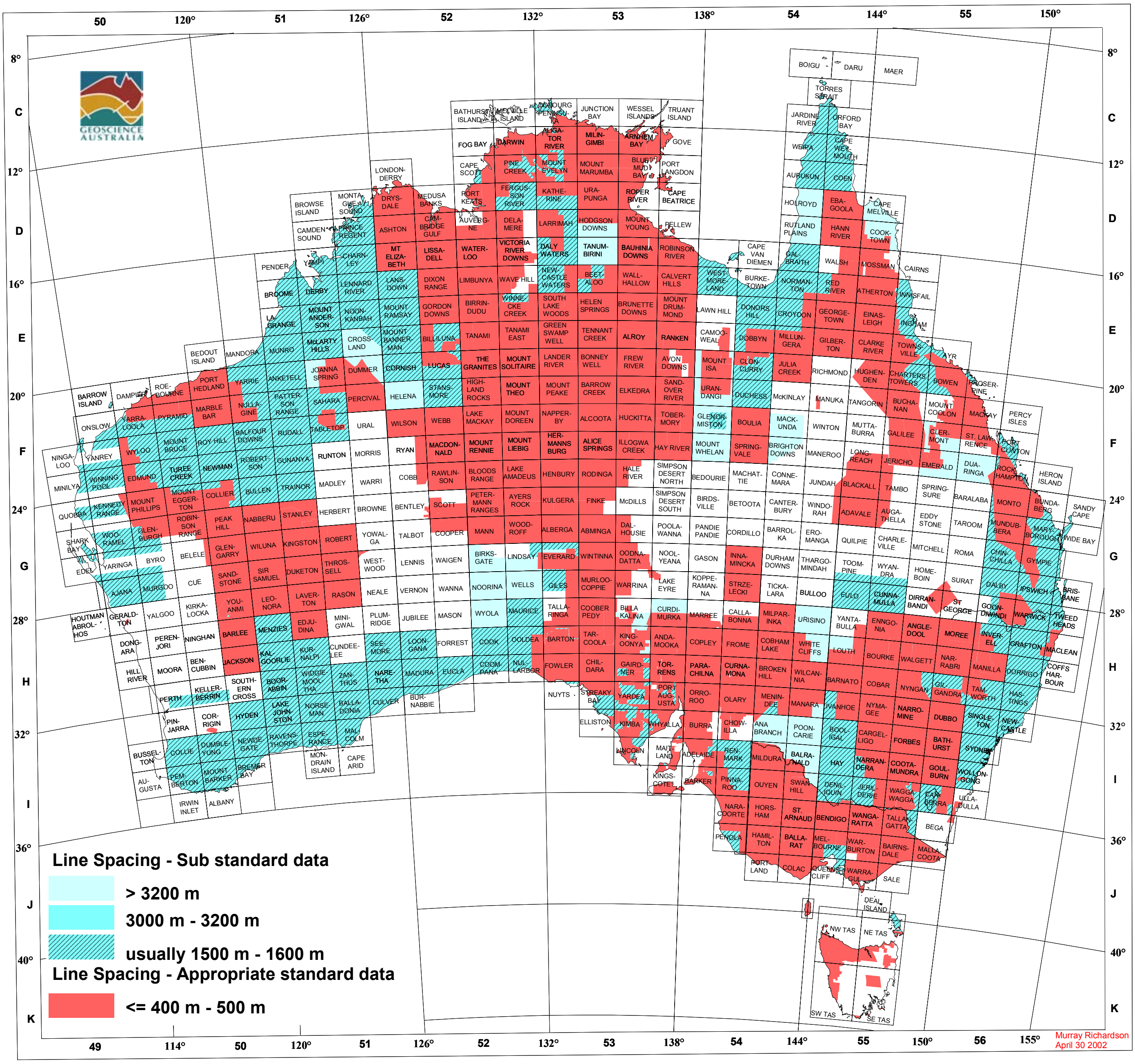

Figure 3: April 2002 - Airborne Gamma-ray Coverage of Australia - Line Spacing. Map Scale 1:25 000 000

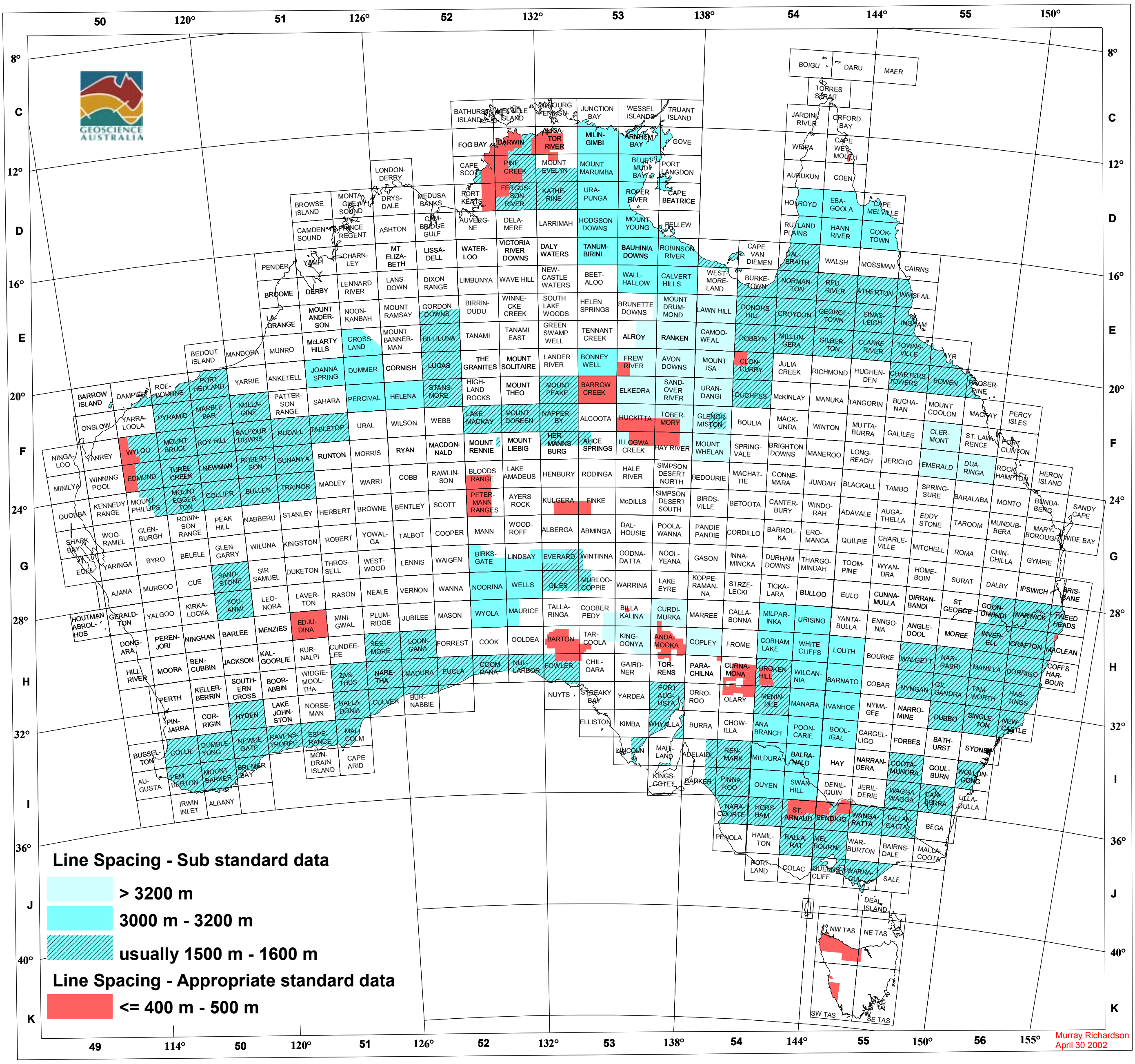

Figure 4: January 1986 - Airborne Gamma-ray Coverage of Australia - Line Spacing. Map Scale 1:25 000 000

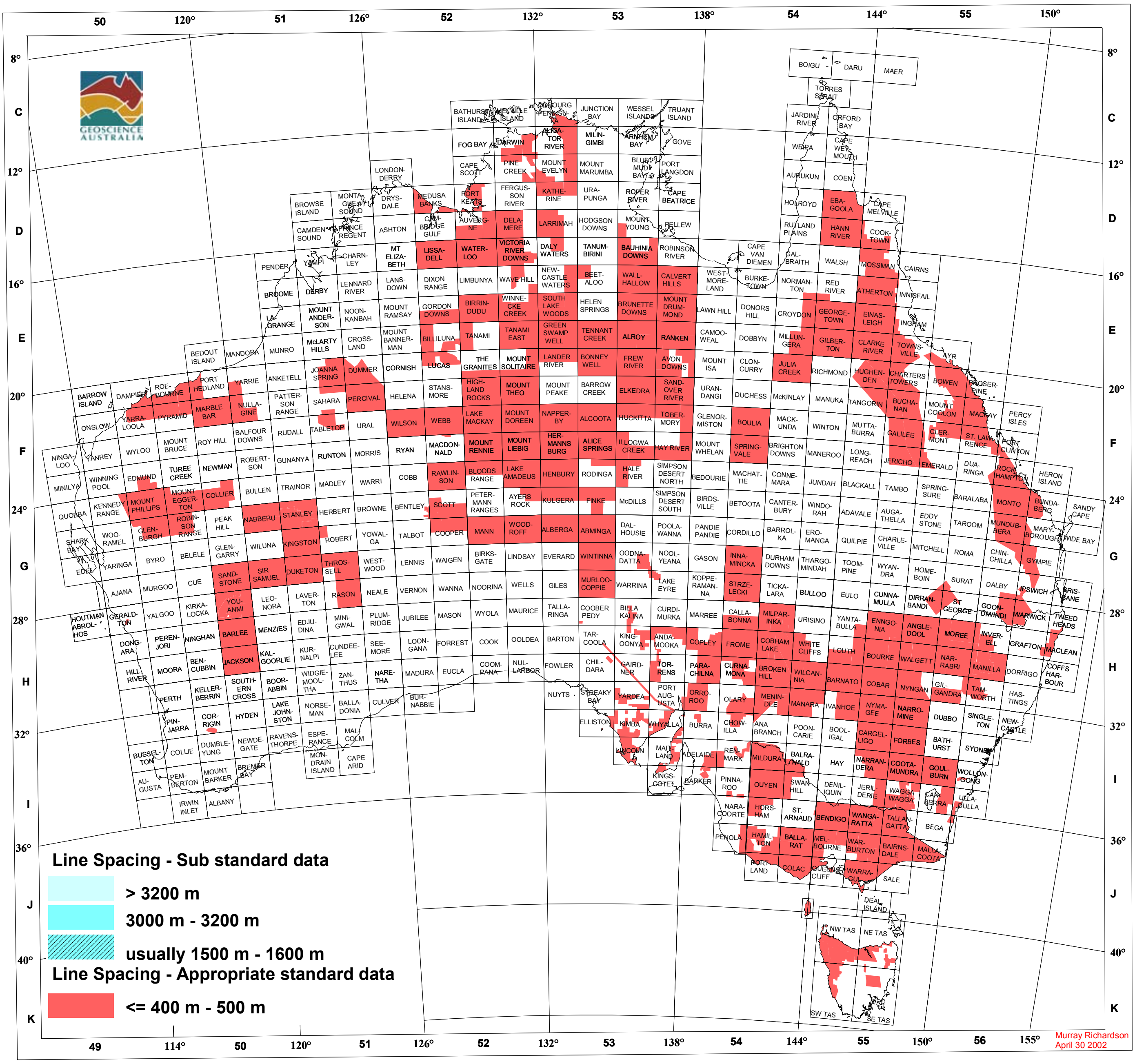

Figure 5: April 2002 - Airborne Elevation Coverage of Australia - Line Spacing. Map Scale 1:25 000 000

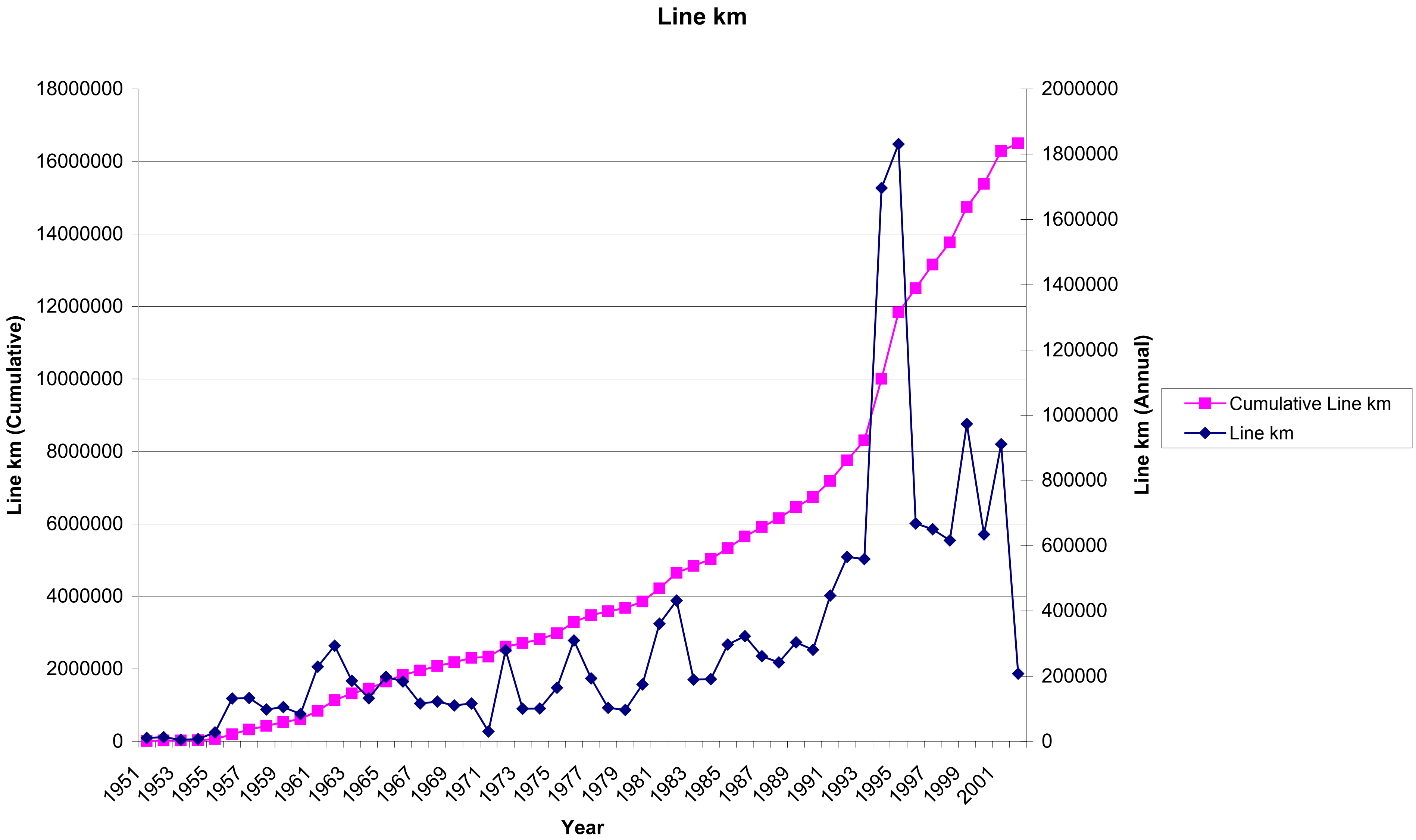

Figure 6: Accumulation of data from State/Northern Territory, Commonwealth Government and Private Company airborne geophysical surveys into the National Airborne Geophysical Database from 1951 to the present.

GRAVITY COVERAGE DENSITY THROUGHOUT AUSTRALIA

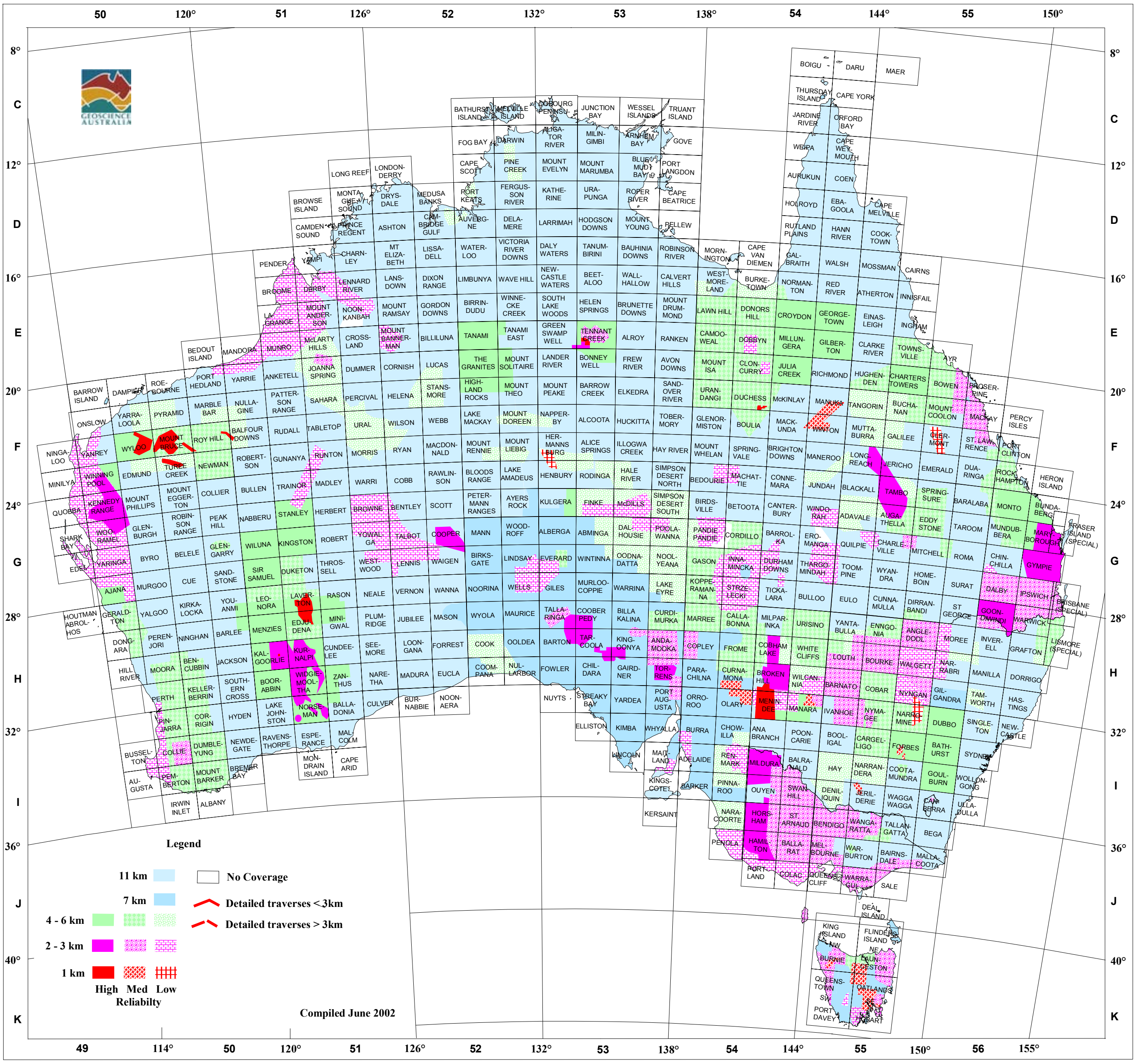

Figure 7: April 2002 - Gravity Station Coverage of Australia. Map Scale 1:25 000 000

GRAVITY COVERAGE DENSITY THROUGHOUT AUSTRALIA PRE 1986

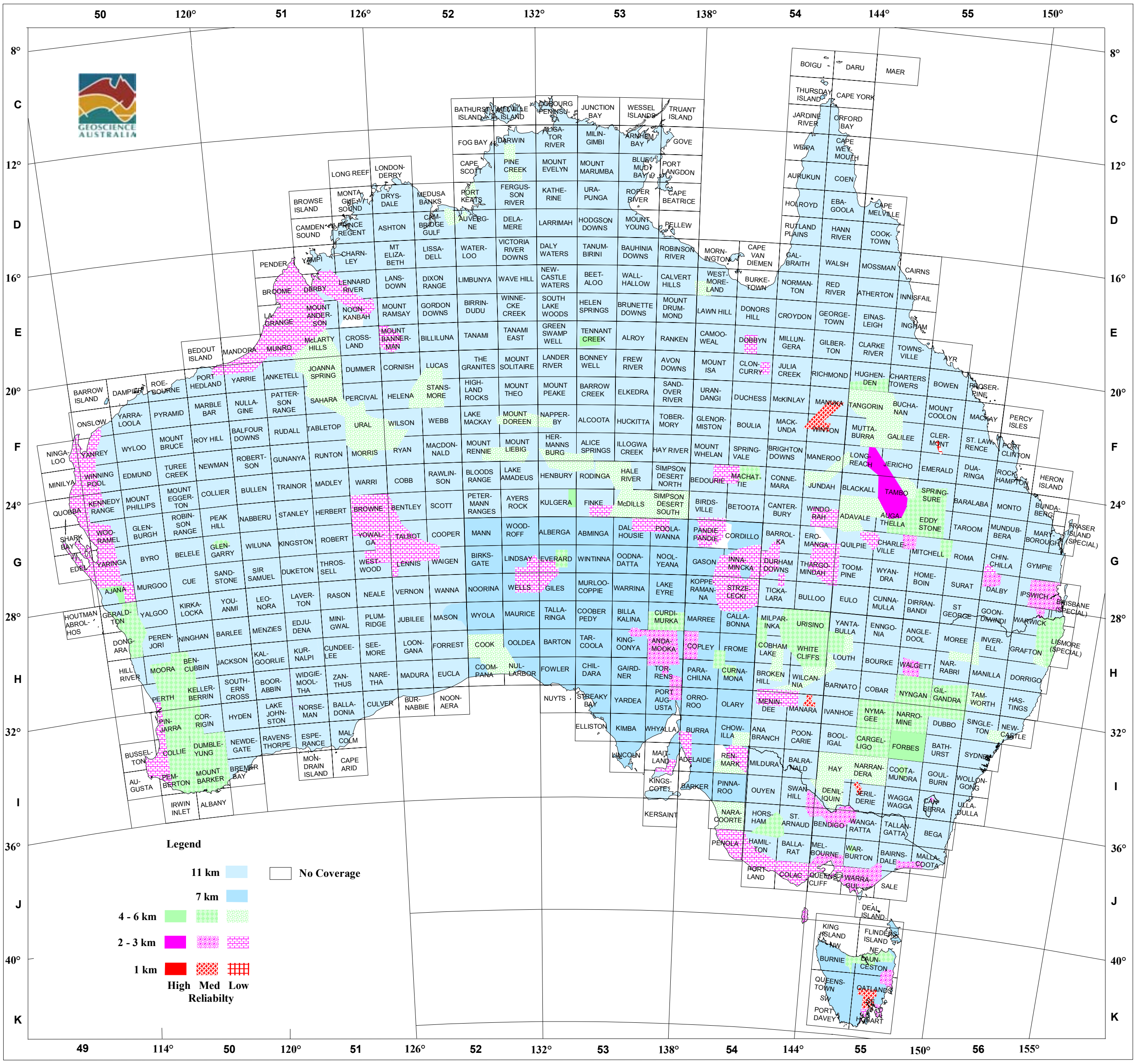

Figure 8: February 1986 - Gravity Station Coverage of Australia. Map Scale 1:25 000 000

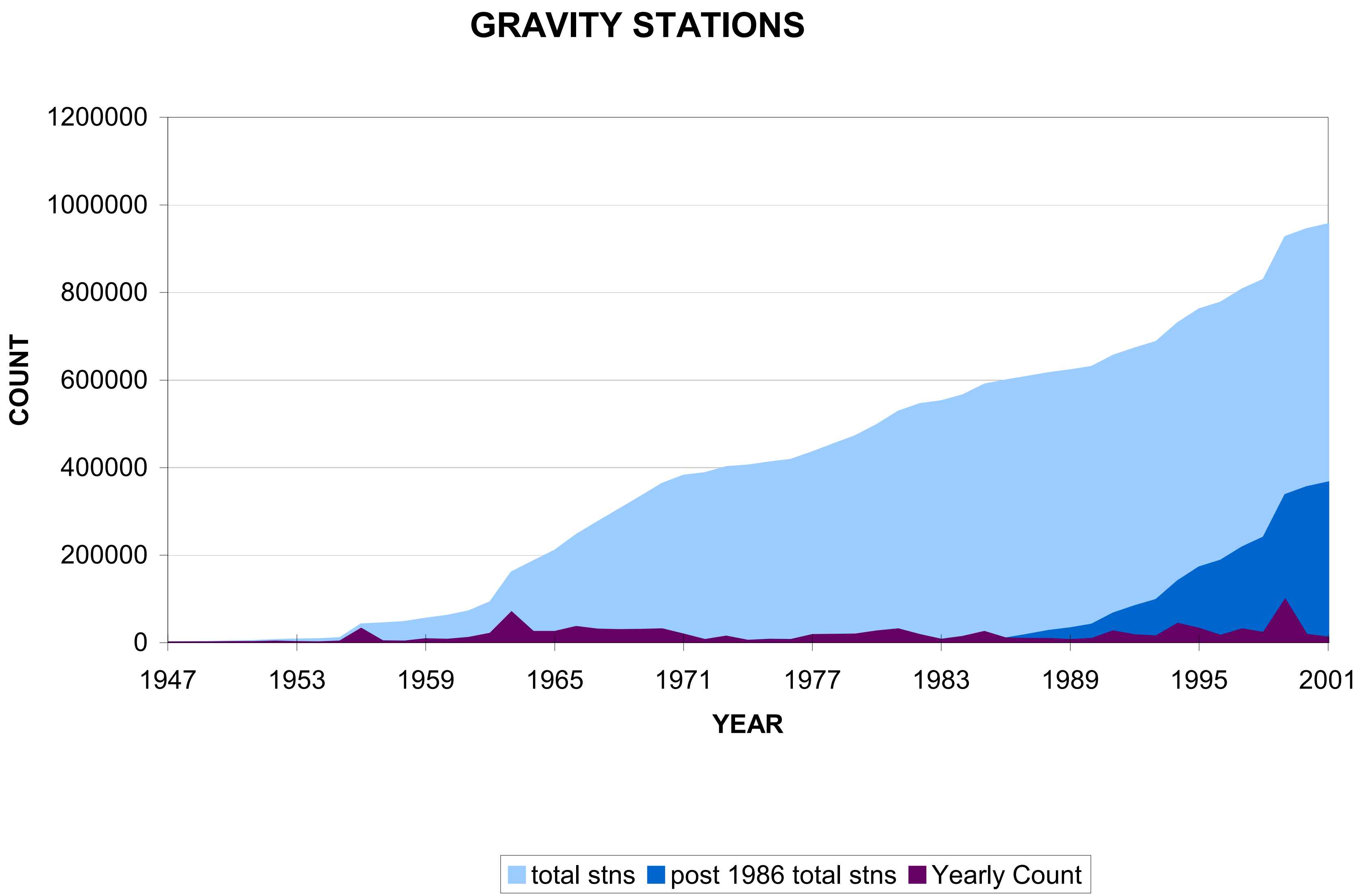

Figure 9: Accumulation of data from State/Northern Territory, Commonwealth Government, Private Company and University gravity surveys into the National Gravity Database from 1947 to the present.

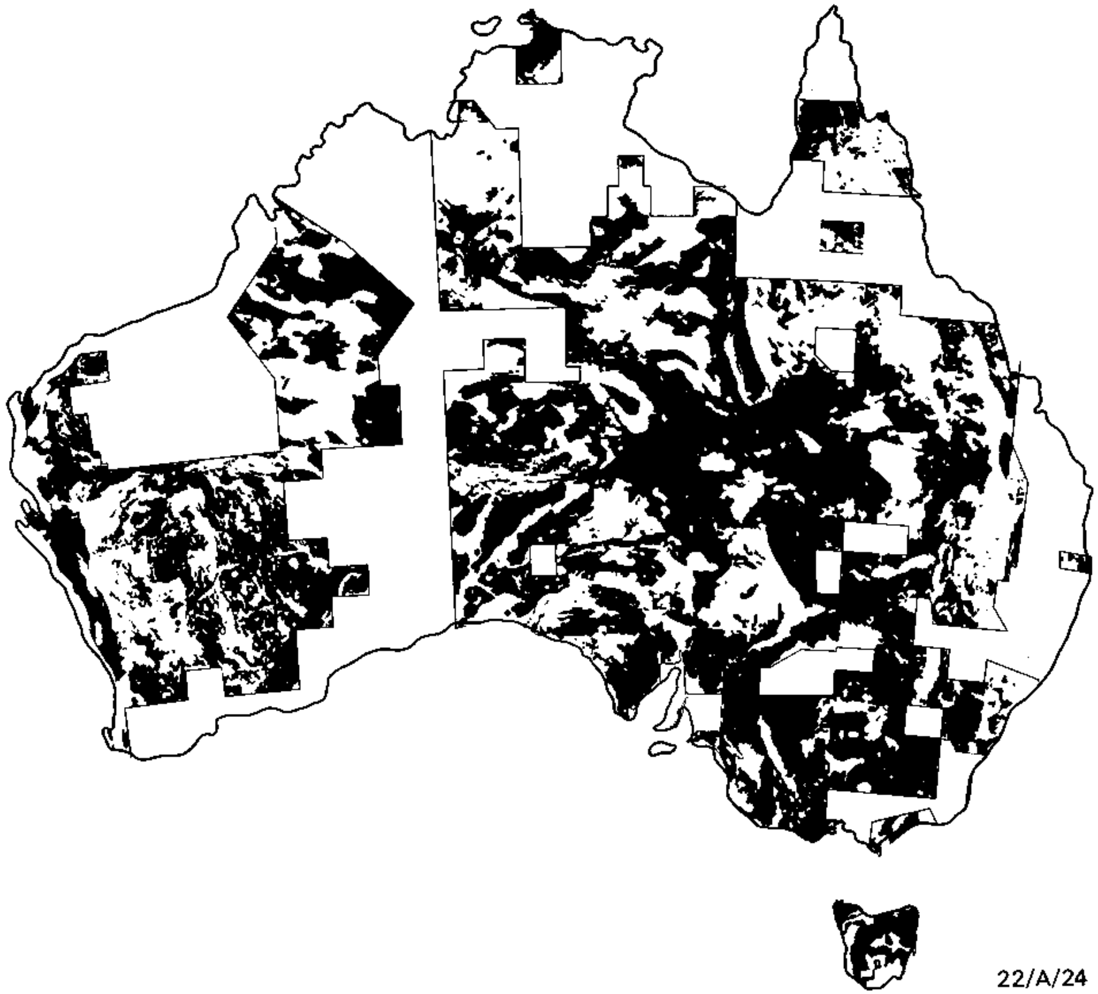

Figure 10: The Magnetic Anomaly Map of Australia - 1986 edition.

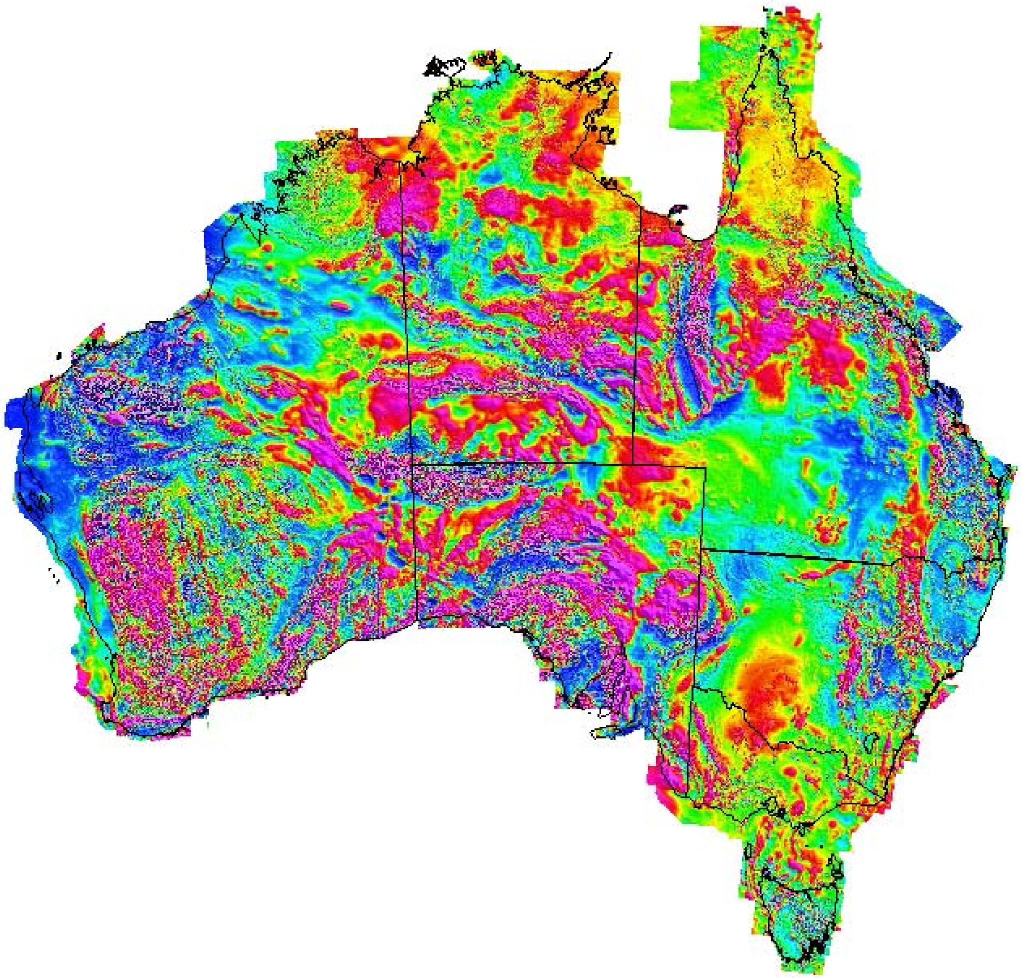

Figure 11: The Magnetic Anomaly Map of Australia - 1999 edition.